Neuro-Developmental Treatment

A Guide to NDT Clinical Practice

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Cathy M. Hazzard
Janet M. Howle
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NDT Practice Model

NDT Schematics

Chapter: Development of the Bobath Approach (by Janet M. Howle)

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Preface

Neuro-Developmental Treatment (NDT) is one of the most commonly used intervention approaches for individuals with cerebral palsy, stroke, or traumatic brain injury worldwide. Since its origination by the Bobaths in the 1940s, the practice model has been taught through extensive continuing education courses, now leading to a specialized certification, and has been explored in research projects. In 2002, the Neuro-Developmental Treatment Association (NDTA) published *Neuro-Developmental Treatment Approach: Theoretical Foundations and Principles of Clinical Practice* that updated the theoretical basis of NDT practice. This project grew from that text.

The NDTA supported work of its Theory Committee to expand the project to not only include the foundational theoretical material supporting and influencing the practice of NDT but to also provide demonstration of the practice in a series of case reports. The text is written by more than 30 practitioners who are experts from all three disciplines (occupational therapy, physical therapy, and speech-language pathology). It is designed to assist therapists ranging from students during their professional training to novice or highly experienced therapists in understanding the foundations and practice of NDT.

Units I–III of the text are organized around answering the general questions of the whats, hows, and whys of NDT. Unit IV is then expanded into a review of the application of NDT practice within the disciplines of occupational and physical therapy and speech-language pathology. Unit V presents a series of case reports that span from infants to adults with both pediatric and adult onset neuromuscular disorders.

Unit I defines *what* NDT is. In this unit, the reader will find a review of foundational components of NDT. Chapter 1 of the unit provides a definition and review of the NDT philosophy as a living concept. Chapter 2 summarizes the theoretical assumptions and principles that form a foundation of the practice. The assumptions are grouped by topics, with each group being expanded within Unit III that explores its theoretical foundations. Chapter 2 unites all of the assumptions into a unified whole. The final two chapters in the unit apply two different models to the practice of NDT. For example, Chapter 3 reviews the International Classification of Functioning and Disability taxonomy developed by the World Health Organization as it is integrated into NDT practice, and the final chapter presents a model of posture and movement and how it could be applied in NDT. As individuals with both stroke and cerebral palsy are viewed as having disorders of posture and movement, this type of model is foundational. By reading this unit, the reader should be prepared to analyze how NDT is practiced and observe its applications.

Unit II focuses on the *hows* of the practice of NDT. For years, writers have alternately referred to NDT as an approach or a theory or a group of techniques. However, when one reviews what a practice model entails, it becomes clear that NDT is indeed a practice model. First, the benefits of a practice model for clinicians are reviewed for the reader. Then, the model itself is presented in Chapter 5. An overview of the model is diagrammed on p. 57. Chapters 6–11 lead the reader through the practice model with chapters on information gathering (Chapter 6), examination (Chapter 7), evaluation and plan of care (Chapter 8), and intervention (Chapter 9) from an NDT perspective. Within each chapter, emphasis is placed on how the NDT philosophy and theoretical foundation form the basis of the specific and unique aspect of the practice model. The next two chapters review the characteristics of the postural and movement disorders associated with cerebral palsy (Chapter 10) and with stroke (Chapter 11). All of the chapters introduce real examples of issues presented in the case reports found in the final unit of the book.

Unit III addresses the *whys* of NDT practice. This unit explores the theoretical assumptions that were introduced in Unit I. Chapter 12 explores theoretical assumptions related to the field of motor control that are applied within the practice of NDT. Neurophysiological understanding has always played an important part in shaping the practice of NDT. Chapter 13 examines how theories of motor learning are applied in NDT. This chapter focuses on how individuals learn the control and coordination to master new skills. Then, Chapter 14 demonstrates how this process expands across the lifespan. Once again, NDT has always included theory based on motor development in the practice model. The ways in which the theoretical assumptions from motor development are integrated into practice are explored in Chapter 14. Finally, Chapter 15 explores current literature on neural plasticity and recovery after central nervous system insults. This information can be interpreted to support the practice of NDT.

Unit IV presents a more detailed view of how practitioners from occupational therapy (Chapter 16), physical therapy (Chapter 17), and speech-language pathology (Chapter 18) practice NDT within the scope of the individual disciplines.

Unit V begins with a review of how evidence-based practice literature influences the overall practice of NDT. It then outlines how the reader can integrate a series of case reports. The first part of this unit features six case reports that highlight the diversity of patient client management for individuals with adult onset movement disorders, while the second part of the unit features nine pediatric onset case reports which span from infancy through adolescence. All individuals featured in the case reports present with disorders of posture and movement; specific diagnoses include stroke, TBI, and cerebral palsy. The case reports also present or highlight different aspects of the practice model while all display the basic tenets that are central to NDT. They model how NDT is employed with different clients, in different settings, and by different practitioners.

The content on Thieme MediaCenter, which accompanies this text, provides the reader with additional examples of NDT in practice, including enhanced tables and figures, as well as supplemental video and still images. Thieme MediaCenter also includes seven additional video-based cases, and an extensive photo gallery which highlights content presented within the text-based case reports.

A comprehensive glossary accompanies the text.

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Acknowledgments

This project began over 10 years ago with an idea for a clinically based manual that would illustrate the practice of NDT for therapists who work with both children and adults with disorders of posture and movement. Like all good ideas it was pondered, discussed, and reenvisioned. As time passed, the idea grew, a conceptual map was created, an outline was developed, and a proposal was written. The road to publication was a bumpy one, with many turns and twists. Ultimately our vision was realized and is now tangible; it is the book you hold in your hands and the Thieme MediaCenter you can access with a click of your mouse. Thank you to all who contributed to our shared vision, who encouraged and supported us, who brought us a caffeinated beverage, and pushed us to keep reading, writing, and editing. Thank you for your encouragement. Thank you for your support.

The editors would like to acknowledge several individuals and groups of individuals for their contributions to *Neuro-Developmental Treatment: A Guide to NDT Clinical Practice*.

A special thank you is extended to the individuals and their families who have graciously allowed their therapy stories to be told and their images to be shared in the text and on Thieme MediaCenter. The sharing of yourself and your story is a generous gift, which is much appreciated and most valued, for without it our vision for this project could not have been realized.

To our contributors, our chapter authors, our case report authors, and our video case contributors, your work has enriched this project. You stepped out of your clinical comfort zone, took a chance, and shared your expertise and insights into NDT-based clinical practice. Thank you for your time, your dedication to this project, and to the practice of NDT.

A special thank you is extended to the Neuro-Developmental Treatment Association (NDTA), its Board of Directors, and its membership for their steadfast support of this project. The financial support and technical resources provided by NDTA have facilitated the growth of our shared idea into a tangible product. With each challenge the board offered words of encouragement, asked what was needed, and asked how they could help. Your faith in us and your support of the vision of our project is much appreciated. We would also like to acknowledge the special contribution of Brad Lund, NDTA Executive Director, for his guidance within the world of business, his expertise as a negotiator, and his willingness to join us on a conference call, no matter how early it was on the West Coast.

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To the NDTA Instructors' Group (IG) and the Executive Committee of the IG, thank you very much for your input and guidance throughout this project. The collective expertise of the IG has helped enrich the vision and content of the book and Thieme MediaCenter. Additionally, a special thank you is extended to all who searched for and submitted the perfect photos for Thieme MediaCenter photo gallery.

A few years ago, while attending a physical therapy conference in Las Vegas, Mary Rose Franjoine, purely by chance, met Angelika Findgott, an acquisitions editor with Thieme Publishers. They chatted about the current state of the publishing industry, and about our "*NDT in Action*" project. Angelika agreed to review our proposal, our manuscript, and our multimedia content. Others joined the conversation and it became apparent that Thieme Medical Publishers would be an excellent choice for our text and web-based content. We had found our publishing angel in Angelika. Thank you so very much for your belief in *NDT in Action*, and your expert guidance as we entered the publication process. Additionally, we would like to thank the members of the Thieme team including Deborah Cecere, Nidhi Chopra, Sapna Rastogi, and Anne Sydor for their expert guidance as we progressed through the publication process. Additionally, we would like to thank Michael Blanz for his expertise in editing and readying our photos and videos for Thieme MediaCenter.

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In closing, *Neuro-Developmental Treatment: A Guide to NDT Clinical Practice* grew from an idea to a text with extensive Thieme MediaCenter content. This would not have been possible without the contributions and support of many. Thanks to all for all that you have contributed to the *NDT in Action* project.

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The editors of *Neuro-Developmental Treatment: A Guide to NDT Clinical Practice* would like to extend a heartfelt thank you to Karl Terryberry, PhD, Associate Professor, Daemen College, for sharing his insights, guidance, and expertise. Karl is the author of *Writing for the Health Professions*, which is a foundational text used in medical writing courses across the United States, Europe, and Asia. Karl's expertise as an editor helped merge the individual writing styles of our many contributors and shape the structure and flow of our text. In the fall of 2011, when the editors approached Karl with our project and requested his help, he willingly agreed to assist. A year later, as we began to send drafts, he provided expert editorial guidance, and continued to assist with the revision process for the next 15 months. Karl willingly gave his time and expertise as an editor, embraced our ideas and shared our vision, and helped make this text a reality. Thank you for your wisdom, skill, and generosity.

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Neuro-Developmental Treatment Philosophy, Theoretical Assumptions, and Models Supporting Clinical Practice

1 Neuro-Developmental Treatment: Definitions and Philosophical Foundations *4*

2 Neuro-Developmental Treatment Practice Theory Assumptions and Principles: An Overview *17*

3 Neuro-Developmental Treatment Practice and the ICF Model *27*

4 Application of a Posture and Movement Model in Practice *39*

I

Introduction

Judith C. Bierman

Neuro-Developmental Treatment (NDT) is a clinical practice model used by occupational, physical, and speech therapists who work with people with stroke, traumatic brain injury, cerebral palsy, or other related disorders. NDT was initially developed by the Bobaths in the mid-1900s and is now practiced worldwide. NDT is identified as a problem-solving approach but simultaneously is known for being a hands-on process. The first unit provides a definition of NDT and then lays the foundational concepts for the problem-solving basis of information gathering, examination, evaluation, and intervention. It then describes the philosophical basis of NDT. The philosophy that was initially developed by the Bobaths as a living concept is presented, and then the modifications in the philosophy which have occurred across the past decades are also discussed.

The second chapter discusses theoretical assumptions that serve as a foundation of NDT practice. A group of core hypotheses or assumptions have been gleaned from a wide field of information and applied to form a unique foundation for the practice of NDT. These assumptions are introduced in this unit and are expanded in Unit III which is related to fields such as motor control, motor learning, motor development, plasticity and recovery. Two models are introduced in the final two chapters of this unit allowing the reader to transfer these philosophical and theoretical assumptions into principles for action. The first model presented in Chapter 3 is the International Classification of Functioning, Disability and Health (ICF). This taxonomy was developed to aid practitioners worldwide to label, categorize, and organize information related to health, wellness, or disease. The model has been applied internationally in a wide variety of settings. The particular fashion in which NDT practitioners apply and relate the terms within the ICF model is introduced and demonstrates how a model can guide a practitioner in the overall framing of practice.

Because cerebral palsy and stroke are viewed as being disorders of posture and movement, the final chapter in this unit demonstrates an application of a theoretical model of posture and movement to develop specific principles for intervention and can guide practice. This model demonstrates how to take theoretical assumptions to develop intervention principles and then use those principles to aid in planning the specific strategies and sequences for a single client.

The constant weaving of philosophy with theoretical assumptions lays a foundation for the development of principles for information gathering, examination, evaluation, and intervention that forms a key component of the practice of NDT.

1 Neuro-Developmental Treatment: Definitions and Philosophical Foundations

Judith C. Bierman

This chapter provides a contemporary conceptual/theoretical definition of Neuro-Developmental Treatment (NDT). It then outlines 10 key philosophical tenets that form the foundation of the more specific theoretical assumptions and the practice model that emerged since NDT's origination with the Bobaths in the 1940s. Clinical application examples of each tenet are provided. The chapter concludes with a summary table listing the 10 tenets with associated classical references from the Bobaths or early supportive works by other authors compared with contemporary references from more recently active clinicians or scientific researchers.

Learning Objectives

Upon completing this chapter, the reader will be able to do the following:

- Define NDT.
- Explain the philosophical tenets of NDT.
- Outline the consistencies of NDT since its origin and contrast them with philosophical and theoretical aspects that demonstrate NDT's growth and maturation.

1.1 Introduction

NDT originated with work by Bobath and Bobath[1,2,3,4,5,6,7,8] in the 1940s for the treatment of individuals with neurological disorders of posture and movement. The Bobaths developed the approach specifically to guide therapists who manage and treat individuals diagnosed with stroke or cerebral palsy (CP). This chapter presents a definition of NDT and discusses its basic philosophical tenets. The key components that have remained constant across the years are discussed and the philosophical foundations that have remained constant are presented. The Bobaths, however, viewed their work as a "living concept"[9] that would change across time based on changes in the populations served, the health care system, new clinical experiences, and scientific research.[9,10,11] Therefore, the practice of NDT as well as portions of the philosophy and theory of NDT have changed across time. These changes have been reported in both the literature focusing on pediatric practice as well as that focusing on adult-onset neuromuscular disorders. The summary of changes in NDT practice and the rationale for these changes have been presented by Bly,[12] Graham et al,[13] and Mayston[14] and are included in this chapter.

1.2 NDT Defined

Definition of Neuro-Developmental Treatment

NDT is a holistic and interdisciplinary clinical practice model informed by current and evolving research that emphasizes individualized therapeutic handling based on movement analysis for habilitation and rehabilitation of individuals with neurological pathophysiology. The therapist uses the International Classification of Functioning, Disability and Health (ICF) model in a problem-solving approach to assess activity and participation, thereby to identify and prioritize relevant integrities and impairments as a basis for establishing achievable outcomes with clients and caregivers. An in-depth knowledge of the human movement system, including the understanding of typical and atypical development, and expertise in analyzing postural control, movement, activity, and participation throughout the life span, form the basis for examination, evaluation, and intervention. Therapeutic handling, used during evaluation and intervention, consists of a dynamic reciprocal interaction between the client and therapist for activating optimal sensorimotor processing, task performance, and skill acquisition to enable participation in meaningful activities.[15]

1.3 Philosophical Tenets of NDT

The basic philosophical statements or tenets of NDT are general or global beliefs or assumptions that are too broad to test via research studies, but serve as a foundation of the entire practice model. In the 1940s and 1950s, the Bobaths[1,2,3,4,5,6,7,8,10] developed a new approach to the treatment of individuals with central nervous system (CNS) disorders of posture and movement. Berta Bobath, a physical therapist, found clinically that it was possible for her to change the muscle tone in individuals who had suffered a stroke or who had CP.[1,3,4,7,8] This finding was contrary to the medical understanding of the time.[10] The understanding of motor control at that time was based on Sherrington's[16,17,18] theories of a reflexive hierarchy.

Based on his wife's findings and his own research, Karel Bobath,[6,19] a physician, wrote theoretical explanations for his wife's clinical findings, and he made recommendations based on his readings and understanding of how she could improve her clinical practice. The revised clinical practice led to more questions and additional exploration of the literature that again modified the treatment approach. The discoveries the Bobaths made were formalized in their writings, and the underpinnings of the approach were outlined in descriptions of an overall philosophy, theoretical assumptions, and specific recommendations for the practice of NDT.

The following philosophical tenets are central to NDT and have been consistent across the years, yet these tenets have also grown and developed as Howle described in 2002.[20] These philosophical tenets lay a foundation and provide a framework for the theoretical assumptions and for the practice model of NDT.

1.3.1 Summary of Philosophical Tenets

Therapy Works

Therapists today assume that therapeutic rehabilitation is an effective intervention for individuals with neuromuscular disorders. Therapists routinely develop plans of care that include outcomes of projected changes in participation, functional activities, and body structure and function for the client. There may be disagreements about the best avenue to reach the desired outcomes, but it is routine for physicians to refer patients with stroke or CP to therapists for evaluation and intervention.

This practice, based on the perceived effectiveness of therapy, is contrary to the generally held beliefs of the 1940s and 1950s when the Bobaths began their approach.[10] At that time, it was commonly believed that patients who had suffered a neurological insult could only expect to learn to compensate for their deficits or to seek orthopaedic surgeries for the subsequent contractures or deformities. The historical basis for therapeutic exercise and the dilemmas present in the middle of the 1900s were outlined and addressed in a month-long conference sponsored by the American Physical Therapy Association (APTA). The Northwestern University Therapeutic Exercise Project was held in Chicago and both the conference and the published proceedings came to be known as NUSTEP.[21,22]

Like the Bobaths, clinicians practicing within the NDT framework today believe that the participation restrictions, functional limitations, atypical posture and movements, and impairments associated with CNS disorders can be changed through therapy. Now, however, we have a growing body of evidence to support that belief. Franki et al,[23,24] in 2012, reviewed evidence for basic physical therapy techniques focusing on lower limb function and found positive results. In an additional review, they found that interventions based on a conceptual framework were effective in improving lower limb function. Specifically, they found evidence that NDT was effective in making positive changes in all domains described in the International Classification of Functioning, Disability and Health (ICF)[25] developed by the World Health Organization (WHO).

Evidence is also accumulating that supports NDT's effectiveness regardless of age or diagnosis. Arndt et al[26] focused on intervention with infants, whereas Adams et al[27] and Slusarski[28] reported on the effectiveness in improving gait in children with CP, and Mikotajewska[29] reported the positive results in gait with adults post-stroke with therapeutic intervention.

Therapists who use the NDT Practice Model also believe that therapy works through prevention. Although stroke, CP, and brain injury are defined as disorders of posture and movement caused by nonprogressive lesions to the CNS,[30,31,32,33,34] the literature provides evidence that, although the lesion may not be changing, the expression of the disorder in terms of the presenting impairments frequently does change over time. Therapists using an NDT problem-solving model look for somewhat predictable patterns in the emergence of secondary impairments and related changes in the individual's functional activity. They believe that it is feasible to avoid or minimize the development of some of the secondary impairments by monitoring and altering the individual's posture, movement, and functional activity across time. Therefore, it is important that they understand the expressions of anticipated impairments from specific pathologies and recognize their occurrence across patient populations and ages. This concept is presented in greater detail in Chapters 10 and 11 on CP and stroke, respectively.

The assumption that NDT intervention is effective is further bolstered by the increasing evidence of plasticity of all the body systems across the lifespan.[35,36,37] A hallmark of human function is the adaptability of all body systems, which can be either positive, leading to increased function or participation, or maladaptive, leading to greater functional limitation and additional impairments. This process is evident in everyone, including those who have had a CNS insult. The basic concepts of recovery, plasticity, and compensation across the life span are foundational tenets of NDT; and are discussed in Chapter 15. Thus, NDT practice is applicable whether one is managing a baby in a neonatal intensive care unit (NICU), a child at a school or outpatient clinic, a teen with a traumatic brain injury being followed in a rehabilitation facility, or an elderly individual at home who had a stroke later in life.

Treat the Individual as a Whole

Since the development and inception of NDT, the clinician has been encouraged to evaluate and treat the client as a whole person.[20] Therapists view an individual who has had a stroke or who has been diagnosed with CP as a unique individual, not as someone with a spastic arm or a hypotonic leg. This philosophy may best be illustrated by sharing one individual's story.

Mike was 21 years old when his parents brought him for therapy. They were interested in obtaining a wheelchair for their son. Mike had been diagnosed in infancy as having severe CP, and his parents had not been given much hope for managing his condition, or even for his survival.

It became clear that he had a mixed form of CP with elements of spasticity and athetosis that were evident in all four limbs. Mike was the first child of his parents and lived in a rural setting. He had never attended public school and, in fact, had not been out of his mother's sight since his birth. He slept in the same room with his parents due to their persistent fear that he might die in his sleep.

Mike demonstrated multiple and severe functional activity limitations. He could not roll over in bed, he could not sit without support, and he could not walk, even with an assistive device. He had to be carried everywhere. He was dependent for all activities of daily living (ADLs) and, in fact, was still fed pureed foods from a baby bottle with the nipple cut open. He could not speak, but he could communicate using a tapping system with one arm to spell out words. Four taps for a *d*, 15 for an *o*, and 6 for a *g*. He also knew Morse code and could communicate via a shortwave or ham radio.

A team of practitioners evaluated Mike, covering various systems and facets of the condition. The team included an occupational therapist (OT), a physical therapist (PT), a physician, a psychologist, and a speech-language pathologist (SLP). In the initial team meeting, Mike's evaluations determined that he was healthy. He had not experienced the anticipated respiratory ailments suggested in his infancy, and his cardiac assessment showed normal function. He did not demonstrate any of the frequently associated disorders, such as seizures. He did not have primary sensory impairments, such as poor vision or hearing. Additionally, the psychologist reported that, although standardized testing was difficult to administer, testing could estimate that his IQ was above 130.

Here was a young man who had a single system (neuromuscular) with impairments, yet this one system negatively influenced his overall quality of life, limited many of his activities, and restricted his participation. The complexity of his situation became clearer when he was asked what he would like to work on in therapy. He replied that he would need time to think about it. The next week he returned and delivered a goal statement, which he had dictated to his mother, stating, "I would like to be able to go to McDonald's by myself, order a Big Mac, French fries, and a chocolate shake, pay for it with my own money, go to the table, eat it, and then leave." He wanted independent mobility in the community (does that mean drive there?) and within a relatively crowded restaurant. He wanted to communicate with staff at McDonald's. He wanted to pay for it with his own money, reflecting a work ethic and interest in employment that was consistent across time. He wanted to feed himself the approximately eight different textures in the Big Mac and to consume the age-appropriate diet. He wanted to be by himself instead of with his mother.

He did not say that he wanted head control or that he wanted better strength or more normal tone. He wanted to be able to participate fully in life, just as any another 21-year-old would report. Mike demanded that we evaluate and treat him as a whole person. We, as therapists, should not look at him as someone with stiff and poorly controlled legs and arms or someone who gags on pureed foods. We must look at him and his desired participations, his functional activities and limitations, and all of his system integrities and impairments within the scope of all of his contextual factors.

Due to this vision, of full participation, OTs cannot exclusively work with the arms and hands, PTs the legs, or SLPs the mouth to achieve the optimal discipline-specific outcomes. For example, for an OT to work with a client to develop a reach overhead, she might be required to work with the client to develop a more stable base from the individual's trunk and lower body. Or in a different case, in order for a client to speak loudly enough to be heard by peers in a crowded cafeteria, the SLP may be required to address thoracic mobility, abdominal strength, and pelvic stability to forcefully control the air flow during phonation. In addition, therapists representing different disciplines cannot hold sole responsibility for addressing a specific system impairment, such as OTs only addressing the sensory impairments or PTs only working on strengthening. The clinician must treat the person as a whole being. The NDT clinician works with the person who has had a stroke or who has CP. The therapist is not just intervening with the neuromuscular impairment nor the ineffective posture and movement. The therapist is not developing a specific functional activity from a menu of generally recognized or developmentally important functions or even encouraging the generalized development of participation. The NDT clinician works with a person and perhaps that person's family, friends, and colleagues. A key philosophical tenet of NDT is to focus on the *whole person* in intervention planning and implementation. The NDT Practice Model includes this key element at every stage of evaluation and intervention.

The Purpose of Therapy Is to Increase the Individual's Participation and Activity

Clinicians using the NDT Practice Model view the desired outcomes of intervention to be improved functional activities and increased participation that are valued by the individual. Therapists know that they must simultaneously minimize impairments and work to avoid potential future disabilities that might develop based on ineffective posture and movements.

From the beginning of their work in this field, the Bobaths identified a relationship between an individual's functional activities and participation in societal roles and underlying issues of posture and movement based on the interactions of all of the body systems. Initially, they described a focus in therapy on developing more typical postures and movement to permit greater skill or functional ability.[7,38,39,40] Clinicians now focus on increasing functional activities or participation through addressing specific impairments in the person's posture and movement and individual body system impairments.[15,20] Across time, the Bobaths' work encouraged therapists to focus on function. As early as the 1970s, their work and research encouraged therapists to work in functional contexts.[9,10] In work with a 2-year-old with CP, for example, therapists could position the child on a potty seat rather than a piece of therapeutic equipment, such as a ball or bench, to help the child develop sitting balance.

Understanding the interaction of functional activities or limitations with related single- and multisystem integrities and/or impairments through careful and ongoing analysis is foundational within the practice of NDT. There is current support for this concept by Saether et al,[41] who reviewed the relationship of trunk control for sitting and gait in children and adolescents with CP. In addition, Curtis et al[42] performed a retrospective study relating trunk control to multiple activities or functional outcomes.

It is also important to consider the influence of multiple contextual facilitators and barriers on those activities and/or limitations. This analysis or problem solving is imbedded throughout examination, intervention planning, and intervention implementation.[15] It is included in home programming with recommendations of how to integrate therapeutic activities into daily life rather than by providing a separate list of exercises to be completed by either the individual or caregivers.

The ICF[25] model clearly defines and outlines different domains of human health and/or disability. This model, developed by the WHO, organizes, labels, or categorizes concepts of health and disability worldwide. It provides the terminology for describing how a practitioner using the NDT Practice Model addresses activity limitations in relationship to body system impairments within specific contextual factors and will be described in greater detail in Chapter 3. Ultimately, the person's function is explored at a body system level, an individual level, and the level of societal roles. Each domain is also viewed within contexts of the individual and the environment. In the NDT approach, the relationship and interactions of these domains are critical. The ongoing relationships of these in evaluation, intervention planning, and intervention are presented in NDT Practice Model.[15]

Build on the Individual's Strengths while Addressing Impairments

The medical rehabilitation model has a history of being a problem-oriented model for care. Individuals with health care needs seek treatment from health care providers who develop interventions to minimize or manage the impairment. The ICF model reflects a change in the approach to care.[25] The ICF model has now moved from identifying a separate health or wellness domain and a separate one of disability to viewing each domain as a continuum from health to disability. Every person is viewed as having aspects of health and disability.[25] The NDT clinician, building on this perspective, expects strengths in every individual and builds an intervention plan based on those strengths. The therapist identifies the strengths in every domain (participations, activities, and system integrities) within the ICF model as well as the participation restrictions, activity limitations, or body structure or function impairments. These strengths are then foundational in planning intervention and in the implementation of the plan on a moment-to-moment basis. The NDT plan of care builds on those strengths rather than only addressing the problems.[15]

Mike, presented earlier in this chapter, was engaged in initial problem solving based on the strength of his intellect. He could use his ability as a good problem solver to aid in solving motor problems encountered in daily life. He also, however, had integrities in several of the body systems where he also had identified impairments. For example, Mike had impairments of the neuromuscular system that contributed to limited motor control in his trunk and all four limbs. However, he demonstrated enough motor control of his upper extremity to communicate via his tapping or use of a radio device for Morse code. During intervention, this effective posture and movement control was built upon and modified to help him develop the skill to control a joystick on a powered wheelchair and to access a more widely acceptable augmentative communication device. Another example is that Mike had nearly full range of motion, so it was possible to work in supported postures with better alignment to develop the graded control in the lower extremities for transfers. The therapist and Mike not only focused on the abnormal control and coordination of the neuromuscular system but worked to build better control and coordination based on the integrities of the musculoskeletal and sensory systems as well as those in the neuromuscular system.

Individualize Intervention

The previous philosophical tenets demonstrate that intervention must be individualized.[15] Using a prescribed set of exercises or implementing a specific, rigid treatment protocol is not a part of NDT. A hallmark of NDT is that it is a problem-solving process that requires ongoing evaluation and modification of the intervention during the entire process.[9,10,20,43] The decision-making process for therapists planning intervention for complex individuals is difficult. Rothstein and Echternach[44] developed the Hypothesis-Oriented Algorithm for Clinicians (HOAC) in 1986 to provide a systematic method for clinical decision making in physical therapy that is independent of the overall treatment philosophy. Included in the eight-step method is the formulation of hypotheses or clinical impressions or predictions at several points of the intervention process.

The evaluation process within the NDT Practice Model begins with information gathering and examination of the individual across all domains of the ICF model. The problem solving starts with the analysis of the relationship of the critical activity limitations and participation restrictions with the underlying body structure and functional impairments. A specific clinical hypothesis of which impairments should be addressed first and in what functional contexts is formulated in an intervention plan. The resulting individualized plan is implemented by the clinician.

However, when implementing the proposed intervention plan, practitioners also include ongoing evaluation. The clinician observes and consistently analyzes the session to determine if the desired outcomes are emerging. Were the initial hypotheses accurate? or do they need modification? In principle, the clinician works in the microseconds and millimeters of examination, evaluation, and intervention suggested by Quinton, in her writings, in her teachings, and in personal communications with other authors and practitioners such as Nelson and Howle.[20,45,46] The therapist does not plan a series of intervention sessions and then reevaluate at the end of the session, the end of the week, or the end of the month or year. Instead, the therapist observes, monitors, palpates, and evaluates every microsecond. The NDT clinician is constantly asking, Is this better or not? Is this the most efficient avenue to success? Should we modify the session and use a different strategy? This problem solving is the hallmark of NDT. NDT is not the regimented use of a specific handling strategy.[15]

Additionally, the therapist also works in millimeters.[45,46,47,48] As an individual moves from prone to sitting, for example, the therapist evaluates the transition being performed during every millimeter of the transition. It is not sufficient to examine the entire transition to determine the level of success. It is necessary to observe where in the transition change occurs. The clinician asks, Where in the transition does the individual have more or less control? Where is it necessary for the therapist to add or lessen the assistance that is given?

The evaluation, plan, and intervention are individually tailored. The intervention is based on the interaction of all the person's body systems, on the mix of effective and ineffective posture and movement, on the functional activities and activity limitations, on the participation and participation restrictions, and on all of the contextual factors that significantly influence and challenge the person.

The intervention is individualized not only because it is based on differences in the person to be treated, but it is also unique in that the therapist provides the intervention and its setting. The process is interactive, based on the individual, the therapist, and the entire team. For example, a therapist who is very tall but not flexible will practice differently than a therapist who is short, very flexible, but perhaps has less midrange control. The taller therapist may be able to stand behind the client and assist ambulation from the client's shoulder girdle or sit on a rolling stool behind the individual when working at the pelvic girdle. The shorter therapist may need to stand behind the individual to do the pelvic girdle stabilization or may need to face the individual from the front to guide ambulation from the wrists or upper body. No single strategy will apply to all therapists in all intervention scenarios.

The intervention will vary if it is offered in the home versus an outpatient clinic or a classroom. It will differ based on the overall health care and educational environment. The NDT Practice Model reveals how individualization is built into all aspects of evaluation, intervention planning, and intervention. This tenet is also a rationale for the inclusion of multiple case reports in this text. It is important to demonstrate how examination and intervention are modified based on the individual being served, the clinician providing the services, and all of the contextual factors influencing the case.

Treat in the Past, Present, and Future Simultaneously

The intervention plan considers individual differences but simultaneously takes into account the person's past, present, and future.[45,46,47,48] Patients' personal and family histories are important. For example, a 60-year-old patient admitted for inpatient rehabilitation following a stroke is initially found to be depressed and somewhat resistant to therapy. His personal history reveals, interestingly, that, as a young man, he had been an Olympic athlete in downhill skiing. Once he and the therapist tap into his athletic abilities and channel his competitive nature, his rate of progress can be accelerated. Compare that scenario to another 60-year-old gentleman who had retired 10 years previously due to emphysema and who had always lived a sedentary lifestyle. This individual was more concerned about missing his TV programs than attending therapy sessions. The intervention for these two gentlemen with similar strokes would need to be significantly different.

This same tenet applies to intervention with a child. Consider, for example, Brian, a 2-year-old twin born prematurely with CP. Since his birth, Brian was irritable, especially at night. Because of his irritability and crying episodes, his parents were sleep deprived, and his mother struggled with participation in therapy if it resulted in any more crying. The mom, at times, needed the time while Brian was at therapy to complete household errands or to care for Brian's twin, who also had special needs. Although the therapist routinely encouraged many mothers to be present during the sessions to learn handling strategies to incorporate into the daily life routine, for this mother with this child, it was better for the therapist to share information at the end of the session rather than throughout the session.

The patient's immediate concerns are also significant in the delivery of intervention services. If a woman arrives later for therapy due to a traffic jam, the intervention will be different than if the same woman arrives following a smooth schedule. A child who just finished a meal who has significant reflux will be managed differently than if therapy began 4 hours after the previous meal. Individuals with disorders of posture and movement have good and bad days, just as everyone else does. The difference, however, is that the good and bad days can more significantly alter the functional abilities, posture and movement, and individual system function and, therefore, the outcomes of intervention. The clinician must be ready to modify intervention based on the day-to-day and even moment-to-moment changes.

Finally, the future plans of individuals and their family can influence the intervention strategy. The plan of care for an individual who will be discharged from a rehabilitation facility to live at home with a supportive and healthy spouse differs from that for a person who can no longer live independently at home and will be discharged to a nursing home. Intervention can be altered if the person plans on returning to work or is planning to move in with an adult son or daughter. Likewise, plans must be modified to accommodate a child who will attend a school in the neighborhood or a child who will be provided homebound education. The person's hopes, dreams, and aspirations for the future change not only the plan but also the specifics of intervention.

Teamwork Is Critical for Best Care

The NDT clinician evaluates and manages each person as a whole and sees each person as a unique being. Because of this approach, the clinician develops an individualized plan of care. In many cases, a team of service providers is necessary to best achieve the desired functional outcomes.[15] The individual seeking intervention is included in every feasible way in the assessment, planning, and intervention process. The family and caregivers are viewed as key members of the team. Many individuals are managed not only by a variety of therapists (OTs, PTs, and SLPs), but their care may be managed by a large health care and/or educational team of professionals. This team can include physicians from a wide variety of specialties, such as primary care physicians, physiatrists, neurologists, orthopaedists, internal medicine specialists, and others. The individual may receive consultations from nutritionists, nurse practitioners, or social workers. If the individual is a child, the educational team may include a school-based team of therapists as well as teachers, psychologists, and paraprofessionals. The family and clinicians must also work with facility administrations, third-party payers, and governmental agencies. In order for optimal care to be provided, services must include the coordinated efforts of all team members. No one professional is able to address all the individual's needs, and each professional's outcomes are enhanced when working with other professionals. Although many approaches rely on teamwork as a key element, NDT has stressed this concept since its origination, and the formal continuing education currently provided in the field stresses an interdisciplinary intervention process.[15] Because this book focuses on the therapists' roles in the rehabilitative process, Chapters 16, 17, and 18 examine the unique contribution of OT, PT, and SLP, and how each discipline works with the other disciplines. However, the bulk of text is written to be applied within all disciplines.

Typical Development Provides an Important Framework for Examination and Intervention

Therapists using the NDT Practice Model recognize that there are general patterns in the acquisition of skills during typical development and maturation.[15,49,50,51] These consistencies can provide a standard of reference for proficient human motor function for the therapist to use during examination and intervention. The Bobaths initially maintained a relatively rigid application of the sequence of motor skill acquisition in developing treatment plans.[39] With time, however, the application of this principle has shifted to one that encourages clinicians to examine the emergence or loss of functional activities based on the relationships of posture and movement and the body system structures and functions across the life span.[20,49,50,51] The therapist can hypothesize the relationship of body structure and function integrities and/or impairments to changes in functional activities or activity limitations during examination and evaluation of the client across time. While developing the individual plan of care (POC), the practitioner may then be better able to identify prerequisites related to body structure and function domain necessary for the client to achieve the desired functional outcomes.

Through examination the therapist may identify the differences in individuals with typical developmental variations and those with atypical or maladaptive motor development. In addition the therapist may use a specific posture or movement strategy typically used to master a specific skill to achieve the same desired outcome during intervention with an individual with atypical or maladaptive development.

The case study concerning Mike allows for further application. Mike could easily be evaluated using many developmental tests and be identified as functioning below the level of a 2-month-old. He could not lift his head. He could not roll or sit. He ate only from a bottle. He could not help with dressing or hygiene. He could not speak words. However, in a holistic assessment, he was nothing like a 2-month-old. His height and body proportions were significantly different from those of a small infant. His joints showed the onset of arthritis. His wealth of experiences and many functional abilities were far outside the scope of an infant. The therapists could not and should not try to duplicate a developmental sequence that does not address his current functional needs. However, the therapist can learn a series of valuable lessons that can guide the therapeutic process. For example, Mike demonstrated poor balance of the trunk flexors and extensors that negatively influenced his ability to function in rolling, sitting, and standing. The clinician could ask a series of questions to guide the intervention process to meet the goal of improved balance, including the following:

- What are the sensory contributions from vision and somatosensory awareness?
- What range of motion is needed?
- What strength is needed?
- How do these components develop via the handling and daily functional activities of living?

The therapist could apply supported upright postures to develop the interaction of all the body systems that lead to improved head and trunk control. Instead of improving control as done by a parent holding a small baby upright supported against the chest, Mike's therapist could accomplish the same task in a partial body weight support system or in a stander. The typical developmental process does not dictate the intervention activities. It does, however, provide another framework for guiding the examination and intervention process.[15]

Positive outcomes derive from evaluation and intervention for individuals with CNS disorders based on the therapist's understanding of typical development. This understanding includes the analysis of the typical acquisition of functional activities, improved control and coordination of posture and movement, and maturation of individual body systems. This information must then be compared, contrasted, and integrated into the understanding of the somewhat predictable patterns that emerge in individuals with CP or for those who have had a stroke. Bly compared and contrasted the components of movement in babies who demonstrate typical development and those with atypical development.[50] Once again, it is necessary to evaluate or assess all domains, including that of limited skill acquisition, the development of less effective posture and movement, and the presence of primary and secondary impairments.

Active Carryover throughout Daily Life Is Important for Best Care

Clinicians using the NDT Practice Model believe that it is critical to plan and include activities to promote the carryover of therapeutic intervention into the individual's home, school, work, and/or community life.[20,52,53] Achieving performance standards during therapy is worthwhile but does not have the same value as promoting functional activities in real-life situations or in increasing participation in these environments. Because of this belief, each session includes specific recommendations of how to incorporate therapeutic activities throughout the day. The purpose is not to perform a series of exercises or engage in therapy each day at home, but to change how a person dresses himself or sits at the table, or how a parent carries a child to help achieve better posture and movement to enhance function and to minimize impairments. Consequently, because of this belief system initiated by the Bobaths,[9,10,52,53] the role of home programs has expanded across the years to include more motor learning strategies. Carryover through home, work, community, or school programming is a critical aspect of NDT.

NDT Reflects a Hands-on Intervention Process to Enhance Outcomes

The NDT Practice Model has always included the use of hands-on intervention.[15,20,45,46,47,48,52,53,54,55] A central philosophical tenet is that handling is a natural method to help others learn the optimal or necessary postures and movements for specific functional activities. Parents of typically developing infants use their handling to help the child learn to hold up her head or to help the child develop the balance necessary to ride a bicycle alone. Teachers of motor skills, such as in ballet or swimming classes, assist learners by guiding movements or supporting postures during the learning process. This tenet of the NDT philosophy begins with the assumption that physical guidance is a part of human relationships in teaching and learning situations that expands when one is working with individuals who have disorders of posture and movement.[15] These individuals may need more assistance or specific assistance to perform desired tasks with the appropriate posture and alignment. These individuals with neuromuscular impairments may not benefit from typically structured practice. The parents of a child who has CP know that just providing opportunities to practice head control or to balance on the bicycle is not sufficient for their child to perform the task. The inclusion of handling and the belief that therapeutic handling benefits people with neuropathology have separated NDT from many other rehabilitative approaches.

Handling is included as a strategy in the evaluation as well as in the intervention process.[15] Therapeutic handling allows the therapist to feel the individual's postural set and responses to shifts in posture and movement during functional activity. Handling can provide boundaries for safe posture and movement as the individual learns to perform new tasks, and handling can be used as a form of feedback on motor performance.

Additionally, the therapist can also use handling to facilitate or inhibit specific postures and movements. Facilitation is used to encourage or make specific postures or movements more likely to occur. For example, sitting with an erect spine can be encouraged by placement of the therapist's hands in the middle of the thoracic spine. Contrastingly, a therapist can inhibit a posture or movement that may be counterproductive to performing the desired task. A particular posture or movement pattern may also be inhibited if repetitions of it could lead to the development of secondary impairments, greater functional activity limitations, or participation restrictions.

Handling should not be confused with passively moving the person through transitions. The individual is always encouraged to be as actively involved as possible. With minimal involvement, a person may be able to transition from sit to stand with the therapist providing subtle input to keep the body weight from shifting too far posteriorly or anteriorly. During the same transition, an individual with more severe involvement may need assistance to lift the body weight, to activate the appropriate muscles, and to guide the direction and magnitude of the weight shift required. The clinician practicing within the NDT framework monitors the response to handling and works to reduce the amount of handling provided to aid the person in gaining greater independence and therefore a better quality of life.

The Living Concept: The Integration of Classic NDT Tenets with Current Scientific Findings and Principles of Neuroplasticity, Motor Control, Motor Development, and Motor Learning

In their extensive writings, the Bobaths expressed each of the basic philosophical tenets presented in this chapter. The original assumptions and observations developed by the Bobaths are all referenced in writings of that time. In 1991, Bly contrasted a historical and current view of NDT to stress the ongoing growth of the practice of NDT.[12] Ten years later, Howle provided a historical perspective on the development of the basic assumptions that were built on Berta Bobath's clinical observations in the final chapter of *Neuro-Developmental Treatment Approach: Theoretical Foundations and Principles of Clinical Practice*.[20] Howle's historical summary chapter is included in its entirety at MediaCenter.thieme.com.

Therapists who use the NDT Practice Model also are aware that some of the core concepts introduced by the Bobaths in the second half of the last century are now being professed by current scientists and practitioners. For example, Merzenich,[56,57] identified by many as the father of neuroplasticity, outlined basic principles of neuroplasticity and principles for best practice or brain plasticity–based therapeutics. He developed these principles by summarizing his previous research findings and the findings of other scientists' research rather than by observing clinical therapeutic practice to determine the most successful strategies. This process is the opposite of the method employed by the Bobaths, who began with clinical observations that were later supported by the literature available at the time. Yet, in comparing the lists of principles, one finds striking similarities. In addition, there are many examples of findings derived from the study of motor learning, motor control, and motor development that support the principles which the Bobaths established decades ago. Other examples of clinicians now verifying early assumptions made by the Bobaths are found in the reports by Saether et al[41] and by Curtis et al[42] in 2015 on the relationship between trunk control in sitting and during gait in children with CP. In addition, the Bobaths' assumption that trunk control was foundational for the development of functional tasks was presented in early writings by Davies, focusing on NDT treatment for adults with hemiplegia.[54,55] Unit III, which describes theoretical support for NDT, outlines these principles and much of the supporting literature in greater detail. **Table 1.1** summarizes some of the current evidence that supports NDT principles that are also presented in the early writings of the Bobaths.

1.4 Summary

The initial concept of NDT was a “living concept”[9] with anticipated growth and modification across time based on changing scientific knowledge, health care policies and practices, and populations served. Because of this concept, modifications of the philosophical tenets across time were introduced to NDT. Although growth has

Table 1.1 A comparison of Neuro-Developmental Treatment (NDT) principles described early in NDT and in 2015

NDT philosophical tenet	The Bobaths: classical references	Contemporary scientific support and resulting principles for best practice
Therapy works.	Berta Bobath reported that it was possible to decrease hypertonus in individuals with central nervous system (CNS) deficits based on her clinical observations.[1] The CNS was capable of recovery and development after injury and could be influenced by sensory feedback from the most effective motor output.[43,58] David Scrutton reiterated the impact of the NDT approach on the practice of therapists in this editorial after the Bobaths' death in 1990.[11]	“Brain plasticity is an incredibly valuable resource in ***every*** brain.”[57] There is evidence that exercise is good for your brain function.[59,60] For examples of this work look at a summary by Ratey and Hagerman.[61] These articles provide evidence as to the effectiveness of NDT: Evans-Rogers et al[62] reported on outcomes of short-term intensive NDT intervention based on parental perspectives and functional outcomes; Girolami and Campbell[63] reported on the efficacy of NDT treatment for infants born prematurely and found improved motor control; Arndt et al[26] report on the effectiveness in an NDT-based trunk protocol in infants. There are several reports on gait remediation in children using an NDT approach with articles by Adams et al,[27] by Slusarski,[28] and with adults post-stroke by Mikołajewska.[29] Franki et al[23,24] completed two systematic reviews on the evidence regarding conceptually based intervention that included NDT within the studies. Recent literature on efficacy of treatment of NDT is looked at more in terms of evidence-based practice (EBP). The concept of EBP and NDT is reviewed in the introduction to Unit V of this text, followed by multiple case reports that provide evidence of the effectiveness of NDT for a wide spectrum of clients across the life span, across diagnoses, and across a wide spectrum of the severity of impairments.
It is important to treat the individual as a whole.	Cerebral palsy (CP) or stroke affects the entire individual in life roles. All of the problems—posture, movement, communication, hearing, vision, perception, and socializing are related.[58,64,65] “The sensori-motor problem of the child is the one that embraces all other problems, which include the emotional, mental and social difficulties. . . .Sensori-motor development is the basis for all our experiences, for all our learning, for our ability to adjust ourselves to the environment, to the people we live with and to the objects we have to handle. If we want to treat the whole child, we have to start from there.”[66] Mrs. Bobath observed that reduction of tone at one joint produced overall tone changes.[3]	Merzenich developed a list of neurological principles to govern or guide best practice in rehabilitation.[57] Several of the principles provide support for the Bobath principle of treating the individual as a whole. They include the following: “It's not about perception or cognition or action control. It's *always* about perception *and* cognition *and* action control.”[57] “No one told the brain that it is supposed to compartmentalize its different actions and feelings and concepts into different neurological boxes.”[57] “Move with your whole body.”[56] “As you move, focus on the feeling of the flow of that movement.”[56] “Consciously remind yourself that you have a whole body made up of parts that work best when they work together.”[56]

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Table 1.1 A comparison of Neuro-Developmental Treatment (NDT) principles described early in NDT and in 2015 *(continued)*

NDT philosophical tenet	The Bobaths: classical references	Contemporary scientific support and resulting principles for best practice
The purpose of therapy is to increase the individual's participation and activity.	"In considering these problems, one must remember that one deals with a . . . .total personality with special needs, emotional, intellectual, and social. An evaluation . . . requires the study of his place in the family as well as the extent and quality of his physical handicap, both sensory and motor."[67] Berta Bobath emphasized that, for treatment to be effective, everyone involved with the client's program, including the family, teachers, and therapists, must provide opportunities for treatment in daily life situations.[39,43,64,65,66] In 1979, Mrs. Bobath outlined the components of examination and treatment of children with CP.[9] Examination began with the observation of how the mother, family, and child played or interacted. It moved to observing functions and then hypothesized as to what limited the functional activities. Intervention was based on the decision of which functional limitations were most critical and hypothesizing as to the causes of those limitations. Thus the aims of treatment were to improve the movement most needed for function.[9,67]	Evans-Rogers et al[62] reported that parents found that their children made functional improvements following intensive NDT intervention. In addition, significant improvements were found in both Goal Attainment Scale (GAS) and Canadian Occupational Performance Measure (COPM) mean scores after the 1- to 2-week intensive NDT intervention. "When conditions are right, your brain advances."[57] "Change *only* occurs when it *matters* to you (your brain)"[56,57] "Change is mostly limited to those situations in which the brain is in the mood for it. If I am alert, on the ball, engaged, motivated, ready for action—the brain releases those chemical modulatory neurotransmitters that enable brain change."[56] Gluck et al[68] provide an overview of how plasticity occurs when the task is important to the individual and when the individual is attentive. "Stereotypy is the enemy. No brain can learn the *rules* of action on a platform of stereotypy."[56,57] In chapters on examination and evaluation in this text, Stamer includes the contemporary view of beginning the assessment with looking at function and participation and moves to the importance of developing functional outcomes not only for short- and long-term time frames but also for each intervention session. This principle is included in this text in Chapter 9 on intervention. In Chapter 13 of this text, Howle's description of motor learning includes a list of NDT assumptions that emphasizes the importance of function or participation for motor learning. An example of one of the assumptions presented by Howle is that "Effective motor learning requires tasks that are goal directed, meaningful, attainable, and of moderate difficulty for the learner" (p. 264). This assumption is supported by Gordon and Magill[69] and Mastos et al.[70]
Build on the individual's strengths while addressing impairments.	Mrs. Bobath encouraged therapists to begin by identifying the individual's abilities and limitations, quality of posture and movement, and the potential for change.[9,67,71]	Jette[72,73] describes the need for a common language in health-related research as well as the trend to move from more of a problem-oriented practice as presented in earlier taxonomies, such as in Nagi[74,75] or the National Center for Medical Rehabilitation Research[76] to current International Classification of Functioning, Disability and Health (ICF).[25,77] The ICF model presents a continuum for each individual from one of health and wellness to one of disease and disability. In Chapter 3 of this text, Bierman presents how those working from an NDT perspective use the ICF model. This concept is then demonstrated in Chapters 7, 8, and 9 on examination, evaluation, and intervention as well as in each case report.
Individualize intervention.	Treatment is a problem-solving process that is flexible enough to be adapted to the impairments of the individual client.[43] The assessment should enable the therapist to make a treatment plan directly related to the individual patient's main difficulties and needs and individually developed goals.[9,10]	Our personal experiences powerfully differentiate our neurology. "'One size fits all' is nonsense. It's all about *personal* therapeutics. All useful training is adaptive (progressive). There is an ideal 'step (challenge) size' for all progressive training."[57] NDT practitioners have always presented the practice as a problem-solving approach and avoided all attempts to develop a "cookbook" of techniques. This is evident in Stamer's Chapter 5 on the NDT Practice Model and in Unit V, which applies the entire book to specific individuals with neuromuscular disorders. Each chapter and case report is referenced with contemporary works that support the examination, evaluation, or intervention selected for that one individual.

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NDT philosophical tenet	The Bobaths: classical references	Contemporary scientific support and resulting principles for best practice
Treat in the past, present, and future simultaneously.	The therapist should decide what is most important for the child to participate in new functional activities or for the performance of current skills to improve in quality.[58]	Quinton presented the concept of a "competition of movement patterns" in her teaching and writings.[45,78] This concept is represented in the more contemporary theories of motor control, such as Neuronal Group Selection Theory[79,80] and the Dynamic Systems Theory.[81,82,83,84]
Teamwork is critical for best care.	The Bobaths wrote from the onset that, due to the fact that it is necessary to treat the individual as a whole, it was necessary to employ a team approach to be most effective. NDT continuing education courses have been interdisciplinary from the very early years.[58,66,67]	One of the major themes expressed by parents and reported by Evans-Rogers et al[62] of children receiving NDT intervention was the benefit of the teamwork between therapists of different disciplines. NDT certification courses have from their inception welcomed physical therapists, occupational therapists, and speech-language pathologists as participants to reflect the importance placed on team interaction in the delivery of services.[85]
Typical development provides an important framework for examination and intervention.	In 1952, Mrs. Bobath wrote, "The normal child develops his motor patterns in a regular sequence. He progresses from one motor activity to the next in definite steps, preparing for one stage by vigorous exercise and constant practice. . . . The more difficult task is only undertaken after the less difficult one is fully mastered." She continues, "In the spastic child development is not simply arrested, but owing to the child's effort to overcome the handicap, [the developmental] sequence is interfered with and it becomes patchy and uneven."[86] The Bobaths initially wrote that it was important to teach control of movement by following a developmental sequence.[3,10,86] However, as they learned and modified their understanding they stated, "Treatment should not attempt to follow the sequence of development described regardless of the age and physical condition of the individual child. Rather it should be decided what each child needs most urgently at any one stage or age and what is absolutely necessary for him to participate for future functional skills or for improving the skills he has but performs abnormally."[87] In 1984, the Bobaths updated their views by saying, "Development does not proceed in a definite sequence. . . children develop many activities simultaneously, which reinforce each other to culminate in a 'milestone.'"[87]	"Implicit abilities critically support more complex (higher level) abilities. You can't construct a good building without a solid foundation."[57] Multiple NDTA course instructors have published on the topic of typical development from an NDT perspective. Bly,[47,49,50] and Alexander, Boehme, and Cupps[51] have described the development of babies with typical motor function. Quinton also discusses the relationship and competition of typical and atypical posture and movement in her works.[45,78] Howle discusses the concept of motor development within the practice of NDT in Chapter 14 of this text.
Active carryover throughout daily life is important for best care.	The Bobaths wrote of their support for the importance of carryover in daily life in the introduction to the Nancie Finnie's *Handling the Young Cerebral Palsied Child at Home*.[88] This text detailed how specific handling and positioning as espoused by the Bobaths could be performed in daily activities, including play and activities of daily living. This concept was presented in many of the Bobaths' early works.[43,67,89]	Merzenich reports that active carryover of therapy is needed for best care.[57] Evans-Rogers et al[62] reported that families valued the individualized home program sessions based on the goals the parents and children had established.

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Table 1.1 A comparison of Neuro-Developmental Treatment (NDT) principles described early in NDT and in 2015 *(continued)*

NDT philosophical tenet	The Bobaths: classical references	Contemporary scientific support and resulting principles for best practice
NDT reflects a hands-on intervention process to enhance intervention outcomes.	Berta Bobath described the use of therapeutic handling in articles over many years.[64,66,89,90,91]	The importance of the role of handling is so critical to the practice of NDT that it is mentioned 12 times in Stamer's Chapter 5 on the NDT Practice Model in this text. Specific guides on handling as key aspects of treatment include those by Bly[47,48] and by Quinton.[45,46] Handling has also been supported by others, including Harbourne et al,[92] who found that infants in a perceptual-motor intervention group who received movement guided by a skilled therapist showed greater variability and exploratory behavior in sitting, whereas those in the home program group actually decreased variability.

occurred, there remains a core of philosophical tenets that are foundational to NDT practice. Other approaches may include one or some of these same philosophical tenets, but the combination and integration of all of the tenets described in this chapter render the practice of NDT unique and recognizable.

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2 Neuro-Developmental Treatment Practice Theory Assumptions and Principles: An Overview

Judith C. Bierman

This chapter begins with a brief explanation of the clinical importance of theories, assumptions, and principles of intervention to guide and aid in decision making within the Neuro-Developmental treatment (NDT) framework. Three categories of questions are presented to organize the development of a theoretical foundation for NDT practice. The chapter then presents an introductory synopsis of the core theoretical assumptions within NDT practice. Related clinical principles for examination, evaluation, and intervention follow each group of assumptions. Each element will be expanded, explained, and demonstrated in later chapters of the text.

Learning Objectives

By the end of this chapter the reader will be able to do the following:

- Define and apply to the clinical practice of NDT the terms *hypothesis, theory, assumptions,* and *intervention principles.*
- Describe three core questions that organize the NDT theory, assumptions, and principles.
- Describe basic assumptions that comprise the NDT Practice Theory.
- Identify core principles of NDT intervention that are based on the NDT assumptions.

2.1 Organizing Problem Solving for Clinical Practice

As a therapist formulates a plan of care (POC) for an individual who is beginning intervention, an immediate decision must be made as to what to do first. What are the important issues that should be addressed? What can be safely ignored? How should the session be organized? A recommended avenue for answering these clinical questions is for the clinician to review the evidence. What evidence is available to help the therapist who is to evaluate or manage a client who has had a stroke or a child with cerebral palsy (CP)? How easy is it to access the source? What do experts in the field recommend? What is the clinician’s previous experience? And, what should the therapist do if there is limited evidence to guide decision making? What if the issues being addressed are very complex or very unique? At this point the therapist begins a clinical problem-solving process based on combining any evidence that is available, observing the individual, and gathering information concerning the family goals.

2.1.1 Shaping Clinical Practice through Hypothesis Generation, Theories, Assumptions, and Principles

The therapist needs to develop a set of clinical hypotheses to guide the intervention process. A *hypothesis* is “a tentative explanation for an observation, phenomenon, or scientific problem that can be tested by further investigation.”[1] Hypotheses can help to direct both assessment and intervention. One example of framing clinical hypotheses in physical therapy is the Hypothesis-Oriented Algorithm for Clinicians (HOAC), described in the work of Rothstein and Echternach.[2] The therapist who uses the NDT Practice Model to develop a plan of care (POC) could hypothesize that one person's inability to stoop down to pick up a box (such as in Case Report A1) is primarily due to musculoskeletal impairments like decreased ROM and weakness. In another case the same activity limitation may be due to decreased somatosensory awareness on the right side. Testing the hypotheses determines the effective POC as well as the choice of intervention strategies for each client. Proceeding in this systematic way, the clinician contributes to the general knowledge base or evidence base for future practice. The ongoing formulation and testing of hypotheses are key elements in NDT practice that are uniquely applied in the individual patient’s evaluation and intervention process.

A *theory* is a collection of hypotheses that have stood the test of time. A theory emerges when the same predictions of phenomena are consistently observed across time. More specifically, Glanz and Rimer[3] define a theory as a set of interrelated concepts, definitions, and propositions that present a systematic view of events or situations by specifying relationships among variables to explain or predict the events or situations. A theory is consistent with evidence-based practice and is useful so long as it is logical, consistent with everyday observations, similar to those used in previous successful programs, and supported by research in the same area. According to Glanz and Rimer,[3] a theory provides a road map for studying problems, developing appropriate interventions, and evaluating their successes. Theories can inform a planner's thinking during all stages and offer insights to translate into better intervention. A theory can be explanatory, describing why a problem exists, or it can be a *change theory,* guiding the development of health interventions. Change theories can enable program planners to explain why they assume a program will work. They can help planners to identify what should be monitored during program evaluation and intervention.

Within broad theories the therapist makes assumptions that guide or frame the entire evaluation, intervention planning, and implementation process. Assumptions are common and useful in day-to-day life. We assume that the sun will rise again tomorrow and that gravity will influence everyone. We assume that it is more important to consider a person's body systems to understand the activity limitations or participation restrictions rather than assuming that the person is lazy, uncooperative, or simply in need of more practice to reach a desired outcome. Assumptions can be explicit and clearly articulated by the practitioner, or they can be implicit and not even consciously acknowledged by the therapist. Explicit assumptions can be made specific enough to be clinically tested, and, based on the findings, the overall theory can be modified. The collection of assumptions shapes the clinician's practice.

For example a clinician may begin every assessment by asking the family about the activity limitations that most restrict the individual's participation. When asked why the examination begins in this the fashion, the clinician may or may not be able to give a theoretical explanation or articulate the assumptions on which this practice is based. However, hidden in this practice is the assumption that intervention is most effective when focused on a functional outcome that the client values. In addition, this method of examination can include the assumption that individuals learn motor tasks rather than a given component of movement. If the clinician holds these assumptions as valid, sessions would be organized around the valued functional outcomes rather than being focused solely on increasing range of motion, strengthening a muscle, or striving to improve a posture, such as developing head control.

The therapist then generates principles to guide the intervention process and aid in forming a practice model. A *principle* is "an accepted or professed rule of action or conduct." Principles can be general; for example, effective treatment should include active work by the client, to far more specific; for example, during intervention for a client with neuromuscular impairments, the clinician should address the patient's inability to recruit specific postural motor units by facilitating sustained isometric contractions of the desired postural muscles in the shortened range of those muscles, as Stockmeyer suggests in Chapter 4. The NDT Practice Model then is framed by our assumptions and guided by our practice theory, and reflects the collective body of principles.

2.2 NDT Practice Theory

The theoretical framework of NDT has emerged across time based on experience and is consistent with the philosophy described in the previous chapter. It forms a foundation for the practice model presented in Chapter 5. The NDT Practice Theory offers potential answers to broad clinical questions. The questions require that the therapist make assumptions because none of the questions have answers that are widely accepted. Assumptions central to NDT practice will be described in the following sections along with the unique clinical application of information gained from the study of motor control, motor learning, and motor development.

There are three major categories of questions addressed by NDT assumptions that are foundational in the NDT Practice Model:

1. How do people function? How are the body systems organized, controlled, or coordinated in individuals without impairments? How do people typically learn to participate in or perform activities? How are functions learned at different ages, physical characteristics, in different contexts, and with different experiences?
2. What goes wrong in the control and coordination of the systems in individuals with neuromuscular disorders, such as CP, or in cases of stroke or traumatic brain injury (TBI)?
3. What is the most effective intervention for individuals with disorders of posture and movement? This final question is based on answers to the first two questions.

2.2.1 How Do People Function?

If a clinician is working to improve a person's ability to participate fully to or have greater or more independent functional activities, it seems reasonable that the clinician should have a theory of how posture, movement, and the working of all the individual systems lead to participation or activity. How does a person achieve a functional outcome? How do activity and participation develop across the lifespan? These questions have been explored and theories developed in the studies of motor control, motor learning, and motor development. Various answers have been proposed. The clinician determines which theories provide the most effective framework for intervention. The clinician must also expect these theories to change across time as core assumptions are tested and either accepted or rejected. The hallmark of an effective assumption is that it lasts—it stands the test of time. The remainder of this chapter explores the assumptions that frame the NDT Practice Theory and provides rationales to explain their usefulness. It then suggests the principles that will help guide effective NDT practice.

How are the functions of the body systems typically organized, controlled, or coordinated to produce participation and functional activity? How do people learn to participate or perform activities? How and why do they change across the lifespan?

NDT Assumptions Based on Theories of Motor Control

For years scientists as well as clinicians have studied human behavior in attempts to understand how the body works to produce effective and efficient posture and movement for activity. The answers have changed based on who was attempting to answer the question and the scientific environment and theories held to be true at the time. Sherrington[4,5,6] proposed one answer by suggesting that his reflexive hierarchy theory should be viewed as a “convenient”[4] even if it was “probable fiction.”[4] The implication is that the theory should be followed so long as it has value or benefit. For the rehabilitation therapist, the test should be, does this theory help me to solve clinical problems? and can clients who receive intervention based on this theory achieve greater functional independence than if a different theory is followed?

Motor control includes information gathering and related activities performed by the central nervous system that organize the musculoskeletal system to create coordinated movements and skilled actions. The study of motor control is a large area of study and includes a wide variety of theories or assumptions. Shumway-Cook and Woolacott[7] report that it encompasses both the control of posture as well as movement. It involves understanding perception and cognition, feedback processes, and biomechanics, to name a few. The NDT Practice Theory has applied assumptions from various theories of motor control to aid in designing and implementing intervention strategies. The following motor control assumptions are integral to NDT practice. Each assumption will be discussed in detail with supporting evidence provided in Chapters 4, 12, and 15.

Based on an understanding of motor control, the clinician using the NDT theoretical framework and related practice model assumes the following:

- Movement is organized around functional activity.
- Human motor behavior/function emerges from ongoing interactions among multiple internal systems of the individual, the characteristics of the task, and the specific environmental context.
- The critical systems to be addressed during examination and intervention will vary client to client, as well as vary with the same client in different environments or on different days. Posture and movement impairments may be related to a single body system, such as the neuromuscular system, or multiple body systems.
- All individuals have elements on the health or wellness end of the spectrum in all of the various domains described in the International Classification of Functions (ICF)[8] that is described in Chapter 3. These attributes of health and wellness in the different domains are identified as participations, activities, or integrities.
- A hallmark of human motor function is the variability of posture and movement organization to meet functional demands.
- The neural control for movement is distributed throughout various levels of the central nervous system (CNS), all contributing to the final motor outcome.
- Plasticity in all systems exists across the lifespan.
- The brain can maximize remaining functions and/or compensate for the loss of function in the event of neuropathology.
- The nervous system has the ability to reorganize in response to intrinsic or extrinsic stimuli.
- Plasticity is linked to brain development across the lifespan.
- Intervention strategies can be designed to capitalize on the brain's ability to modify functions based on experience and the environment.
- There are anatomically and functionally distinct yet overlapping and interactive structures and function to control and coordinate posture and movement during activity. The systems can be recruited separately. Refer to Chapter 4 on posture and movement for supporting assumptions and literature.
- The postural system provides the ability to maintain the upright position against gravity through vertical lift. Postural responses also maintain the center of mass (COM) over the base of support (BOS). In addition to the whole body responses, the postural system maintains the integrity of the joint structure. The term *stability* describes much of the goal of the postural system.
- The movement system is a primary controller to overcome inertia and is also needed when a wider range and faster speed of motor responses are required. The term *mobility* describes the goal of the movement system.
- Posture and movement represent a continuum but are organized by different descending systems. Posture is organized through the medial descending systems and movement through the lateral descending systems.
- There are distinctions between motor unit types as well as muscle architecture that correlate with a postural versus a movement system.

Based on these assumptions the clinician develops specific principles to guide, organize, and increase the efficiency and effectiveness of the examination, evaluation, and intervention for any given individual. These principles are presented in detail in Chapters 5, 6, 7, and 8. The particular modifications demonstrated among the different disciplines will be discussed in Chapters 16, 17, and 18. In addition, the specific application of these principles will be presented in the case reports at the end of the text. The NDT theoretical assumptions and the specific evaluation and intervention principles are best demonstrated when observed *in action* with each individual who seeks intervention and with each therapist offering that intervention.

Principles of Information Gathering, Examination, Evaluation, and Intervention Related to Motor Control

The following principles are based in the study of motor control and are central to NDT practice. The therapist should perform the following:

- Organize the evaluation and intervention process such that participation, participation restrictions, activities, activity limitations, and the individual's desired outcomes drive the process.
- Develop specific outcomes for each session. The short-term as well as long-term POC focuses on the desired activities or participations outlined by the client.
- Provide all intervention within the context of functional activities whenever possible. For example, the therapist will work to increase range of motion at the ankle joint into dorsiflexion within the context of transferring an individual to and from the wheelchair rather than performing passive range of motion while the patient is lying supine in the bed.
- Plan to alter activity by addressing individual body systems or functions, by changing the environmental contexts, or by altering the task or activity itself. This principle also implies that the therapist must simultaneously consider all of these elements to understand, plan, and implement a successful intervention.
- Begin the evaluation and intervention process with individualized problem solving or task analysis of the identified desired outcomes.
- Perform a task analysis that takes into account all of the body systems and structures that can be the critical factors which limit or support the desired outcome.
- Individualize the examination, evaluation, and intervention and vary the POC and intervention day to day, therapist to therapist, as well as client to client. This practice will include structuring an individual session differently on different days, even with the same client, as the organization of the body structures and functions changes.
- Gather information from the client and the family on an ongoing basis that outlines the individual strengths as well as the limitations or impairments.
- Build on these strengths or competencies within the intervention. Each session builds on the individual's contextual facilitators, activities, and integrities.
- Observe the client during examination and evaluation to determine the variability of posture and movement organizations to produce functional activity.
- As soon as possible, include in intervention the introduction of variations in task performance so that the client does not develop stereotypical postures and movements to complete specific tasks. The therapist should aid the individual in developing a wide variety of muscle synergies to complete tasks, vary the tasks, and vary the environmental constraints in which the tasks are performed within the session and in providing home programs.
- Identify the body systems that demonstrate the greatest limiting impact on activity performance and also those systems with the greatest potential for change in a client. In addition, the therapist looks for episodes in the individual's lifespan indicating greater plasticity. In anticipation of or in response to these factors the therapist will alter the intensity of intervention, change the focus, or modify the specific strategies used in the intervention process.
- Continually adapt the POC based on the ongoing examination and evaluation.
- Use multiple sensory inputs, handling strategies, and contexts in different activities to alter the overall organization and therefore neuronal control for functional tasks.
- Identify impairments of body structure and function, including multisystem postural and movement issues as well as single-system issues through observation of functional activities during examination and intervention.
- Provide input through handling to specifically recruit postural or movement systems within functional tasks.

NDT Assumptions Based on Theories of Motor Learning

In addition to striving to understand how an individual controls posture and movement for activity and participation, therapists have sought to understand the process by which people learn typical activities and participation. How do children learn to brush their teeth, walk across the yard, tell someone when they hurt or want something? How do we relearn those tasks if we have a CNS insult that leads to functional limitations? What can therapists do to promote motor learning? Do children and adults learn the same way? Do we learn the same way after a CNS insult as before one? Once again the clinician faces a large group of questions without universally accepted answers. Although there is some literature to help guide the clinician, there is once again a need to develop an NDT POC based on a list of NDT theory practice assumptions and specific principles that are derived from the study of motor learning theories.

First a few definitions must be agreed upon. Schmidt[9] has defined *motor learning* as that process or group of processes that leads to a relatively permanent change in motor behavior. Independence in performing a task is only one measure of success. A person may be able to put on a jacket independently, but if it takes 35 minutes to complete the task due to poor posture and poor coordination, the accomplishment may not be viewed as being functional or as increasing participation.

Schmidt defines *motor performance* as the "observable attempt of an individual to produce a voluntary action. Motor performance is susceptible to fluctuations in temporary factors such as motivation, arousal, fatigue, and physical condition."[9] This definition also reflects a change that occurs based on the quality of the posture and movement during an activity or task. If an individual is learning to play tennis and for the first time hits a ball with a smooth forearm stroke that crosses the net and lands in an appropriate court, one can say that the person has an improved performance but cannot yet say that the person has learned the skill of playing tennis. Likewise, if a client in therapy sits for 10 seconds with the head and shoulder girdle held in midline over the pelvic girdle, it is not possible to state that the person has learned to sit independently for dressing. There has been a change in performance but not yet a change in activity or skill. Accomplishing the task for the first time is a success that is frequently celebrated in therapy sessions. However, before it has meaning in daily life it must be present more consistently. A skill,[9] then, is the consistent attainment of a motor task with economy of effort. It reflects producing a performance with maximum certainty, minimum energy, and or a time factor. Motor learning, therefore, is a set of underlying events or changes that enables a person to become consistently skilled at some task.

Because it is usually assumed that the desired outcome of therapy is a relatively permanent change in activity or participation, it is important for all therapists to consider the role of motor learning in the context of therapy sessions. It is not sufficient for a client to perform an activity in a therapy session and yet be unable to function in the home, school, or community setting. The goal of therapy is for the individual to be able to participate fully without the assistance of the therapist or the caregiver. The NDT Practice Model includes assumptions and principles of intervention that are derived from theories of motor learning.

The therapist assumes the following:

- Motor learning is organized around functional tasks that are valued by the individual. Tasks or functional outcomes for a therapy session that the learner selects as being meaningful and achievable are more likely to result in real motor learning.
- An optimal state of readiness for motor learning in an individual includes specific personal as well as environmental contextual factors.
- An optimal state of readiness for motor learning in an individual includes specific personal as well as environmental contextual factors. Motor learning can be enhanced by preparing the individual's attentional, physical, emotional, cognitive factors, among others. We learn best when in an active alert state, but not one in which we are terrified or giddy with laughter. We learn better when the body is well positioned and well aligned for the task. We learn best if we know what we are going to learn.
- Motor learning is enhanced when the learner is actively involved in the process. It is not sufficient to passively go through the activity. The level of active participation can vary according to the ability of the individual. An individual who has more severe and multiple impairments may be actively involved in a standing transfer by increasing the push with the extensors of the lower extremities and the coactivation of the muscles in the arms while supported in standing with arms resting on the therapist's shoulders. Another individual who is more able-bodied may independently reach and hold a grab bar with an arm to complete the transfer. It is also important to know that active movement does not refer solely to consciously directed movements that are readily observable. Anticipatory postural adjustments and the compensatory postural adjustments performed as part of skilled activities can represent the individual's active involvement in performing a new skill.[10]
- Motor learning is improved with accurate instruction and feedback. From an NDT perspective this includes both verbal and nonverbal instruction and feedback, including handling and physical prompting.
- Handling can play an important role in motor learning, especially during the early phases of learning.
- Hands-on guidance is a naturally occurring, motor-teaching strategy that influences motor learning and is particularly useful when eliciting specific behavior or when limiting the scope of error in performance aids motor learning.
- Physical or verbal guidance during the task can be an effective method for limiting movement errors during the performance of a task and assists the learner through the postural adjustments and movements needed for task completion.
- Learning or relearning motor skills and improving performance require both practice and experience. Motor learning results as the individual gains experience and practice in functional contexts. Repetition through practice is an important component in motor learning. Activities that are task specific and that the client repeats, both in an NDT therapeutic session and in functional ways in other settings, have a better chance of becoming part of the client's movement repertoire.
- Practicing novel skills, with increasing degrees of challenge, is important to motor learning.
- Changes in motor skills occur under conditions that most closely resemble the conditions the client will normally encounter during the performance of that skill.

Principles of Information Gathering, Examination, Evaluation, and Intervention Related to Motor Learning

Based on a composite of these assumptions related to motor learning, the therapist, using an NDT practice model, works to promote motor learning during intervention. The therapist should perform the following:

- Interview the client and family to discover the participation and functional outcomes that are most critical for the individual and the family to achieve.
- Identify the contextual factors (personal and environmental), including both facilitators and potential barriers, that will influence motor learning.
- Establish an environment that enhances motor learning by making it comfortable, yet challenging. In addition, select activities that are intrinsically motivating for the individual.
- Prepare the individual for activities and participation through optimizing the alignment and body position.
- Explore the individual's contextual facilitators during the information gathering and examination process, then tap into to these facilitators during the intervention process to increase the likelihood of success.
- Organize each therapy session and each block of intervention (short-term and long-term blocks) around a desired activity. Focus each session on helping the client reach a specific desired outcome, such as eating a lunch independently or transferring in and out of the family vehicle with the caregiver's assistance. Select outcomes that are both important to the client and a challenge to achieve. Strive to discover the *just right challenge* for each client.
- Use specific physical, cognitive, verbal, and nonverbal instructions, and provide both verbal and nonverbal feedback.
- Select instructional strategies that reflect the client's stage of learning. Present these strategies in such a way that clients gradually select and then optimize the strategy that best matches their needs and capabilities with the task and the environment.
- Incorporate handling judiciously as a strategy to enhance motor performance and motor learning.
- Guide the client through the stages of motor learning while remembering that it must be an active process for the client.
- Allow the client to learn from (safe) errors that occur during movement.
- Provide opportunities for repetition; it is an important component in motor learning.

NDT Assumptions Based on Theories of Motor Development

Motor development can be defined as the body system processes underlying emergence and changes in motor skills that occur across the life span based on experience, maturation, and aging. NDT theory has always included assumptions based on the study of motor development. In the past decades the understanding of typical motor development has changed as have the implications for the rehabilitation specialist. As discussed in Chapter 1, NDT therapists recognize that general patterns exist in the acquisition of skills during typical development and maturation.[11,12,13] These consistencies can provide a standard of reference for proficient human motor function for the therapist to use during examination and intervention. An analysis and understanding of these consistencies in the development of the control and coordination of posture and movement, the maturation of the individual systems, and the related changes in functional activities is used in planning intervention. The clinician using the NDT Practice Theory includes information that is based on theories of motor development and assumes the following:

- Motor development is a dynamic process that occurs throughout the lifespan rather than a linear progression and then a gradual decline.
- Motor development emerges from the cooperation and changes in all of the body systems, which are influenced by maturation, experience, and learning in various contexts. Motor development is not dictated by the maturation of the CNS alone. Body systems develop at different rates, enhancing or constraining the development of various motor behaviors.
- Motor milestones appear as discontinuous, discrete behaviors with a definable onset, but they actually result from continuous processes involving all the developing body systems.
- There is not an ideal path or sequence across the years that leads to optimal functional abilities and full participation in life activities.
- Motor development is shaped by contextual factors, both personal and environmental, and the integration of all the maturing or changing body systems and functions.
- NDT recognizes that parents' normal daily handling of their infants influences motor development, as well as affecting positive parent–infant relationships. Physical guidance, as a therapeutic strategy, strives to duplicate this natural relationship between two individuals, whether adults or children.
- Variability and competition among motor patterns are essential components of motor development.
- Understanding typical and atypical motor patterns underlying motor function is used to recognize differences in movement in both children and adults with CNS pathology.
- The study of motor development provides guidelines for creating intervention strategies that are age appropriate and facilitate variation in movement and enhance motor learning.
- Directionality of development, such as cephalocaudal and proximodistal, is only a general schema; functional, skilled movement is a composite of postural stability and mobility patterns that support the observable function.

Principles of Information Gathering, Examination, Evaluation, and Intervention Related to Motor Development

The therapist is responsible for the following:

- Examine each client within a life-cycle framework.
- Use knowledge of motor development to respect individual differences and recognize common and typical patterns in the developmental process that prepare and enhance skill performance commensurate with age and current ability.
- Use knowledge of development of posture and movement components in designing treatment strategies.
- Look for prerequisites for participation in both single and multisystem integrities. The clinician studies typically developing individuals to observe what postures and movements precede specific skill acquisition.

2.2.2 What Goes Wrong?

Once the clinician has developed assumptions and principles based on the understanding of how posture and movement are controlled and coordinated in normally functioning individuals, it is possible to start thinking about the second major question identified at the start of this chapter.

> What goes wrong in the control and coordination in individuals who have neuromuscular disorders, such as cerebral palsy (CP), or in cases of stroke or traumatic brain injury (TBI)?

The clinician once again is faced with a group of questions: Do people who have incurred a neurological insult have the same system of control as those who have not had an insult? Why do people with similar neurological insults have different impairments, functional limitations, and participation restrictions? Is it possible to predict primary impairments based on known pathophysiologies? Are there predictable secondary impairments that emerge based on the primary impairments?

The definitions of CP, stroke, and TBI only begin to answer these questions.[14,15,16] Therefore, the clinician immediately develops more questions. If it is possible to predict some of the impairments that will face an individual who has an insult, can the therapist then prevent or minimize some of the anticipated impairments, functional limitations, and participation restrictions through the intervention process? How does the concept of plasticity apply to individuals who have CP or who had a stroke or TBI, and how is it altered through the concepts of recovery and compensation? Is there both an adaptive as well as a maladaptive process that occurs in the recovery process? Can the therapist modify that process through intervention?

Once again NDT theory includes potential answers to these questions.[17,18] These answers are in the form of clinical assumptions with associated principles of practice. The assumptions and principles are based on research done in the basic sciences. This work includes studies in the area of CP, stroke, and TBI and also specifically in the fields of plasticity, compensation, and recovery. The foundations for these assumptions will be described in detail in Chapters 10, 11, and 15. The following is a summary list of the assumptions and the principles of intervention based on the assumptions:

- Impairments of posture and movement are primary impairments (multisystem) in CP, stroke, and TBI.
- Primary and secondary impairments are relatively predictable. There is a relatively predictable natural course or progression that follows a CNS insult when there is minimal or no intervention offered.
- Secondary impairments develop in part based on the individual's participation, activities, habitual postures and movements, and interactions of other body structures and functions. Due to this dynamic nature of the secondary impairments, they can be prevented or minimized by carefully planning for and providing specific intervention to alter any one or all of these factors or the interactions of those same factors.
- There is an ongoing and dynamic interaction of body systems, the environment, personal attributes, activities attempted, and participation desired in all individuals, including those who have CNS pathology with associated participation restrictions, activity limitation, and impairments.
- Plasticity in all systems exists across the life span in all individuals, including those with CNS insults.
- Recovery after an insult does occur but is altered by the specific nature, location, and timing of the lesion.
- Recovery is complicated by the development of and the interaction of adaptive and maladaptive changes in body structure and functions.
- Recovery is influenced by many contextual factors, including personal facilitators and barriers as well as environmental facilitators and barriers.
- One contextual factor influencing recovery is the intervention provided. The nature, timing, and intensity of the intervention are key variables that influence the impact of the intervention.
- Compensations are motor strategies that are adopted by individuals with CP, stroke, or TBI to accomplish activities, albeit with reduced effectiveness or efficiency.
- The repetitive use of compensations can lead to the development of secondary impairments, other activity limitations, participation restrictions, and even additional pathologies.
- Compensatory or maladaptive behaviors are also plastic and adaptable based on personal facilitators and barriers as well as environmental facilitators and barriers. These contextual factors include the intervention provided.

Principles of Information Gathering, Examination, Evaluation, and Intervention Related to What Goes Wrong

The principles based on what goes wrong include that the clinician is responsible for the following:

- Expect recovery with improved participation and increasing functional independence in patients/clients across the life span that is enhanced with NDT-based intervention.
- Understand the pathologies present in an individual seeking intervention as to frequently associated impairments and other pathologies as well as known predicted courses of recovery.
- Obtain a comprehensive medical and social history as well as reports on all contextual factors that may influence the recovery process and habilitation/rehabilitation progression during the ongoing data collection phases of intervention.
- Examine and evaluate all systems as potential contributors to activity limitation and participation restrictions. Perform ongoing examination and evaluation to note changes that occur across time.
- Identify primary and secondary impairments and then prioritize them based on their impact on activity limitations or participation restrictions.
- Analyze the impact of the primary and secondary impairments in light of the contextual influences.
- Predict the effects of long-term primary and secondary impairments on a person's function over the life span and design intervention to minimize their impact.
- Educate the individual and the family as to the current impairments and implications on current and future activities and participation.
- Analyze the performance of activities to determine the underlying primary and secondary impairments and the implications of these impairments for the future participations, activities, body structure and function, and other pathologies.
- Weigh the benefits and negative effects of compensatory postures and movements across the life span when developing the POC.
- Develop a POC and select intervention strategies that develop a balance between promoting and supporting recovery and allowing functional compensations as the client seeks independence in functional activities.
- Diligently observe, handle, and test posture and movement organization and execution used for function to determine if changes are adaptive and useful or maladaptive and harmful to present and future functioning.
- Include handling and other intervention strategies to support adaptive behaviors and to minimize the emergence of secondary impairments during intervention.

The therapist must also acknowledge that there is not enough evidence to predict if changing single-system impairments consistently changes posture and movement (multisystem) and the activities they support. It is also not clear if posture and movement themselves reorganize without clinically significant changes in single-system structure and function to achieve outcomes. Many levels of research are needed to help discover this information to develop the most effective and efficient intervention principles.

2.2.3 How Can We Provide Effective Intervention?

The third broad question is how can we provide the best possible intervention.

> What is the most effective intervention for persons with disorders of posture and movement?

NDT is often recognized by the unique clinical demonstration of the evaluation and intervention process.[19,20,21,22,23,24] There is clearly the possibility that another clinician can accept many of the assumptions outlined above and yet make different intervention assumptions and therefore design very different plans of care. These intervention assumptions have formed a cornerstone of the NDT Practice Model for decades. Key to these assumptions is the underlying philosophical tenet that therapy works to help individuals, especially those with CP or those who have had a stroke, gain or regain activities and fuller participation. Included in these core intervention assumptions are the following:

- Intervention for individuals with CNS insults is best when organized and directed by a clear explicit theory and practice model.
- It is possible to change functional activity and participation of clients through intervention using the NDT theoretical framework and practice model.
- The aim of therapy is to improve activity and participation for individuals with CNS disorders, such as CP, or for those who have had strokes. Clinicians using the NDT Practice Model assume that it is more effective to design intervention by establishing functional outcomes in partnership with the client and caregivers. An outcome that is valued by the individual is more likely to be achieved than one that is generated from a checklist of generally occurring activities.
- The best avenue to achieve desired activity outcomes is by changing single- and multisystem impairments in a task-specific context.
- Intervention is best when it is individualized to meet specific participation or activity outcomes within the individual's specific contextual factors.

- Ongoing evaluation must occur throughout every intervention session.
- Intervention demonstrating best practice involves active initiation and participation of the client along with the therapist's manual guidance and direct handling.
- Intervention programs are designed to serve clients throughout their lifetime.
- Intervention is more effective during recovery and/or phase transitions.

Principles of Information Gathering, Examination, Evaluation, and Intervention Related to Effective Intervention

These theoretical assumptions are revealed in examination, evaluation, and intervention as the clinician follows these intervention principles. The therapist should do as follows:

- Acknowledge that there may be multiple pathways to outcome attainment and remain open and creative in designing a POC.
- Consider each client during information gathering, examination, evaluation, and intervention as a unique person with multiple competencies and limitations.
- Incorporate an interdisciplinary therapeutic management team that includes and respects the client and the family as primary and active participants in the decision-making process.
- Set outcomes in partnership with the client, family, and intervention team.
- Include planning for and solving motor problems by the client in each intervention session.
- Include functional outcomes that are measurable in long-term, short-term, and single-session POC that are identified and valued by the individual and the family.
- Include in the information gathering, examination, evaluation, and intervention a careful consideration of the components of posture and movement that are efficient or inefficient in persons with stroke or CP.
- Design a POC and intervention to build on the client's strengths.
- Include judicious use of therapeutic handling in the intervention process.
- Encourage the most active participation in goal-directed activities possible for the individual such that movement is initiated and actively performed by the client.
- Include preparation and simulation of critical foundational elements of the task as well as practicing whole-task in intervention.
- Create an environment that is conducive to cooperative participation and support of the client's efforts. Include intervention activities that are appropriate for the client's age as well as appropriate for all of the contextual influences and the current activity and participation abilities.
- Continually evaluate the effectiveness of intervention within the session.
- Recognize and respect the communicative intent of the client's motor behavior.
- Provide the client and families with information regarding the client's restrictions, limitations, and impairments and their management as they are able to understand and assimilate the information. Make suggestions to the family that are as practical as possible.
- Provide activities that are motivating and have purpose to engage the client fully in developing and reinforcing activities and the desired posture and movements for those activities.
- Modify the task or environment to take into account the current level of performance and capacity for function.
- Provide time for the client to self-organize, move freely and independently, develop motor plans, and learn. In other words, wait.
- Recommend interdisciplinary model of service when appropriate to meet client and family needs.
- Coordinate evaluation and intervention with of all other medical, therapeutic, social, and educational disciplines to ensure a life span approach to solving the client's problems.
- Individualize each session based on the specific client and clinician, allowing it to change moment to moment based on the individual's response to the intervention process.
- Use movement analysis to identify missing or atypical elements that link functional limitations to system impairments.
- Address the multisystem impairments of posture and movement to enable more energy-efficient performance within age-appropriate tasks.
- Focus on all of the specific characteristics of each domain in the ICF (see Chapter 3) from both ends of the health and wellness disease/disability spectrum for that individual client. In addition, consider the domains within the framework of all of the contextual factors, facilitators, as well as hindrances and barriers.
- Identify specific strengths and weaknesses of the clinician and include them in developing and implementing the intervention plan.

2.3 Summary

All of these assumptions and principles form the NDT Practice Theory, which underlies all aspects of client–therapist interactions. The therapist using the NDT Practice Theory accepts the NDT assumptions and thus begins by observing participation and activities the client engages in. Then the therapist hypothesizes how the body systems, the environment, and personal factors interact to allow function or to interfere with function. The therapist speculates about the relationships of participation and/or activity to the body systems and the body systems' functioning to each other. Finally, the therapist uses the data gathered to formulate the POC and develop intervention strategies. This unique and systematic problem-solving method forms the foundation of NDT practice.

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3 Neuro-Developmental Treatment Practice and the ICF Model

Judith C. Bierman

The International Classification of Functioning, Disability and Health (ICF) was developed by the World Health Organization to provide a common language with which to organize, label, and classify multiple health conditions. The ICF taxonomy is presented, and the implications for Neuro-Developmental Treatment (NDT) practice are discussed. The emphasis is on the particular problem-solving process within NDT practice that includes analysis of the relationships between the ICF domains and the contextual factors during information gathering, examination, evaluation, and intervention for clients with cerebral palsy or a traumatic brain injury or for those who have had a stroke.

Learning Objectives

Upon completing this chapter the reader will be able to do the following:

- Describe, define, and give clinical examples of the components of the ICF.
- Describe how an NDT practitioner will relate, analyze, and prioritize the components of the ICF model.
- Apply the ICF model within the NDT Practice Model.
- Analyze a plan of care for an individual with disabilities based on an NDT interpretation of the ICF model.

3.1 The ICF Model of Health and Disability

The International Classification of Functioning, Disability and Health[1,2] (ICF) is a framework that organizes, labels, and categorizes biological and social perspectives of health and disability. It was approved by the World Health Organization (WHO) in 2002 and revised multiple times. It was developed as a complement to the International Statistical Classification of Diseases and Related Health Problems (ICD-10),[2,3] a diagnostic tool that classifies diseases and other health problems.

The ICF taxonomy describes the many facets of human functioning that may be affected by a health condition, as seen in **Fig. 3.1**. It provides a common language that permits comparisons of data across countries, health care disciplines, services, and time.[2] The framework is a classification system and not a measurement system, although it is possible to identify the severity of each factor. The classification system explores health or disability within three different domains: social functions (participation or participation restriction), individual (activities or activity limitation), and body structure and function (integrities or impairments). The classification system considers domains as interactive and dynamic rather than linear and static. In addition, the ICF taxonomy includes contextual factors that are either facilitators (contribute to health, wellness, or functioning) or barriers (contribute to disability). The contextual factors take into account both the environmental impact as well as multiple personal factors that affect an individual's ability to participate, affect functional activity, and affect the body structures and function themselves. In the ICF framework, functioning and disability are viewed as encompassing a complex interaction between the individual, the environment, and the health condition. Health and disability are seen in a different light, with these conditions appearing as an ever-changing continuum rather than as two separate distinct categories. An individual may display different degrees of functioning or disability across time or when one is considering different aspects of functioning. Therefore, the classification schema is applicable to all people because it does not address specific health conditions or diseases.

The ICF model has also been modified to more adequately address the information in children and youth who are rapidly developing and demonstrating dramatic changes in physical, social, and psychological function. The ICF used for children and youth (ICF-CY)[4,5,6] has been derived from the ICF to document the characteristics of children and youth

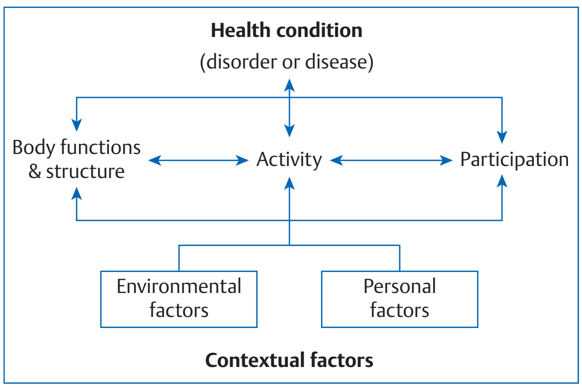

Fig. 3.1 The International Classification of Functioning, Disability and Health model demonstrating the Health/Disability Continuum.[1,2] Reproduced, with the permission of the publisher, ***Towards a Common Language for Functioning, Disability and Health: ICF***, Geneva, World Health Organization, 2002 (http://www.who.int/classifications/icf/training/icfbeginnersguide.pdf, accessed September 8, 2014).

in the first 2 decades of life. It now includes descriptions of functions that are more unique or particularly relevant to childhood, such as play. It omits descriptions that are not related to childhood or youth, such as menopause.

Both the ICF and ICF-CY include the same three domains (social: participation and participation restriction; individual: activity and activity limitation; and body structure and function: integrities and impairments). Each domain is subdivided into chapters which are listed in the first column of **Tables 3.1, 3.2,** and **3.3**.

3.1.1 Social Function (Participation and Participation Restriction)

Participation reflects a person's functional involvement in a life situation at any point in the life span. Participation restrictions, on the other hand, reflect problems that an individual may encounter in those same real-life situations, no matter what the cause. Function in the social domain includes the performance of an activity within a specific relevant environment or within a specific societal context, as seen in **Table 3.1**. Participation includes how the person functions in multiple environments and therefore considers all contextual factors. It is more likely to include multiple functional activities and sequences of those activities. It usually involves other people and is based on the person's value systems or goals. It is related to the overall quality of life. Within the ICF model, each domain is subdivided into chapters that more clearly focus the attention.

For adults, we look at participation as reflecting how individuals meet their expected social roles.[7,8,9,10] It can include the roles in family life, including accepting roles within a nuclear and extended family, whether as a child in the family, a spouse in a young couple, a parent raising a child, or an adult caring for an aging parent. It also includes the roles related to education, both formal and informal, and work or employment. It includes descriptions of involvement in the community, such as in churches, community groups, and government and within the worldwide community.

For a young child the social roles may initially appear less clear.[11,12,13,14] However, there are still definite participations, even in infancy. In the first months, the infant is typically expected to be an active participant in home and family life. Initially, this participation may be as simple as sleeping when the rest of the family sleeps and eating when everyone else eats. With age, the expectation of participation increases to include playing with the parents and siblings, taking turns with others, waiting, and eventually taking on simple chores to improve the family's overall quality of life. The roles gradually expand to include a wider expanded family and then a network of friends.

The child begins to expand the roles learned in the family to include those outside the family. These participations extend to community settings as well as schools. The child may attend a day care center, mother's-day-out program, or preschool. Most children start attending school and are expected to learn to play and to be part of larger groups, such as a class of 20 children, rather than as a member of a family only. For quite some time, these participations are led or supervised by an adult. However, before the age of 10 children begin to develop a network of friends and play without direct supervision or leadership of the adult. The child may play in the yard alone or with friends, with a parent checking in sporadically. They may have sleepovers with friends or visit the grandparents without the parents being present for short stays. This is the age where children join clubs with other peers in their age group, such as Boy Scouts, Rainbow Girls, or church groups.

The ICF and ICF-CY use the term *chapter* to subdivide participation or participation restrictions.[1,4] Clinical examples that might be encountered in clinical practice are described in the following section.

Participation/Participation Restriction Case Report Example

A comprehensive clinical example of the social function domain and the chapters within it can be found in Case Report B8. Also look at Thieme MediaCenter for photo gallery. Brandon is a child diagnosed with cerebral palsy. He has a twin brother and a younger brother who also live at home with their parents and a half-sister. His life demonstrated the ever-changing shifts on the health wellness/disability continuum in the social function domain. He was born at 25 weeks gestation and lived for 4 months in the neonatal intensive care unit (NICU), as did his twin. He was not able to participate in the typical home life of a newborn infant; rather, he required the support of an entire medical team. He was discharged from the NICU at 4 months of age and lived at home with his parents while his twin brother continued to be supported at the NICU. He developed increasing medical problems, had to return to the hospital, and was readmitted to the pediatric intensive care unit (PICU) for an additional month and a half. Once he returned home he began fuller participation in family life. As a young infant Brandon lived at home, although he and his twin brother had separate rooms to accommodate the medical equipment necessary for Brandon's care. He attended a school in his community for his preschool and early elementary years, although he attended a self-contained class for children with severe cognitive impairments. He therefore demonstrated participation in that he attended the same school as his brother, yet he had participation restrictions because he could not ride the same school bus as his friends or attend classes with his neighborhood peers. He could not participate in play in his neighborhood. He did not develop friendships outside of his family. As his health diminished across the early years, he could no longer attend classes but was provided homebound education. He could continue to participate in public education, but his participation restrictions now included that his education was provided in his own home with a teacher, but without the interaction of children or other teachers from the school. He no longer participated in bus rides, even on the school bus with a wheelchair lift. He did participate in outpatient therapy services and participated not only with a physical therapist (PT), occupational therapist (OT), and speech-language pathologist (SLP) but also observed those same services with his brother. He met other professionals who interacted with him and his family. He met other families, including children with special needs. He also met the children's parents as well as their siblings, who functioned both typically and atypically. He

Table 3.1 International Classification of Functioning, Disability and Health social domain with clinical examples across the life span

Chapter[1,4]	Participation examples	Participation restriction
Learning and Applying Knowledge	Learns at age level at neighborhood school. Can learn new concepts necessary to play video game with grandchildren.	Must attend self-contained class with limited curriculum so graduates without high school diploma. Cannot learn how to use new computer system at work so does not get promotion.
General Tasks and Demands (undertaking single or multiple tasks)	Able to complete science project on time with all steps. Able to budget for the month based on all expenses.	Unable to handle stress of moving to new school and meeting new teachers and peers, so elects homebound education. Forgets to pick up children at school because sidetracked at grocery store doing weekend shopping.
Communication (communication with spoken and nonspoken messages, speaking and holding conversations, producing nonverbal messages	Able to communicate wants, concerns, and ideas with friends in setting without adults present. Able to communicate with extended family during holiday gathering.	Unable to tell stranger name or phone number when lost at the mall. Unable to express fears or goals during therapy session.
Mobility (lifting and carrying objects, picking up and grasping objects, walking, moving around using equipment, using transportation, driving)	Able to move in crib to obtain pacifier to return to sleep at night. Able to drive grandchild to daycare, including placing child in car seat and following rules at day care center.	Unable to walk across community playground and get on and off equipment. Unable to carry laundry basket up and down stairs of house to do family laundry.
Self-Care (washing, toileting, dressing, eating, drinking, caring for body, and looking after own health)	Able to drink from cup provided by fast food restaurant while on family trip. Able to takes own medications on schedule as prescribed by physicians when living independently.	Unable to locate and put on coat and backpack at end of school day in time to catch bus to go home. Unable to use bathroom independently in favorite local shop because it does not have raised seat and grab bars.
Domestic Life (housework, acquisition of goods and services, assisting others)	Able to load and unload dishwasher after dinner without request as chore for the good of the family. Able to do back to school shopping for all children in family.	Unable to help younger sibling with homework while parent prepares dinner. Unable to help spouse get in and out of bathtub as was previously performed.
Interpersonal Interactions and Relationships (basic and complex interactions, relating with strangers, formal relationship family relationships, intimate relationships)	Able to be calmed by staff at day care setting in addition to being calmed by both parents. Able to politely interact with in-laws during family reunion.	Does not have any friends outside of the immediate family. Does not recognize spouse of 40 years, so does not engage in any intimate relationships.
Major Life Areas (formal and informal education, employment, economic self-sufficiency)	Able to attend neighborhood school in regular classroom setting. Able to find gainful employment in local community.	Unable to learn rules of simple childhood games, so excluded from playing with others at recess. Unable to continue online college coursework to advance career.
Community, Social, and Civic Life (community, recreation and leisure, religion and spirituality, human rights, political life and citizenship)	Able to attend YMCA summer camp program with friends. Able to participate in community Americans with Disabilities Act (ADA) action group to advocate for curb cuts.	Unable to participate in community soccer league because walker is not permitted on field of play. Unable to play bridge at community center with seniors group because there is no community bus service that accommodates wheelchairs.

had nursing care from a variety of adults and adjusted to new caregivers. The additional care allowed him to remain at home for as many years as feasible. As his respiratory difficulties and seizures increased, his participation restrictions continued to increase. Brandon had frequent hospitalizations that limited the opportunity to participate as fully in family life. In addition, Brandon had more frequent absences from therapies due to his illnesses.

If one considers the habilitation/rehabilitation field, it is clear that a major role of therapists is to improve an individual's ability to participate and to limit participation restrictions. Carey and Long[15] outline a role of the therapist for advocating for and evaluating pediatric participation. There is, however, great diversity in participation in all individuals with neuromuscular disorders.[7,8,9,10,11,12,13,14] Multiple factors impact the person's participation, ranging from contextual factors, such as the family priorities,[12] to the availability of assistive technology or adaptive equipment.[16] In addition, the individual's functional activity level is related. Those individuals who are more severely involved physically or with significant communication limitations are more likely to participate with individuals only within the family or within the home.[9,11]

3.1.2 Individual Function (Activities and Activity Limitations)

Activities[1,3] describe an individual's functioning as a whole person. They reflect the execution of a task or an action by a person. Activity is a person's positive performance of a task, and activity limitation is the difficulty that the individual may have in executing that task. The tasks are more discrete in nature. This domain does, however, still include contextual factors in the description of the task. The concept includes the fact that performing a task in one setting can be very different from performing the same task in a different setting. For example, a person may be able to feed him- or herself a meal at home, but eating the same meal at a restaurant with a large group of the spouse's coworkers may not be feasible. There are usually multiple activities that must be performed in complex and specific environments to allow participation. Outcome measures for both adults and children are being designed to specifically examine a client's abilities to perform functional activities.[17,18]

The line between the social and individual domains is not, however, always distinct. A task at one point in life may be a focus for an individual, such as when a child learns to walk or when an adult first walks with a cane after a stroke. The activity may have such relevance and value to the family that it is viewed as participation. The child who has learned to walk may no longer have to be carried by an adult and therefore moves freely through the yard for play. Or the adult who is able to walk 50 feet with a cane can be discharged from the inpatient rehabilitation facility. However, later this same skill may become only one activity in a more complex participation, such as walking from the classroom to the school bus while carrying books and talking with friends, or cleaning the house, including vacuuming, dusting, and putting away household items in appropriate cabinets.

This individual function domain includes the entire spectrum of activities and activity limitations, as seen in Table 3.2. The chapters for activities are the same as those listed under the participation domain.

Activity/Activity Limitation Case Report Example

In Dennis's case report (A6) in Unit V, the therapist looked initially at reports from him and his wife concerning what he could do and what he could not do. This information was supplemented by the therapist's observation during sessions. Initially, Dennis and his wife reported the he

Table 3.2 Individual functioning domain with examples of activities and activity limitations across the life span

Chapter[1,4]	Activity	Activity limitation
Learning and Applying Knowledge	Able to label items in environment, such as "ball," "book," "car." Able to learn to use a calculator to add and subtract.	Unable to learn multiplication tables. Unable to learn how to open email.
General tasks and Demands	Able to finish homework independently. Able to follow simple recipe.	Unable to turn on IPad and select correct icon for desired game. Unable to follow home exercise program on a daily basis.
Communication	Able to call parent loudly enough to be heard from another room. Able to place a telephone call.	Unable to be understood by an unfamiliar person. Unable to construct and send a written message.
Mobility	Able to get in and out of bed. Able to climb stairs without railing.	Unable to ascend or descend stairs. Unable to get in or out of a car.
Self-Care	Able to " go potty" when requested. Able to shower self.	Unable to put on a T-shirt. Unable to feed self an entire meal with utensils.
Domestic Life	Able to clean up room. Able to cook dinner for family.	Unable to open food packages. Unable to make own bed.
Interpersonal Interactions and Relationships	Able to play with a same-aged peer for 5 minutes without adult intervention. Able to establish new friendships.	Unable to initiate play with unfamiliar but same aged peer. Unable to change personal schedule to accommodate the schedule of others.
Major Life Area	Able to play independently for 10 minutes. Able to perform skills needed in a familiar recreational activity.	Unable to ride bicycle independently. Unable to perform physical tasks required for desired job.
Community, Social, and Civic Life	Able to play a game with family. Able to play bridge with peers.	Unable to sit through church service without being disruptive. Unable to navigate through bookshelves at community library.

was able to move in bed independently but slowly. Dennis provided much of the information to the therapist, so he was able to communicate with others verbally.

He had been left-handed prior to the stroke and could do most everything with the left hand. His handwriting was "getting better." He did have difficulty with reading. He could walk without a cane but with an AFO at home and with a cane and an ankle-foot orthosis (AFO) in the community. He could get in and out of the family vehicle. He therefore could go on short community outings with his wife. He was unable to get out of a chair on his first attempt. He could not get off the floor without the support of furniture. He could not get in or out of the shower independently. He could not walk community distances. He required a rail for support supervision and verbal cueing to go up or down stairs.

Dennis's goals were to return to work and to be able to walk, ride his bike, and travel again. He and his wife were also planning to be able to spend more time after retirement with their grandchildren who lived nearby. The therapist in the case report reveals how these goals related to desired participation and activities of the client, his current activities, and activity limitation level to shape long-term and short-term outcomes for therapy, as well as including these valued activities within intervention sessions.

3.1.3 Body Function and Structures (Integrities and Impairments)

The third domain in the ICF model considers the functioning of systems within the body itself. Body structures are anatomical parts of the body, including the organs, limbs, and trunk and their components. Body functions[1,3] are the physiological and psychological functions of body systems. The functioning/health end of the continuum in this domain is referred to as integrities, and the disease or disability end of the continuum is labeled as impairments. Body structure impairments are problems in structure seen as a significant deviation or loss. Impairments of body structures or function are the inability of body parts or organs to function typically.

The system integrities and impairments can be linked to a single system, such as a deficit in the auditory system, or may be linked to multiple systems, such as poor balance, which may include the interaction of deficits in the visual and vestibular systems as well as limited axial strength and decreased spinal mobility in the musculoskeletal system, and a deficit in the timing and sequencing of muscle activation reflecting deficits in the neuromuscular system. Once again within the ICF model, the body functions and structure are divided into nine chapters. In this domain the chapters have a specific organ or system focus.

- Mental functions related to the nervous system structure.
- Sensory and pain functions related to sensory structures such as the eyes or ears.
- Voice and speech functions related to the structures of voice and speech.
- Functions of the cardiovascular, hematological, immunological, and respiratory systems based on the structures of the cardiovascular system, the immunological system and the respiratory system.
- Functions of the digestive, metabolic, and endocrine systems based on those structures.
- Functions of the genitourinary and reproductive systems based on those structures.
- Functions of the neuromuscular system and movement-related functions based on the structures related to movement.
- Functions of the skin and related structures and the structures of the skin and related structures.

In evaluating an individual for health care intervention, it is important to be able to identify specific body structure and function abilities (integrities) and impairments, as seen in **Table 3.3**.

Table 3.3 Body structure and function integrities and impairments with examples across the life span

Chapter	Integrity	Impairment
Mental functions	Behaves appropriately in different settings, demonstrating executive function.	Short attention span.
Sensory and pain functions	Two-point discrimination abilities.	Poor midline orientation.
Voice and speech functions	Articulates with voice loud enough to be heard across room.	Dysarthria.
Cardiovascular, hematological, immunological respiratory systems	Energy Expenditure Index is age appropriate.	Blood pressure drops when in upright postures.
Digestive, metabolic, and endocrine systems	Eats regular diet.	Reflux after each meal.
Genitourinary and reproductive systems	Controls bladder for toileting.	No menstrual cycle occurs.
Skin and related structures	Skin and fascia heal rapidly after surgery.	Skin breakdown over both ischial tuberosities.
Neuromuscular system– and movement-related functions	Good single-leg standing balance Full passive range of motion (PROM)	Inability to recruit postural motor units. Weakness of scapular adductors or depressors.

3.1.4 Contextual Factors

ICF and ICF-CY models also include the impact of contextual factors[1,4] on each domain. These contextual factors can be identified as either facilitators or barriers according to the impact on the individual. The contextual factors include environmental influences as well as personal factors as seen in **Fig. 3.1** previously in this chapter.

Environmental factors are those features of the physical, social, and attitudinal world that create the backdrop of an individual's life. The environmental factors could include scene-setting factors, such as the climate or culture, and can change the opportunities or imperatives for the individual's involvement in the participation domain. Examples of these environmental factors could include a region's job market or the family's economic status. They could also include a family's religious beliefs, a teacher or boss's perspective on inclusion of individuals with disabilities in standard environments, or a given culture's perspective on the importance of play. It could include immediate environmental factors, such as the family home, school, or work setting, and potential living environments, such as group homes or nursing homes. They could also include the availability and use of assistive technology, such as the type of AFO selected, the particular walker that is ordered, the availability of an augmentative communication device, or even the clothing that the individual wears.

The personal factors[1,3] are divided into three proposed categories that include scene setting personal factors, potentially modifiable personal factors, and social relationships. Some of these factors include simple identifying factors, such as gender, age, height, weight, or educational background. Personal factors can also include more complex factors, such as personal goals and motivations, the ability to cope with changes or learn new motor tasks, the ability to deal with frustration, or a knowledge base pertaining to general health or the condition a person is facing. The contextual factors influence all activities and all body structures and functions and are also a major link to participation or participation restrictions.

3.1.5 Interaction of Concepts

The ICF model treats the domains as interactive and dynamic. Domains are not viewed as being linear or causative in nature. The ICF model shifts the focus from a disease- or condition-based approach to one based on varying levels of functioning. Therefore, practitioners should no longer plan care for the "right hemiplegic" or even for the "child with diplegia" but instead should plan to meet the desired outcomes within each domain based on the individual's status at a given moment in time.

The ICF model is integrated into all aspects of health care. In evaluation and diagnosis, individuals may be classified within each domain rather than receiving only a global diagnosis based on pathology. In terms of a therapist's examination, standardized tests are being developed and evaluated based on each of the different domains. For example, there has been a shift from tests that considered generalized developmental milestones to tests that now focus on participation and activities or that specifically test a single body structure or function, such as testing muscle strength, range of motion, blood pressure, or respiratory rate.[17,18] There are also separate tests that look at balance, gait pattern, or the swallowing mechanism. The overall outcomes from therapy are viewed as targeting improved participation or activities with supporting objectives targeting body structure and function. Intervention strategies are developed and implemented to address each domain specifically. Interventions are then evaluated based on how they influence that specific domain. Franki[19,20] specifically reported on the effectiveness of Neuro-Developmental Treatment (NDT) on each of the domains within the ICF model.

This individualized intervention planning is at the heart of NDT. The ICF model provides a compatible framework with consistent vocabulary to discuss NDT practice. However, to understand the NDT Practice Model it is necessary to delve further into the ICF model from the perspective of the NDT philosophy, theoretical assumptions, and principles as presented previously in the first two chapters of this unit.

3.2 The ICF Model from an NDT Perspective

NDT practitioners recognize that they work within a large health care environment and an even larger global environment. A key to successful integration of NDT is clear communication among therapists, health care practitioners, researchers, outside governmental agencies, and international groups that regulate or influence the provision of health care to individuals in all practice settings across the life span. Although the ICF framework is very effective in providing consistency in vocabulary, it was not designed to describe how the different domains are related to each other.

In NDT practice, the clinician looks very specifically and carefully at each domain and the relationships among the domains presented in the ICF model. Hypotheses about these relationships are made during information gathering, examination, evaluation, and intervention planning, and within every intervention session. The NDT clinician also looks at the body structure and function domain and further discriminates general issues of posture and movement (multisystem functions) from issues of single-system function. In addition, the therapist carefully analyzes the impact of the environmental and personal contextual factors on each of the domains.

The ICF model does not suggest to a clinician how to help an individual to reach desired activity outcomes or how to improve a client's participation. It does not aid the clinician in developing an intervention plan. This clinical decision-making process is what the NDT Practice Model does (see Chapter 5). NDT describes, explains, and demonstrates the relationships of the domains and the processes of clinical decision making.

In the NDT philosophy it is clear that the individual is at the center of the entire information gathering, examination, and evaluation process, as seen in **Fig. 3.2**. The task of organizing all of the information can be challenging, however, for the clinician to develop a plan of care that is most effective. The ICF model can be helpful in organizing all of the observations. The clinician moves from getting to know the individual to categorizing information into the different domains.

When using the NDT Practice Model the therapist moves outward in the schematic seen in **Fig. 3.2** to considering the three sides of the triangle. Initially, the therapist gathers information about the social and individual functioning domains, noting specific examples of the participations/participation restrictions and activities/activity limitations that are reported and observed, as seen on two sides of the triangle. The examination then moves to the more detailed review of the bottom line of the triangle, that of the body structures and functions. The participation/restrictions and activities/limitations are viewed as growing out of the underlying body structure and function integrities and impairments. Yet they also interact and lead to changes in body structure and function status. No side of the triangle exists in isolation of the other two sides. The examination and intervention is thus always based on the ongoing interaction of these three elements.

The NDT practitioner then moves further outward in the problem-solving process as seen in the square of **Fig. 3.2** to consider the influence of the contextual factors on each of the domains individually and also on the interactive group (the triangle). The contextual factors include both the personal factors and the environmental factors.

The practice of NDT then is represented as the circle because it encompasses how the therapist gathers, examines, observes, handles, evaluates, and prioritizes information, and then intervenes, within all the domain and contextual factors for each individual. The remainder of this chapter focuses on a more detailed review of this process as a foundational model of NDT that will then be expanded in the remaining chapters of the book.

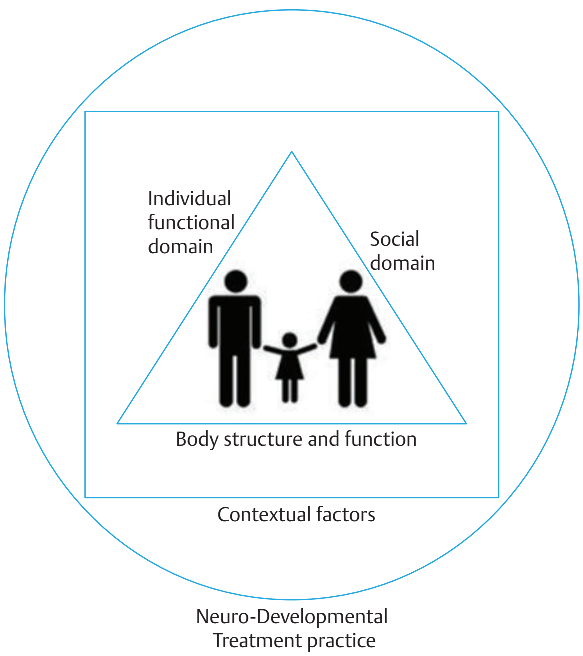

Fig. 3.2 The Neuro-Developmental Treatment evaluation and intervention schema depicting integration and relationships with the International Classification of Functioning, Disability and Health model. (Modified from Howle.[22])

3.2.1 The Social and Individual Functioning Domains from an NDT Perspective

The clinician using an NDT approach sets improved participation and independence in functional activities for the client or patient as the critical outcome. The desired participations and functional activities to be addressed are identified by the individual or family rather than having the clinician select the functional outcome based on a generalized or predetermined menu of participations or activities. The participation and functional activities are therefore viewed as inherently being tied to the contextual factors of the person seeking therapy. In addition, functional activities and participation are viewed as being based on the development or emergence of key body system structure and function. Therefore, to reach a desired activity or help to develop greater participation, the therapist addresses prerequisite changes in the posture or movement and addresses all the specific single-system impairments that are seen as preventing the desired activity or participation. All of the intervention is performed considering the contextual factors tied directly to that participation restriction or activity limitation.

3.2.2 The Role of Body Structure and Function from an NDT Perspective

The ICF model clearly identifies a separate body structure and function domain. The ICF model separates this domain according to issues of structure, such as a boney deformity versus issues related to function, such as poor sensory processing or spasticity. NDT problem solving, however, includes a closer look or deeper analysis of this domain.

Both cerebral palsy and stroke are viewed as disorders of posture and movement. In the ICF model there is no distinction between issues of effective or ineffective posture and movement that are based on the interaction of multiple body systems, such as head control or symmetry/asymmetry or balance, and issues related to a single-system structure or function, such as strength from the musculoskeletal system or vision or hearing in the sensory systems. The NDT clinician makes a distinction between multisystem posture and movement issues and single-body system structure and function to aid in more precise examination, evaluation, and intervention. The importance of this differentiation becomes more evident as one focuses on developing a plan of care for intervention.

In the ICF model, within the body structure and function domain, there is no differentiation between complex multisystem concepts, such as balance or posture, and the more single-system issues, such as poor vision or hearing, decreased strength, or spasticity. But the clinician who uses the NDT Practice Model does make this distinction in evaluation, intervention planning, and intervention itself. First the broader, more complex system factors are considered here, and then the single-system factors. In addition, there are examples of how the NDT clinician analyzes the relationships in these two subcategories in the body structure and function domain.

Posture and Movement: An Example of Multisystem Factors

There is a collection of motor behaviors or performances that neither represent single-system function nor reflect an activity or participation. Examples of these behaviors include head control, symmetry, balance, posture, and alignment. Therapists often refer to these concepts by talking about the quality of movement observed or about how the posture or movement is performed as opposed to solely listing if the activity or task is achieved.

During evaluation and intervention, a clinician might note that a client cannot maintain the head in upright position for social engagement, communication, eating, or other daily functions. This observation does not reflect a functional activity or participation. The therapist analyzes what factors contribute to the poor control. Does it come from neuromuscular impairments, such as an inability to recruit the postural motor units in the trunk and neck? Is it based on an inability to coactivate or cocontract the cervical flexors and extensors for stability? Is it that the thoracic spine does not have adequate mobility into extension to align the head over the shoulders? Does the individual have the sensory awareness of the head position from the visual, vestibular, and somatosensory receptors? Does the individual have adequate strength to hold the head up? Options could continue to be presented.

If a therapist limits intervention strategies to only practicing to develop the missing posture or movement, intervention can be less effective. It is possible to find children who have been provided opportunity to practice head control in therapy for years without notable changes in performance. The NDT problem-solving process would suggest that the clinician analyze which systems lead to the ineffective posture in this one client. Once the therapist hypothesizes which systems are most likely contributing to the ineffective posture and movement, a specific plan of care can be developed. Strategies to improve head control due to lack of strength would be very different than ones based on a visual field deficit or decreased somatosensory awareness.

It is also important for the NDT clinician to look carefully at the relationship of posture and movement to functional activity and participation. It is possible to see two very different relationships emerge. First, it is possible for the development of more effective posture and movement to complement more functional activity and participation. For example, as a person develops better head and trunk control, more functional sitting for play, work, or activities of daily living (ADLs) can emerge. In addition, as the person sits and reaches out farther in space or picks up heavier items, the postural control of the trunk continues to improve. In addition, new and more complex activities may occur. These new activities then lead to improved participation in social environments.

However, a markedly different course is feasible. It is possible for the two domains to become antagonists rather than complementary processes. An individual with a hemiplegia might open a water bottle using the teeth and the less involved hand. The activity is present, but with the habitual performance of this function in this atypical fashion, there may be a simultaneous development of greater asymmetry in the trunk and upper extremities as well as in the oral motor region. In this scenario, the functioning leads to more inefficient posture and movement rather than improving the control and coordination. It can also result in a failure to develop additional activities and can contribute to greater participation restrictions. The individual may not develop skills that require the dexterity of two hands, such as putting the hair into a ponytail, and may find that the strategy of using the mouth for some tasks is socially inappropriate and thus restricts community-based participation.

It is also necessary to consider the contextual factors that either facilitate or act as potential barriers to the performance. If an adult is sitting in a therapy session and is being asked to perform tasks that are perceived as meaningless and undignified, the person's head may be dropped with an apparent lack of head control. If the contextual barrier is the critical factor in the person's posture and movement, then the therapist's focus on the single- or multisystem impairments and their relationship to the functional activities is inadequate.

Single-System Structure and Function or Impairment

The clinician also looks at each single system individually to determine how the specific body structures and functions contribute to or limit participation, functional activities, or the multisystem functions of posture and movement. Classically, in medicine and in education, there has been a clear identification of single systems in the body. In the ICF model, there is a long list of body systems that includes mental, sensory, cardiovascular, hematological, immunological, respiratory, neuromuscular, musculoskeletal, digestive, metabolic, genitourinary, reproductive, and integumentary systems. Each single system is carefully examined to identify and understand specific impairments.

It is not enough to say that a client has decreased passive range of motion (PROM). The NDT clinician is careful to examine and evaluate the influence of muscle and other soft tissue length, joint mobility (ligamentous, capsular, and bone structure), and the contribution of active tension in a muscle group or in antagonists to overall mobility. The function of each system is usually related to the functions of multiple other single systems. Although it may be viewed that all functions are multisystem in nature, there is benefit in analysis to looking at each system individually. In individuals who have had a stroke or who have cerebral palsy, primary impairments are more common in the neuromuscular and sensory systems. Chapters 10 and 11 review the single-system impairments associated with the diagnosis. The individual system integrities and impairments are then analyzed as they relate to functional activities and participation in each of the case reports in Unit V.

All people are seen to have systems that are more intact or more impaired for them. Some of the impairments do not seem to significantly limit an individual's ability to function or to participate fully. They may or may not influence a person's posture or how that person moves. Other impairments have a devastating impact. The clinician is responsible for deciding which impairments impact most negatively on an individual's ability to perform a desired activity or participation outcome. To make this decision, the clinician must have a good understanding of each system and then carefully examine each system. The system must be evaluated in the context of the desired functional activities or participation outcomes as well as the person's overall posture and movement. Finally, the influences of the personal and environmental contextual factors must be considered. The details of how this occurs in each component of NDT practice are described in Unit II, and examples are provided via the case reports in Unit V.

Further Analysis of Single-System Contributions

In addition to the analysis of posture and movement versus individual system structure and function, the NDT clinician takes a closer look at factors viewed as being single-system integrities or impairments, differentiating between primary and secondary impairments. For the NDT clinician, these differences are important distinctions to make. A deeper look at these differences will be further described throughout this text.

Body system impairments can be differentiated into primary or secondary impairments based not on a priority ranking for the individual but, rather, for identifying those impairments directly related to the primary pathology. A primary impairment[21] is one that occurs or results directly from the original pathology. For example, a primary impairment resulting after a stroke might include a hemianopsia. A secondary impairment[21] does not result directly from the original pathophysiology and generally develops across time. For example, the individual with a hemianopsia might develop a scoliosis from constantly using asymmetrical postures to accommodate the visual impairment. The scoliosis would be a secondary impairment because it is not directly caused by the stroke. It is important for the NDT clinician to identify potential secondary impairments associated with frequently encountered conditions so that the therapist can intervene to prevent or minimize their manifestations.

Primary and secondary impairments can also be classified as either positive or negative impairments. A positive impairment[22] is a sign that is present because of some pathophysiology or some condition. For example, if one observes sustained clonus in an individual, one assumes that there is some underlying cause for that sign because individuals functioning typically do not demonstrate that sign. A negative impairment[22] is a behavior that is absent because of the pathophysiology. An example of a negative sign could be decreased awareness of the left arm. Typically, a clinician would expect intact body awareness.

The clinician must therefore be able to identify both primary and secondary impairments and positive and negative impairments. It is frequently easier to observe positive signs rather than negative ones. It is also tempting at times to allow a client to function using a posture and movement pattern that will lead to significant and perhaps more debilitating secondary impairments. Part of NDT education is studying the development of secondary impairments based on the interactions of the domains within the ICF model. It is also part of the NDT Practice Model to intervene with a focus both on immediate improvement of functional activity and on preventing or minimizing the development of greater secondary impairments. Therefore, the patient's performing a desired functional outcome with a very atypical posture may not be encouraged because it may lead to more significant functional activity limitation in the future as well as the emergence of more severe secondary impairments. Parents use this same theory when they encourage their children to sit up straight at the dinner table and to chew with their mouth closed. The immediate task (activity) of eating dinner is not really changed if the mouth is opened or closed during chewing or if the posture is straight or slouched such that the head rests on the table surface. However, the parent knows that constant open-mouthed chewing and slouching at the table will limit participation in a wide variety of settings (eating at an important dinner function at a sales meeting) and also might lead to the development of a kyphosis in adulthood.

3.2.3 The Role of Contextual Factors from an NDT Perspective

Chapter 1 described the NDT philosophy and introduced the concept of therapeutic intervention with the person as a unique individual. This tenet is important, and is a statement of how the NDT clinician integrates the environmental and personal contextual factors into information gathering, examination, evaluation, intervention planning, and actual intervention.

The individual or personal factors are noted from the beginning contact and through each session in relationship to each of the three domains. It matters if the child just failed a math test, or an adult had a battle with her college-age child over finances and is feeling frustrated and angry. These factors not only will change how the individual may participate in the intervention that day, but can also change the presentation of single-system impairments or posture and movement impairments. The individual may be hyperresponsive to sensory input due to these personal factors or may have a rounded, slumped posture as an expression of depression or frustration. In addition, the critical functional activity outcome or participation may change either for the day or for the near future based on changes in the personal factors. The clinician using the NDT Practice Model will alter the evaluation and intervention based on the individual's personal factors.

The environmental factors must be considered in establishing activity outcomes and planning for participation. It matters if the family home is a one-level or a trilevel house. It matters if the child will move to a middle school with stairs when none have been present in the elementary school. It matters if the neurologist most familiar with the client is moving away and a new team member must be found. It matters if the new teacher has a critically ill child and is more focused on personal family issues than on the child's individualized educational plan (IEP). Once again, each contextual factor is seen as either a facilitator or a barrier and can be studied in relation to each of the three domains. Some parents may work through soft tissue limitations with an active home program, whereas others have elected to have surgery to address the same impairment because they honestly cannot do any more at home. The same impairments may be considered to be slightly problematic in some societies and as incredibly interfering in others.

3.2.4 The Role of NDT Practice

The circle surrounding the schematic represents NDT practice. NDT clinicians propose that there is an ongoing but changing relationship of the domains in individuals with central nervous system–based disorders of posture and movement. The focus at the start is with the individual pictured in the center of this schematic. The clinician then moves outward to consider the domains and the contextual factors for this one individual at the one point in time. The ongoing and changing relationship of the domains, if understood, can help to predict the natural course in these disorders and is foundational for the clinician to plan effective intervention, as seen in **Fig. 3.3**.

After a stroke or the insults that result in cerebral palsy, there is a pathophysiology that leads to primary impairments in at least the neuromuscular system. There may be additional impairments in other systems, such as in a sensory system, in cognition, or in the regulatory system. At this point, discussion will begin with a focus on the primary neuromuscular impairments.

Immediately after the insult there is usually a period of time when it is difficult for the person to recruit motor unit activity. This is especially true of postural motor units. Thus an individual poststroke may have limbs that flail or may be unable to move. The infant born with cerebral palsy generally presents with generalized hypotonia. This primary impairment can lead to predictable ineffective posture and movement control or coordination. The adult may be unable to hold one arm up against gravity when positioned in supported sitting and may develop generalized trunk asymmetry. The infant, if positioned in prone, may demonstrate a "frog leg" posture and can demonstrate poor head control such that it is difficult to lift the head off the support surface.

The inefficient posture and movement can clearly contribute to a loss of functional activities. The adult may no longer be able to perform ADLs requiring the use of both arms. If the dominant arm is more involved, the person may not be able to perform activities routinely done with that hand, such as self-feeding, tooth brushing, or grooming activities. The infant may be unable to roll over to reposition in the crib or to sit alone with hands free for play.

The activity limitations can lead to participation restrictions. Adults who are unable to groom themselves or feed themselves may be unable to return to work or engage in social activities with friends and family. Infants who are unable to roll over alone or hold their head erect for feeding or play may not be able to attend a local day care center or be fed by the usual family babysitter.

Conversely, activity limitations and participation restrictions can lead to more ineffective postures and movements and the emergence of secondary impairments. In the example above, the adult who cannot return to work and spends much of the day watching TV in a recliner may find it increasingly difficult to get up from the chair (neuromuscular impairments: decreased strength and muscle recruitment), and may experience increased thoracic rounding (musculoskeletal impairments). Increasing thoracic rounding positions the shoulder girdle in a posture of risk for subluxation. It can contribute to poorer alignment

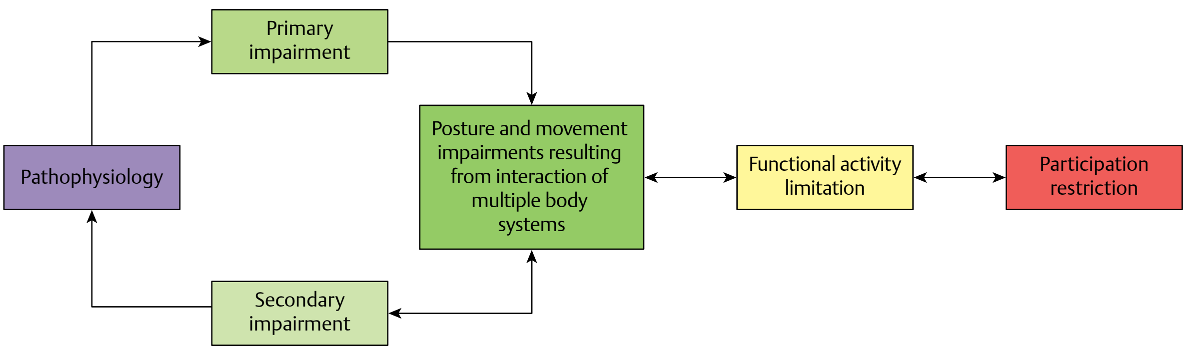

Fig. 3.3 Neuro-Developmental Treatment problem solving and decision making (created by Monica Diamond).

of the upper extremity for functional use. The person can develop overstretched ligaments of the anterior shoulder and can overstretch selected muscles of the upper extremity. This can lead to disuse atrophy and true weakness in the upper extremity. Therefore, the secondary impairments of atypical soft tissue mobility and muscle weakness emerge. In addition, the sedentary lifestyle can contribute to greater or new cardiovascular impairments. In fact, it may lead to additional pathology and another cycle of primary and secondary impairments with additional ineffective postures and movements, activity limitations, and participation restrictions. These secondary impairments can now contribute to additional activity limitations and participation restrictions. This interactive cycle can continue across time and can lead more domains to shift from the health and wellness portion of the ICF continuum to the disability end of that continuum.

A child with cerebral palsy can experience these same interactions of the ICF domains. A child with spastic diplegia might learn to W-sit and to bunny hop to move around the house. In W-sitting, the child sits with the pelvis centered between two internally rotated lower extremities. There is a wide base of support. In bunny hopping, the same basic posture is observed as in W-sitting, and during movement the lower limbs move in phase with each other rather than out of phase, as seen in reciprocal creeping on hands and knees. The movement may be very functional for moving around the household and playing on the floor. However, with repetitions, the child may begin to lose range of motion at the hips with limited external (lateral) rotation, abduction, and hip extension. These are new single-system impairments. As the bones shape in response to the mechanical stresses placed on them and by the active pull of the muscles, the child is seen at being at greater risk for developing femoral anteversion or antetorsion. If the bones demonstrate this deformity, it then becomes more difficult for the child to develop smooth ambulation skills and all the functional activities related to walking or running. Participation at school and in the community can become more restricted. This functional activity limitation of reduced ambulation can in turn lead to greater severity of the single-system impairments and to more ineffective posture and movement. On the other hand, perhaps if the child is positioned on a small chair for play, and lateral weight shifting in sitting is facilitated, the child may be prepared for more effective reciprocal creeping and supported ambulation.

3.3 Summary

As therapists provide intervention, they must attend to all domains described in the ICF. The desired outcome is for each person to develop functional activities in meaningful life settings. The ability to participate more fully is inherently tied to the development of more effective postures and movements and avoid the development of secondary impairments. For this reason, the therapist using the NDT Practice Model strives to not only increase independence, but to also develop effective postures and movements to avoid secondary impairments, which over time may limit both functional activities and participation.

The interaction of the body functions or impairments with activities or activity limitations and participation is complex. If a client wishes to meet a set of specific activities outcomes to participate in community-based activity, the therapist must determine which individual system impairments have the greatest impact on reaching the desired functional activity outcomes. The therapist must then decide which strategies for intervention will be most effective for this one client. In addition, the therapist must decide if the posture and movement of the client are preventing the client from functional activity success. The therapist may also consider, however, that the individual's functional history and habits have led to the development of ineffective postures and movements and possibly the development of several secondary single-system impairments.

It is clear that, to be most effective in intervention, all domains and all subcategories of all domains, anywhere on the function to disability scale, must be simultaneously addressed and managed. This unique process is at the heart of the NDT Practice Model. This focus continues in Unit II describing NDT information gathering, examination, intervention planning, and intervention. The model varies to fit within the scope of OT, PT, and SLP according to the practice of the specific discipline.

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4 Application of a Posture and Movement Model in Practice

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This chapter presents an example a theoretical model as applied to intervention planning and implementation. The first section includes the source material for a posture and movement model. Findings from neuroscience and musculoskeletal studies are presented to explain and support components of the model. The second section presents the therapeutic principles of intervention for individuals with posture or movement impairments. These principles, derived from the source material, guide the choice and progression of intervention strategies for strengthening weak movement and postural systems.

Learning Objectives

Upon completing this chapter the reader will be able to do the following:

- Define the differences in the anatomical features of the posture and movement systems.
- Identify impairments associated with failure in one system and imbalance when both systems do not integrate.
- Explain the physiological mechanisms that are operating when each system is active.
- Translate the scientific findings to their practical application.
- Apply therapeutic principles when designing and implementing intervention.
- Progress from initial intervention to more demanding levels based on therapeutic principles.

4.1 Introduction

This chapter continues the process of applying theory to practice in the form of a model. This model of motor control defines the concepts of posture and movement and their application to intervention strategies. Source material from neurological and musculoskeletal fields forms the basis for proposing two distinctly different systems as components of the posture/movement model. The intent here is for the practicing therapist to see the relationship between basic sciences and clinical practice.

The basic sciences give rise to the rationale for the options a therapist has in designing intervention activities. The options are presented in the form of therapeutic principles that are the *rules of action*. Principles are not laws, but they can be regarded as working hypotheses being tested. Each decision made in each intervention session of a given client can be more easily made when the rationale for that choice is clear. The posture and movement model translates into a method that can be used in intervention with clients having disorders of either or both posture and movement.

4.2 A Posture and Movement Model

4.2.1 General Concepts

Posture and movement represent two subsystems of motor control that are integrated to achieve coordination for functional tasks. The distinct roles of the subsystems are opposite in their goals, yet they are complementary when their interaction occurs in purposeful activity. The general nature of the postural system's work is stabilization through maintenance of body position and orientation in space, maintenance of balance during movement, and modulation of the movement system. The general nature of the movement system's work is to project the body or part of it through large excursions and to provide speed, especially in the responses of the limbs. The movement system mobilizes the body to move into space and acts upon the environment. A posture/movement model can also be defined as a stability/mobility model.[1,2,3,4,5,6,7]

4.2.2 Distinct Roles of Subsystems

Although the general concepts of posture and movement provide an overview, it is useful when assessing and providing intervention for people with impairments to have more detailed descriptions of the various functions of each subsystem. The subsystems in any one individual can be selectively damaged or both can be affected. The following are summaries of the subsystems functions.

Functions of the Postural System

- The postural system provides the ability to maintain the upright position against gravity through vertical lift.

- Postural responses also maintain the center of mass (COM) over the base of support (BOS) in two ways. First, in anticipation of movement that would place the COM outside the BOS, postural responses act to prepare the body to remain balanced. This anticipatory preparation occurs prior to the disturbance of posture and equilibrium by movement. Second, during the process of moving the COM, the postural system reacts with a compensatory balance response that maintains alignment. These reactive functions of the postural system are dynamic, involving small adjustments of the body on itself, but do not project the body from one place to another.[6]
- In addition to the whole-body responses, the postural system maintains the integrity of joint structure through active cocontraction of antagonistic muscles. When velocity or load is high enough to lead to mechanical instability of the joint, cocontraction increases dynamic joint stiffness to prevent damage.

Functions of the Movement System

- The movement system is a primary controller when a wider range and a faster speed of motor responses are required.
- To initiate fast responses, the movement system will recruit the high levels of tension required to overcome inertia.
- Although axial regions do not have the same wide excursions in many functional tasks that the limbs do, their range in transitional activities can signal the need for a movement component.
- In distal and rostral areas, rapid alternating patterns require the full participation of the movement system.

The term *mobility* describes the goal of the movement system and is used here in a different way than when describing the independence of the whole individual moving in the environment.

Integrated Functions of the Subsystems

As described in the introduction to this section, the two subsystems have roles that are opposite and yet complementary when integrated for purposeful activity. Examples of this integration follow.

- The accuracy of limb placement is dependent not only on the movement system activity for projection but also on the postural system providing cocontraction as well as synergistic activity related to the pattern of movement. The variability of end range placement is directly related to the postural system guidance.[8]
- Patterns of new motor learning manifest excessive recruitment, which gradually reduces with development of skill.[8,9] When a subject is learning a novel movement, cocontraction is greater at the beginning and gradually reduces over the course of acquisition. This excessive cocontraction is often seen as a form of fixation called in to prevent excessive movement. It would appear that refinement of motor functions occurs as selection of necessary movement components is accompanied by more exact postural guidance to overcome excessive degrees of freedom.
- Transitions from one posture to the next, as in rolling over, moving supine to sit or sit to stand, and walking and running, require the integration of the movement and posture systems. The large excursions of movement and, in some cases, the speed of movement require the functions of the movement system. At the same time, the postural system is needed to maintain balance and orientation during the transitions.

4.2.3 The Anatomical Basis for the Posture and Movement Model

Gross Characteristics of Muscles

The anatomical support for the model begins with a description of the gross characteristics of skeletal muscles that identifies them as being more suited for either postural activity or movement, as seen in **Table 4.1**.[10] This categorization is not an exact dichotomy because many muscles can function in both systems depending on the task and the context of the action.

Table 4.1 Characteristics of muscles better suited for either postural or movement activities

Characteristic	Muscles better suited for postural activities	Muscles better suited for movement activities
Overall shape	Bipennate or multipennate	Fusiform
Fiber orientation	Oblique in relation to axes	Parallel to long axis
Length of fibers	Shorter	Longer
Attachments	Broad and aponeurotic	Small and tendinous
Location	More proximal, medial, deeper	More distal, lateral, superficial
Number of joints crossed Location	One	Two or more
Type of contraction	Cocontraction	Reciprocal
Speed and extent	Small excursion, holding	Wide excursion, high velocity
General function	Stability	Mobility

The therapist can begin by observing gross muscle structure when considering functions and impairments. This observation can aid in identifying the altered state of the posture and movement contributions. Four frequently observed clinical examples will be given describing situations where postural muscles are severely weakened and the remaining movement system attempts to compensate.

Clinical Observation #1

Function

Maintenance of alignment of the head and neck upright with a chin tuck position.

Clinical Picture

A patient has a forward head (as seen in **Fig. 4.1**) with the lower cervical region flexed and the upper cervical region and the atlanto-occipital joint extended so the chin is up. Often, heavy bands of superficial muscle on each side of the midline with a deep groove between can be seen in the neck posteriorly.

Posture/Movement Impairment

The deep intrinsic muscles of the neck (rectus capitis posterior major and minor, obliquus capitis inferior and superior, rectus capitis anterior and lateralis) are failing to stabilize the neck through cocontraction with the deep flexors. The head is being held up by the more superficial extensor movement muscles (i.e., semispinalis capitis, longissimus capitis, cervical parts of the sacrospinalis). Movement is restricted as the movement muscles adapt and become stiffer in an attempt to substitute for the nonfunctioning postural muscles. As the person attempts to bring the neck into a flexed position, there can be a sudden drop of the head with loss of all extensor activity.

Fig. 4.1 This child sits supported with a forward head posture, stabilizing with superficial neck muscles.

Clinical Observation #2

Function

Maintenance of the trunk and neck in an upright position in sitting.

Clinical Picture

A patient sits in a slumped, flexed position with the head up from neck extension in the high cervical region. The pelvis is in an extreme posterior tilt with the weight back on the sacrum. The spinous processes are prominent, especially in the thoracic area. When requested, the person might be able to sit erect but will come to sitting with an abrupt movement and be unable to hold the position for long, as seen in **Fig. 4.2a, b**.

Posture/Movement Impairment

The deep intrinsic extensor muscles of the trunk (multifidus, rotatores, interspinalis, intertransversarii) are failing to stabilize the trunk bilaterally. These muscles would usually pack the vertebra, filling in around the spinous process and making only the tip visible. If the movement trunk extensors (iliocostalis, longissimus, spinalis) are still active, it will be possible for the person to move into full extension, but these muscles will fatigue rapidly. On the anterior side, the transversus abdominis is failing to cocontract with the deep intrinsics, such as the multifidus.

Clinical Observation #3

Function

Stabilization of the scapula so that its movement participates in the normal glenohumeral rhythm.

Clinical Picture

At rest, the scapula is abducted so far that its lateral border can be seen in the axilla, and its medial border is winged. The scapula and the humerus appear to be fused when the patient moves the arm, as seen in **Fig. 4.3**.

Posture/Movement Impairment

The weak scapular adductors (especially the middle trapezius) cannot hold the scapula in a position where the serratus anterior can be kept on a stretch. As the adductors become overstretched and the scapula abducts widely, the serratus anterior is unloaded, loses its ability to contract, and the scapula wings. This combination of the loss of active adduction and abduction removes a dynamic postural response that is required for the next in-line stabilization of the humerus through cocontraction at the glenohumeral joint. The movement system

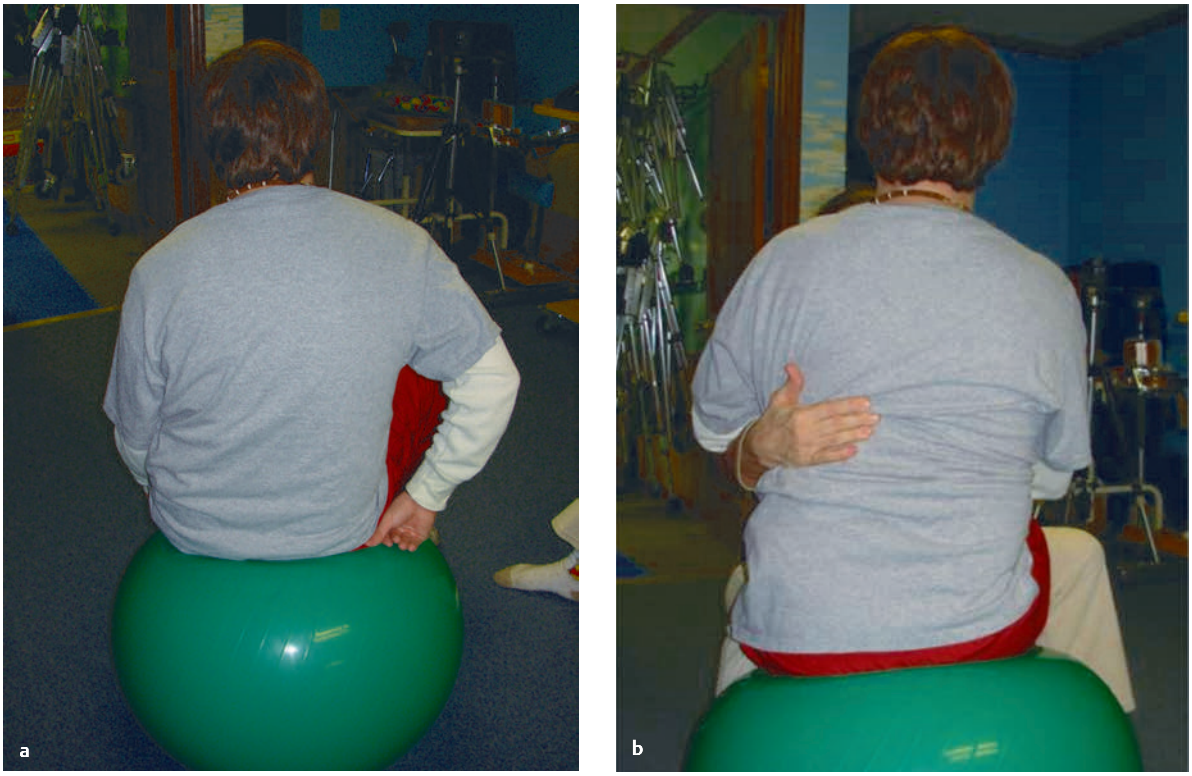

Fig. 4.2 **(a, b)** Young adult demonstrating usual sitting with rounded back. He is unable to hold full extension, although he can hold with cueing momentarily.

attempts to stabilize the joint; however, the response is not cocontraction of the rotator cuff muscles but fixation by more superficial muscles. The infraspinatus and the posterior deltoid, as part of the postural extensor pattern, are also weak and overstretched, leading to internal rotation of the humerus.

Clinical Observation #4

Function

Maintaining the upright position in the lower extremities during standing.

Clinical Picture

The patient is able to stand only with the hips and knees in flexion. During ambulation, the flexed posture continues.

Posture/Movement Impairment

Postural extensor muscles should be able to respond to stretch from the pull of gravity in their shortest range. This postural response means that the postural hip extensors, gluteus maximus, knee extensors, and vasti of the quadriceps should be able to hold in full extension. When they are weak, the set point for that response can be in a longer range. The patient sinks down until those muscles hit the longer set point, as seen in **Fig. 4.4a**. This

Fig. 4.3 Child demonstrating scapular abduction with insufficient stabilization on thoracic wall.

Fig. 4.4 **(a, b)** This young man stands in a crouched posture even though with support full extension is possible at both the hips and the knees.

patient might be able to come to full extension as seen in Fig. 4.4b but will have to use the movement system to do so. The result will be rapid fatigue and a return to the flexed position.

Muscle Fibers and Motor Units

Support for the posture/movement model also comes from the examination of different types of muscle fibers and motor units of skeletal muscles. Lieber[11] has pointed out that several schemes for classifying muscle fiber types have been developed. He proposes that the most useful scheme is one based on physiological, biochemical, and morphological measures.

The three groups of muscle fibers are fast glycolytic (FG), fast oxidative glycolytic (FOG), and slow oxidative (SO). When glucose is oxidized in the absence of oxygen, glycolysis occurs. The anaerobic contractions that result cannot last much longer than 10 to 30 seconds.[11] When glucose is metabolized in the presence of oxygen, oxidative phosphorylation occurs. This aerobic form of metabolism is more efficient than glycolysis.

Motor units can also be classified based on the physiological properties of their muscle fibers, as seen in Table 4.2. A motor unit consists of an α-motor neuron and all the skeletal muscle fibers it innervates.

In terms of the posture/movement model, the SO motor units would be more appropriate for postural activity that requires sustained contractions with low levels of fatigue. The fast fatigable (FF) units would allow brief fast excursions of the limb where high tension was needed to overcome inertia and impart momentum. Fast fatigue resistant (FR) units would be needed where the activity was fast, repetitive movement.

Medial and Lateral Descending Motor Organization

Well before and into the 20th century, the motor system was defined by two supposedly independent systems: pyramidal and extrapyramidal. This classification is questioned as a basic organizational scheme because it does not include structures that are important parts of the motor system (i.e., the cerebellum, brainstem nuclei, and red nucleus). In addition, pyramidal and extrapyramidal structures are extensively interconnected. From an applied view, this classification does not provide the foundation for therapeutic intervention for disorders of motor control. The terms are still used in some neurology contexts.

Table 4.2 Classification of motor units

Motor units	FF motor units: fast fatigable	FR motor units: fast fatigue resistant	S motor units: slow
Size of axons	Large	Medium	Small
Muscle fibers	Many large (FG)	Many (FOG)	Few small (SO)
Metabolism	Glycolytic, anaerobic	Some aerobic capacity	Oxidative, catabolism, aerobic
Tension generated	Large	Moderate	Low
Fatigue	Rapidly	Less than FF	Low

Abbreviations: FG, fast glycolytic; FOG, fast oxidative glycolytic; and SO, slow oxidative.

In 1963, Kuypers[12] proposed a different model of organization for the motor system based on the position of motor neurons in the spinal cord and the descending pathways that terminate there. His work continued as he collaborated with Lawrence[13,14,15] to define the details of the model, which he presented again at a later time.[16]

Spinal Cord Organization and Descending Pathways

The pools of motor neurons (motor nuclei) in the anterior horn of the spinal cord are organized along a medial to lateral axis as seen in **Fig. 4.5**. The most medial motor neurons innervate the muscles of the neck and trunk (axial), and the most lateral motor neurons innervate muscles of distal regions (limb). Between these two groups are the motor neurons that innervate the proximal muscles (girdle). A ventral/dorsal gradient of organization has also been identified so that the cell groupings are often referred to as *ventromedial* and *dorsolateral*.

Descending Pathways

The descending pathways controlling the motor nuclei are divided into two main groups: medial (**Fig. 4.6a, b**) and lateral (**Fig. 4.7a, b**).[16,17] All the pathways in the medial system have a bilateral influence on axial and proximal functions. The medial pathways of the brainstem are the pontine reticulospinal, the vestibulospinal (medial and lateral), and the tectospinal tracts. These pathways terminate on interneurons in the ventromedial part of the intermediate zone of the spinal cord and on the medial motor neurons. The interneurons connect bilaterally to the medial motor neurons that innervate axial and proximal muscles.

The lateral pathways have a contralateral influence on distal functions.

Effects of Lesions of Medial and Lateral Systems

The separate functions of the medial and lateral systems can be illustrated by the effects of selected lesions that dissociate the systems. Lawrence and Kuypers undertook extensive studies of the descending pathways of the medial and lateral systems in monkeys.[14,15] When the corticospinal tract was interrupted bilaterally, the monkeys lost individual finger movements permanently and "all movements were slower and fatigued more rapidly than in the normal animal."[14] The lateral corticospinal tract is part of the lateral system. If the lateral system provides not only control of distal functions but also speed for all movements, then it could be part of the system for the movement part of the posture/movement model presented in this chapter. The animals with destruction of the corticospinal system (lateral motor system) retained their ability to maintain posture and to balance (medial motor system).

When the medial brainstem pathways were interrupted bilaterally, the animals were unable to right themselves and demonstrated a severe deficit in axial and proximal limb functions. "When sitting they tended to slump forward, with shoulders elevated and the arms flexed at the elbows and adducted to the trunk."[15] The medial pathways provide the innervation for the axial and proximal regions of the body. The medial system can be considered the controlling system for the postural part of the posture/movement model presented in this chapter.

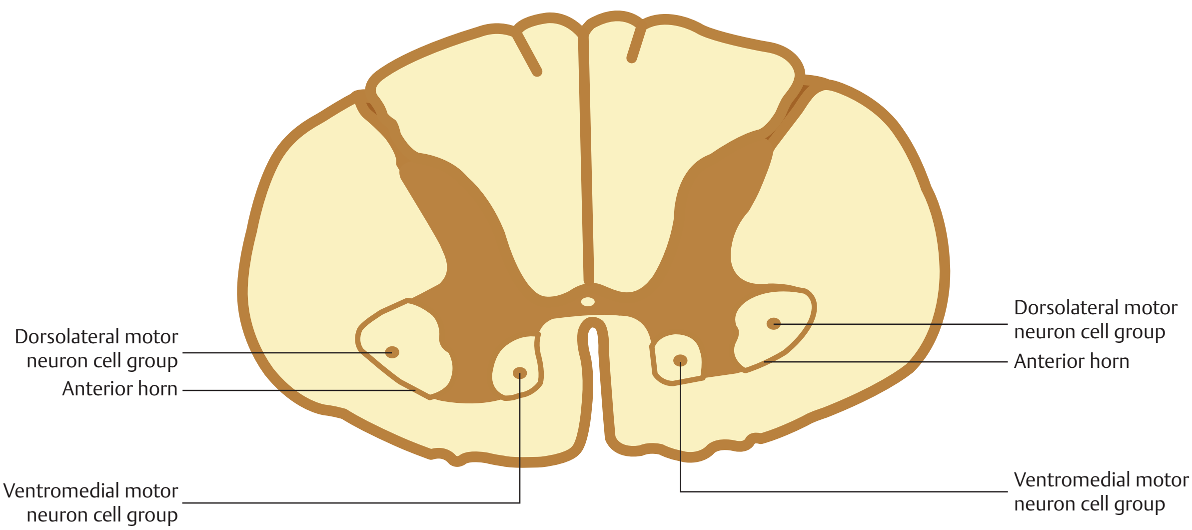

Fig. 4.5 Cross section of the spinal cord: organization of the anterior horn.

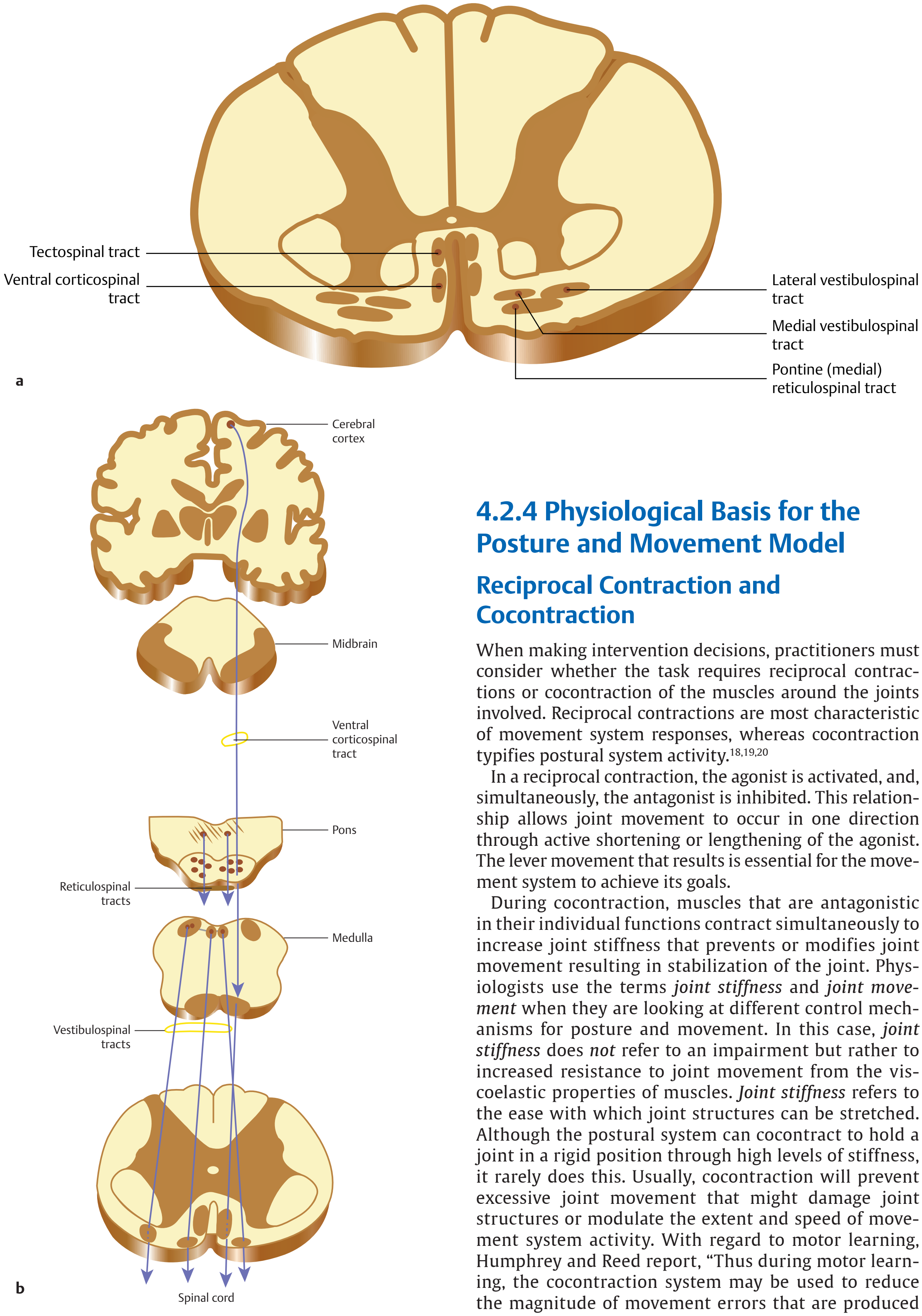

Fig. 4.6 **(a)** Medial pathways: termination in the spinal cord. **(b)** Medial pathways: course through the central nervous system.

4.2.4 Physiological Basis for the Posture and Movement Model

Reciprocal Contraction and Cocontraction

When making intervention decisions, practitioners must consider whether the task requires reciprocal contractions or cocontraction of the muscles around the joints involved. Reciprocal contractions are most characteristic of movement system responses, whereas cocontraction typifies postural system activity.[18,19,20]

In a reciprocal contraction, the agonist is activated, and, simultaneously, the antagonist is inhibited. This relationship allows joint movement to occur in one direction through active shortening or lengthening of the agonist. The lever movement that results is essential for the movement system to achieve its goals.

During cocontraction, muscles that are antagonistic in their individual functions contract simultaneously to increase joint stiffness that prevents or modifies joint movement resulting in stabilization of the joint. Physiologists use the terms *joint stiffness* and *joint movement* when they are looking at different control mechanisms for posture and movement. In this case, *joint stiffness* does *not* refer to an impairment but rather to increased resistance to joint movement from the viscoelastic properties of muscles. *Joint stiffness* refers to the ease with which joint structures can be stretched. Although the postural system can cocontract to hold a joint in a rigid position through high levels of stiffness, it rarely does this. Usually, cocontraction will prevent excessive joint movement that might damage joint structures or modulate the extent and speed of movement system activity. With regard to motor learning, Humphrey and Reed report, “Thus during motor learning, the cocontraction system may be used to reduce the magnitude of movement errors that are produced by inappropriate commands from the joint movement control system.”[18]

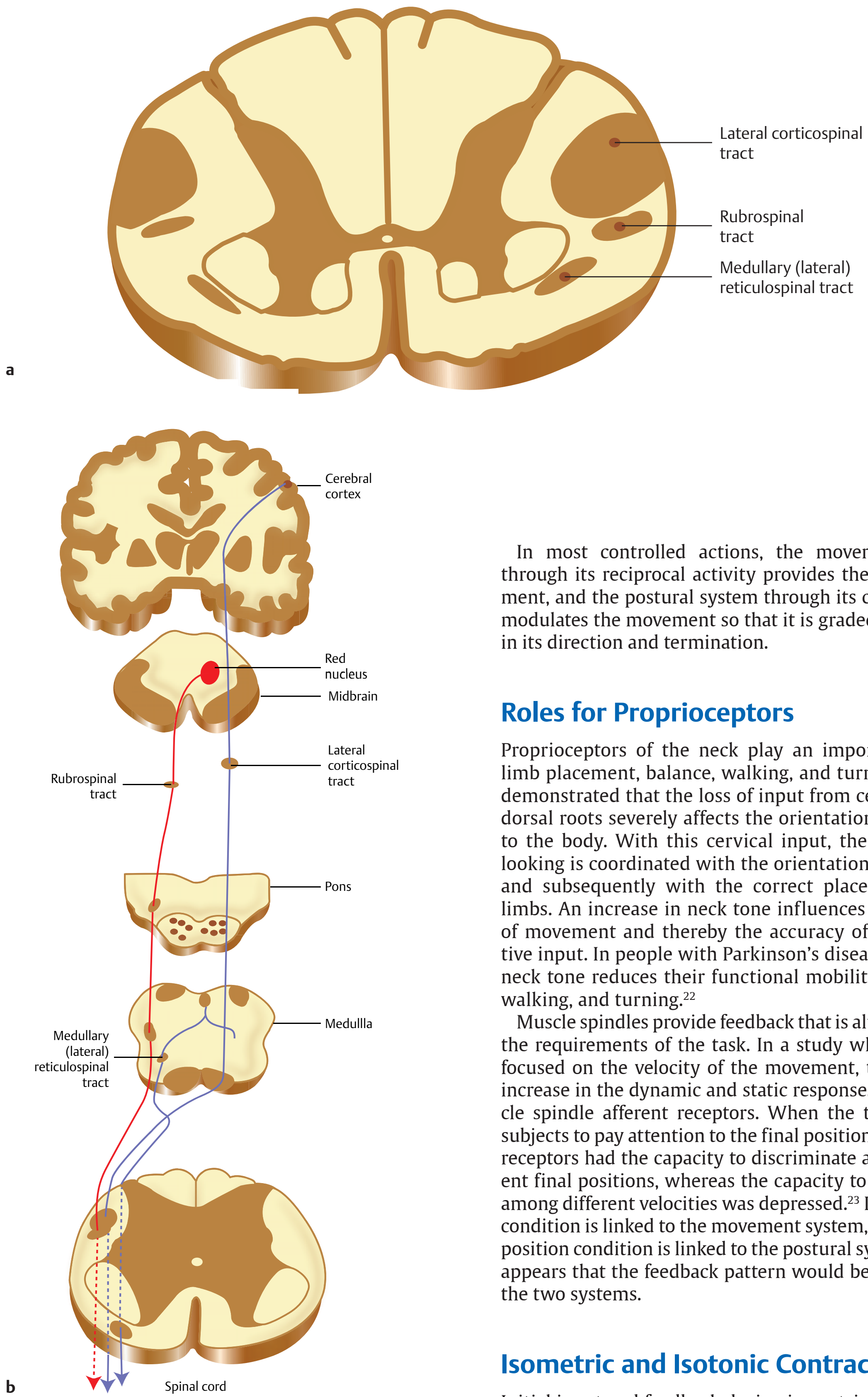

Fig. 4.7 **(a)** Lateral pathways: termination in the spinal cord. **(b)** Lateral pathways: course through the central nervous system.

In most controlled actions, the movement system through its reciprocal activity provides the lever movement, and the postural system through its cocontraction modulates the movement so that it is graded and precise in its direction and termination.

Roles for Proprioceptors

Proprioceptors of the neck play an important role in limb placement, balance, walking, and turning. Cohen[21] demonstrated that the loss of input from cervical 1 to 3 dorsal roots severely affects the orientation of the head to the body. With this cervical input, the direction of looking is coordinated with the orientation of the trunk and subsequently with the correct placement of the limbs. An increase in neck tone influences the freedom of movement and thereby the accuracy of proprioceptive input. In people with Parkinson's disease, increased neck tone reduces their functional mobility in balance, walking, and turning.[22]

Muscle spindles provide feedback that is altered to meet the requirements of the task. In a study where the task focused on the velocity of the movement, there was an increase in the dynamic and static responses of the muscle spindle afferent receptors. When the task required subjects to pay attention to the final position, the afferent receptors had the capacity to discriminate among different final positions, whereas the capacity to discriminate among different velocities was depressed.[23] If the velocity condition is linked to the movement system, and the final position condition is linked to the postural system, then it appears that the feedback pattern would be different for the two systems.

Isometric and Isotonic Contractions

Initial input and feedback during isometric and isotonic contractions can be different for postural and movement actions.[24] An isotonic contraction is a shortening contraction that results in lever movement. Before the contraction begins, sensory input concerning the goal, the orientation of proximal regions, and the position of the part to be moved are available to controlling centers.

Proprioceptors provide important information about the initial length and tension of the muscles involved. During the shortening contraction, the muscle spindles are unloaded (i.e., the external stretch is removed and feedback is reduced). At the end of the contraction, there is an increase in stretch sensitivity and muscle spindle activity.[25] If the movement system muscles begin with good alignment and correct sensory input at the start and facilitation at the end of the isotonic contraction, they will be strengthened if their weakness is of central origin.

An isometric contraction is one in which muscle length does not change as tension is increased. This contraction results in holding a position and is characteristic of much of the work of the postural system. Because muscle length does not change, the muscle spindles are not unloaded, and through activity of the gamma motor neurons, feedback will continue throughout the contraction.[26] This continuous feedback is necessary for the slow (SO) motor units to sustain activity for holding in the postural muscles.

4.3 Formulating Therapeutic Principles from Basic Information

A principle is a *rule of action*. It tells clinicians what to do under certain conditions. In the case of therapeutic principles derived from information in the posture and movement model, they guide the decisions concerning intervention choices. The following paragraphs summarize the therapeutic principles that guide therapists in addressing specific impairments of each system. Then each principle is described in greater detail.

4.3.1 Summary of Therapeutic Principles That Guide the Initial Intervention for Postural System Weakness

- Position weak postural muscles in their shorter range.
- Activate an isometric contraction (holding) in the shorter range.
- Elicit a postural response using small movements of the center of gravity (COG) over the BOS.
- Keep resistance low during holding.
- Activate small excursion movements of the proximal segment on the distal segment in weight bearing.
- Position weak postural muscles in their shorter range.

> Note: Weakness can result from peripheral origin or central origin, depending on the structures involved.[27] In the case of a *peripheral origin,* musculoskeletal structure impairment is implicated. In the case of a *central origin,* it is necessary to think of motor neurons receiving too little facilitation or too much inhibition, resulting in thresholds too low to fire.

Position Weak Postural Muscles in Their Shorter Range

Postural muscles that are weak often rest in an overstretched position. Prolonged overstretch alters the number and length of muscle sarcomeres.[28] Overstretch also changes the set point for the stretch sensitivity of muscle spindles. The changes are adaptations to allow the muscles to work in that longer range as a new functional range. However, the adaptations alter the ability of postural muscles to work effectively in their shorter range where they are usually called upon to hold against gravity and move in small excursions. Even when overstretch is not obvious, weak postural muscles are not able to hold in their shorter range. To address the problem, readaptation to a more functional shorter range is the goal.[29,30,31]

Activate an Isometric Contraction (Holding) in the Shorter Range

Readaptation requires postural muscles to be active in the shorter range for a long duration. A combination of continuous isometric contractions and very small excursion movements until the muscles begin to fatigue constitutes the desired response. The isometric contraction is chosen as the beginning activity where a postural muscle is very weak because it provides the best proprioceptive feedback.[26] This feedback from the muscle spindle is autogenic facilitation of the motor neurons to the muscle in which the spindle lies. The long duration is an essential factor in establishing this short length as the *new functional range* requiring readaptation.

Elicit a Postural Response Using Small Movements of the COG over the BOS

Postural muscles are activated primarily by changes in the relationship between the COG and the BOS. They are activated by a demand for maintenance of equilibrium. Intervention begins with correct alignment, and then small movements in and out of the position create the need for a small balance response. The patient will respond by holding at a certain point. When that point is determined, the therapist releases support and moves the patient very slightly in and out of the range, thereby stimulating a buildup of a holding response.

Keep Resistance Low during Holding

Working from an upright position toward a slightly off-vertical position for the trunk and head provides less resistance than working from horizontal to upright where the load from body weight starts out as maximal. High loads have the same negative effect as long stretches do on postural muscles. Overload can result in loss of strength that might have been gained through lighter loads.

Activate Small Excursion Movements of the Proximal Segment on the Distal Segment in Weight Bearing

Weight bearing on the extremities can activate postural muscles if several conditions are met: the weight-bearing joints are positioned actively or passively in alignment, the distal part of the limb (hands, elbows, feet, knees) is weight bearing, and small movements of the proximal segment on the distal segment and back to alignment are repeated. The patient is monitored to determine where and when holding takes place, and that range is emphasized. Large excursions and *collapse* out of the weight-bearing position are prevented because they usually result in overstretch of the postural muscles needed for holding.

Position Weak Postural Muscles in Their Shorter Range

When a patient is at rest, even momentarily, between active efforts, weak postural muscles are supported in their shorter range. Every effort is made during long periods of inactivity to relieve overstretch through the use of positioning, supportive equipment, and taping. Everything gained in the shortened range will be lost if there is a return to the original overstretched position.

4.3.2 Summary of Therapeutic Principles for Progression of Strengthening in the Postural System

- Activate postural muscles from short- to midrange positions—avoid long ranges until holding is strong.
- Activate slow and limited-range eccentric contractions progressing to the longer ranges.
- Increase resistance gradually.
- Increase the excursion of movement.
- Introduce higher loads of weight bearing.

Activate Postural Muscles from Short- to Midrange Positions—Avoid Long Ranges until Holding Is Strong

To develop the postural system's ability to stabilize at all ranges and to modulate the movement system activity, postural muscles must be able to work at all points in the range. The progression for developing these abilities is to work from short to mid to long range, being sure to avoid the long range until other positions are secure. In the long range, the stretch on a postural muscle could be inhibitory unless proprioceptive feedback has raised the level of excitability of motor neurons so that inhibitory influences do not dominate.

Activate Slow and Limited-Range Eccentric Contractions Progressing to the Longer Ranges

Once a postural muscle can hold in the shorter position, the part can be slowly lengthened using an eccentric contraction. If a rapid collapse into the long range occurs, the gains will be lost, and muscles may be more difficult to activate again. If work is done in the range just before the point where the position is lost, gains can gradually develop, and work in longer ranges can be done without collapse.

Increase Resistance Gradually

As postural muscles become stronger, the positions in which they are activated can become gradually more demanding. Gravity can play a role in offering more resistance. For example, neck and trunk activity can be done closer to the horizontal where gravity exerts its full force. In the extremities, the fully extended limb will provide more resistance than one with the intermediate joint flexed because of the longer lever. If a patient cannot hold at the gravity maximal position, start by giving assistance, and progress by gradually reducing resistance as the patient takes hold. Resistance will increase proprioceptive feedback, facilitating motor neurons as the demand for more recruitment of motor units occurs.

Increase the Excursion of Movement

Gradually increase the range from very small excursions to wider ranges where the postural system will be working more with the movement system (see Principles for Integration in Section 4.4.4). Continue to keep the movements slow to allow proprioceptive feedback to facilitate the motor neurons of the postural muscles, especially the slow motor units. There is a lack of certain feedback during wide-excursion, rapid movement because of the muscle spindle's unloading.

Introduce Higher Loads of Weight Bearing

Progression can be accomplished by changing the activity from bilateral to unilateral weight bearing. In addition, weight bearing on one joint can progress to multiple joints, such as from on the elbows to on the hands or from kneeling to standing. In the trunk, symmetrical sitting can be progressed by shifting weight laterally far enough to elicit a balance response; the same can be done in standing. Small movements within the weight-bearing position can progress to larger movements that challenge balance. Some movement of the COG on the BOS is necessary because bilateral symmetrical weight bearing does not challenge the balance system.

4.3.3 Summary of Therapeutic Principles That Guide the Initial Intervention for Weakness in the Movement System

- Select activities that require shortening (isotonic) contractions that start in the long range and go through the full range.
- Encourage isotonic contractions at a variety of speeds.
- Keep resistance low enough that it does not prevent movement.
- Encourage wide-excursion movements.
- Activate the movement system through the use of verbal commands and visual and tactile stimuli.
- Rest movement system muscles in a long but not extreme length.

Select Activities That Require Shortening (Isotonic) Contractions That Start in the Long Range and Go through the Full Range

Following shortening contractions of muscles, such as the finger flexors, there is increased activity and increased stretch sensitivity of their muscle spindles.[25] This increase in feedback will facilitate the motor neurons of these movement muscles. In contrast, isometric contractions of the finger flexors frequently reduce the stretch sensitivity of their muscle spindles.[25] In a stretched position, all muscle spindle receptors of a movement muscle will provide feedback that is facilitating to the motor neurons of that muscle. Quick, small stretches in the long range are designed to stimulate the Ia endings of the muscle spindles, providing autogenic facilitation.

Encourage Isotonic Contractions at a Variety of Speeds

Faster movements will require activity of the FF motor units, which, if they are not used, might atrophy. At very fast speeds, muscle spindles are unloaded, and feedback is minimal during the contraction; however, the aftereffects are of facilitation.[32] In spastic muscles that are maintained in a hypertonic state, fast units either atrophy or are converted to slow (SO) motor units.

Keep Resistance Low Enough That It Does Not Prevent Movement

Resistance will increase the recruitment of motor units. However, if it is so high that it prevents movement, the contraction becomes isometric, and the muscle spindles in movement muscles will have reduced sensitivity to stretch.[25] Then the benefits of the isotonic contraction for the movement muscles are lost.

Encourage Wide-Excursion Movements

Wide excursions are facilitating to movement muscles and inhibiting to postural muscles. Reaching for an object beyond arms-length and stepping up on a high step are examples of activities that encourage wide ranges of movement. In the trunk, segmental rolling from full supine to full prone and back provides the wide range that engages the movement components of the trunk.

Activate the Movement System through the Use of Verbal Commands and Visual and Tactile Stimuli

When activation of the movement system is required, and large range and speed are desired components, verbal commands can drive the system. If the postural system is not functioning, and a verbal request for an integrated response is made, only a functioning movement system will respond. For example, the verbal request to “sit up straight” is made to a patient who is slumped into flexion. The patient responds by quickly coming to an erect posture but holds it only momentarily. The quick response is made by the faster movement system. The full range is achieved, but fatigue of fast motor units sets in rapidly. The nonfunctioning postural system is unavailable to hold a stable trunk position for longer functional periods.

Movements such as reaching and stepping often require visual guidance. In a study of the coordination of eye, head, and hand movements investigators found that “coordination was maintained by delaying the hand movements until the eye was available for guiding movement.”[33] In another study, the findings were that “participants used vision not only to ‘hone in’ on the current target but also to prepare subsequent movements.”[34]

A study of the role of vision during stepping revealed that the occlusion of vision at the point of foot-off leads to an increase in foot-placement error. Visual information can be used during the swing phase to adjust foot trajectory.[35] Vision is an important modality for guiding walking up and down stairs. Gaze is usually fixated three to four steps ahead of the location of the feet when guiding immediate action. Because the last look-down occurs when the steps disappear from the visual field, it is proposed that the end of the stairs is controlled from memory.[36,37]

One of the most important links between touch and movement occurs during the process of exploring objects and surfaces. "Active touch sensing"[38] involves movement that seeks tactile/kinesthetic information by controlling the contact pattern of the sensors. Perception of the object or surface follows the repeated movement and sensing as the exploration occurs. This haptic (tactile) perception is usually studied in the hand as it explores and acts upon the environment. A similar form of sensing through movement occurs in the feet from the point of heel contact and as the weight is shifted from the fifth over to the first toe. Perception of the contact surface by small movements of the volar surface of the foot informs the balance system.

Rest Movement System Muscles in a Long but Not Extreme Length

Even at rest, adaptation can occur in muscles, although slowly. If adaptation to a shorter range occurs in movement muscles, their stiffness will increase, and they will not have the extensibility needed for their full range of activity.

4.3.4 Summary of Therapeutic Principles for Progression of Strengthening in the Movement System

- Vary the starting position so that movement can be initiated from any length.
- Continue with isotonic contractions through the range, varying the speed.
- Increase resistance through the use of gravity, longer levers, less assistance, and amount of weight of grasped objects.
- Include isometric activity to strengthen movement muscles after isotonic strength is well established.

Vary the Starting Position so that Movement Can Be Initiated from Any Length

The goal of therapeutic procedures for strengthening is to increase the excitability of the motor neurons innervating the muscles of the system. As this goal is achieved, focus can be placed more on muscle strengthening. The starting position for an activity no longer has to provide the maximum facilitation that would have come from full stretch. Other starting lengths and ranges can be used according to the needs of the task.

Continue with Isotonic Contractions through the Range, Varying the Speed

Continue emphasizing tasks that require isotonic contractions that involve the muscles, motor units, and muscle fibers that are specialized for movement. Patterns of sensory input will be used differently for very fast movements compared with slow to moderate movements. Very fast ballistic movements use the sensory pattern existing prior to the movement as part of the information needed to preprogram the motor output but do not use feedback during the movement to alter the response. Initial alignment before a fast movement is critical to the success of the movement. Slow to moderate movements use feedback during the movement to guide and alter the movement if necessary to accurately accomplish the task.

Increase Resistance through the Use of Gravity, Longer Levers, Less Assistance, and Amount of Weight of Grasped Objects

Examples of progressions that increase resistance follow. A progression for upper extremity reaching could begin in sitting with the arm supported on a low friction board with the shoulder at 90° flexion. Initially, the patient starts with the arm flexed close to the body and slides the arm out to reach and grasp an object and bring it back. The dependence on the board for support is decreased by lifting the arm slightly for some or all of the movement. The weight of the object can be gradually increased. The distance reached can be increased to require that the full length of the lever (the arm) is moved without support carrying a weight.

Lower extremity movement progressions can be done through rolling and creeping activities. If the patient can stand, the progression begins with plantigrade standing. One foot slides forward and back and side to side in contact with the floor. Next, the foot is picked up and placed, the normal stride length being the eventual goal. The same progression can be used standing without the upper extremity support provided in plantigrade. Placing the foot up and down on varying heights of steps and at increasing speeds contributes to the swing phase in gait.

Progression of movement in the trunk begins with rotation in the sitting position in the aligned upright position with the pull of gravity at a minimum. Resistance from gravity can be increased by combing rotation with flexion or extension and changing the amount that the COG is moved off the BOS.

Include Isometric Activity to Strengthen Movement Muscles after Isotonic Strength Is Well Established

Movement muscles need to be selectively strengthened for each type of contraction: isotonic and isometric.[24] The isometric activity is included in an intervention program for movement muscles later in the strengthening progression because it results in decreased feedback for the motor neurons.[25] If enough facilitation has been provided through isotonic activity and the muscle has strengthened, the isometric activity will recruit motor units effectively.

4.3.5 Summary of Therapeutic Principles for Activities Requiring the Integration of the Posture and Movement Systems

- Activate visual, auditory, and tactile orienting followed by exploration.
- Include in the program transitional functional activities that require integration of posture and movement.
- Activate the postural system to guide the movement system.
- Use a sequence of stability/mobility functions to guide the choice of integrated activities.

Activate Visual, Auditory, and Tactile Orienting followed by Exploration

Orienting is part of a process that eventually leads to exploration and perception of the environment. Orienting begins with a stimulus that the central nervous system locates within a wider receptive field. The movement system is then activated to move parts to a position that is then held by the postural system. Now the sensory system can focus on the stimulus, and through scanning or exploratory movements, a percept is formed. For example, a visual stimulus received by the retina is sent first to the superior colliculus, which identifies its location in the whole visual field. From the superior colliculus, instructions are sent to the eyes and neck and possibly the trunk to turn toward the stimulus so that it falls on the fovea. From the fovea, the information is sent to the thalamus and then on to the visual cortex. The object is now explored through scanning eye movements and identified. Eventually, the information is projected to other areas of the cortex via one of the two *visual streams* for perception or action.[39]

Orienting in the child also occurs in the hand in response to touching any region. The hand is moved into a position where it can grasp the touching object and then explore it for identification (haptic perception). It is likely that the foot, as it touches the floor, orients to the contact surface to provide input about its characteristics. Small exploratory movements would result in the formation of a percept about the configuration of the support surface, information essential for balance control.

Include in the Program Transitional Functional Activities That Require Integration of Posture and Movement

Activities such as creeping, moving from supine to sit, moving from sit to stand, walking, and climbing involve the full participation of both movement and posture. Change in position where movement is done against gravity requires maintenance of balance throughout the activity. The transition will be accomplished only if the movement system has adequate range and speed to reach the goal. The postural system must anticipate, maintain, and restore balance needs as the movement changes the relationship of the COG to the BOS.

Activate the Postural System to Guide the Movement System

The postural system needs to be well developed for distal skills to be successful. The developmental axiom that control develops from proximal to distal has more than one explanation. Stabilization of proximal points through holding by the postural system is needed mechanically for the distal parts to be steady. Of equal importance is the guidance role that the postural system plays in controlling movement. Accuracy in the trajectory and the final placement of the distal end of a limb is accomplished by ongoing and combined posture and movement controls.[8,40]

Use a Sequence of Stability/Mobility Functions to Guide the Choice of Integrated Activities

Mobility is first seen in the gross movements of the newborn where the movement system is very active and the postural system is just beginning to work against gravity. Stability begins to develop in the neck and upper trunk as the infant lifts her or his head in prone. The postural system is especially active in the prone position where most postural muscles hold against gravity. In the supine position, the postural system holds for limb movements.

A major step in working toward a skill level occurs when one is combining mobility with stability in a weight-bearing position where the larger part is moving on a fixed distal part. For example, when weight is shifted in the quadruped position, the trunk, hip, and shoulders are moving while the distal parts, hands and knees, are fixed and weight bearing. A more advanced combination of mobility and stability occurs when the distal part is free and moving and the proximal parts are dynamically holding.[41]

4.4 Summary

This chapter describes a model that can guide intervention choices through the application of therapeutic principles. The neuroscience and neuromuscular basis for the model is presented as an explanation and support for the principles. Posture and movement are regarded as subsystems for motor control that involve different structures and functions for their execution. Considering these differences assures that selective attention will be given to both systems in intervention. This model has a wide application to many musculoskeletal and neurological disorders of children and adults.

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Clinical Practice Using the Neuro-Developmental Treatment Practice Model

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II

Introduction

Marcia Stamer

The philosophy of Neuro-Developmental Treatment (NDT) frames the beliefs of clinicians. Unit I defined NDT, its philosophical foundations, and theoretical assumptions that frame practice. Unit II describes NDT practice with a detailed look at how occupational therapists, physical therapists, and speech-language pathologists interact with their clients during the entire therapeutic process.

NDT is a philosophy and structures a practice framework that a clinician uses to organize practice. Because there is a therapeutic relationship among client, family, and clinician with an NDT philosophy of interaction, a model for practice can be constructed to show the problem-solving process. The result is the NDT Practice Model. In Unit II, the NDT Practice Model is described and explained in detail. Ultimately, the NDT Practice Model emphasizes the ongoing, interwoven problem solving that translates philosophy into practice.

NDT is a complex problem-solving and decision-making process that differs from a treatment method or protocol. Therefore, the practice model shows this complexity, focusing on the multiple sources of information the clinician uses to make decisions. Chapter 5 explains the NDT Practice Model in an overview, whereas the following four chapters focus on a specific aspect of the Practice Model. Keep in mind that, although each of these four chapters has a focus, readers will be continually reminded that a hallmark of NDT practice is that all components—information gathering, examination, evaluation, the plan of care, and intervention—are always interrelated.

The last two chapters in Unit II provide specific information about the pathophysiology and functioning of people with cerebral palsy and stroke. This information is a part of the vast declarative knowledge clinicians rely on as they practice their profession using the NDT Practice Model.

5 Neuro-Developmental Treatment Practice Model

Marcia Stamer

This chapter introduces and defines the Neuro-Developmental Treatment (NDT) Practice Model. It emphasizes the difference between models for clinical practice and theories that inform practice. The NDT Practice Model is unique in its emphasis on communication between the client/family and the clinician during all phases of the therapeutic relationship. It is also unique in its emphasis on the interweaving of all portions of the model.

Learning Objectives

By the end of this chapter the reader will be able to do the following:

- Describe the purpose of the NDT Practice Model.
- Define the difference between a practice model for clinical application and theories that inform practice.
- Describe the client/family and the clinician's roles in the therapeutic process using the NDT Practice Model during the following:
  - Information gathering.
  - Examination.
  - Evaluation.
  - Intervention.
- Describe the meaning of the statement, "The NDT Practice Model depicts the interwoven process between the client/family and clinician during all aspects of the therapeutic relationship."
- Describe what is meant by the statement, "Information gathering, examination, evaluation, and intervention often occur simultaneously and interweave."

5.1 What Is a Practice Model?

Practice models provide a written description of the complexity of clinical practice for the purpose of analyzing, problem solving, and predicting functional outcomes of intervention. They describe and explain practice.[1] Neuro-Developmental Treatment (NDT) is a philosophy with direct clinical applications to intervention; therefore, a practice model can be created.

The NDT Practice Model (**Fig. 5.1**) shows how therapists who use the NDT philosophy gather, synthesize, and analyze information relevant to management of their clients. The practice model illustrates the complexity of clinical practice and the interrelationships of each component of the process. This model also shows descriptive and procedural knowledge that therapists need in their problem-solving process, including specific NDT philosophy. The explicit depiction of the relationship between a person seeking therapy and the therapist emphasizes the importance of collaboration in clinical practice using NDT.

The NDT Practice Model illustrates the constant interrelationships of communicating, observing, thinking, analyzing, and actions that can move in any direction as the clinician and client interact. Information gathering, examination, evaluation, and intervention are components of practice that are interwoven processes rather than discrete and separate ones. All of these components occur in every session, not just initially or with formal updates. This model provides a constant interconnection among the client/family and therapist at all times. NDT also emphasizes that information gathering, examination, evaluation, and intervention occur simultaneously and constantly influence one another. Processes are not linear or even cyclical; rather, all information gathered during any part of practice informs all other processes.

Clinicians who practice using the NDT Practice Model are licensed in the speech and language pathology profession or the physical or occupational therapy professions. Clinicians practice according to their state licensure practice acts in the United States and are governed by ethics codes and statements of practice from their professional associations. Canadian therapists are licensed in their provinces, and each profession also has practice laws and guidelines.

The American Speech and Hearing Association (ASHA), the American Occupational Therapy Association (AOTA), the American Physical Therapy Association (APTA), the Canadian Physiotherapy Association, the Canadian Association of Occupational Therapists, and the Speech-Language & Audiology Canada organization all have statements about practice scope, guidelines, or frameworks. All currently recognize the International Classification of Functioning, Disability and Health (ICF) in their organization of these practice scopes, frameworks, and guidelines.

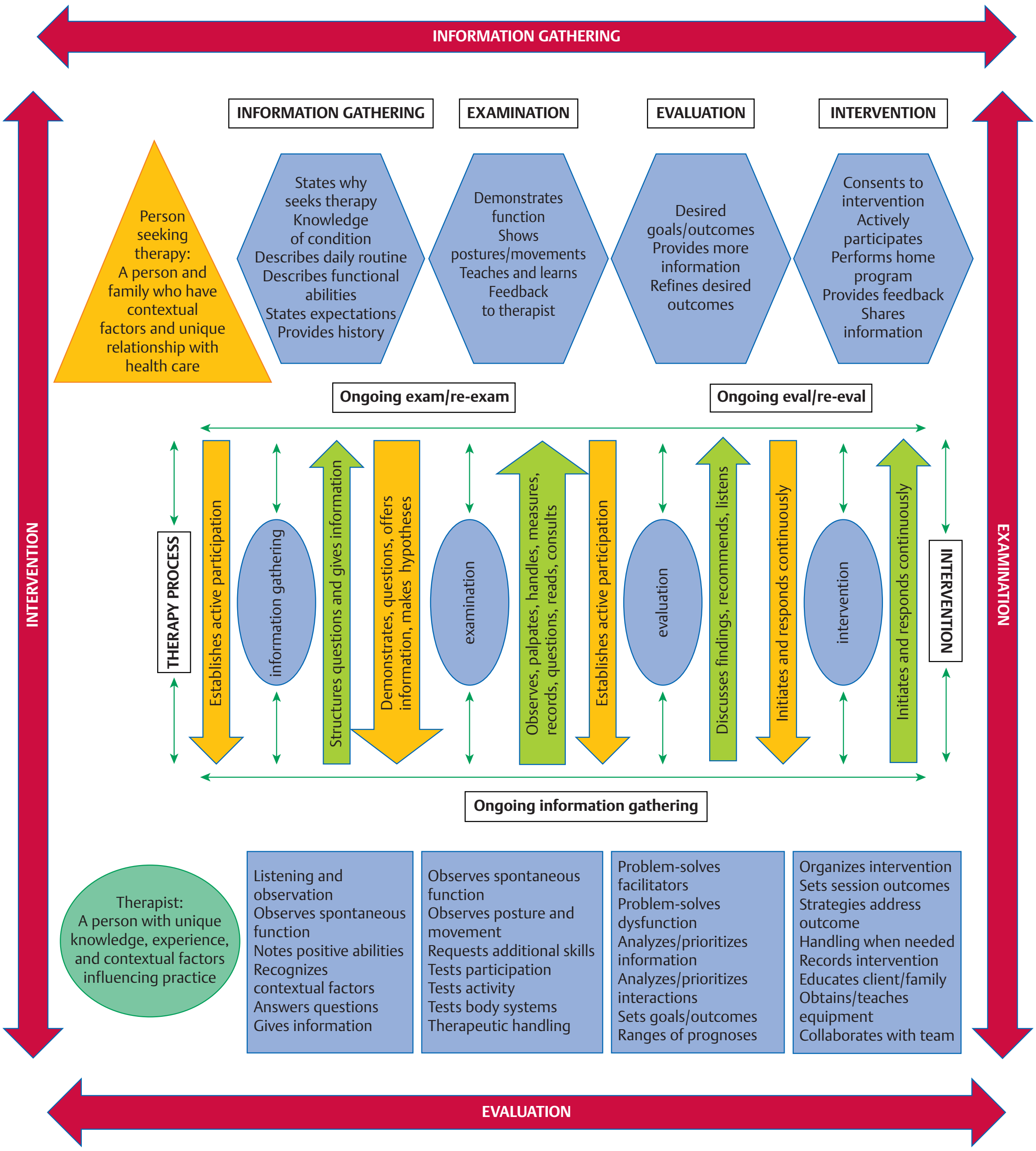

Fig. 5.1 The Neuro-Developmental Treatment Practice Model.

In addition, the APTA *Guide to Physical Therapist Practice*[2] shows a cycle of information gathering, examination, evaluation, and intervention as the means for interacting with patients and clients. The AOTA's Occupational Therapy Practice Framework[3] states that there is ongoing interaction among evaluation, intervention, and outcomes during the therapy process, and relates that to clients as individuals. The scope of practice described by ASHA[4] follows the ICF model in its application to practice. However, none of these practice guidelines shows the constant interweaving of the information gathering, examination, evaluation, and intervention to the extent that the NDT Practice Model does.

5.2 The NDT Practice Model and Theories That Support It

Theories relevant to clinicians who treat clients with neurological impairments consist of explanatory statements that make predictions about human functioning from many branches of science and the humanities. Theories take shape from research study results, experience, and creative thinking. Therapists use knowledge originating from motor control, motor learning, motor development, neuroplasticity, compensations in body systems, rehabilitation practice, cognition theories and development, language theories and development, psychology, and sociology theories to assist them with problem-solving skills related to intervention.

Base knowledge from many theories, both descriptive and procedural, changes continuously with the knowledge we gain from research, experience in our professions, each person we treat, and our successes and failures with intervention. How a clinician understands and integrates the ever-changing base knowledge into daily practice depends on the practice model or models that the therapist uses. All clinicians use a philosophy and practice model, whether they are able to articulate it or not. Base knowledge informs their interactions with clients and is the basis for clinical hypotheses, outcomes identified, and how therapists interact with their clients. Those who practice using practice models other than NDT may interpret descriptive knowledge derived from theories and research studies or apply it procedurally in a different way than those who use the NDT Practice Model.

Theories that support clinical practice are often confused with a clinical practice model. Changes in our understanding of human functioning derived from theories generated in disciplines of study may be viewed as an abandonment of a practice model rather than the necessary adjustments to changing information. A person may say, "You can't just absorb every new thing that comes along and call it NDT. NDT isn't everything, you know." The mistake is that the speaker or writer is confusing a practice model with knowledge of the theories of human functioning that inform the base knowledge of any clinical practice.

5.3 Current Descriptive Knowledge Used in NDT Practice

Current knowledge in the fields of motor control, motor learning, motor development, and neuroplasticity is found in Chapters 12 through 15.Therapists realize that information from these areas of study will undergo changes in theoretical understanding, refinement of ideas, and evidence from research studies. Therapists who practice using NDT seek constant information and evidence in the basic and applied sciences to integrate into the larger picture of the NDT Practice Model.

5.4 Procedural Knowledge Used in NDT Practice

In this text, case reports will serve the purpose of assisting therapists to deepen their knowledge of the hands-on application of NDT practice. Therapists learn procedural knowledge in many ways, beginning in their university education, and proceeding through NDT certificate courses, working with mentors, and through peer discussions and cotreatment sessions. However, the procedural knowledge specific to NDT is useful only within the entire scope of the NDT Practice Model. Procedures are tools only and can be used well only within the entire practice of NDT. The problem solving, synthesis, analysis, and relationship with the client and family are all critical in determining the selection and ordering of procedural knowledge (intervention strategies).

5.4.1 The NDT Practice Model: Overview

The NDT Practice Model depicts the relationship of the person seeking therapy with the therapist along the continuum of the therapy process. There is a partnership in the communication between the client, family, and therapist at all times, with each having responsibility in the relationship of working toward meaningful outcomes.

5.4.2 The NDT Practice Model: Information Gathering

Information gathering (Fig. 5.2) may start prior to meeting directly with the person seeking therapy with verbal

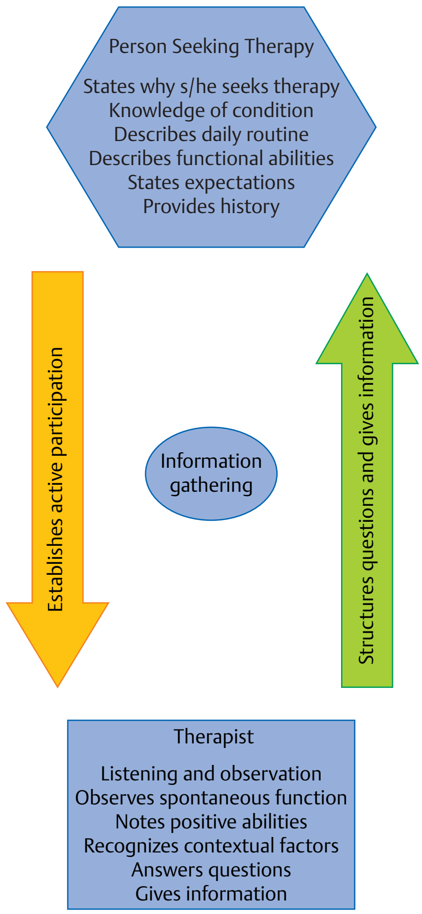

Fig. 5.2 Information gathering using the Neuro-Developmental Treatment Practice Model.

or written information provided by referral or by the client or other team members. If that is not the case, information gathering begins the moment the therapist meets the client, family, and other care providers. They provide their perspectives on why they seek services and what they hope the therapist can offer them. They may state their understanding and perspectives of the conditions for which they seek assistance. By listening carefully to the client and family, the therapist gathers this information in a nonjudgmental manner. This information is important to the therapist who uses the NDT philosophy of individualized care because the client's reasons for seeking services apply directly to setting individualized outcomes. This active and reactive listening also helps establish rapport between the client and therapist.

The therapist listens to and observes both the verbal and the nonverbal communication from the client and family. The therapist is interested in the client as a unique person whose function includes complex contextual factors influencing participation, activities, and body structures (this is one use of the ICF model in the NDT Practice Model). The therapist is interested in the positive attributes the client possesses in the domains of participation, activity, and body structure and function. The therapist listens to gain information about the client's values, personality, cultural beliefs, attitudes about the outcomes of therapy, family life, and community support systems. The therapist listens to any spontaneous offerings of information from the client and then asks structured questions to establish more information about the client's life. These questions include asking about relevant medical history and precautions, relevant social history, and current health status. They also include asking for a detailed description of the client's daily routine, including typical activities performed, work or education history, hobbies and interests, social interactions, and recreation.

The therapist deepens an understanding of the client's daily routine by asking questions that will enhance an understanding of the environmental conditions in which each activity is performed and how much and what type of assistance or support is required for daily activities. The therapist directs questions according to the profession he/she belongs to, while staying attuned to information that may lead to referrals to other team members. This attention to referral to other team members is a key component of NDT practice.

An example of information gathering shows the interaction of a speech-language pathologist with a 10-month-old baby and her parents. The therapist might ask how often the baby nurses and how long each nursing session typically lasts, or how many ounces the baby drinks from a bottle. Who bottle-feeds the baby? Is there choking or coughing? What sounds does the baby make when awake? Do the sounds mean anything particular to the family? Are there positions or ways the family holds and supports the baby for these sounds or times of the day when the baby is more vocal? Does the baby use nonvocal communication with family members? How does the baby respond to unfamiliar people and situations? What would the family like the therapist to do to help the baby eat or communicate better or more?

As the therapist asks specific questions and listens to the answers, as well as to spontaneous offerings of information, the therapist begins to formulate priorities about how to best examine the client. This assessment is based on many sources during information gathering—what the client has shown and described as abilities and inabilities in functioning, the emphases that the client and family place on desired outcomes, and the knowledge and beliefs about the conditions to be addressed during intervention.

The therapist who uses the NDT Practice Model brings a context and background to intervention and other management, just as the client does. Although each therapist has his or her unique knowledge, therapists who practice using the NDT Practice Model value common sources of knowledge. During information gathering, they rely on the following:

- Knowledge of the NDT philosophy, and the history and changes in NDT practice over the years. This knowledge includes the belief that people with disabilities and those living with conditions that impair functioning have value and worth. It also includes the belief that therapeutic intervention can positively influence life skills of people with disabilities and conditions that impair function.
- Knowledge of theories of motor control, motor learning, and motor development. Knowledge of the causes and effects of compensatory postures and movements originating in various body systems.
- Knowledge of a model of human functioning. Currently, the most widely used model is the ICF created and endorsed by the World Health Organization.[5]
- Knowledge and experience with a variety of neurological conditions that may impact functioning. Stroke, cerebral palsy, traumatic brain injury, and genetic disorders are historically the most common conditions NDT was developed to address.
- Knowledge of growth, development, skill acquisition and loss over the life span, and how participation, activity, and body systems change both functionally and dysfunctionally as a result.
- Knowledge of cultural diversity, family dynamics, human beliefs diversity, human values diversity, and ethics.
- Knowledge of human behavior, specifically reactions to disability and illness.
- Knowledge of human learning styles and how these may be affected by neurological impairments.
- Skilled observation of participation, activity, posture and movement, and body systems within the typical contexts used by each client.

5.4.3 The NDT Practice Model: Examination

The examination portion of the NDT Practice Model (**Fig. 5.3**) continues the communication process among the client, family, and therapist. Now the focus is on joint discovery and learning more about the specifics of the

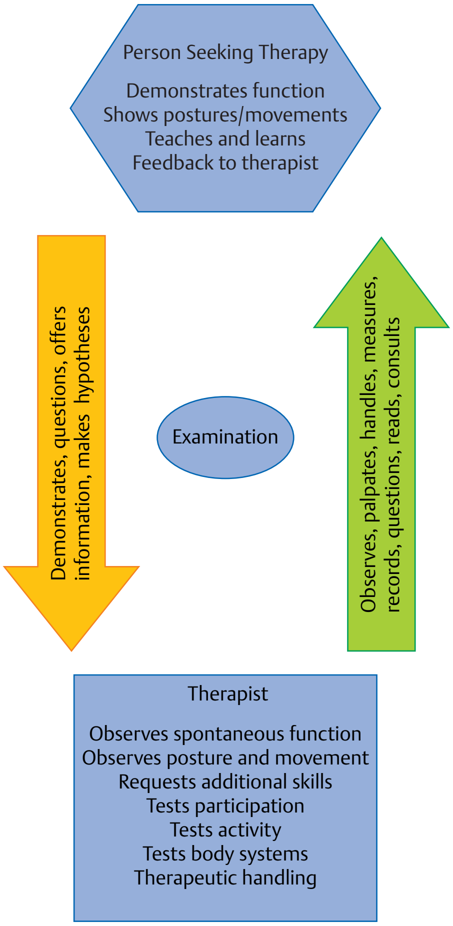

Fig. 5.3 Examination using the Neuro-Developmental Treatment Practice Model.

client's functional participation and activity abilities and limitations. This individualized understanding of each client is one of the distinguishing hallmarks of NDT and is considered of utmost importance. A model of human functioning, such as the widely accepted ICF model (**Fig. 5.4**), is a useful tool for organizing the examination. The therapist records observations of the client's participation abilities and restrictions and activity abilities and limitations; examines body structures and functions (i.e., single systems, such as neurological, musculoskeletal, integumentary, respiratory, sensory, cognitive, behavioral) for integrities and impairments; and hypothesizes about the origins of impairments caused by the interaction of more than one body system, such as posture and movement.

The therapist using the NDT Practice Model looks at these three domains of the ICF model or a similar model and combines this information with historical information about the client's functioning with prognoses of future functioning in mind. Therapists who practice NDT believe that the current domains of functioning are shaped by the client's past and that future functioning may have various paths (prognoses) based on how successfully the client, the family, and the rest of the team

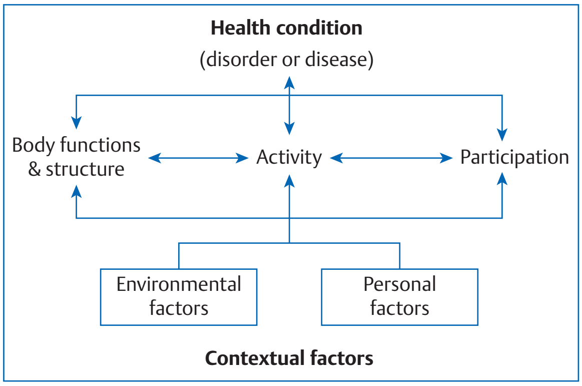

Fig. 5.4 Human Functioning and Disability Dimensions of the International Classification of Functioning, Disability and Health (ICF) model.[5] Note that all levels interact. Reproduced, with the permission of the publisher, *Towards a Common Language for Functioning, Disability and Health: ICF*, Geneva, World Health Organization, 2002 (http://www.who.int/classifications/icf/training/icfbeginnersguide.pdf, accessed September 8, 2014).

can build on the client's abilities while intervening with the causes of disability.

Note that therapists who use the NDT Practice Model focus on differentiating the interactions of multiple body system impairments, such as postures and movement, from single-system impairments. Posture and movement capabilities are expressed in part as the result of the interaction of single-system body system integrities and impairments and their influences on secondary integrities or impairments.

However, there is much more to consider in the makeup of effective and ineffective postures and movements than body system integrities and impairments (**Fig. 5.5**). Growth and development will influence postures and movements, just as they influence the other domains. Compensatory postures and movements at any age, used to attempt function, will influence postures and movements overall and may cause secondary impairments or alter growth and development. Contextual factors, such as physical environments, culture, community, and personality, influence postures and movements. The person's work, recreation and leisure, and beliefs and values also influence postures and movements.

Postures and movements require careful observation. Their expression relies on understanding the relationship of motor control, motor learning, motor development/skills, sensory and perceptual development/skills, social development/skills, cognitive and language development/skills, and behavioral organization. Observations of postures and movements also rely on testing body system integrity and impairment and hypothesizing how participation, activity, and single-system impairments interact over a life span. Frequently used activities and participation affect the postures and movements a person most often uses (and therefore practices). All of this must then be placed in the contextual factors of a person's life for deeper understanding.

As the therapist examines the client using the ICF or a similar model, including observing postures and movements to assist in explaining function and disability,

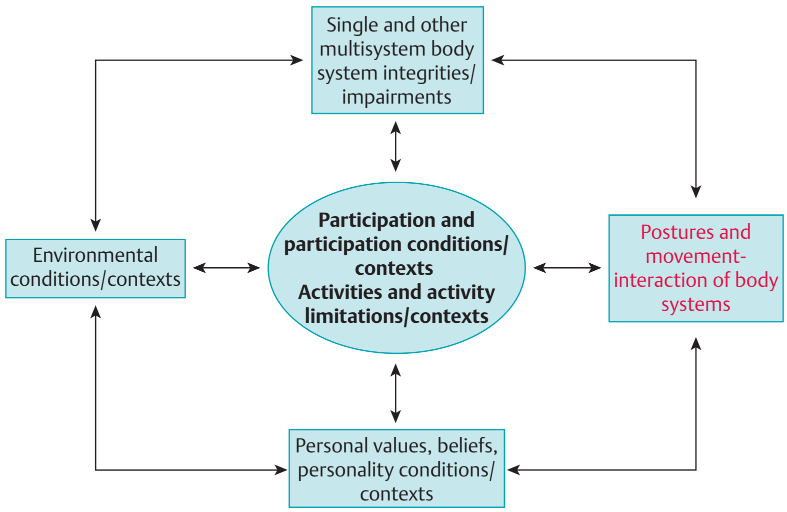

Fig. 5.5 Participation and activities are domains of function. Function is influenced, and in turn influences, single-system body system integrity; multisystems, such as postures and movement; the environments a person functions in; and the personal factors that shape how a person interacts.

the therapist chooses standardized and nonstandardized tests to help measure these different dimensions of functioning and disability. This is one of the purposes of using the ICF model: to measure health and disability worldwide with the use of a common language and tests/ measures to communicate with all of those interested in health and disability.[5] Therefore, the therapist who uses the NDT Practice Model adds the ICF or a similar model to help structure the examination and to provide communication with the rehabilitation professions worldwide.

During the examination portion of the NDT therapy process, the therapist and client may think of more questions to ask and more information to share, strengthening the collaboration among client, family, and therapist. Each member of the team provides teaching and learning opportunities for the others. This interaction demonstrates the interweaving of information gathering and examination in the therapy process.

Therapists who use the NDT Practice Model rely on many sources of knowledge to inform their practice during examination. This information includes, but is not limited to, the following:

- Knowledge of function (participation and activity) and its influence on future functioning.
- Knowledge of effective and ineffective postural control and movement execution.
- Knowledge of body system integrities and impairments.
- Knowledge of motor control, motor learning, motor development, and neural plasticity.
- Knowledge of how and why multiple systems develop compensations.
- Knowledge of cognitive/learning theories, communication theories, and psychosocial theories.
- Knowledge of handling skills to examine body systems and note effects of key points of control on function, posture, and movement.
- Knowledge of standardized and nonstandardized tests.

5.4.4 The NDT Practice Model: Evaluation

The evaluation portion of the NDT Practice Model (**Fig. 5.6**) focuses on analysis and problem solving. The therapist, client, and family have collaborated during information gathering and examination, and now the therapist works to categorize and prioritize all of the information, analyzing the relationships among the domains of human functioning and contextual factors using the ICF or a similar model with the added analysis of postures and movements. Although the initial evaluation and reevaluation are recorded in the written official record, it is essential to share verbal and written information with the client and family at each session because new information, further discoveries on examination during each session, and the synthesis of evaluation are ongoing.

The therapist records hypotheses regarding these relationships that lead to prognoses of a range of outcomes, both short term and for life. These prognoses will be refined and revised as the therapist, entire team, and client work together.

Components of the Evaluation

The evaluation includes the following:

- Summary of participation and restrictions of participation, prioritizing them according to the client and family's view of importance in their lives.
- Summary of activities and activity limitations, prioritizing them according to the client and family's view of importance in their lives.
- Summary of the effective and ineffective postures and movements the client uses to function or attempt to function.

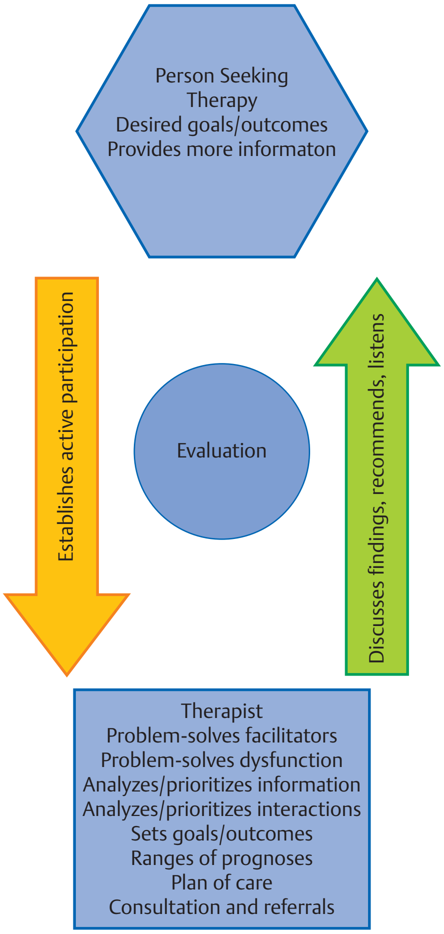

Fig. 5.6 Evaluation using the Neuro-Developmental Treatment Practice Model.

- Summary of body system integrities/impairments and a prioritization of these as they affect posture and movement, activity, and participation.
- Session and functional outcomes.
- Analysis of the relationships among participation, activity, and body system integrities and impairments. Analysis includes prioritizing both the positive and the negative influences on each domain, as well as all of the influences on effective and ineffective postures and movements.
- Analysis of the potential for change. Description of a range of possible prognoses, short and long term.
- Plan of care. For an evaluation that covers weeks to months, a general plan is stated. For a daily note, more specific intervention strategies, impairments, postures and movements addressed, activities or parts of activities practiced, and equipment needed are described.
- The plan links action to the hypotheses generated for the specific causes of participation restrictions and activity limitations.
- Referrals to team members if needed.

Evaluation consists of professional clinical problem-solving and decision-making skills. The additional steps include analyzing postures and movements with the analysis of the relationship among any of the domains of a human functioning model, determining the influence of past and present domains on future domains, and determining a range of possible prognoses distinguish NDT from other practice models.

Analysis proceeds from participation/restrictions and activity/limitations to the ineffective postures and movements, then to single-system body impairments that contribute to the restrictions and limitations. This process can be more difficult than it seems. Rather than proceeding with analysis this way, therapists may first identify ineffective postures and movements in their clients, then plan interventions around these postures and movements. However, starting with ineffective postures and movements, such as poor head control, often results in losing sight of the activity and participation that head control is used for. Humans use head control for a purpose, and head control is not an all-or-nothing skill (i.e., head control when supine on a firm surface for the activity of reading a book is very different from the head control required to prevent head contact with a cement sidewalk when falling backward while running).

For example, a child with cerebral palsy or an adult poststroke may be identified as having poor head control (**Fig. 5.7a, b**).This example is quite familiar to therapists and families alike, who can readily identify this ineffective posture but may have limited options for addressing it. If simple practice with verbal reminders and stimuli, such as exciting toys and games to encourage head lifting, were effective, then we should not need to develop or re-establish head control through other practices. However, simple practice and verbal reminders are seldom enough. Why?

Fig. 5.8 depicts the problem-solving process therapists who are knowledgeable of NDT use to determine some influences on a person identified as lacking head control. The figure is not all inclusive; there may certainly be other factors to consider. Remember that head control is neither a single-system body integrity/impairment nor simply a combination of single-system impairments. It is also not, in and of itself, a function (activity in the domain of the ICF). It is an ineffective posture. The therapist must identify the functional activity that the person needs head control for, because head control is not an all or nothing posture (i.e., head control requirements vary depending on the function attempted, body position and support, environment and concurrent postures and movements, and other contextual factors).

First, an activity or participation outcome must be identified that includes the head control. An occupational therapist might write, "Johnny will feed himself his toast placed directly in front of him on the kitchen table on a nonskid placemat within 5 minutes using either hand while he sits in his wheelchair with the seat belt and anterior chest support strapped, bringing his hand to his mouth while he sits upright."

This outcome dictates the antigravity posture and the support of that posture Johnny requires from his environment and, as such, dictates how much visual, cervical,

Fig. 5.7 **(a, b)** Both Carol, poststroke, and Jimmy, with cerebral palsy, could be said to demonstrate poor head control. They are nothing alike, however, in their participation restrictions, activity limitations, and body structure and function impairments that result in poor head control. Each person must be individually examined and evaluated to determine the complex interaction of all factors that lead to ineffective head control.

and trunk control Johnny will need. It describes the activity that includes head control. The activity (function) is feeding himself breakfast, and head control is a part of that function. In this case, the systems of visual motor control and the motor control and coordination to bring the hand to the mouth (after grasping) while sitting upright may be the focus of the therapist's intervention. The therapist has also defined the task as one where Johnny will sit at a particular table in a particular chair with a particular type of placemat. It does not yet indicate that Johnny will feed himself his toast anywhere under any condition, so full participation may still be restricted for this activity. Johnny's therapist will also be attuned to the fit of his wheelchair and its support system for his entire body. Consequently, part of the management for this outcome is proper wheelchair fit. In addition, the therapist using the NDT Practice Model is thinking about how the way Johnny eats or feeds himself now could affect how he feeds himself in the future and how this task affects other tasks. If he is currently flexing his thoracic spine so that his mouth is close to the plate as he attempts to scoop his toast to his mouth, how will the repetition of this posture and movement affect other tasks he attempts? Is it possible that the repetition of such a posture and movement could cause other skills to deteriorate over time or interfere with the attainment of new skills? Could the repetition of thoracic flexion to reach cause secondary impairments in the musculoskeletal system, respirations, and in visual perception?

A similar figure (Fig. 5.9) focuses on the ineffective movement of knee hyperextension, seen frequently in the gait pattern of adults poststroke (Fig. 5.10) and in some children with hemiplegic and diplegic cerebral palsy. Knee hyperextension occurs because of the interaction of several body system impairments under the conditions imposed by floor reactions during gait. Gait is commonly a large part of human activity and participation and is practiced daily.

Remember that knee hyperextension is neither a single-system body impairment nor simply a combination of single-system impairments. It is also not in and of itself a function (activity in the domain of the ICF). It is an ineffective movement (or an inefficient alignment). The therapist must identify the functional activity that the person needs knee control for because knee control is not an all or nothing movement (i.e., knee control requirements vary depending on the function attempted, body position and support, environment and concurrent postures and movements, and other contextual factors).

First, an activity or participation outcome must be identified that includes the knee control. A physical therapist might write, "Carol will walk indoor distances in her home (low pile carpet and linoleum surfaces) without an assistive device, walking at a speed of 65 m/min, achieving extension, but not hyperextension, of the left knee in midstance."

This outcome dictates the posture, movement, and alignment that Carol requires to complete the activity and, as such, dictates how much knee control Carol will need. It describes the activity that includes knee control.

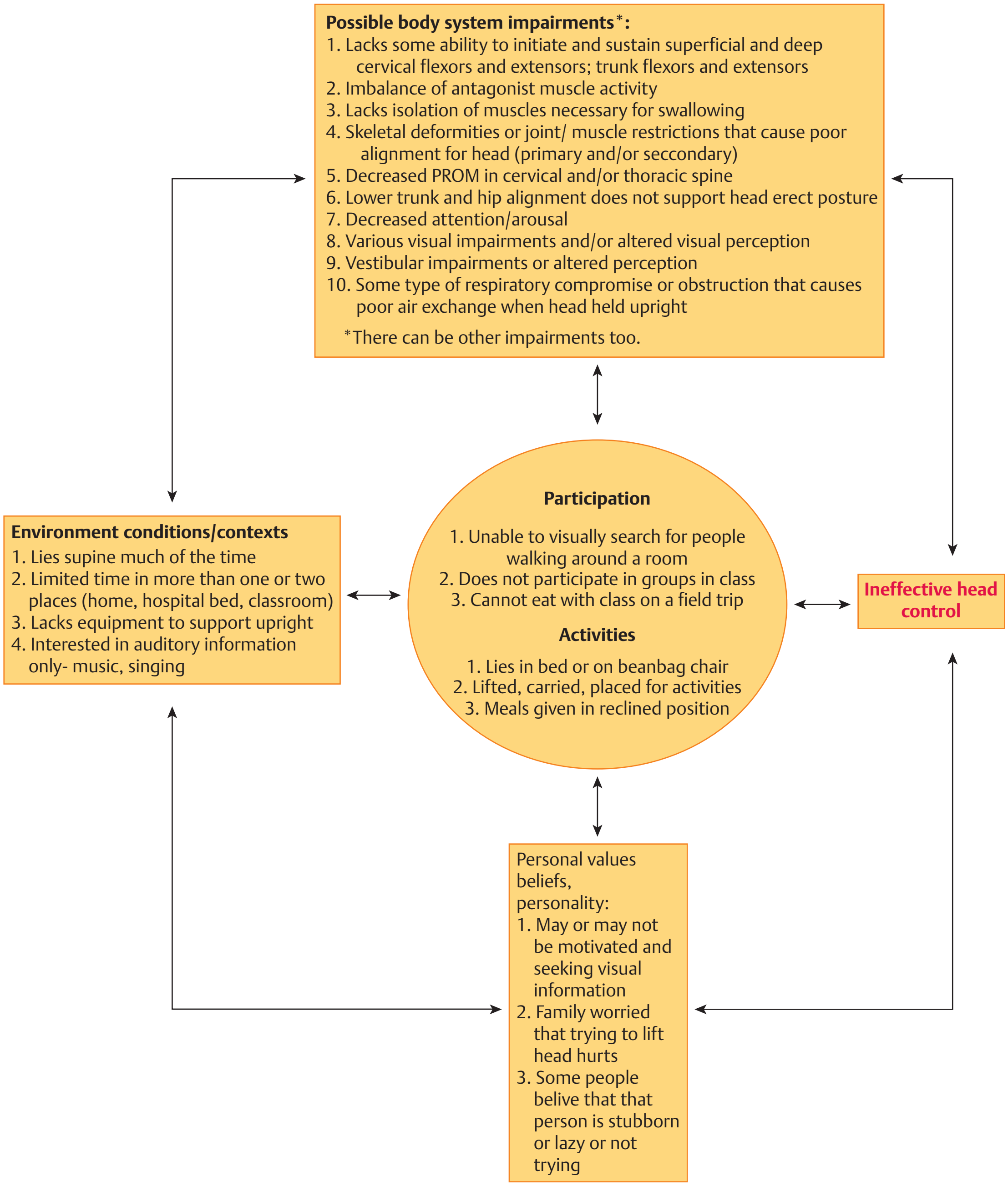

Fig. 5.8 An example of problem solving around the ineffective posture of poor head control.

The activity (function) is walking indoor distances, and knee control is a part of that function. For Carol, the physical therapist hypothesizes that the neuromuscular and musculoskeletal systems need to coordinate muscular activity of trunk, hip, and knee extension with isometric soleus muscle activity throughout the early to midstance phases on that leg. The two systems also need to grade knee movement while Carol is walking indoor distances. The therapist has also defined the task as one where Carol will walk on particular surfaces, at a specific speed, and over defined distances without assistive devices. It does not yet indicate that Carol will walk anywhere under any condition, so participation in other environments may still be restricted for this activity. In addition, the therapist using the NDT Practice Model is thinking about how the way Carol walks now could affect how she walks in the future and how this task affects other tasks. If she is currently hyperextending her knee every time she walks so that the ligaments and joint capsule are repeatedly stretched, how will the repetition of this movement and alignment affect other tasks she attempts? Is it possible that the repetition of such an alignment could cause

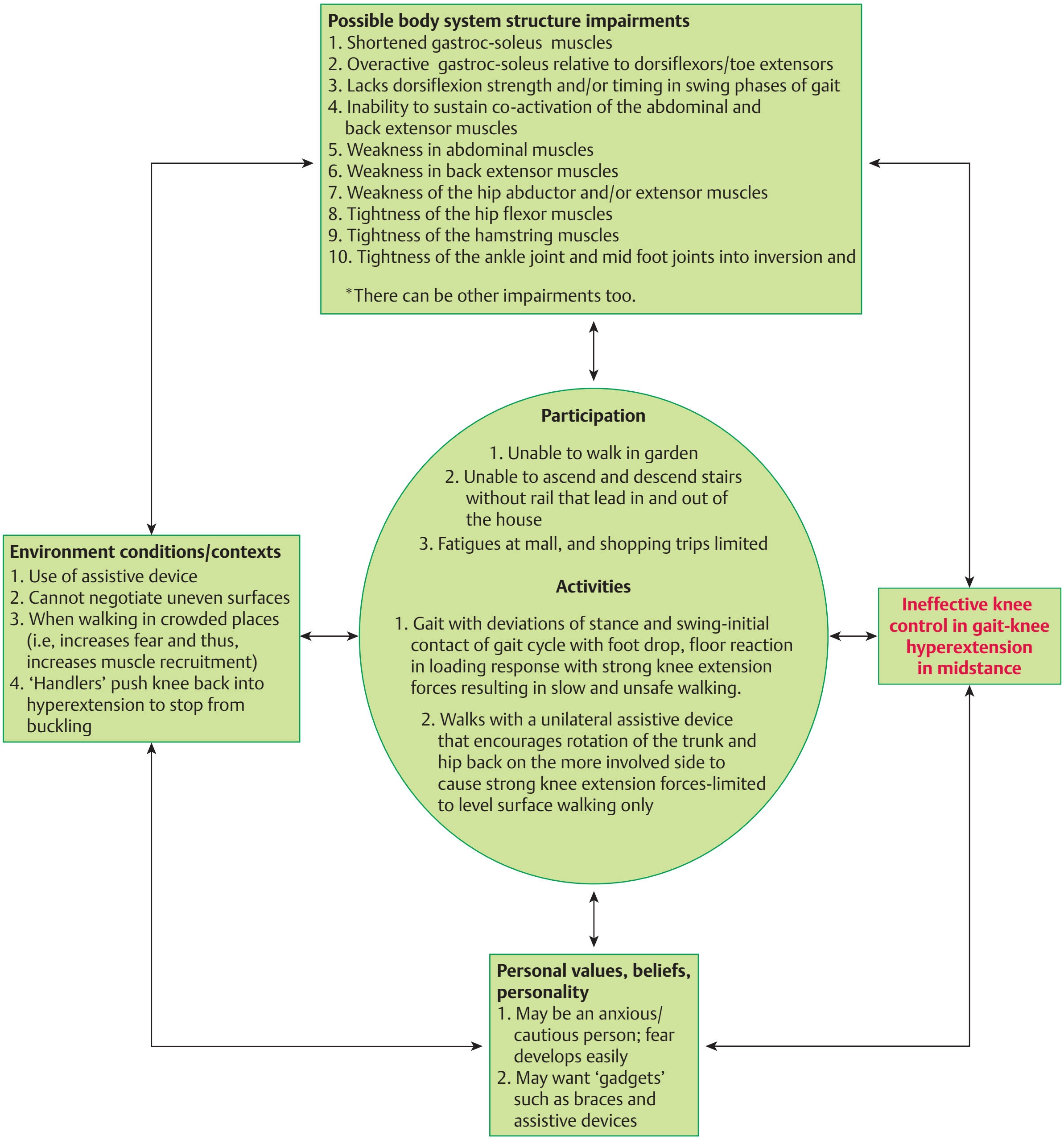

Fig. 5.9 Example of problem solving around the ineffective movement or alignment of knee hyperextension.

other skills to deteriorate over time or interfere with the attainment of new skills? Could the repetition of knee hyperextension while walking cause secondary impairments elsewhere in the musculoskeletal system?

During the evaluation portion of the therapy process, a therapist using the NDT Practice Model relies on the following:

- The analytic skills of comparing and weighing the influence of participation/participation restrictions, activities/activity limitations, body system integrity/impairment, and effective/ineffective postures and movements on a client's functioning and disability. This requires the application of information from the basic and applied sciences and humanities. The therapist's experience with a particular disability or condition influences the breadth and depth of analysis.
- The ability to foresee a range of prognoses. This range of prognoses is based on the analysis from skills described previously, applying the potential influence of all factors associated with life skill outcome. Prognoses are also based on the therapist's understanding of typical and atypical development or typical and atypical skill performance with the

Fig. 5.10 Carolyn Bush, who is poststroke, shows knee hyperextension of her right knee in the loading response to midstance phase of gait.

ability to predict how current skills influence future impairments and skills.

- The ability to prioritize the effects of all the previous points influences future functioning within tasks and related tasks. The therapist who uses the NDT Practice Model is aware of current functioning and its potential effects on future functions. Sources of this knowledge are descriptive knowledge, procedural knowledge, clinical insights, and experience level.
- The ability to work with a team of people who serve the client. This team includes, foremost, the client and family.

5.4.5 The NDT Practice Model: Intervention

The Bobaths said, "Treatment is an unending interchange between the therapist's actions and the child's response to them."[6] Intervention (Fig. 5.11) and other forms of management involve participation on the parts of the client/family and therapist. Each intervention session is organized around a functional outcome, and all the sessions move toward multiple functional outcomes for the longer term. Both the client and the therapist have responsibility for initiating and responding to intervention and/or consultation that is structured to meet intervention goals and outcomes. Although the therapist plans intervention as described in the section on evaluation, the client and family are responsible for several important activities. They communicate updates about the client's health conditions, changes in participation and activities, how well the home program worked or did not work, what other team members said and did in their interaction with the client, and what the client and family would like to focus on in the session today.

The therapist uses intervention strategies that address the impairments interfering with functional activity, including therapeutic handling skills. Handling is used to evaluate the responses to intervention as well as to provide guidance and assistance to participation, activities, postures and movements, and single-system body

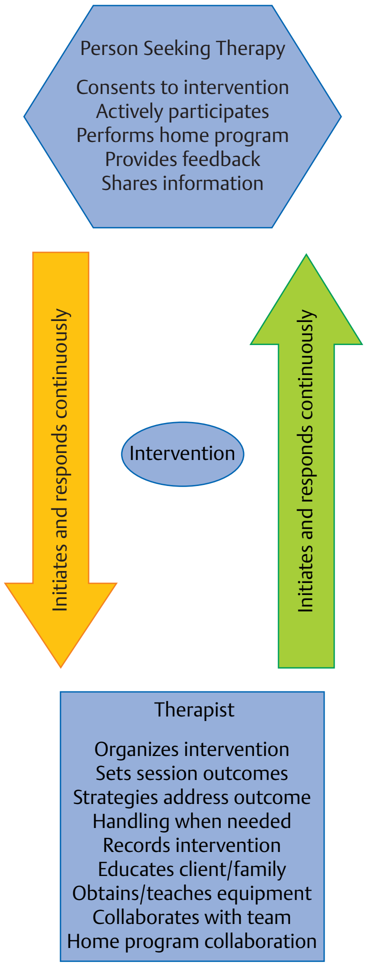

Fig. 5.11 Intervention using the Neuro-Developmental Treatment Practice Model.

structures and functions across a variety of contexts. Therapists who use the NDT Practice Model constantly update and modify intervention through handling, observing responses, monitoring changes in any aspect of the client's behavior, and monitoring changes in function.

Handling is a highly developed assessment and intervention skill taught in NDT education. Handling involves the ability to perceive discrete sensorimotor responses (here it is being used as an examination tool); the ability to assist the client to initiate, sustain, and terminate muscle activity; the ability to assist the client to use more effective postures and movement synergies; the ability to assist the client to grade movement appropriately from powerful and ballistic to smooth and sustained as needed; and the ability to practice repetitive movements for strengthening, perceptual accuracy, and motor learning. Handling's key points of control change as the therapist perceives changes in the client. Handling may be continuous throughout an intervention session if the therapist determines the need, and it can also be sporadic if the therapist determines so. Some sessions require little to no handling for intervention.

The therapist using the NDT Practice Model also includes the following in intervention sessions, based on Howle.[7]

- The therapist organizes intervention around a functional activity or participation outcome with specific contextual factors that have been set/revised in partnership with the client and family.
- The therapist engages the interest and participation of the client/family in the session, using knowledge gained from the information gathering, examination, and evaluation processes.
- The therapist purposely engages the client's body system integrities, activity abilities, and contextual preferences to ensure that intervention is meaningful.
- Intervention strategies are performed with a purposeful relationship between handling, verbal, and environmental cuing and the functional activity desired as the outcome of intervention.
- Intervention strategies include preparation of body systems for practicing part of or entire tasks.
- Intervention is designed to allow as much initiation of posture and movement as the client is capable of, and to continually obtain active responses from the client when the client cannot initiate or complete a posture, movement, or activity efficiently or independently.
- Intervention allows the client to make safe and acceptable errors in posture and movement; the therapist decides if the client can self-correct or correct and learn from the errors with assistance. This practice with correction allows the development of motor planning and motor problem solving for the client.
- Repetition of part of or the entire task performed to the best of the client's ability is incorporated into each session for motor learning. The therapist decides on the type of practice as well as the frequency, intensity, and type of feedback while practicing.
- The therapist constantly responds to the client's behavioral, communication, and sensorimotor actions during intervention, adjusting and revising the plan of care accordingly.
- The therapist and client/family develop a home program based on successful and purposeful activity obtained during the intervention session. This program is designed to allow successful practice outside of intervention.
- The therapist and client/family discuss any communication that will be shared with the intervention team as a result of the session. The therapist also listens to recommendations from other team members, modifying the intervention in future sessions if needed.

The therapist who uses the NDT Practice Model works to develop and refine the following descriptive and procedural knowledge for intervention:

- The ability to set functional outcomes for each intervention session. This outcome may be a short- or long-term outcome, a less demanding outcome related to the short-/long-term outcome, or a portion of an outcome. Selection of intervention strategies is designed around this outcome.
- The awareness to continue information gathering, examination, and evaluation during intervention. This awareness is accomplished through direct verbal and nonverbal interaction with the client and family, handling skills that are used to both examine and intervene, and the client's responses to intervention, including changes in activity/participation, changes in posture and movement, and changes in body system function.
- The use of knowledge from basic and applied sciences in a therapeutic and client-friendly appropriate manner to elicit positive responses.
- The use of handling skills to examine, evaluate, and intervene with the client.
- Collaboration with the client, family, and other team members for the best possible life skill outcomes for the client and family.
- Communication with verbal, nonverbal, and written communication to promote the best possible client and family outcomes.

5.5 Summary

This chapter introduces the NDT Practice Model to describe and explain NDT practice. Four sections of the model, Information Gathering, Examination, Evaluation, and Intervention, are explained in detail as the therapist and person seeking therapy work together to design an individualized plan to improve functional life skills. These four sections are not entirely separate in actual practice because information gathering continues throughout formal evaluation and during intervention sessions, whereas examination, evaluation, and intervention interweave as the therapist and client work together. The chapter introduces the skill sets and critical thinking of therapists who use this model.

This chapter serves as an overview of the NDT Practice Model. Subsequent chapters will examine each part of the process in detail, with examples from case reports to depict and describe clients involved in therapy. The NDT Practice Model serves as the basis of clinical reasoning and analysis for the individual case reports in Unit V. Each case report will highlight various aspects of the NDT Practice Model.

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6 Information Gathering

Marcia Stamer

This chapter expands on the Neuro-Developmental Treatment (NDT) Practice Model's Information Gathering section, describing the problem solving and actions involved in the relationship among all who are seeking intervention and other management of a client with a neurodisability.

Learning Objectives

Upon completing this chapter the reader will be able to do the following:

- List at least five contributions of the client/family and the clinician to the process of information gathering.
- Explain why information gathering is a critical portion of the NDT Practice Model.
- Discuss why information gathering permeates the entire therapeutic process and why it occurs throughout all intervention sessions.
- Explain why knowledge of pathology; lifelong change; motor development, motor control, motor learning, neuroplasticity; psychosocial functioning and human behavior; and participation, activity, and posture and movement are important during information gathering using the NDT Practice Model.

6.1 Information Gathering Using the NDT Practice Model

Chapter 5 introduced the Information Gathering portion of the Neuro-Developmental Treatment (NDT) Practice Model (**Fig. 6.1**). The key feature of information gathering is the interaction between client/family and clinician. NDT views this communication as critical to establishing baseline information, just as the initial examination establishes baseline information. For the clinician using NDT, *who* the client and family are is just as important as *what* examination findings reveal. NDT does not limit its interest to medical information only; rather, it incorporates the biopsychosocial scope of the ICF model into its practice. NDT views the relationship with a client and family as one where the clinicians' roles are to provide professional services within the client's expressed goals, which clinicians document as intervention outcomes. The information provided by the client, family, and clinician is expressed in both verbal and nonverbal communication among all present and is received by the clinician in a nonjudgmental manner.

6.1.1 Building Trust

NDT philosophy advocates building trust so that the client/family feels comfortable expressing their concerns, needs, and successes. The client and family are encouraged to express their understanding and perspectives about the purpose and results of intervention. The clinician is interested in whatever the family says and does not discourage expression of information or desired outcomes that seem unreasonable or unlikely in the clinician's viewpoint. Clinicians are likely to spend considerable time with the client and family over weeks, months, and perhaps years, and the first consideration they desire is the family's trust to freely express themselves.

If families or clients express the desire to walk or walk again, talk or talk again, feed themselves or play soccer again, they may express this regardless of the likelihood of achievement of these outcomes. Our clients and their families are coping with the consequences of an oftentimes devastating disability. They express sadness, outrage, fear, and confusion. Their stories can be an emotional experience for the clinician, but listening is crucial for building trust. It is not possible for most people to cope with the consequences of disability without the support, repetition of information, hard work in intervention management, and individualized care that the situation demands.

Example

An 8-month-old baby newly diagnosed with spastic diplegic cerebral palsy visits a physical therapist who uses the NDT Practice Model. The baby and mother attend the initial session. Later, the therapist interacts with the baby's father and several grandparents, including the paternal grandfather, who is the one bringing the child to most therapy sessions over several years' time. The mother initially asks when the baby will catch up since his development is delayed (this description is her understanding of her baby). The therapist repeats information for months that gradually allows the mother to think about a different course of development for her child, rather than thinking he will catch up. The therapist is patient with repetitive questions and with the

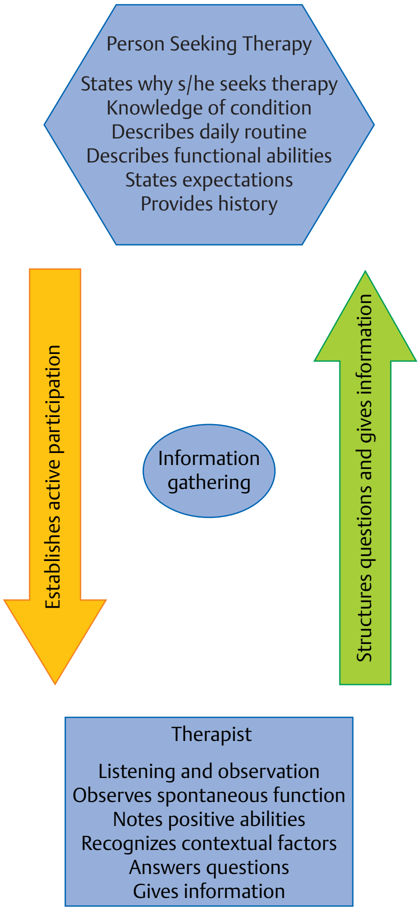

Fig. 6.1 Information gathering using the Neuro-Developmental Treatment Practice Model

mother's posing of ideas and scenarios for helping her son walk normally. The therapist realizes that this information is difficult for the mother to cope with. It is not that she doesn't understand what the therapist is saying; it is that the information is too emotionally demanding to simply accept. The therapist encourages questions and suggests that the mother ask the same questions of other team members.

When the child is a teenager receiving periodic episodes of care, the mother reflects about her early experience to the therapist one day. She tells the therapist that she still has a difficult time some days coming to terms with the differences in her son's physical abilities, although she is very proud of how well he excels socially and academically. She further notes that she varies in her ability to accept her son's cerebral palsy, and she guesses she will always be that way. When her son encounters new difficulties, as he did when figuring out how to negotiate a college campus, her own fears increase and a certain level of sadness overtakes her. The therapist listens, reflecting on the meaning of cerebral palsy to the teen and his mother over their lifetimes so far. The therapist deepens her own understanding of the meaning of a lifelong disability for this family. Information sharing is therefore crucial to the growth and understanding of each person involved with this teen and how it affects all of their lives.

6.1.2 Establishing Communication

By establishing a system of communication, NDT values active participation of the client and family in all aspects of care. The client and family are encouraged to take the lead by providing information that they know more about than anyone else does. This initially takes the form of providing information about the client's unique personal attributes and abilities, likes and dislikes, and relationships to key people in his or her life. This contextual information is critical in assisting the client and family to establish and measure profession-specific outcomes for therapeutic intervention.

Example

Mr. Hayden had a stroke due to right middle cerebral arterial ischemia with resultant left hemiparesis and spatial neglect. He is concerned about his role as the family financial provider. Although close to retirement, he says that he wants to work for a few more years. His wife states that the family is able to manage if he cannot return to work, but Mr. Hayden's goals for physical and occupational therapy are all focused on the physical skills he thinks will allow him to return to work. Mrs. Hayden provides details about how her husband is faring within the home environment, which helps his therapists gauge how functional he is becoming in that setting.

Mr. Hayden's outpatient rehabilitation therapists learn about his physical skills as they work in therapy, but the therapists learn even more about how he can use those skills in the home as Mr. and Mrs. Hayden provide information. They also learn about Mr. Hayden's personal desires and goals, as well as the role his wife plays in his rehabilitation, seeing both as critical in establishing and updating intervention outcomes, home programming choices, and monitoring life skills. *Who* Mr. Hayden is and *what he wants* from therapy form the basis for his therapists' intervention and management.

6.1.3 A Typical Day

NDT practice encourages therapists to gather information in a systematic way consistent with the time and place of service delivery. NDT practice encourages the clinician to determine the best system for gathering information because clients and families are all unique, with individual competencies and limitations.[1] During the initial session with a client and family, the clinician learns about a typical day in their lives. One way to organize information gathering that clinicians may find useful is to record a narrative of a typical 24-hour day. In this way, the client, family, and therapist create a picture of current life for the client, which includes participation and participation restrictions, and activities and activity limitations in the context of family, school, work, and leisure routines.

The client/family's support system; culture; social relationships; work, school, and hobby interests; and types of recreational activities naturally unfold in this type of history taking.

The clinician guides the narrative with pertinent questions to understand all of these interacting features of the client's life. This history taking allows the clinician to ask questions related to medical conditions and precautions that affect current functioning and allows the client and family to include their goals and desired outcomes from therapeutic intervention based on how they perceive satisfaction or dissatisfaction with their daily lives.

Example

An occupational therapist (OT) makes a home visit to a new client, Taylor. The family she visits includes parents and two children, ages 14 and 16. The 16-year-old daughter returned home from inpatient rehabilitation 2 days ago. She had been hospitalized for traumatic brain injury (TBI) that occurred 2 months prior due to closed head injury from a motor vehicle accident.

Today, the client's mother is home while her father is at work and her sister is at school. The OT greets the teen, who looks at her in response but does not vocalize or change her facial expression. The teen's mother sits on the couch with her daughter, inviting the OT to sit in a nearby armchair. After restating her name and professional credentials, the OT asks the mother and daughter about their previous experience with occupational therapy.

The mother responds, "I'm not sure which therapists at the rehab center were OTs. There were so many people who worked with us. They were all nice, and they worked hard, trying to get Taylor to work with them. She did make tremendous gains while there—she couldn't even hold her head up when she first arrived. Now, she can sit by herself and walk if I hold her arm. She makes sounds sometimes, but we haven't understood any words. I don't know if she is trying to say any words or not."

The OT begins by stating that she wants to get to know Taylor and her family so that she can work on the outcomes they want to accomplish. She asks Taylor's mother to describe the new routine at home now that Taylor has returned. She asks about Taylor's ability to move around the house, her abilities to dress and feed herself, and what she prefers to do while her mother is occupied with other tasks. Once Taylor's mother gives her information, the OT asks more specific questions. For example, she might ask how Taylor feeds herself, which utensils she can use, what foods she prefers, how long it takes her to eat, whether she has a good appetite, and whether she is taking any medications or has complications that influence her eating. She could then ask to schedule a visit at lunchtime so that she can observe Taylor feeding herself and the assistance required from her mother. Once she has an opportunity to see this, she would observe and hypothesize about any difficulties Taylor has with posture and movement, making notes to test specific body system functions after lunch.

The OT also asks about Taylor's life prior to the accident in a way that allows her to understand Taylor's interests and preferences. She asks about friends and family who see Taylor now or who will see her in the near future. She asks how Taylor responds to various familiar people. She asks what Taylor's mother would like her to help Taylor with now and in the future.

Within a few visits, Taylor's OT finds that Taylor is the most focused and invested in the work they do together when she has her favorite CDs playing. She learns that Taylor has no interest in practicing dressing skills, but she works hard to use both of her hands on the computer keyboard when they look at the postings of her friends on Facebook. Taylor tries to hold her cell phone and attempts to text her friends too, although Taylor's mother and OT have not noted an ability to spell words. Her OT notes that when Taylor is assisted with texting she vocalizes spontaneously; the OT makes a note to discuss this with the speech-language pathologist who will begin working with Taylor next week.

The OT discusses and explains to Taylor's mother that she is working on the two-handed (bimanual) tasks that they would all like Taylor to achieve in the context of activities that Taylor shows the most interest in. She shows Taylor's mother a couple of key strategies to assist Taylor in achieving wrist extension stability while Taylor uses the computer keyboard. She shows Taylor's mother two intervention ideas that include physical assist to sitting posture with hand placement on the lower thoracic spine that she has found works well to facilitate forward reach with Taylor's more involved upper extremity. She emphasizes that Taylor's mother can use these strategies whenever she sits with Taylor to help her view Facebook postings.

Taylor's mother shows the OT the five pages of exercises that she was given in the rehabilitation center to do with Taylor each day in the prone and supine positions, and the OT explains her preferences for her current choices (as just described) and her rationale for giving only a few home programming ideas in the context of functional activities.

6.1.4 Knowledge of the NDT Philosophy

Clinicians who practice using the NDT Practice Model actively learn and update their learning in many aspects of human behavior to enhance their information-gathering skills. In the example of Taylor, her family, and her OT, the OT is thinking about her intervention philosophy during *every interaction*.

Taylor's OT defines NDT as a therapeutic problem-solving model for intervention with Taylor. The importance of NDT for Taylor's OT is the individualized examination, evaluation, and intervention planning that are ongoing and interactive. She believes that careful listening, observation, and planning for future function in the context of Taylor's life and her family life are paramount to the therapeutic relationship. She finds that therapeutic, judicious handling skills are vital for detailed examination of posture and movement and intervention to increase its efficiency and effectiveness for functional gains.

6.1.5 Knowledge of Basic and Applied Sciences

The OT's practice is informed by knowledge of theories of motor control, motor learning, and motor development and the constant new knowledge that emerges in all of these fields, as well as knowledge of the causes and effects of compensatory postures and movements originating in various body systems. Taylor's OT possesses detailed information about effective and ineffective postures and movements and the body systems that may contribute to Taylor's current postures and movements. Her study of typical development and typical posture and movement assist her in understanding the difference between efficient and inefficient/detrimental postures and movements. She does not believe that her knowledge of normal or typical or efficient postures and movements implies that Taylor should repeat a normal developmental sequence.

She has experience that assists her in facilitation of more efficient postures and movements and how postures and movements interact, reinforcing each other and influencing postures and movements in other parts of the body. She organizes postures and movements around function, as the current motor control literature supports, and begins to select ideas for activities according to Taylor's interests and level of motivation gleaned during information gathering. Later, she will help Taylor to practice and repeat parts or whole postures and movements for motor learning after evaluating how Taylor learns best (which sensory systems she learns best through, what verbal and nonverbal prompts are most effective, how much frustration Taylor can cope with, how quickly Taylor's attention and motor systems fatigue with repetition). Part of information gathering is initial exposure to a client's and family's learning style.

6.1.6 Knowledge of a Model of Human Functioning

Taylor's OT learned about the International Classification of Functioning, Disability and Health (ICF) model in OT school, and she learned to use it to organize her therapeutic practice process during her NDT education. She organizes her questions about Taylor's life around the interaction of participation, activity, and body structure and function.

6.1.7 Knowledge and Experience Health Conditions

Taylor's OT has studied pathology, body-system impairments, and multisystem impairments commonly seen in people with TBI. This study includes declarative and procedural learning, as well as reading research literature and discussion with peers and mentors. This dedicated study assists her in focusing her questions about Taylor's posture and movement and her initial hypothesizing about their effectiveness/ineffectiveness.

6.1.8 Knowledge of Life Span Skill Development

Taylor's OT is constantly alert to the possible effects of any posture or movement that Taylor performs now as it relates to more skillful posture and movement now and in the future. She seeks information about long-term consequences of TBI in single body systems as well as with efficient and ineffective repetitions of postures and movements. She hypothesizes how all of these interactions may affect Taylor as she matures into adulthood and into older adulthood. Information about life span effects of TBI combined with aging influence the intervention choices and outcomes Taylor's OT sets for her *now* in conjunction with the family's input.

6.1.9 Knowledge of Family and Societal Influences

Taylor's OT will find herself immersed in teen culture specific to Taylor and her family's culture and values. She must become and remain actively involved in this aspect of Taylor's current and past life to assist Taylor's motivation and interest in achieving outcomes that Taylor must work hard to attain.

6.1.10 Knowledge of Human Behavior

Declarative and procedural knowledge about typical and atypical teenage behavior, Taylor's reaction to a markedly changed life, and Taylor's family and friends' reactions will assist her OT in designing an intervention plan and assist in constant communication with Taylor and her family.

6.1.11 Knowledge of Learning Styles

Taylor's OT's entry-level and NDT education addressed examination and evaluation skills pertaining to the contributions of sensory systems, motor control, perceptual development, cognition, and experience to learning, in both typical and atypical function. During information gathering, Taylor's OT attends to the global picture of Taylor's interaction with the world through these various systems. This guides her specific examination that follows.

6.1.12 Skilled Observation

Taylor's OT spent many hours in her entry-level and NDT education observing and discussing all contributions to typical and atypical posture and movement as well as the effects of impairments, context, and learning on posture and movement. She discusses her observations with peers and mentors and continues formal education opportunities and stays current with the literature throughout her career. This experience allows her to begin observational examination of posture and movement during the information-gathering portion of her first few visits with Taylor, streamlining the subsequent examination, evaluation, and intervention-planning process. By making observations of posture and movement within the most natural setting possible, and without hands-on interference, Taylor's OT can begin recording baseline information for the next phase of the therapy process: examination.

6.2 Summary

This short chapter shows a part of the NDT Practice Model that permeates not only formal written documentation, but every session and interaction with the client, family, and other caregivers. Gathering information about the client's past and present daily life and expectations from therapeutic intervention shapes all therapist-client interventions and other management strategies toward functional outcomes. The therapist who uses the NDT framework values what the client and family have to say about their understanding of diagnosis and prognosis; their personal and environmental contexts for function; their dreams and desires; and strategies they would prefer to employ in therapy.

As this chapter and the NDT Practice Model show, the therapist who uses NDT relies on many sources of knowledge and beliefs to inform practice during information gathering. These include, but are not limited to, the following:

- The belief that people with disability and illness have value; the belief that therapy can influence functional outcomes.
- The practice of empathic listening.
- Knowledge of the NDT Philosophy.
- Knowledge of cultural diversity, family dynamics, human belief diversity/respect, human values, and ethics.
- Knowledge of psychology, human behavior, and reaction to disability/illness.
- Skilled observation of functional skills and of posture and movement.
- Knowledge and experience with disability, illness, and other health conditions.
- Knowledge of a model of human health and functioning (in this text, the ICF model is used).
- Knowledge of self—the therapist's own functioning, posture and movement, body size and shape, and experience with other clients and families.

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7 Examination

Marcia Stamer

This chapter details the examination process of the Neuro-Developmental Treatment (NDT) Practice Model. Emphasis is on the observations, handling, and clinical hypothesis generation that the NDT clinician organizes for the purpose of understanding how clients function and move the way they do. Examination is described as clinical observation, handling, and testing. Posture and movement are described and explained as multisystem body functions that affect participation and activity.
The chapter includes a detailed review of body systems that the clinician using the NDT Practice Model examines, with current research information about each system.

Learning Objectives

Upon completing this chapter the novice clinician will be able to do the following:

- List and define the different components of an NDT examination.
- List at least three different purposes of examination and explain how the structure of an examination varies according to those three purposes.
- Explain why information gathering, examination, and evaluation are interwoven and interdependent in the NDT Practice Model.
- Explain the process of individualized examination according to the desired functional outcomes anticipated for a client.
- Define at least eight reasons why a clinician uses handling in the NDT examination.
- Describe the difference between a multisystem integrity/impairment and a single-system integrity/impairment.
- Define posture and movement and then be able to create a list of posture and movement impairments for clients examined in daily practice.
- List at least eight single body systems' structure and function characteristics.

Upon completing this chapter the experienced clinician will be able to do the following:

- Generate questions and comments with clients and their families during examination, the answers to which provide direction to further individualize the examination.
- Immediately use examination information to generate hypotheses about multiple influences on a client's participation and activity.
- Generate hypotheses about how the structure and function of single body systems interact with each other to produce multisystem functioning in clients.
- Generate hypotheses about the contributions of single systems and personal and environmental contexts to a client's multisystem integrities and impairments not detailed in this chapter, such as learned disuse, fear, and pain.

7.1 Examination Using the Neuro-Developmental Treatment Practice Model

Examination involves systematically gathering observations and measurements of the client in all International Classification of Functioning, Disability and Health (ICF) domains: participation, activity, and body systems. The Neuro-Developmental Treatment (NDT) clinician organizes the examination based on these domains, as well as on the particulars of the information gathering previously described. This examination provides information that the clinician will use to seek an understanding of relationships among the domains during the evaluation portion of practice (**Fig. 7.1**).

Where and how should the clinician begin examination? The NDT clinician starts with function, or observations of participation and activity. What can the client do today? Then the clinician begins to ask *How*? How does the client do what he or she does? How leads to examination of participation and activity, then to examination of multisystem structures and functions, such as posture and movement. Examination includes the environmental and personal contextual factors in which participation, activity, and posture and movement usually occur for that client. Finally, the clinician examines the contributions of body systems specific

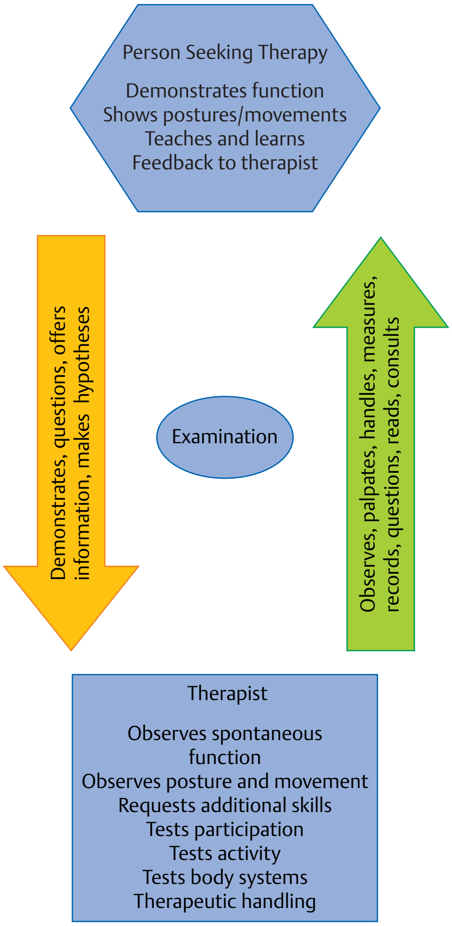

Fig. 7.1 Examination using the Neuro-Developmental Treatment Practice Model.

to the client's functional abilities and inabilities. This structure leads the NDT clinician to an individualized organization of the examination with flexibility that meets the needs of each client. *How* will later lead to *why* during evaluation once the clinician gathers data from the entire examination.

7.1.1 The Purpose of Examination

There is no official NDT examination format. Each clinician, working with each client and family under particular advantages and constraints, structures an examination that fits the context of the situation.

Examination may serve different purposes. Sometimes, an examination is a screening for further examination or referral to another agency, such as when clients attend specialty clinics (e.g., a spasticity clinic). An examination may serve the purpose of qualifying a client for services, such as special education, Medicare-approved visits, placement in a skilled nursing facility, or early intervention. These types of examinations are therefore specific to the criteria for qualification for services and are often limited in scope.

A large part of practice for many clinicians consists of performing in-depth examinations with recommendations for intervention (episodes of care). Examination is detailed in this situation and is shaped by the environment where subsequent intervention management will occur, such as in the home, or in a school, rehabilitation center, or long-term care facility. These considerations affect the emphasis of what is examined under particular conditions. For example, a school therapist who will implement an individualized educational plan (IEP) along with other professionals considers the functional outcomes that are most necessary for a child to succeed in a particular classroom at a particular school with particular teachers. The examination may therefore begin with observing functions the child can and cannot perform in the classroom, cafeteria, or gym class and at recess.

A therapist working in home health care with a retired mechanic who had a stroke structures the examination around functioning the client can and cannot perform within the home and in excursions from home to other places in the immediate area and community, focusing on the relatively new retirement routine the man had begun to establish. If this man had recently taken up a gardening hobby, the therapist will examine his ability to tend to the garden as well as examine function in the basic daily routine.

Because there are many purposes and environments for examinations, clinicians and facilities tend to develop their own formats and forms to suit their needs. The clinician using NDT may work within these formats and specific forms to create an examination that allows for observation and measurement of participation, activity, multisystem structures and functions, and single-system structures and functions. This chapter therefore presents comprehensive examination strategies that each clinician will then tailor to each client's situation.

7.1.2 The Roles of the Clinician and Client/Family in Examination

What should be examined? Should every body structure and function be examined and measured? As the reader will soon discover with the review of systems in this chapter, examining each one of them, thoroughly measuring each category in each system, would require an inordinate amount of time, as well as exhaustive work for both client and clinician. Therefore, the clinician streamlines and customizes examination based on the initial interview and observations.

Prior to examination, the clinician has seen and heard the concerns of the client/family, observed posture and movement within some activities, and asked the client and family to state their goals for intervention. All of this information determines what the clinician will emphasize in examination and helps to prioritize what will be examined in detail.

7.1.3 Examination: An Overview

Observation

During the initial portion of the examination, the clinician observes function. For example, the case report of Perry in Unit V (B3) of this text describes him as a 9-month-old boy with left hemiplegia due to right middle cerebral artery infarct (**Fig. 7.2**). He lives with his parents and two older siblings. Perry gestures for communication and uses his right arm, but not his left, in play. His mother says that he is able to sit in a high chair and is carried for mobility. He attends an infant/parent group at a university setting with his mother.

Perry's examiner notes that he makes no transitional movements between positions (supine or prone to sit, up and down from standing), refuses to move away from his mother, and cries when the examiner tries to encourage him to use his left hand in play. His mother can place him in sitting, and he grasps toys using only his right hand as he sits. He takes weight through both legs when held in a standing position.

With only a sample of Perry's participation and activities and a few observations of his posture and movement skills, the clinician examining Perry questions why he does not move between postures, why he does not use his left hand, and why he cries when the examiner touches his left hand. The examiner may or may not be concerned about Perry's unwillingness to separate from his mother. (Developmentally, 9-month-olds frequently show reluctance to separate, and this could be a sign of Perry's appropriate cognitive and social awareness. Furthermore, the examiner is a new person to Perry, and he may be appropriately wary of new people.) The examiner discusses with Perry's mother her priorities and global goals for intervention.

Fig. 7.2 Perry at 4 months of age. Although this picture shows asymmetry of his cervical and upper extremity posture, Perry's therapist observes him in various postures and positions under different contexts (held by his mother, placed on the floor, sitting on his mother's lap, standing with support) to note whether this position persists or whether he has more variety to his postures.

The examiner will try to engage Perry, perhaps through play with his mother, to determine if he shows any more postures and movements not seen so far. The examiner would like to place her hands on Perry but knows he may react adversely and so may choose not to do this at first, saving handling until rapport is established, or touching Perry only briefly in playful activity. This strategy is used because the examiner knows that establishing rapport, even if the first few sessions do not yield as much information as the examiner would like, is important for the long-term relationship with Perry and his family.

The examiner observes Perry's posture and movement, including alignment, symmetry/asymmetry; responses to the environment; and interaction with his mother. The examiner will attempt interaction with Perry, offering him toys or giving them to his mother for them to play with. The examiner continues to watch, listen, and ask questions about Perry's abilities in function in the context of his life. With this work, the clinician begins to formulate clinical hypotheses about why Perry functions as he does. Is his nonuse of the left hand likely due to muscle activity imbalance, sensory sensitivities or ineffective processing of sensory information, lack of postural stability in the trunk and left shoulder for which he compensates by increasing distal muscle contraction, or loss of joint mobility? The clinician continues to observe and consider these options, perhaps adding more options or beginning to prioritize which she or he thinks are more likely.

At this point, the examiner may suspect neuromuscular and sensory impairments as the most likely systems interfering with function for Perry and will examine these through handling when possible, to feel muscle activity and tension, assess how easily Perry changes muscle activity, and gauge how he responds to various types of touch. Opportunities and needs to examine other systems will evolve as the clinician begins to work with Perry.

The clinician chooses the systems to examine based on a knowledge of stroke pathology in infancy; the knowledge of sensorimotor, cognitive, and social development and how Perry is faring in his development; observations of Perry's posture and movement; and Perry's mother's descriptions of what he can and cannot do. The examination is therefore focused and customized for Perry.

As shown in the example of Perry, observation during examination starts with observations of activity (functional skills) and any participation that is possible in the examination setting. The skills observed spontaneously and by request will vary according to the profession of the clinician performing the examination and the setting (e.g., home, school, outpatient rehabilitation center, long-term residential center, etc.), but these are usually the easiest and most spontaneous domains to observe in any examination session. The clinician begins by recording activities and participation the client can perform, tries to perform but cannot complete, and cannot perform at all.

Clinicians focus on activities and participation particular to their profession. Speech-language pathologists (SLPs) are interested in the ability to communicate in its varying verbal, vocal, gestural, and technical assistance forms. Some may also specialize in feeding skills and nutrition. Occupational therapists (OTs) specialize in occupation; this varies according to the client's age and other factors. They expertly analyze and treat clients to address activities of daily living: self-feeding, dressing, bathing, shaving, and cooking are examples. They address daily skills that many people engage in, such as handwriting, keyboarding, play activities, and access to toys. Physical therapists (PTs) specialize in how people achieve and functionally use mobility. Each of these three professions has common needs in examination of posture and movement, as well as diverse needs in the details and functional outcomes of postures and movements. Practitioners in these three professions are the primary intended audience of this book.

Activities and participation are also the domains that the client and family know about in detail, so beginning with these aspects can be empowering to them; they find that they can question, comment on, and demonstrate these domains confidently, and they remind the clinician that participation and activity occur in a variety of contexts (see Chapter 6, Information Gathering). Rapport and trust building are therefore encouraged, and the examination is truly a team effort.

For example, an SLP may examine the activities of communication and speech, observing the variety of successful and less successful abilities of a client in the examination setting. The SLP will observe how the client produces any sounds or gestures or otherwise communicates to others and will note the contexts under which the communication takes place, specifically observing the variety of postures and movements the client achieves. An SLP examining a 2-year-old may start with trust building among the parent, child, and SLP by engaging the child in activities the parent mentioned were favorite activities. The SLP observes a range of information as the child plays and interacts with the parent and therapist. The SLP notes the various ways the child communicates with parent, therapist, and the environment, using spontaneous gestures, vocalizations, and verbalizations. Then the SLP notes postures and movements available to the child for this interaction: respiratory pattern, depth, endurance, and coordination with swallowing and voicing; arousal and attention span; preferences and variety of play; and interaction skills. This list is not exhaustive.

During this observation, the SLP begins to hypothesize about how to structure the handling portion of the examination and which tests and measures would be the most appropriate for this child. The SLP may wonder, "If the child's postural and respiratory muscles were more actively sustained in contraction when she voices, could she vary the pitch and loudness of her speech or say more words per breath?" Then during the handling portion of the examination, the SLP could support trunk position and posture, including rib cage support, to note the effect on respirations and voicing. The SLP might elongate the pectoral muscles to enable more thoracic extension for posture and position of the trunk, noting the effects on the quality and quantity of speech production. The SLP may leave her hands in full contact with the trunk, waiting until the child voices to note what segment of the body or muscle groups the child uses to initiate voicing.

The observations of activity directed the SLP in specific handling choices and will direct the choices of tests and measures too. Although the SLP may have preselected a language test based on the child's age, she may decide that other tests that measure the same domain may be more appropriate because the child has more or fewer capabilities than most children her age.

The foregoing example demonstrates how observation and measurement of participation and activity lead the clinician to select which multisystem and single-system body structures and functions to focus on first in examination. The clinician asks, "What can this client do and not do? What postures and movements do I observe this person using to perform participation and activities? Which single-system body structures and functions probably contribute to these postures and movements that I should test? Which test or measure would be the most appropriate to gain this information?"

Finally, our current understanding of motor control and motor learning (see Chapters 12 and 13) shows that posture and movement selection, along with all of the supporting contextual factors, is organized around a functional task. The clinician using NDT will therefore examine postures and movements within the context of functions and will later design intervention around functional outcomes (see Chapter 9 on session intervention).

In summary, in any examination situation, the client, family, and clinicians all have roles to perform during information gathering and observation. Examination in NDT continues as multidirectional communication with all participants. The client reports and demonstrates participation and activity (function), both spontaneously and by request. The client, family, and other caregivers ask questions of the therapist and offer further information as they demonstrate skills. For example, a client may say, "I can walk on the kitchen hardwood floor like I'm doing it here, but our bedroom carpet is so thick that I often trip and I'm afraid I'll fall." Or, "When I feed her formula out of the bottle, she drinks like you see her doing now, but after about two minutes she seems to get so tired that she can't suck any more out of this nipple. I wonder if another type of nipple would work better." The last statement is a hypothesis that the family generated based on their description of how their infant bottle-feeds.

Baseline observation of participation, activity, and body system functions initially requires hands-off as much as possible, and information-gathering questions will continue to be generated as the clinician performs the examination. The clinician observes spontaneous activities, postures, and movements. The clinician may request that the client, or client and family together, demonstrate a particular activity, posture, or movement that the clinician has not yet seen the client perform. Once satisfied that the client has demonstrated a good sample of the repertoire of each ICF domain, the NDT clinician begins hypothesizing about why some functions, postures, and movements cannot be completed or are completed inefficiently.

Therapeutic Handling

The clinician begins hands-on handling of the client to examine muscle activity, respirations, structure of the musculoskeletal system, and responses to the sensory input of the handling. The clinician also examines how easily the client changes muscle activity, sensory organization and responses, arousal/attention, behavioral organization, posture, movement, alignment, and range of motion to specific handling strategies. This information assists the clinician in determining how the client changes and adapts. Thus it ultimately affects outcome setting.

Handling involves placing the hands (and sometimes forearms or segments of the trunk and lower extremities) in physical contact with the client to sense the following:

- Muscle initiation and how long the muscle stays in contraction.
- How many muscles contract together and the order of recruitment.
- Stiffness and compliance of body segments.
- Joint stability/instability.
- Reactions to graded support of a body segment.
- Active weight shifting initiated by the client, which assists in determining which muscles and body segments participate.
- Sensitivity and reactivity to tactile and deep-pressure contact.
- Respiratory pattern, timing, and rate.
- The speed and ease (or difficulty) of change in any of the above—this information will be used when setting functional outcomes.

For example, a clinician handles the trunk and shoulder complex of a client poststroke. She notes the tension in various muscle groups. She supports the trunk to assist posture and notes if the client is able to control more stability and movement options in the shoulder complex of the involved arm with this minimal postural support. This information assists the clinician in determining how quickly she thinks the client will be able to achieve functional outcomes, such as picking up the newspaper from the bedside tray table or using a fork to eat dinner.

Standardized and Nonstandardized Testing

After observation and handling for examination, the clinician selects specific tests to measure the domains of human functioning. The clinician chooses these measures carefully based on the domains the test is designed to measure. Many times, the clinician needs to measure participation and participation restrictions, activities and activity limitations, and body system integrities and impairments. Tests are designed to measure one or more of these areas, and it is the clinician's responsibility to select appropriate measures. For example, handheld dynamometers measure force production. This is a measure of body structure and function integrity/impairment. The results of this test indicate strength and duration of strength, but they do not measure activity or participation. A dynamometer will not measure a client's ability to feed himself dinner.

This example seems obvious, but clinicians may not always think about choosing a test to measure specific domains. For this reason, the clinician must understand the validity of a test (the test measures what it is supposed to measure, and the clinician understands what the test is supposed to measure) and the domain of human functioning the test was designed to measure.

Clinicians who work with clients with neurodisabilities often select several tests to measure each of the three domains of human functioning (according to the ICF). Table 7.1 gives examples of tests a PT who examines an adult client poststroke may select. An OT working with a 7-year-old with cerebral palsy (CP) at her school selects testing shown in Table 7.2. An SLP examining a teenager post–traumatic brain injury (TBI) selects the following test items shown in Table 7.3.

Examining the Interaction of System Integrities and Impairments within the Context of Participation and Activity: Posture and Movement

According to the ICF model, impairments in single systems and multisystem impairments, such as absent or delayed balance, ineffective posture and movement, apraxia or dyspraxia, fear, and pain, are all categorized under the Body Structure and Function domain. However, clinicians using the NDT Practice Model perform a detailed analysis

Table 7.1 Examples of tests specific to International Classification of Functioning, Disability and Health (ICF) domains

ICF domain	Tests (examples)
Participation	Stroke Impact Scale
Activity	Timed Up and Go Dynamic Gait Index 10-Meter Walk Test
Body structure/function	• Gait and observational movement analysis • Modified Ashworth Scale • Fugl–Meyer: LE • Berg Balance Scale

Table 7.2 The tests that an occupational therapist testing a child at school may select

ICF domain	Tests (examples)
Participation	School Function Assessment
Activity	Manual Ability Classification System
Body structure/function	Posture and movement observation and handling; Sensory Profile; goniometric measures of passive range of motion (PROM)

Table 7.3 Examples of tests a speech-language therapist might use with a teenager posttraumatic brain injury

International Classification of Functioning, Disability and Health domain	Tests (examples)
Participation	Functional Independence Measure (FIM) plus Functional Assessment Measure (FAM)
Activity	Comprehensive Assessment of Spoken Language (CASL); Test of Early Communication and Emerging Language (TECEL)
Body structure/function	Posture and movement observation; respiratory pattern, rate, endurance, coordination with voicing and swallowing; oral examination of motor abilities and sensory reception; Rancho Los Amigos Scale (cognitive functioning)

of multisystems because they involve the interaction of many single body systems and contextual factors. To sort out the contributions of single systems and the interaction of these systems as they relate to participation and activity, these multisystem impairments must be thoroughly analyzed to effectively manage clients. Posture and movement as multisystem integrities/impairments are considered first.

Posture

Posture refers to alignment of body segments, the positions of those segments, and the relationship of body segment positions to each other.[1] Therapists are interested in the characteristics of this multisystem function. Active posture encompasses postural tone and postural control (orientation, alignment, symmetry, weight shifting, and balance).

Postural Tone

Often, when PTs, OTs, and SLPs talk about muscle tone, they are referring to dynamic posture and movement. The Bobaths defined normal muscle tonus as "sufficiently high to give proper support tonus, but low enough to permit movement."[2] Their definition is akin to current definitions of postural tone. Shumway-Cook and Woollacott[3] refer to the readiness to contract muscles in quiet stance as postural tone, whereas Smith et al[4] use the term to mean muscular tension used to hold alignment in various positions. Gurfinkel et al[5] correlated electromyographic (EMG) activity in trunk musculature to torque during slow movements in very small degrees of rotation to avoid stretch reflexes and biomechanical influences, showing that muscle activity produces resistance to the imposed torque. They referred to this active resistance as postural tone, and it measured higher in trunk musculature relative to the active resistance of similar imposed motions of the neck or hips in adults without disability. Years prior to this study, the Bobaths focused on postural control and adaptations in their descriptions of CP and stroke. They viewed postural adaptations as "provid[ing] the constantly changing background for every movement."[2]

Historically, the term *postural tone* was used to describe the big picture of neuromuscular activity that contributed to antigravity control. Clinicians noted stereotypic, predictable, and limited repertoires in movement patterns in clients with stroke, TBI, and CP and referred to this collection of movement patterns as tone. However, this labeling did not direct the clinician to examine the possible components of tone.

Currently, the term *postural tone* encompasses a multisystem phenomenon of change in muscle activity to maintain the body upright against gravity.[3] All sensory systems, body segment alignment, muscle length and fatigue levels, muscle morphology, emotions, attention, and nervous system structure and functioning influence postural tone. Researchers study the relationships of the many systems contributing to postural tone with the hope that understanding this multisystem phenomenon may assist in a better understanding of the mechanisms of neural activity regulated by the central nervous system (CNS), including reflexive muscle tone.[5]

Research has shown a relationship between abnormal passive muscle reflex activity (muscle tone) and mechanical and morphological changes in muscle,[6,7,8,9,10] thereby suggesting that expression of muscle tone itself could be a multisystem phenomenon, just as postural tone is. Its neurological and biomechanical components are difficult to examine clinically with passive movements testing, even when consistent body and joint positions are ensured; several consistent velocities of passive movement are repeated in testing; consistent environmental conditions are ensured; and consistent client cooperation/relaxation is attained. As clinicians using the NDT Practice Model examine, evaluate, intervene, and constantly assess the outcomes of intervention, they can provide clinical insights to researchers and other clinicians about the complexity of muscle tone that may lead to new questions about this phenomenon.

Postural Control

Postural control and movement were introduced in Chapter 3 as multisystem body structure and function. Postural control orients a person with the head vertical and the eyes horizontal to the external environment. Postural control is a complex skill that relies on the interactions of multiple body systems.[11,12] These systems include biomechanical constraints, movement strategies, sensory strategies (somatosensory, visual, and vestibular), perception of an upright position, control of dynamics (center of mass changes), cognitive processing, and the environmental context. Motor expression through CNS output to the musculoskeletal system is adjusted to contextual conditions through sensory input and perceptual processing.[13] In addition to orientation, postural control includes balance. Postural control develops during human development gradually, as neuromuscular coordination and balance control become more skilled.[14] The Bobaths stated as early as 1964, "Postural changes not only accompany a movement but also precede it."[2]

Postural Control: Orientation

Postural orientation is one of two functions of postural control. This multisystem function includes alignment of the trunk and head with respect to gravity and support surfaces, the visual environment, vestibular structure and function, proprioception (especially from the head and neck), and internal body referencing (interoception).[11,15]

In a study on reaching skills, typically developing babies first gained head and gaze stabilization as a frame of reference for reaching, followed by successful reach and grasp movements, and eventually achieved multijoint coordination by age 15 months.[14] Reaching skills were first referenced relative to a support surface. Roncesvalles et al[14] hypothesize that the trunk is the first body segment reference for orientation in reach, followed by gravitational referencing in older children (ages 7–9), similar to that of adults.

Contraversive pushing after stroke is hypothesized to challenge gravitational orientation to posture primarily in the frontal (coronal) plane (**Fig. 7.3**).[16,17,18] Researchers are searching for networks in the human body that receive and process graviceptive information. Karnath[16] also proposes that the spatial neglect seen in other patients poststroke represents damage to networks that perceive and adjust body position and awareness in the transverse plane. Still other patients poststroke diagnosed with visuospatial impairments have shown that they misperceived vertical orientation in the sagittal and frontal planes compared with controls and that their errors were statistically significant.[12]

Postural Control: Alignment

Postural alignment is a part of orientation and balance and refers to the relationship of one body segment with another or of the position of the entire body to the base of support.[3] Postural alignment contributes to the selection of movements a person makes to change position. Postural alignment also refers to joint angular measurement and its deviation from a predetermined neutral position.[19] Joint angle neutral positions would need to be determined for a particular position of the body and would be based on age, functional task, and context for any research study examining alignment.

Alignment for posture and movement depends on more than the integrities or impairments of the musculoskeletal system that affect muscle length and joint range of motion. Ineffective alignment may be assumed because of decreased muscle strength, delayed muscle onset latencies and decreased EMG amplitude, and sensory or perceptual impairments. In two studies of children with spastic diplegic CP, Tomita et al[20,21] hypothesize that any of these impairments may affect the standing alignment and characteristics of muscle activity (selection, latencies, and direction-specificity) during voluntary anterior and posterior sway control (**Fig. 7.4**).

Wilson Arboleda and Frederick[22] hypothesize that malalignment of head and neck position in relation to the trunk and hip position affects the length–tension relationship of the muscles that elevate the larynx and consequently affect pitch control and resonance of voicing.

Fig. 7.3 Carol, a client poststroke with contraversive pushing who is described in Case Report A3 in Unit V, practices orienting her body with visual vertical. The therapist works with Carol with active postural control and movement as well as using visual environmental cues to orient her posture for functional skills, such as moving through her home.

Postural Control: Symmetry

Symmetry in posture and movement refers to the distribution of a person's mass and pressure on a support surface and is considered to be one aspect of postural control.[23] Although symmetry can be observed and measured in all three cardinal planes, most descriptions of symmetry and research examine the frontal plane (right/left symmetry).

Gait and single-leg balance studies in children and adults without impairments show slight asymmetries between right and left limbs; asymmetry is therefore considered to be an expected finding.[24,25] However, studies that have analyzed more marked asymmetrical sitting

Fig. 7.4 This young man assumes a crouched alignment for standing. According to Tomita et al,[20] crouch must be controlled largely by the quadriceps femoris muscles for the person to stand successfully. People who cannot control trunk and hip extension may rely primarily on these knee extensors to stand as they assume a crouched alignment. In another study, Tomita et al[21] showed in one child with spastic diplegic cerebral palsy that training the trunk and hip extensors to control postural sway improved standing alignment for the child.

and standing postures in people with neurological impairments are concerned with the inefficiency of postural adjustments or the initiation of movement and with fall risk when asymmetry of posture and movement affects balance responses.[23,26,27]

Clinicians are also concerned that marked asymmetry in any cardinal plane could increase the severity of body system impairments over time and limit function. Clients with CP who develop scoliosis or hip subluxation/dislocation may show asymmetrical weight bearing in sitting (**Fig. 7.5**) with a resultant poor ability to sit, even with custom-made adaptive seating.[28,29,30] Scoliosis may continue to worsen after bone growth is complete.[30]

Asymmetry in upper extremity neuromuscular control, musculoskeletal structure and function, and sensation may interfere with upper extremity movements and the ability to use bimanual skills. In assessments of neonates poststroke, Guzzetta et al[31] found a correlation between asymmetry of wrist movements and the developmental of hemiplegia at 3 months of age. Adults poststroke show alterations in bimanual coordination,[32,33] which respond favorably to both unimanual and bimanual rehabilitation. Bimanual skill practice may access interhemispheric neural networks that unimanual activities do not.[32]

Postural Control: Weight Shifting

Weight shifting refers to the ability to redistribute body mass through muscle activity. Weight shifting is used both during active position changes and to recover

Fig. 7.5 Many of our clients show asymmetry in posture with head, trunk, and/or extremities.

balance. Clinicians are interested in efficiency of this weight redistribution and its safety. Weight shifting is performed in an infinite number of transitional movements from one position to another, and the clinician using NDT observes and handles the client to determine if the weight-shifting strategies a client uses are efficient and safe.

Strategies to gain and regain control of upright standing are the most frequently researched weight-shifting studies. Researchers and clinicians are interested in assisting clients to use successful weight-shifting strategies to recover posture during sway conditions to prevent falls.

Several common strategies in standing are used in children and adults with and without postural impairments. In many instances of postural sway, a combination of these strategies may be used:

- *Trunk strategy:* Trunk and limb movement in the transverse plane can be a part of weight shifting strategies in standing (**Fig. 7.6**). Trunk rotation may serve the purpose of reducing the sway at the ankle in standing sway[34,35] and is used in people with and without neuromuscular impairments. Trunk and limb transverse plane strategies are coupled with strategies in the lower extremities.

Fig. 7.6 JW, who is described in Case Report A2 in Unit V, works with her therapist to incorporate trunk and hip rotation into her standing-balance and weight-shifting strategies.

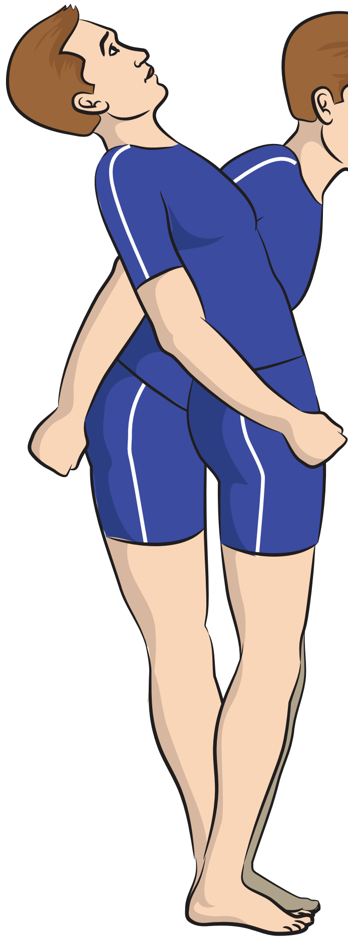

Fig. 7.7 Hip strategy.

- *Hip strategy:* Movement of the body's center of mass occurs primarily at the hip in large, fast disturbances of posture (**Fig. 7.7**). Activity of the abdominals and quadriceps femoris muscles in forward sway and activity of the paraspinals and hamstrings in backward sway control posture to maintain upright.[3,36] Hip strategies are used in adults and children, both with and without neuromuscular disabilities.[3,36]
- *Ankle strategy:* Postural stability is controlled by movement primarily around the ankle joint. In people without neuromuscular impairments, it is the strategy most commonly used to respond to smaller and slower disturbances of posture.[3] In people without neuromuscular impairments, the sequencing of muscle activity starts at the ankle and moves up (distal to proximal sequence) (**Fig. 7.8**). In forward sway, the gastrocnemius contracts first, then the hamstrings, then the paraspinals.[3,36] With backward sway, the anterior tibialis is active first, then the quadriceps, then the abdominals.
- *Change-in-support strategy:* Changing the base of support under the body's center of mass when standing—a stepping strategy—is a strategy to recover an upright position in fast, destabilizing conditions (**Fig. 7.9**).[3,36] These strategies assist balance recovery as well as protect the body from injury. In the upper extremities, these types of strategies are referred to as protective extension strategies.

In studies with visually guided weight-shifting practice, adults without disability and adults poststroke have been able to improve the timing and effectiveness of postural sway to maintain an upright position,[35,37,38,39,40] although more time may be needed to complete the strategy in those poststroke. School-aged, ambulatory children with CP have showed improvement in their speed of muscle-contraction onset and muscle-activation organization, and reduced muscle coactivity during postural sway strategies with practice in reactive balance.[41]

Sitting postural sway has also been studied, showing activity of the trunk and lower extremities when the person is

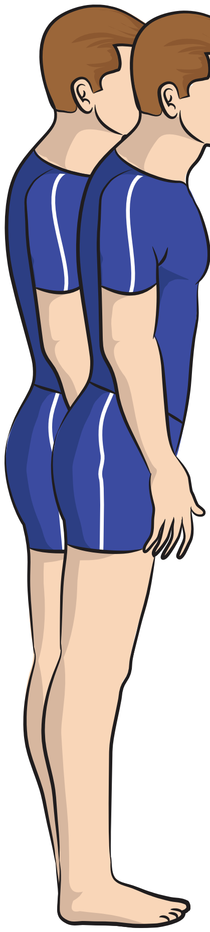

Fig. 7.8 Ankle strategy.

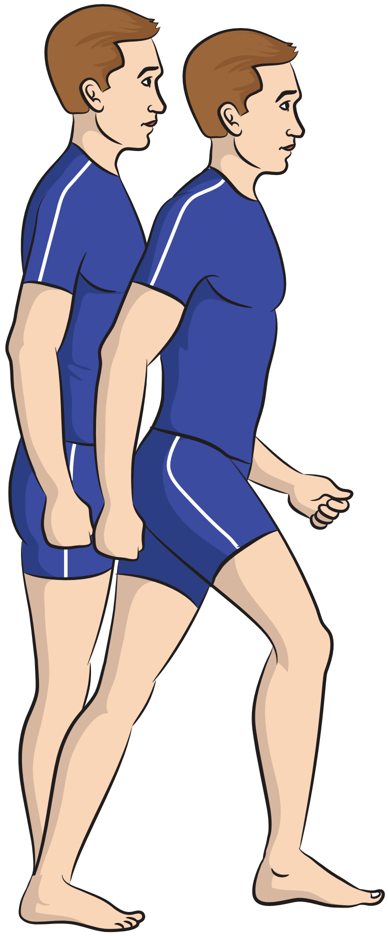

Fig. 7.9 The stepping strategy is a change-in-support strategy of the lower extremity.

swaying in the sagittal plane.[36] In older children and adults, muscle activity includes extensor activity of the hips, trunk, and neck in forward sway with the anterior tibialis recruited in reaching if the feet are planted (**Fig. 7.10**). To re-erect from the forward position, the gastrocnemius is recruited. In backward sway, the hip flexors, abdominals, and neck flexors are recruited (**Fig. 7.11**).

Postural Control: Balance

Balance is the ability to control the body's center of mass within the base of support,[3] taking into consideration that the base of support is often changing (dynamic balance). Balance requires the coordination of responses to all forces acting on the body to produce stability.[11,42] These include external and internal forces, which require multisensory detection. Body systems that participate in balance include the biomechanics of the musculoskeletal system, all sensory systems, and many areas of organization in the CNS to produce precise motor responses while remaining flexible to changes in evolving movement.[43,44]

Balance, also known as postural stability,[3] can be challenged in several ways[42]:

- Reactive balance occurs in response to external forces acting on the body, changing the base of support or disturbing the position of the center of mass. Sensory feedback is required to initiate the process of response. An example of reactive balance is the body's response to being hit with an opening automatic door at the grocery store.
- Anticipatory balance occurs in anticipation of internally generated destabilizing forces as a result of the body's own movement. Postural adjustments occur prior to the initiation of a movement action to counteract expected perturbations to ensure stability.[45,46] Experience refines this process, which relies on feedforward to act. An example of anticipatory balance is the entire body's motor activity prior to picking up a stack of books from the countertop.
- Adaptive balance allows changes in postural control as the task and environment change while posture and movement unfold. This type of balance requires continual and complex interactions among sensory systems, CNS processing, motor responses, and musculoskeletal alignment.[44] An example of

Fig. 7.10 This woman uses extensor activity of the hips, trunk, and neck with feet pushing against the surface as she leans forward.

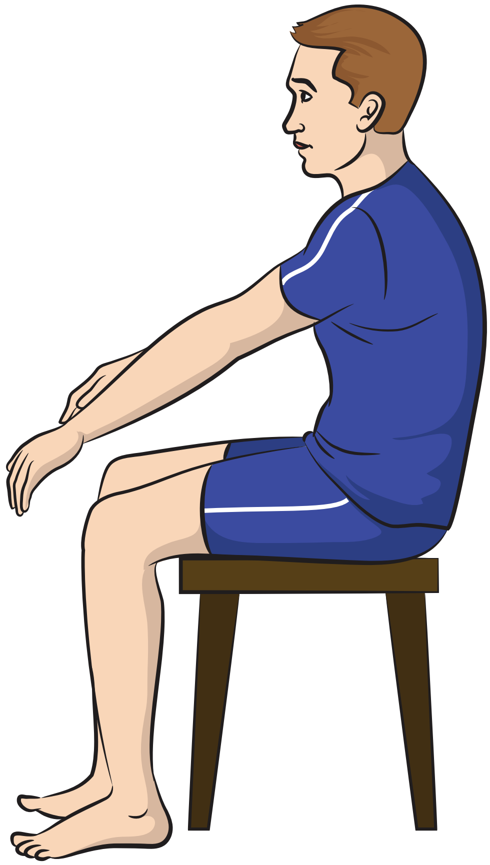

Fig. 7.11 This man recovers balance from a backward sway.

adaptive balance is the body's ongoing changing motor activity when the individual is kicking a playground ball in a game of kickball.

Balance can be examined using clinical standardized and nonstandardized tests, and the clinician ensures that all three types of balance are tested. Whereas researchers can use computerized posturography to objectively measure the postural sway during platform translations or rotation along with varying the sensory conditions surrounding the platform, the clinician usually relies on simpler tools to examine balance.

Balance requirements vary according to how large the base of support is (creeping on all fours vs. standing without support or standing independently vs. standing while holding onto a walker or cane) and how far the center of mass is from the base of support. The clinician therefore tests balance in the postures that the client typically uses in functional tasks and may challenge the client with postures that are unfamiliar.

Balance requires, in part, the ability to recruit direction-specific muscle groups to control body sway.[47,48,49,50,51,52,53] Recruitment order of these muscles typically follows a developmental as well as a position and task-specific sequence. Under some conditions, people with various neuropathologies can show different recruitment order, more variability with repetitions of the same task, less flexibility in adjusting recruitment to specific tasks, and the use of altogether different muscles to attempt the same functions as people without neurodisabilities.[20,47,53] Compare the alignment during postural sway in **Fig. 7.12a, b**.

One neural strategy to increase postural stability for control of balance is to coactivate muscles in various synergies or to coactivate producing cocontraction around a joint.[54] This strategy is seen in people with and without neurodisabilities. The degree of coactivity distinguishes efficient from inefficient postural stability. Children with CP often show higher levels of coactivation when compared with children without disability.[55,56]

Adults poststroke have shown larger sway areas than controls without disability in sitting unsupported, with poor postural control of trunk musculature implicated.[57]

Brogren et al[51] tested reactive balance in children ages 7 through 11 with spastic diplegic CP while they were seated on a movable platform (most were nonfunctional ambulators). The children recruited balance responses in a proximal to distal order similar to those seen by young children without disability and by adults without disability in unstable positions. The children with diplegia also often used coactivation of antagonistic muscles, perhaps as a way to provide greater stability.

Hadders-Algra et al[48] studied babies ages 4 through 18 months with CP in sitting and lying down positions as

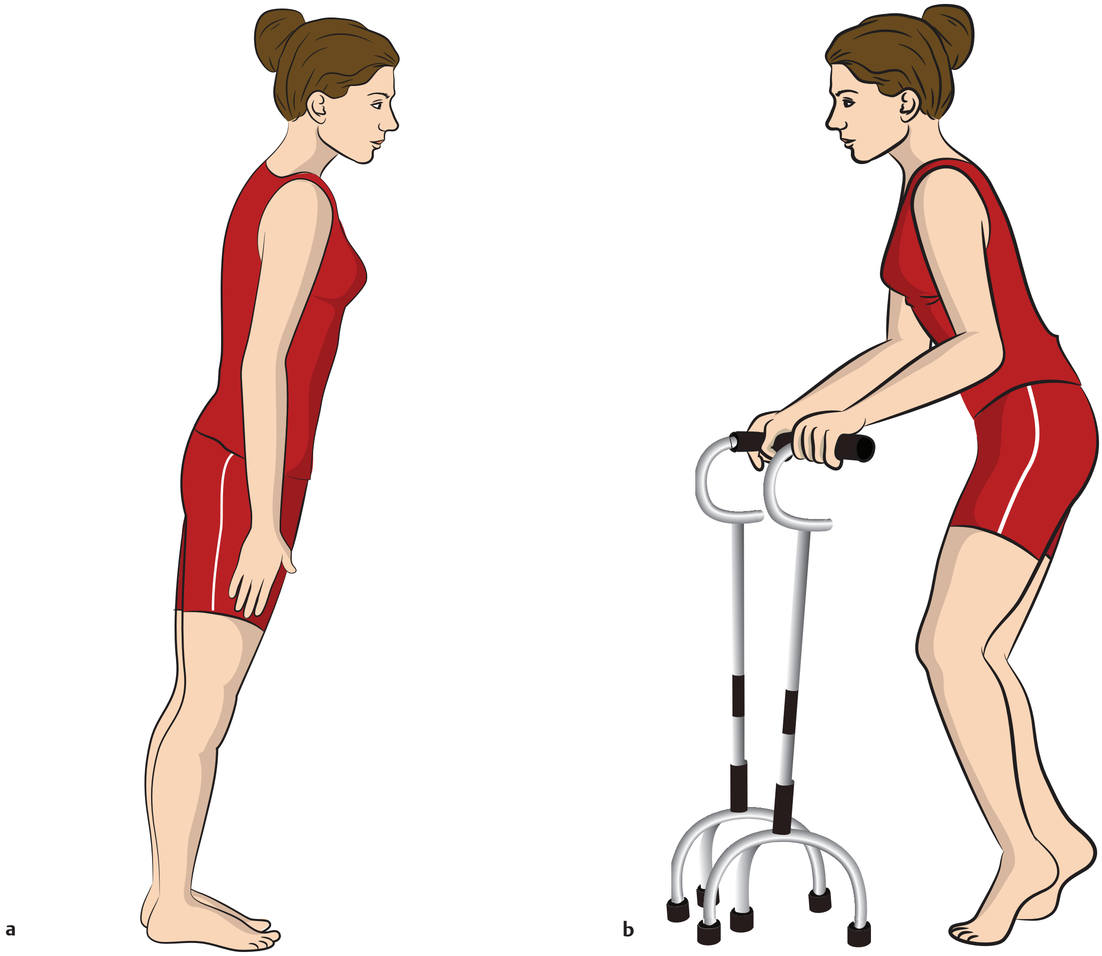

Fig. 7.12 **(a, b)** As the young woman on the left leans forward, she is likely to recruit muscle activity distal to proximal, using gastrocsoleus, hamstrings and quadriceps coactivity, gluteals, and trunk extensors. The girl with spastic diplegia on the right may recruit activity primarily from her upper body first, then after a latency of a few milliseconds, recruit activity in the lower body. Note that, even if the same muscles are used to attempt postural control, the girl with diplegia will be using her muscles in different body segment alignment and may be using concentric contractions where eccentric are more effective and vice versa.

they reached and therefore tested anticipatory postural reactions. They found that, although most of the babies could recruit basic postural organization, they had difficulty modulating that activity to the reaching task and tended to use excessive coactivation of antagonists.

Woollacott and Shumway-Cook[41] tested reactive balance in standing in children with spastic diplegia and spastic hemiplegia who could stand independently for at least 30 seconds, finding increased lengths of time compared with children without disability to recover balance due to delays in muscle contraction onset, recruitment of muscle activity proximal to distal, and increased coactivation of antagonistic muscles.

Ferdjallah et al[34] found that in quiet standing with eyes-open and eyes-closed testing conditions, children ages 5 to 13 with spastic diplegic CP who were independently ambulatory used limb and trunk movements in the transverse plane to maintain balance rather than ankle dorsi-/plantar flexion and inversion/eversion. This strategy compensated for poor abilities to generate ankle movements. Children without disability used limb and trunk rotation only when there was excessive sway; their preferred strategy was ankle movement during small arcs of sway.

Tomita et al[21] studied anticipatory balance in teenagers with spastic diplegia and children without disability as they stood and moved their arms. Both groups activated erector spinae and medial hamstrings prior to the anterior deltoid, although the EMG amplitudes were significantly smaller in the group with CP in the erector spinae and hamstrings while the peak arm acceleration showed no significant differences between groups. Center of pressure on the feet was more anterior in the initial standing position in the teens with CP, and their displacements were larger with reach.

Dickstein et al[58] studied anticipatory balance in the trunk with limb flexion movements from an initial position of sitting with feet flat on the floor. Fifty people post–middle cerebral artery stroke and [30] adults without disability were tested. Muscles on both the right and left sides of the trunk were active when a limb on either side of the body moved in both groups of participants. Results also showed reduced activation of the lateral latissimus dorsi and the external abdominal obliques on the hemiparetic side in those people poststroke when moving either the arm or the leg in flexion on either side of the body, with delayed onset of postural muscle activity.

In a pilot study with ambulatory veterans post–severe TBI in an inpatient rehabilitation center, Pickett et al[44] used computerized posturography testing with force platforms while performing the six conditions of the Sensory Organization Test. Results showed primarily vestibular impairments related to balance impairments with vision used to compensate. Vestibular nerve shearing caused during blast injuries in this population may be a part of the pathology.

Movement

Movement is a multisystem body structure and function. Movement selection is shaped by the neuromuscular system, musculoskeletal system, sensory systems that provide feedforward and feedback, context (personal and environmental), and behavioral intentions.[1,13] It is a response to input from various body systems[1] and to environmental and personal contexts. Movement is controlled and coordinated in milliseconds through the integration of a body that responds, executes, interprets, and adjusts to continual feedback.[1] The nervous system, musculoskeletal system, and all sensory and perceptual systems are a part of this integration, responding to contextual demands, growth, development, aging, and disease or disability. The cardiovascular, respiratory, and digestive systems provide nutrition and energy to allow movement to take place.

Development and control of movement are described in Chapters 12 and 14 on motor control and motor development in Unit III. The NDT clinician will consider these questions while observing movement and handling the client to note characteristics of movement:

- Are movement strategies selected that are safe and efficient and meet functional demands?
- Are graded movements available when needed—large and small movements, ballistic and targeted movements?
- Is movement generated along with active postural support? If postural control is ineffective, are movements that would be necessary to complete a task suppressed or exaggerated in attempts to substitute for postural control? (For example, the upper extremity may be held against the body in an effort to control the trunk in an upright position if the trunk and hip posture is ineffective; or the eyes, jaw, cervical, and lumbar extensors may act together to attempt to hold a person's head erect if postural control is ineffective.)
- Can a client control and coordinate movement at multiple joints in the same limb (intralimb coordination) or between limbs and the trunk and head (interlimb coordination)?
- Are extraneous or involuntary movements present that contribute to ineffective or inefficient control and coordination?
- What contributes to movement dysfunction in the single systems—neuromuscular, musculoskeletal, all sensory systems, cognition, respirations, cardiovascular, digestive—for this client?

7.1.4 How Does the NDT Clinician Examine Posture and Movement?

- *Visual observation:* The clinician uses visual inspection to examine how the client organizes postures and movements. The clinician may decide that a video recording of the examination will assist because of the replay capabilities and the ability to play the recording on slower speeds.

  The clinician observes how one segment of the body moves and what the rest of the body does to control posture and stability as that part moves. The clinician also observes consistency or inconsistency in repeat performances of postures and movements. The clinician notes how the client acts and reacts to naturally occurring changes in body position and environmental conditions (**Fig. 7.13**). For example, what happens to stance and walking control when the client encounters an uneven surface after walking on a smooth surface? What happens to oral motor control when the client attempts to eat a different texture of food? What happens when the next toy is bigger and heavier than the previous one?
- *Palpation:* The clinician places fingers over a muscle group to note activity during rest, posture, and movement (**Fig. 7.14**).
- *Handling for examination:* The clinician manually contacts a body segment to note when the segment is active, how long it is active, and which muscle groups are active as the client attempts posture and movement. The clinician may provide manual stability or correct alignment, adjust the base of support, and then observe how the client responds to these changes. The clinician may control certain body segments or joints to observe how the client adjusts posture and movement when there are fewer segments or joints for the client to control. The clinician may provide graded sensory input through handling to observe how the client responds. For example, an SLP may place firm pressure on the midline of the tongue with a gloved finger to observe whether the tongue can respond with a cupping shape.
- *Standardized and nonstandardized testing:* The NDT clinician may use standardized and nonstandardized testing to assess aspects of posture and movement. For example, there are several balance tests available for use in pediatric and adult populations with neurological impairments. The NDT clinician is cautious when interpreting results of these tests as they apply to intervention. For example, balance tests may not be able to predict under which contexts will balance

Fig. 7.13 As Mark, described in Case Report A1 in Unit V, lifts his left arm and shifts weight onto his left leg, he is able to lift his right leg in either a balance reaction or voluntarily to step.

Fig. 7.14 As Mark's physical therapist asks him to reach with his right arm, she can palpate the musculature around the scapula to detect activity. She can also support and reposition his scapula as he moves his arm with her hand positioned this way.

responses fail, and they do not indicate which impairments are responsible for the failure or what strategies will be most effective in intervention.[11]

7.1.5 Identifying Ineffective Postures and Movements

Recall the head control and knee hyperextension diagrams presented in Chapter 5. In viewing the diagrams of the head control and knee hyperextension postures and movements, we see the dynamics of many influences on activities (and the shaping of those activities into participation). Posture and movement are examples of the interaction of body systems (and within postural control are orientation, alignment, symmetry/asymmetry, weight shifting, and balance), but their expression and constant reshaping do not result simply from a combination of single-system structures and functions. The diagram in **Fig. 7.15** includes many of the influences that shape expression of posture and movement at the moment and reshape it throughout a person's life span.

7.1.6 Identifying Other Multisystem Body Functions: The Interaction of System Integrities and Impairments within the Context of Participation and Activity—Two Examples

Praxis and Motor Planning

Praxis, meaning *action* in a general sense, refers to the ability to do something, whether it is the practice of art, science, or movement skill. When used in the field of habilitation and rehabilitation, *praxis* refers to movement skills. Praxis is doing.[59] Specifically, *praxis* describes goal-based purposeful and complex motor actions, including gestures and tool use.[60,61,62,63] According to Sanger et al,[61] examination of praxis needs to consider the following:

- The age of the person examined—the movement must be developmentally appropriate; in the case of an adult, a skill that has been learned, and in a child, one that should have been learned at that particular age.
- The person's familiarity with the skill or gesture.
- That the movement was adequately explained or demonstrated to the person.
- That the person understood the verbal instructions or a demonstration of the movement.
- That the person possesses adequate muscle force, selective voluntary control, balance, endurance, and range of motion to perform the task.
- That the person is motivated to perform the task.

Praxis involves three processes, which are gleaned from the current literature only by reading about impairments in praxis.[60,61,64,65,66,67,68,69] Although Ayres[70] defined these

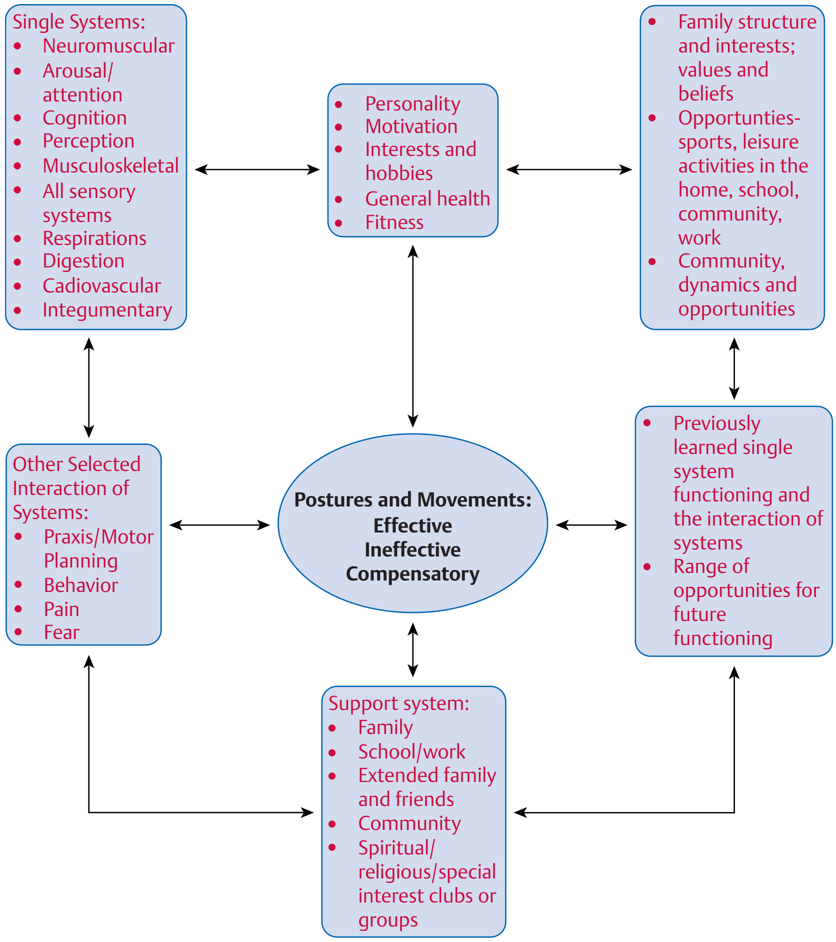

Fig. 7.15 Posture and movement affect all aspects of a person's life, and in turn, are affected by all aspects of a person.

processes many years ago, definitions of *praxis* are difficult to find in the current research literature. These processes are as follows:

1. *Ideation:* Conceptualization of the motor skill, gesture, or tool use; ideation involves cognition (working memory and goal selection), attention, and perception.
2. *Planning:* "Computing" the movement; the ability to initiate and sequence a task with anticipatory forces, the use of mental imagery to create an internal model of the movement, the ability to select salient sensory cues relevant to the task, the ability to scan for movement errors through the sensory systems and make adjustments through sensory feedback, the ability to predict body or body segment position at the end of the movement; all of these abilities are modified with practice and experience.
3. *Movement execution:* The selected postures and movements performed in a coordinated and efficient sequence specific to the task.

There is some inconsistency in terminology between *praxis* and *motor planning* within the literature. *Motor planning* is defined as the "ability to predict the future state of the motor system or the consequences of its action."[65] Crajé et al[71] and Janssen and Steenbergen[72] use a similar definition. In the praxis literature, no universal model differentiates between motor planning and praxis. Motor planning problems are defined as types of apraxias, and apraxias are referred to as motor planning impairments. Sometimes, *planning* seems to refer to the big picture of motor planning/praxis, and at other times, it is used in a more restricted sense to mean the second process of praxis.

The definitions of impairments in this multisystem function are more clear and consistent than the motor planning and praxis definitions. *Apraxia* is a term used for adults with lesions that disrupt praxis. Apraxia is a group of disorders of conceptualization, planning, and execution of learned, skilled movements, gestures (especially sequences of gestures), and/or tool use despite intact motor and sensory systems, comprehension, and cooperation.[61,73,74,75]

Apraxia is often categorized as ideational or ideomotor. Ideational (conceptual) apraxia is a failure to conceptualize the task automatically or on command either because the person no longer understands the act or cannot remember the idea of the task, especially a task with multiple steps (e.g., preparing a sandwich).[67,73] A client with ideational apraxia may hold a comb and when asked to comb his hair, respond by placing the comb in his mouth or try to write with it. He may not be able to explain what a comb is used for. A client asked to prepare a sandwich may be able to open the bread wrapper, hold a knife and spread with it, pick up meat, and squeeze the mustard container (all motor execution), but he may spear the meat with the knife, fold the bread in half and lay it aside, or place the meat inside the bread wrapper.

Ideomotor apraxia describes impaired performance of a learned skill despite having sensory, motor, and language skills to perform the skill.[73] The client can describe how a task is performed and can perform a task automatically but cannot perform the task on command, especially a multistep task. A client with ideomotor apraxia may walk across the kitchen and place her plate in the dishwasher after dinner. However, if she is asked to pick up her plate, rinse it, and place it in the dishwasher, she will not be able to do so. When specifically asked to walk to the sink from the table, she may demonstrate an awkward gait pattern.

The lesions responsible for apraxia are often located in the parietal cortex, which has connections with the supplementary, premotor, and motor cortices.[68,69,76] Lesions in the left hemisphere may cause more severe apraxias than lesions in the right hemisphere[61,68,77] and may be seen with aphasia. Lesions in the cerebellum may also be implicated in motor planning impairments.[66]

Developmental dyspraxia is a term used to describe children with impairments similar to those of adults with apraxia[63] who have difficulty using tools, sequencing gestures, and sequencing motor tasks without muscle weakness, sensory loss, incoordination, aphasia, or cognitive impairment.[62,78,79,80] The lesions in dyspraxia are unknown but may be associated with early mild global cortical injury.[61,81]

Ayres,[70] who first studied developmental dyspraxia, said that children with this disability know what they want to do but can't do it. She emphasized that dyspraxia involves impairment(s) with ideation and planning separate from the motor execution of a task. She noted that children with CP may or may not have dyspraxia. To examine children with CP for dyspraxia, the clinician must be familiar with the motor control the child possesses and then examine praxis separately from motor execution.

Developmental dyspraxia has been studied in children with CP in those who are capable of producing the movements required for the task and who can complete standardized and nonstandardized tests.[65,71,72,78,82] Researchers have been able to detect impairments in motor imagery,[71] visual-spatial planning,[65] anticipatory fingertip force planning,[82,83] and unilateral and bilateral grasp.[72] Most of the children in these studies were classified as spastic hemiplegic or diplegic.

Psychosocial Behavior State

Behavior refers to the actions and reactions of a person in response to both the internal and the external environment. In this section, the psychosocial aspects of behavior are considered as a multisystem phenomenon. Psychosocial interaction involves arousal, attention, motivation, goal-direction, sensory perception, and motor expression. Although it is beyond the scope of this text to discuss details of all of the contributions to psychosocial behavior, some these single systems that contribute to psychosocial behavior will be discussed.

Performance outcomes of clients depend not only on posture and movement but also on personal factors, the environment, and the neural substrates that control behavior. The clinician practicing with the NDT Practice Model values these factors just as much as the contributions of sensorimotor factors. Therefore, the NDT Practice Model includes examination of personal attributes and the environmental context of activity and participation. The clinician administers formal or informal questions or surveys about psychosocial functioning and requests and/or integrates plans from the professional evaluations of team members, such as neuropsychologists, teachers, vocational instructors, and guidance counselors. The clinician values formal and informal surveys that the client and family complete as part of the examination of all factors that influence activity and participation.

Research regarding motivation, self-worth, perceived competence, and externalized/internalized behavior expression has been studied in children with CP.[84,85,86] These researchers often consider their conclusions to be preliminary and exploratory because research in this area is relatively recent. Schuengel et al,[85] in surveying children with CP and their parents, found that their general sense of self-worth and perceived competence were similar to those of children without disabilities. Like children without disability, there was an association between those who reported lower perceived competence and self-worth and internalizing behaviors such as depression, anxiety, withdrawal, and somatization.

Sipal et al[84] found that behavior impairments were higher in a group of children with CP ages 9 through 13 when compared with children without disabilities, but problems diminished over a 3-year period. Parents and caregivers rated each child's behavior while a physician rated the severity of CP according to the Gross Motor Function Classification System. Family support and stress factors were related to behavior, while in turn, the children's behavior was also found to affect the family environment. This relationship was similar to the relationships found in families with children without disabilities in other studies. There was a positive association of total behavior problems to the severity of CP and to level of pain.

Majnemer et al[86] investigated motivational mastery (the intrinsic drive to attempt to master a skill that is at least moderately challenging). This motivation was viewed as related to personal beliefs about how well people perform and how much value is assigned to the task personally. Persevering when challenged was perceived to be based on past experience, current abilities, environmental context, and personal desire to achieve. Preliminary results suggest that children with CP may have lower motivational levels than peers without disabilities, and they were correlated to lower cognitive ability and motor function and to higher levels of perceived parental stress. Behavioral difficulties were correlated with lower motivation to persist as well.

Finset and Andersson[87] compared coping styles for apathy and depression of student controls with people poststroke and post-TBI. Using multivariate analyses, they found no association between coping strategies and lesion location in either experimental group. They concluded that there is a complex interplay between the lesion and psychological factors such as premorbid personality and coping repertoire.

Lack of motivation, or apathy, is common poststroke and may be associated with cognitive impairment, damage to some nuclei of the basal ganglia, and thalamic lesions.[88]

Aggression after TBI may be the most common behavior impairment, seen in all severity levels. In 208 patients with mild head injury in a study by Benedictus et al,[89] one of three had behavior impairments, and these impairments were more prevalent than physical impairments in all severities. In the group with mild head injury, behavior impairments were important (along with cognitive impairments) in predicting return to work.

7.1.7 Examining Single-System Body Structures and Functions

Clinicians using the NDT Practice Model learn how to examine body system structures and functions in their academic education programs. The purpose of accredited academic programs is to prepare clinicians for general practice, and these programs have tremendous amounts of material for students to learn, so each body system cannot be covered in depth, especially with all of the pathologies a program must introduce. Clinicians in many related professions learn body system structure and function with various emphases, depending on each profession's specialty. As clinicians who use the NDT Practice Model, we examine body systems within the confines of our professional practice acts and our academic preparation.

Because this text is written primarily for OTs, PTs, and SLPs who treat clients with neuromuscular diseases and disabilities, this section will describe single-system structure and function related to stroke, TBI, and CP. Ultimately, the clinician is responsible for using this information within the confines of professional practice acts and codes of ethics.

Neuromuscular System

Much of our knowledge about neuromuscular structure and function comes from experimental research studies that measure parameters of muscle tone, muscle recruitment activity, timing and sequencing, force production, and intra- and interlimb coordination with the aid of EMG and computer analysis.[20,21,45,46,47,51,53,56,83,90,91,92,93,94,95,96,97,98] These studies increase a clinician's descriptive knowledge of nervous system control and coordination, but they rarely add to procedural knowledge for clinical intervention.

Muscle Tone

The clinician uses consistent methods of testing, consistent joint position and alignment, consistent measurements in a variety of body positions, consistent environmental conditions, and a consistent definition of muscle tone that is written in the documentation to examine muscle tone. Standardized and nonstandardized clinical tests of normal and abnormal tone can be used. The clinician will be aware of the reliability and validity of these tests, their sensitivity, subjectivity versus objectivity of measurements, and their correlation to functional activity and participation.[99,100,101]

The term *muscle tone* has probably been the most widely used term historically in neurorehabilitation, but it is also the term that is most confusing in its definition and application for both researchers and clinicians.[99] Most definitions of *muscle tone* refer to reflex excitability of a muscle or resistance to passive stretch or readiness of a muscle to contract,[3,4,5,8,99,101,102] but tone may be influenced by body segment position, mechanical properties of the musculoskeletal system, and the client's ability to cooperate and relax.

The mechanisms that influence normal and abnormal muscle tone are largely theoretical,[5,103,104] although both excitatory and inhibitory influences at supraspinal and spinal levels of the CNS have been hypothesized,[105] as well as stretch responsiveness due to secondary changes in the motor units themselves.[8] Increased abnormal tone is thought to be due to mechanisms that decrease the threshold firing of spinal motor units, resulting in decreased thresholds to monosynaptic stretch.[106] In addition, van Doornik et al[106] found phasic increases in muscle activity during passive lengthening of elbow muscles in children with dystonia, while Lebiedowska et al[107] found no EMG activity in the knee joints of children with dystonia at rest.

NDT advocates for a strict definition of *muscle tone* as resistance to muscle length from passive externally imposed forces while the client attempts a relaxed state as defined by a consensus workshop at the National Institutes of Health,[108] with the full awareness that clinical measures of this phenomenon are fraught with subjectivity. Muscle tone is therefore tested with passive movement to determine muscular resistance. Current recommendations include consistency of joint position and speeds when testing, and testing several joints at different velocities, since most definitions of spasticity include velocity-dependent abnormal responses to stretch and position-dependent responses to stretch.[100,101] Muscles can also be palpated at rest to determine muscle activity.[108] Reflexive muscle tone may be difficult to impossible to test in the clinic for many clients, due to uncertainty as to their state of true relaxation, level of voluntary contraction of muscle, and difficulties on the part of the clinician in separating reflexive activity from active contraction and muscle structure.[100]

Muscle tone is described in the literature and on neurological examination forms as a part of the neuromuscular system. The most common impairment of muscle tone reported in the literature on stroke and CP is spasticity, and it is described as part of the upper motor neuron syndrome. However, the pathophysiology causing spasticity is hypothesized to be in various locations in upper motor neuron lesions,[109] and spasticity itself may change over time.[101] Researchers who study the pathophysiology of spasticity posit several hypotheses for its development. Because spasticity develops over time in injuries such as stroke, spinal cord injuries, TBI, and CP, researchers suggest that the development of spasticity may be due to adaptation of neural networks on the cellular level.[103,104]

Furthermore, spasticity and other abnormal neural activity may cause mechanical and morphological changes in the muscle, which may in turn influence velocity and position-dependent stretch reflex responses to passive movement, creating a relationship between neural activity and the muscular system.[6,7,8,9,10] We may be wise to consider abnormal muscle tone as causing multisystem impairments. For this reason, postural tone was defined under the heading Examining the Interaction of System Integrities and Impairments within the Context of Participation and Activity, at the beginning of this chapter.

Muscle Recruitment Activity

The clinician observes, palpates, and handles the client to examine the recruitment of muscles. The clinician examines how various body segments respond with muscle activity when other body segments make postural adjustments or move. The clinician examines the variety of muscle activity combinations that the client typically uses or attempts to use.

The clinician observes the entire body and then may focus observation on particular body segments. The clinician may time how long a muscle or muscle group takes to initiate, how long it can sustain, and how muscle activity terminates. The clinician notes if muscle groups can move or hold against gravity or naturally occurring external resistance or weight.

Delayed initiation and termination of muscle activity, or long latency in muscle response onset to anticipatory postural adjustments (feedforward) or perturbations (feedback), are widely documented in a variety of neurodisabilities, including CP and stroke.[52,58,94,110]

Timing and Sequencing

The clinician observes, palpates, and handles to examine speed of initiation and termination of muscle activity, comparing these parameters to activity intent. The clinician examines and records length of sustained muscle activity, if this is a factor in the attempted activity. The clinician observes, palpates, and handles to determine the sequence of muscle activation, bearing in mind that muscle activity occurs in milliseconds and is unlikely to be fully discernible clinically.

EMG studies have consistently shown abnormal timing and sequencing of muscle activity with voluntary, functional posture and movement attempts in a variety of neurodisabilities.[96,110] In one study of direction-specific postural sway during reach, children with CP were more likely to recruit muscle activity in a top-down sequence than their age-matched peers without disability, who varied their recruitment order.[47] Depending on the severity of CP, muscle recruitment order, the specific muscles recruited, and the degree of coactivation of muscles differed from those of age-matched peers without disability.[53,91] Researchers noted that the coactivation in the children with CP increased during positional instability or when balance was threatened, concluding that excessive coactivation is compensatory at times.[52,91]

Children with hemiplegic and diplegic CP often showed a poor ability to modulate timing and amplitude of muscle activity in a grasping task in a study by Eliasson et al.[111]

With adults poststroke, significant differences in initiation and termination of muscle activity in the paretic arm versus the nonparetic arm were noted in the study by Chae et al,[110] the severity of which correlated with level of overall motor impairment and physical disability.

People with cerebellar lesions show abnormal timing and sequencing of phasic bursts of agonist/antagonist muscle pairs, causing delays in initiation of muscle activity.[112] Cerebellar lesions or damage to connections to and from the cerebellum are seen in some people with CP, TBI, and stroke.

Muscle Force Physiology and Muscle Fiber Morphology

The clinician tests muscle force and observes whether muscles can scale force smoothly. The clinician may examine the client's ability to repeat muscle activity and record muscle endurance during attempted activities. The clinician observes and palpates tension in muscles, noting if tension matches the needs of the function the client is attempting.

Although force production of muscles is generally thought of as a musculoskeletal system structure and function, muscle activity would not be possible without neural excitation. Muscle force is generated through excitation of muscle fibers via the α motor neuron supplying them (motor unit). Motor units are classified as slow or fast twitch.[13] Slow-twitch units predominate in postural muscles and fast-twitch fibers predominate in muscles that are used for speed and power. In most movements, slow-twitch fibers are recruited first but can be modified according to functional need.

The force of a muscle contraction is determined by the number of active motor units *and* by their firing rate.[9,95] Motor unit activity and firing rate indicate that force production (strength) depends on constantly changing neural excitation. Excitatory input from the CNS determines motor unit recruitment order to scale (increase or decrease) the amount of tension in a muscle. There is evidence that children with CP have difficulty increasing the firing rates due to deficient excitatory drive.[56] This decreased firing rate has been implicated in contributing to musculoskeletal impairments, measured clinically as weakness. People with dystonic and athetoid CP show loss of single-joint force control, resulting in rapid and variable movements without the ability to control force.[113]

There is also evidence[9] that excessive coactivation affects peak force generation of muscle contraction, thereby contributing to weakness. Many people with CP and stroke generate excessive coactivity around joints to attempt joint and body segment stability. If excessive coactivity can cause weakness over time, then in this situation, weakness is a secondary impairment.

The presence of abnormal muscle and postural tone, especially hypertonia, may cause atrophy of muscle fibers, especially type II fibers (fast-twitch). In research subjects with hypertonicity due to stroke or CP, the gastrocnemius increases its proportion of type I (slow twitch) fibers over time.[8,9] Type I fiber predominance suggests secondary changes due to prolonged low-frequency motor unit firing rates,[95] which in turn affects motor control. The clinical correlate to these changes is weakness.

Researchers note increased intramuscular fat and connective tissue in involved muscles, more evident in more people severely affected with CP.[9,10] This altered tissue includes increased collagen content, which may be partially responsible for increased passive muscle stiffness.

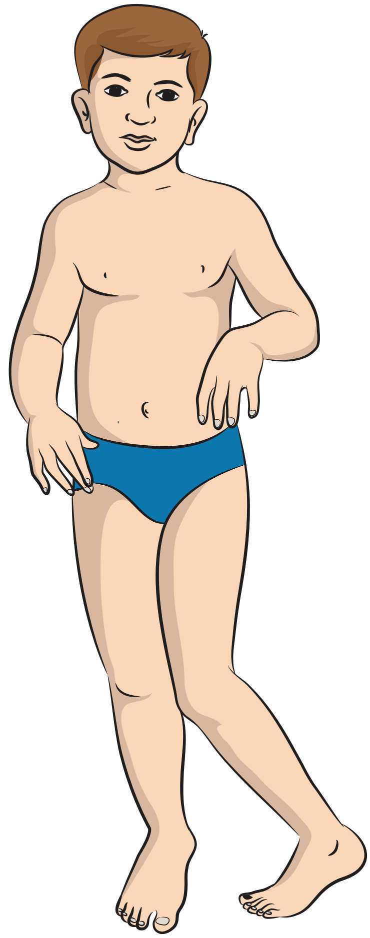

Fig. 7.16 This child with hemiplegia shows increased muscle activity on the left side of his body and/or loss of muscle extensibility. Without examination and evaluation, the clinician does not fully understand the impairments that cause this posture. He may have spasticity, loss of selective control with overflow of muscle activity with movement, changes in his musculoskeletal system, compensatory cocontraction to attempt stability, or any combination of these impairments and compensations. These neuromusculoskeletal impairments may be difficult to differentiate in some clients.

Selective Voluntary Control and Intra- and Interlimb Coordination

> The clinician observes overall posture and movement to note how postures and movements in one part of the body affect other parts. The clinician examines the client for mirror movements and overflow of activity from one body segment to another, noting if any observed movements are developmentally or functionally appropriate. The clinician observes intralimb and interlimb activity, looking for the variety or lack of variety of posture and movement combinations. This includes the ability or lack of ability of selective control of body segments or muscles (isolated activity).

Movement requires selective voluntary motor control and relies on the interplay between reciprocal activation and cocontraction. Loss of selective (or isolated) motor control in children with spastic diplegia has been documented.[97,98] The neural mechanisms are assumed to be many of the descending pathways from the CNS that include pre- and postsynaptic and interneuronal influences. Loss of selective control with excessive cocontraction indicates damage to pathways subserving reciprocal inhibition. Excessive cocontraction can also be a compensatory strategy to attempt control of posture and movement.[55] Clinically, it may be difficult to differentiate spasticity from voluntary cocontraction from loss of selective control (**Fig. 7.16**).

Children with dystonic CP often demonstrated cocontraction during isometric tasks when attempting maximal isometric contractions in one study.[107] Adults with athetoid CP showed a variety of movement patterns when attempting voluntary elbow flexion, including firing of the antagonist prior to the agonist (this is characterized clinically by the appearance of “winding up” to move), movement of the limb only in the opposite direction of intention when the antagonist fired first, alternating activity of the agonist and antagonist, cocontraction of the agonist and antagonist, and prolonged agonist activity.[114] All patterns indicated excessive muscular activity, often in inappropriate muscles, termed overflow (**Fig. 7.17**). In a research study by O’Dwyer and Neilson,[96] adults with athetosis who could speak used increased levels of muscle activity that suggested simplified control characteristics and increased energy cost in muscles of the lips, tongue, and jaw. The researchers suggested that slowed articulation heard in people with athetosis may represent voluntary attempts to improve accuracy of abnormally controlled

Fig. 7.17 As this young man speaks, tension increases in many of his cervical muscles. His facial and jaw tension may be attempts to make oral movements for speech consistent because he cannot rely on the timing and length of muscle activity or even which muscles may initiate when he speaks.

movements rather than representing involuntary movements, since the speech patterns were reproducible in each subject across repetitions of a test sentence.

Kline et al[115] noted exaggerated antigravity muscle activity of the paretic arm and leg in people poststroke, with walking increasing finger flexion and elbow coactivation of the paretic arm. Likewise, during active finger flexion of the paretic hand, significant activity of unnecessary arm muscles for the task and ipsilateral leg muscle activity were recorded by EMG (and not present in the controls without disability). Kamper and Rymer[116] found that attempts to actively extend the metacarpal–phalangeal joint of the index finger in 11 patients poststroke with various lesion sites resulted in coactivation of flexors and extensors and/or decreased excitation of the extensors. Dewald and Beer[117] showed that people without disability and the nonparetic arm in people with hemiplegia due to stroke generate torques in synergists in the shoulder and elbow joints during experimental isometric activity. The hemiparetic arm in those with hemiplegia showed activation of different synergies described years ago by Brunnstrom: the elbow flexed with shoulder abduction, external rotation, and extension, while the elbow extended with shoulder adduction and internal rotation.

Sensory Systems

Sensory systems allow the ability to receive and register internal body events and external environmental events that affect a person's function. Sensory information from within the body concerning homeostasis is termed interoception and involves receptors that sense visceral sensations, hunger, thirst, internal pain, and skin sensations, such as itch.[118,119] Interoceptors ultimately arrive at the insula, which lies in the sulcus between the frontal and temporal lobes. The insula (Fig. 7.18) is considered a part of the limbic system and routes a range of sensory inputs and feelings to motivation and motor components for behavioral expression.[118] Part of insular function is self-recognition. Some tactile afferents (C fibers) travel to the insula rather than to the primary somatosensory cortex. Therefore, although these afferents would be classified structurally as exteroceptors, their information travels to the insula and may be involved in an affective interpretation of certain types of touch.[120]

Sensory information about the body in space comes from mechanical and stretch changes within muscles, joints, and skin afferents and is termed proprioception. Proprioception can further be classified as conscious or unconscious (Fig. 7.19). Conscious proprioception includes kinesthesia (the sense of limb movement) and joint position sense (static limb position).[121] Conscious proprioception is conveyed from receptors through the dorsal columns of the spinal cord, crossing in the medulla, traveling through the thalamus, and finally to the primary somatosensory cortex of the parietal lobe.[122] Unconscious proprioception arises from muscle stretch and tension receptors and from spinal interneurons that regulate motor output. Information travels through several pathways to the cerebellum, primarily the dorsal spinocerebellar tract. Unconscious proprioceptive information is necessary for the maintenance of normal muscle tone and posture as well as for coordinated, smooth movements.[122]

Exteroception is the term used to denote information coming into the body from the environment. This includes tactile information (light touch and two-point discrimination), temperature, external causes of pain, and vibration. Two-point discrimination and vibration senses follow a path similar to conscious

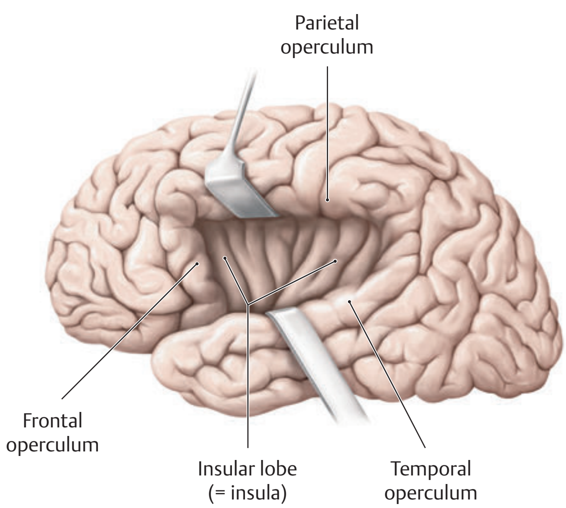

Fig. 7.18 The insula lies deep to the frontal, parietal, and temporal lobes of the cerebrum. Reproduced from Gilroy, *Atlas of Anatomy, 3rd edition* © 2016, Thieme Publishers, New York.

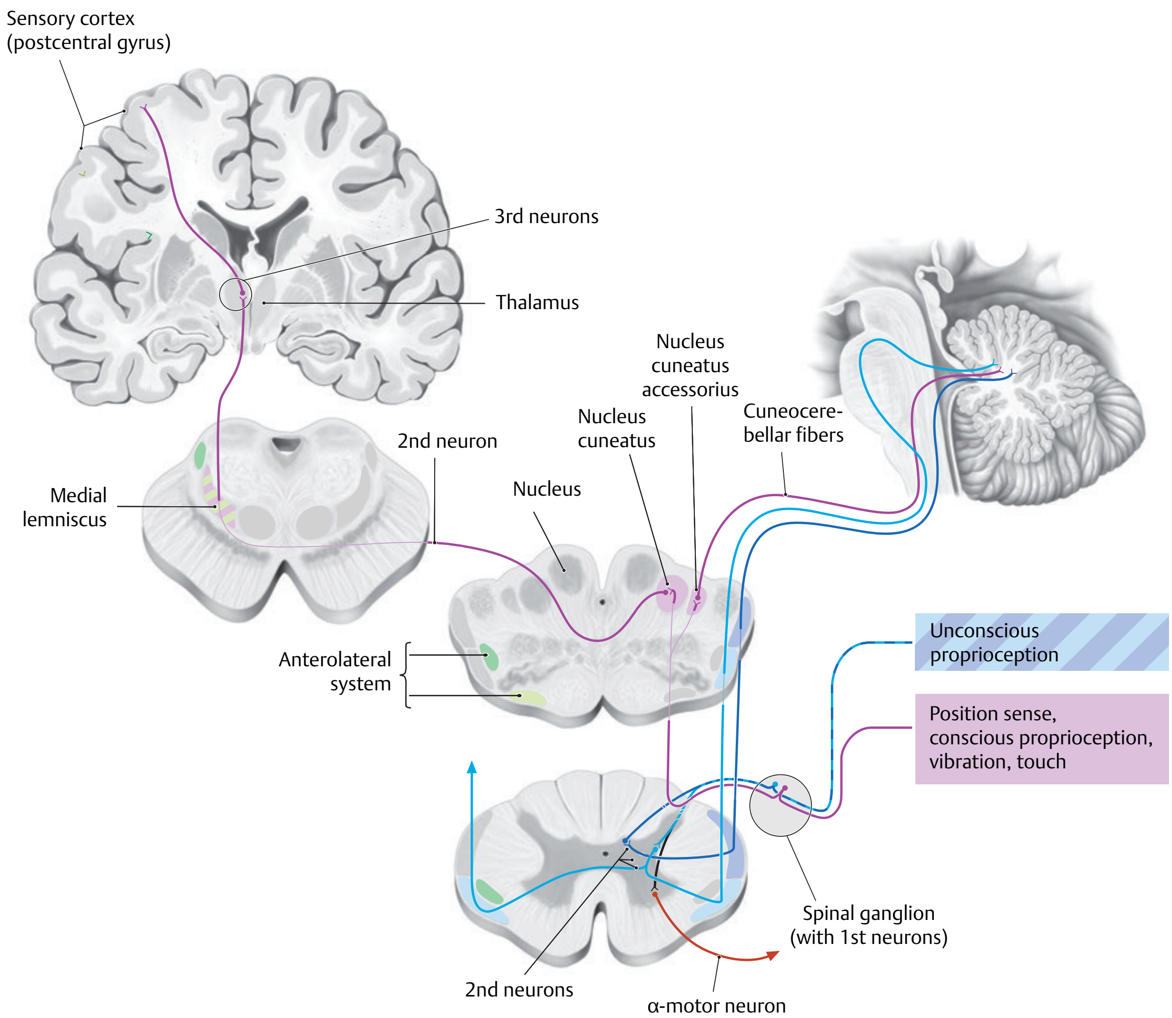

Fig. 7.19 On the left, the pathway for conscious position sense, conscious proprioception, well-localized touch, and vibration is shown from the first order through the third order neurons. The third order neurons synapse in the sensory strip of the parietal lobe. On the right, the route of unconscious proprioception is shown to the cerebellum. Information about muscle stretch and tension route to the cerebellum through the spinocerebellar tracts (light and dark blue). The cuneocerebellar fibers (purple) arise above spinal level C8, carrying stretch and tension information from the upper limbs to the cerebellum. Reproduced from Gilroy, *Atlas of Anatomy, 3rd edition* © 2016, Thieme Publishers, New York.

proprioception, whereas pain, temperature, and light touch travel anterolaterally in the spinal cord, through the brainstem and thalamus, to the primary sensory cortex.[122] Exteroception also includes the special senses of vision and hearing, vestibular functions, taste, and smell, all of which have their own pathways through the CNS and will be described briefly in the following paragraphs.

Sensory processing describes the organizing, modulating, and interpreting connections the CNS uses to route sensory reception information to form behavioral responses.[123] Each sensory system has specific pathways from external receptors to often multiple areas within the CNS and will be very briefly reviewed in the following paragraphs as well. Sensory processing standardized tests examine the behavioral responses that people make to various sensory stimuli to understand a person's interactions with others and choices of environment.[124]

Vision

The clinician using NDT is aware that the incidence of visual impairments is high in clients with neurological impairments and advocates for examination by ophthalmologists and optometrists. The clinician examines the client's use of vision with activity and participation, noting how the client focuses the eyes, uses visual pursuits and gaze shifts, and adjusts eye and head postures and movements in coordination with entire body posture and movement. The clinician administers standardized and nonstandardized tests of vision as it relates to participation, activity, and posture and movement.

Researchers and clinicians often cite the visual system as a baby's first and most primary link to exploring the environment.[125,126] Visual development in humans is highly complex. The anterior portion of the visual system includes the eyes and optic nerves as they travel to the optic chiasm. The posterior portion of the visual system includes the optic tracts, lateral geniculate nuclei, optic radiations, and occipital cortex (**Fig. 7.20**).[127]

From the occipital cortex, visual information proceeds in two separate pathways through a dorsal and a ventral path (**Fig. 7.21**). The dorsal path (occipito-parietal system) travels from the occiput to the parietal lobe, then to the frontal motor cortex and eye fields. It is responsible for visual cognition, localization of objects in space, and visually guided movements. The ventral path (occipito-to-temporal system) projects to the limbic system. It is responsible for perception of the physical attributes of visual images.[125]

Children with CP show high incidences of anterior visual system impairments as compared with the general pediatric population.[125,126,128,129] These impairments include acuity deficits, strabismus, refractive errors, lack of smooth pursuits, impaired accommodation, early-onset nystagmus, and optic nerve atrophy. Uncorrected anterior eye impairments can lead to lack of binocular vision development, reading problems, poor accommodation of gaze shift from near to far, and amblyopia.

Children with CP can also show posterior visual system impairments, including visual field losses (primarily homonymous hemianopia) and cortical visual impairment. These impairments affect orientation and mobility through space, such as cervical rotation away from the

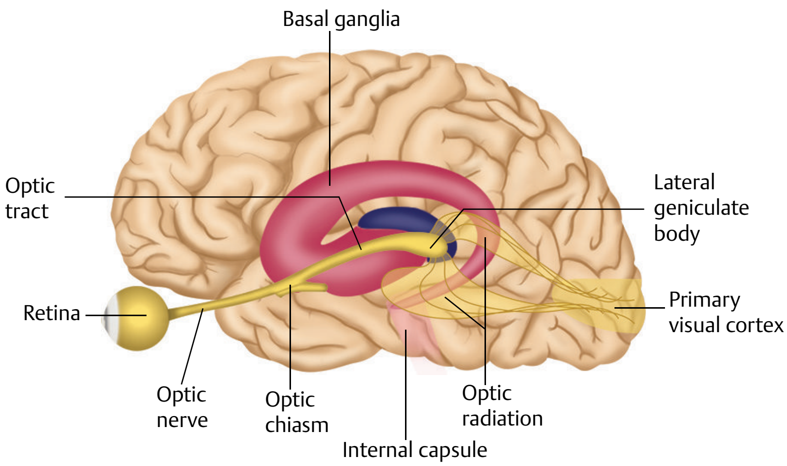

Fig. 7.20 Pathway from the eyes to the visual cortex. The optic tracts are quite large and can be damaged in ischemic or hemorrhagic lesions, such as occur in stroke, developmental malformations, and periventricular leukomalacia. Modified from Schuenke, Schulte, Schumacher, *Head, Neck, and Neuroanatomy, 2nd edition* © 2016, Thieme Publishers, New York.

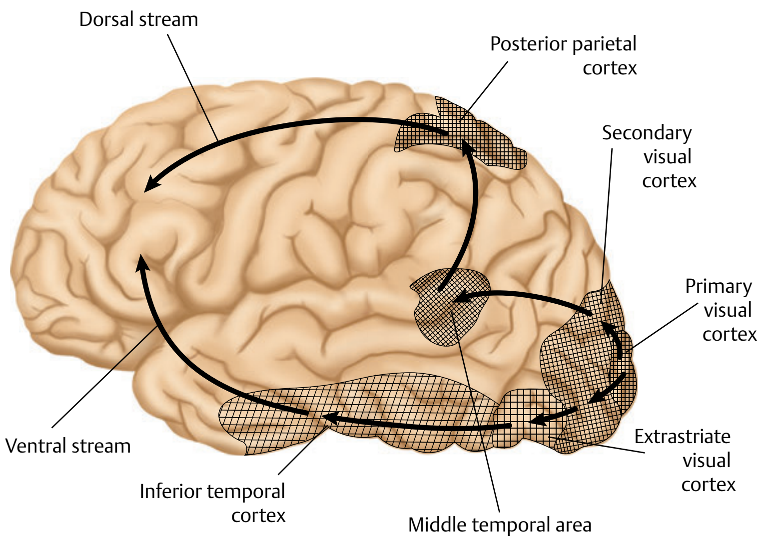

Fig. 7.21 Pathways from the visual cortex to visual functions. The dorsal stream processes the location of visual information in the environment, whereas the ventral stream identifies what is in the environment. Visual processing from the eyes to the visual cortex back to the eyes covers extensive areas of the brain. Modified from Gilroy, *Atlas of Anatomy, 3rd edition* © 2016, Thieme Publishers, New York.

intact visual fields in hemianopia,[127] as well as decreased sensitivity to weakly lit stimuli.[130]

Clients poststroke and post-TBI show similar visual impairments. Researchers report acuity losses additional to those pre–brain injury, decreased eye mobility (including strabismus), late-onset nystagmus, reduced convergence ability, and visual field losses, including homonymous hemianopia, inferior or superior quadrantanopia, scotomas, altitudinal defects, and macular defects.[131,132,133,134]

Tactile

The clinician examines the client's patterns and preferences for seeking, detecting, and discriminating tactile information through observation, direct measurement (if possible), and self-/family report. The clinician administers standardized and nonstandardized testing of tactile reception, processing, and behavioral responses.

Tactile receptors allow people to detect and discriminate information from the environment. Myelinated tactile mechanoreceptors located in the skin respond to pressure, sending afferent information through the dorsal columns of the spinal cord to the thalamus, and finally to the primary sensory cortex in the parietal lobe (**Fig. 7.22**).[122]

The mechanoreceptors located in glabrous (nonhairy) skin contain several distinct types of receptors that sense tension, texture, rapid vibration, and sustained touch and pressure. Receptors in hairy skin detect pressure, sending afferent information about the location of touch and discrimination of patterns of touch.[135] All of these mechanoreceptors are classified as type A receptors and provide high-resolution spatiotemporal information to the CNS.[120] Each type of receptor in the type A group has a different rate of adaptation to stimuli, with some returning rapidly to a normal pulse rate with a high rate of stimulation, and others adapting more slowly. In addition, a single sensory neuron's receptive field varies in size; in the hand, lips, and tongue, the field is small, allowing detection of fine detail, whereas the large fields in the back and legs detect tactile information in a wider area with less precision.

Another group of tactile receptors located in hairy skin provides low-resolution information about gentle moving touch across the skin. These are smaller unmyelinated type C fibers.[120] These fibers travel through the spinothalamic tract (along with temperature and pain afferents) to the insular cortex. Although considered exteroceptors, these type C tactile receptors function more as interoceptors, giving the body information about its well-being (homeostasis). Both A and C fibers are stimulated when touch moves across the skin's surface. See the section on the integumentary system later in this section for further descriptions of the sensory receptors in the skin.

Tactile information is processed in the CNS to perceive and locate stimuli, orient to the environment, identify objects and the characteristics of objects, and grade (scale) the amplitude of force in fingertip grips and oral control.[111,136] Tactile information processing results in behavioral responses, including posture and movement responses, under conditions where sensory feedback is used. Modulation of tactile responses is believed to be important in adaptive behavior.[136] People who are overreactive, underreactive, or show fluctuating responses to tactile stimulation may show maladaptive behavior,[136] such as hitting, crying, avoidance of other people or toys, delayed or no response to dangerous objects, fear or lack of fear, or overstuffing food in the mouth.

Children with dystonic and with spastic diplegic CP have shown decreased abilities on tests of two-point discrimination compared with controls without CP.[137] Riquelme and Montoya[138] used somatosensory evoked potentials (SEPs) to examine sensory processing in children and adults with CP. Children with CP showed reduced touch sensitivity (and increased pain sensitivity) when compared with children without CP, whereas there were no differences between the adults with CP and adults without CP. Hoon et al[139] studied children born prematurely who developed CP using diffusion tensor imaging. They found a correlation between the degree of injury to the posterior radiation pathways from the thalamus to the sensory cortex due to periventricular leukomalacia and the degree of reduced tactile and proprioceptive thresholds.

Tyson et al[140] found tactile discrimination deficits in a majority of patients they tested 2 to 4 weeks poststroke who had anterior circulation strokes. Tactile detection was impaired to a lesser extent. Conversely, Connell et al[141] found about one-third of patients tested 15 days post–first stroke showed impaired tactile sensations, whereas two-thirds showed proprioception impairments. The two studies used different sensory assessments.

Proprioception

The clinician tests conscious proprioception insofar as the client is able to participate in the test. The clinician observes participation, activity, and posture and movement for discrepancies between control with and without visual guidance/tactile cues as much as possible to examine motor behavior guided by unconscious proprioception, and looks for signs or absence of cerebellar ataxia (hypotonia, tremor, dysmetria).

The proprioceptive system was described at the beginning of this section on sensory systems. Impairments can be classified as conscious proprioceptive impairments (sensory ataxia) or unconscious proprioceptive impairments (cerebellar ataxia).[13] Tests of conscious proprioception include the well-known "up/down" kinesthesia test,[121] which relies on cognitive and language skills, as well as proprioception, to report whether the examiner has moved a limb or individual joint passively without the client's visual regard. This test is often impossible to perform with children. If the client is able to report reliably, the up/down joint-position test reveals impairments in those with sensory ataxia, but it shows integrity in cerebellar ataxia. In addition, the Romberg test would show better standing with eyes open than

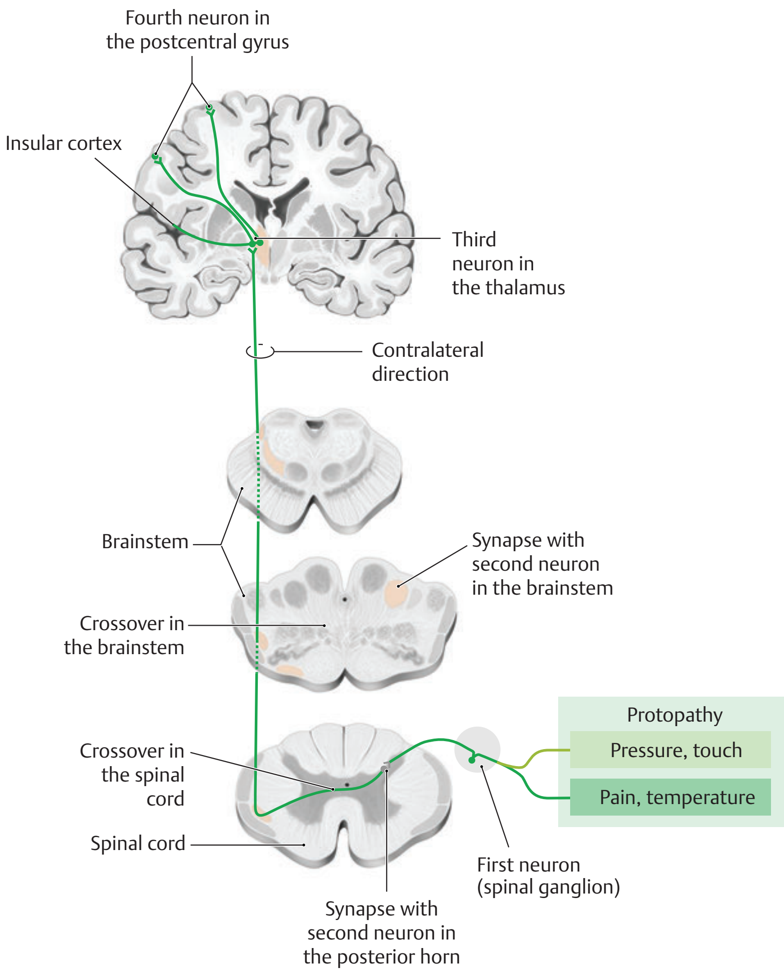

Fig. 7.22 The spinothalamic tract carries pain, temperature, and tactile information from sensory receptors through the thalamus, and on to the primary sensory strip of the cerebral cortex. Some of the ascending sensory neurons are routed to the insular cortex and may be more involved in a person's sense of well-being. Reproduced from Schuenke, Schulte, Schumacher, *Head, Neck, and Neuroanatomy, 2nd edition* © 2016, Thieme Publishers, New York.

closed in sensory ataxia, whereas with cerebellar ataxia, testing both with eyes open and with eyes closed would show loss of balance. Testing for conscious proprioception integrity/impairment should also include tests of static limb position, tested by the client matching a limb position to the contralateral limb the examiner has placed passively.[121]

Children and adults with CP often show abnormal processing of conscious proprioception, demonstrated in research studies where participants can reliably report a sense of movement or imitate contralateral limb placement with the eyes closed.[121,138] Joint-position sense (static limb position) errors noted in the study by Wingert et al[121] led the researchers to conclude that proprioceptive impairments were likely due to damage in the thalamocortical projections of the somatosensory cortex. In addition, however, they questioned the possibility of additional secondary proprioceptive processing errors based on preferred limb positions used functionally in children with hemiplegia and diplegia and the possibility of these habitual positions changing the sensitivity of the muscle spindle, changing muscle stiffness, and altering the muscle–joint relationship.

Tyson et al[140] found that approximately a quarter of the patients they tested post–anterior circulation stroke had impaired proprioception. Using a different assessment tool, Connell et al[141] found a higher percentage than Tyson et al of proprioceptive impairments in patients studied poststroke. They discussed that the difference in their findings from Tyson's study may be due to the tests used; their test had more items about proprioception than the test used by Tyson et al.

Leibowitz et al[142] studied patients poststroke with a system that required matching the nonhemiplegic upper extremity (UE) to the hemiplegic UE placed underneath a table in various positions by the examiner. Examiners could measure distance errors with their system. Patients poststroke made significantly higher mean distance errors than a control group without stroke.

The effects of loss of unconscious proprioception due to lesions in the spinocerebellar tracts and/or the cerebellum are expressed as motor control impairments due to the lack of sensory feedback from spinal interneurons or from joint position and muscle stretch and tension. With spinocerebellar lesions, the use of vision to compensate for proprioception assists coordination.[13]

Motor control impairments seen in spinocerebellar and cerebellar lesions include hypotonia, dysmetria, a low-cycle intention tremor and/or postural tremor,[143] delayed initiation of movement, poor timing/prolonged agonist or antagonist activity of the triphasic bursts in control of joint position (agonist–antagonist–agonist), and abnormal coordination of multijoint movements.[144,145]

Auditory

> Although auditory impairments are reported less than impairments in other sensory systems in clients with CP, stroke, and TBI, they can be present. The impairments are as varied and complex as those of other sensory systems. The clinician using NDT examines the client's ability to orient and localize toward sound and use auditory information to guide activity and participation. The clinician advocates for referral to audiologists when auditory impairments are suspected.

The auditory and vestibular systems share the same receptors and cranial nerve.[146] The auditory pathway detects sound as it passes from the outer and middle ear to the inner ear, where hair cells conduct sound waves through the auditory nerve. The auditory nerve enters the brainstem, with fibers splitting to dorsal and ventral cochlear nuclei, both ipsilaterally and contralaterally. Outputs to the auditory cortex in the temporal lobe project both ipsilaterally and contralaterally as well (**Fig. 7.23**). Blood supply for the entire auditory system comes from cerebral and basilar arteries, and along the pathway, often has multiple arteries supplying each area.

Auditory impairments in people with CP are usually reported in conjunction with pathology due to asphyxia or neonatal hyperbilirubinemia. In a small study by Sano et al,[147] all six patients with CP due to asphyxia or hyperbilirubinemia were found to have peripheral auditory lesions, specifically in the cochlea or cochlear nerve. Bilirubin easily crosses the immature blood–labyrinth barrier as well as the blood–brain barrier, whereas prolonged

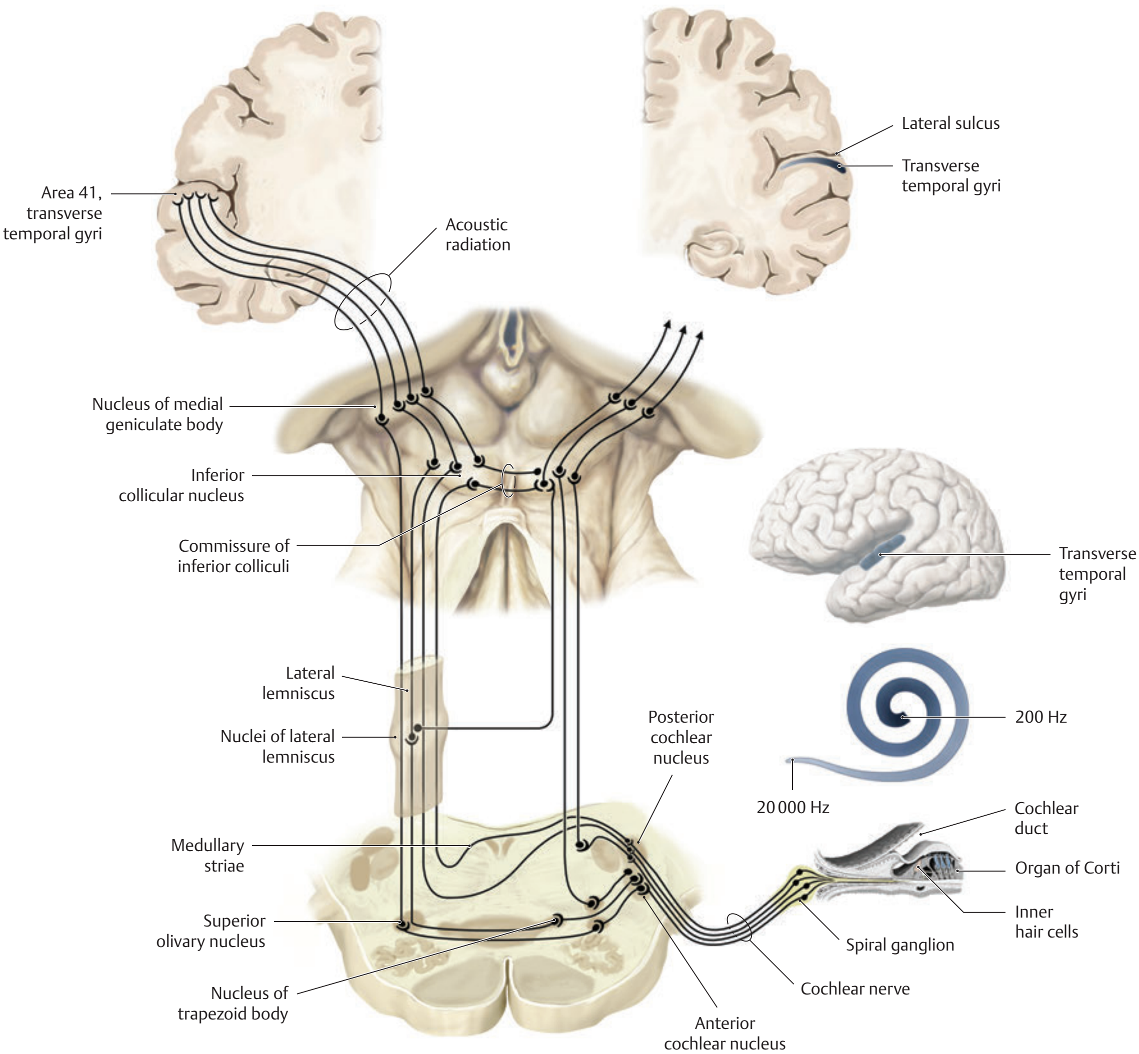

Fig. 7.23 Each ear sends auditory information to both cerebral hemispheres. Reproduced from Schuenke, Schulte, Schumacher, *Head, Neck, and Neuroanatomy, 2nd edition* © 2016, Thieme Publishers, New York.

hypoxia can damage the outer hair cells of the inner ear. The researchers credit their diagnoses to more advanced audiometry.

Because of the rich blood supply to the auditory system, and perhaps due to other impairments that seem more urgent to address, patients with stroke rarely complain about hearing loss.[146] The most common complaints are tinnitus, which may take several days poststroke to become apparent to the patient. Patients may also report hearing loss or auditory hallucinations (bees buzzing, roaring, bells ringing, etc.) or hyperacusis (increased sound sensitivity). Symptoms may be unilateral or bilateral and are commonly associated with brainstem or midbrain strokes. Hemispheric strokes with temporal lobe involvement may cause hyperacusis, cortical deafness, or auditory agnosia, although hearing dysfunction in hemispheric lesions is usually subtle.

Clients with TBI may have lesions in the brainstem or, more commonly, in the temporal lobes that could cause impairments in the auditory system, although one prospective study of clients post-TBI from 1988 to 2002 reported impaired audition as uncommon.[148] However, because military personnel can incur TBI with blast injuries, this population may show higher rates of auditory impairments than other causes of TBI. Due to body armor protection, some military personnel are surviving blast injuries. Some survive with TBI, which includes a high incidence of visual, auditory, or dual visual/auditory injuries.[132] The damage to the auditory system can occur anywhere from the outer, middle, and inner ear to the auditory cortex. Blasts or noise exposure from gunfire can temporarily or permanently alter the threshold in the hair cells of the cochlea, decrease stiffness of the hair cells, rupture the tympanic membrane, or cause swelling of the auditory nerve endings. Blasts send pressure waves that can damage the peripheral or central auditory system.[149] Examination can be impeded by the polytrauma of the injury, including coma or altered cognition.

Vestibular

The clinician using the NDT Practice Model examines vestibular contributions to activity and participation using standardized and nonstandardized tests when possible. The clinician is aware that it is not always possible to separate vestibular, proprioceptive, and visual impairments from each other clinically when observing postural impairments in clients who cannot follow specific requests and instructions. The clinician observes postural alignment in various positions, observes any signs of ataxia, observes deviant eye gaze stability or lack of smooth pursuits, and observes the client's perception of upright. The NDT clinician refers to specialists when a peripheral or central vestibular lesion is suspected.

The vestibular system is specifically designed to detect a person's head position and movement in relation to gravity to control balance and postural stability.[149] The peripheral vestibular anatomy is located in the inner ear and consists of the semicircular canals and the otolith organs. Within these canals and organs, fluid moves over sensitive hair cells as the head moves, which transmits afferent signals to the vestibular nerve. From the vestibular nerve (a branch of the vestibulocochlear nerve—cranial nerve VIII), information is carried to the medulla and pons in the brainstem and to the cerebellum.[13] Here, information from the vestibular, proprioceptive, tactile, and auditory systems is received. Efferent signals to eye movements, autonomic functions, and postural muscles travel from these brainstem and cerebellar nuclei (Fig. 7.24).

Clients with stroke or TBI can have peripheral or central vestibular lesions. Specific testing for vestibular lesions is described in detail in other sources.[13,145,150] These tests require cooperation with specific instructions. In central vestibular ataxia, limb movements are normal when the client is lying down but ataxic with walking.[13] Stance is more stable with eyes open than closed, and in sitting, rapid alternating voluntary movements are normal. Vertigo and nystagmus may be present but are often mild.

Central vestibular lesions may occur in stroke.[150,151,152,153] Brainstem lesions, lesions in the posterolateral thalamus, and insular lesions appear to be sites that cause central vestibular output impairments, including gait ataxia and poor balance, poor vertical sensory orientation, and lateropulsion. Cerebellar stroke can mimic acute peripheral pathology of the vestibular system.[153]

A pilot study by Pickett et al[44] found vestibular dysfunction underlying postural (balance) instability in

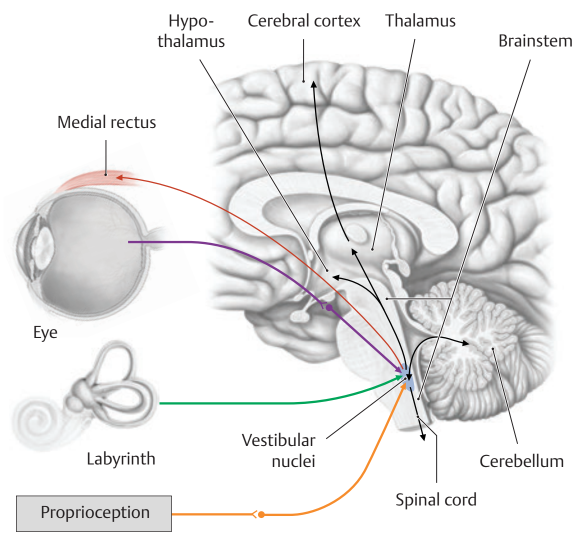

Fig. 7.24 Vestibular information is routed to the cerebellum and visual systems to control eye movements and balance. Reproduced from Schuenke, Schulte, Schumacher, *Head, Neck, and Neuroanatomy, 2nd edition* © 2016, Thieme Publishers, New York.

a group of patients post-TBI consistent with earlier studies with this population. They tested patients under conflicting sensory conditions using computerized posturography. They cite other researchers who hypothesize that impairments in the vestibular system may result from damage of the vestibular nerve during shearing forces often sustained during TBI. Fausti et al[149] state that blast injuries that cause TBI in military personnel can damage the peripheral and/or central pathways of the vestibular system.

Taste/Smell

The clinician refers the client to other team members if altered senses of taste and smell are reported by the client or suspected by family members.

There is very little information in current research studies or textbooks about the senses of taste and smell in people with CP, stroke, and TBI. These sensory pathways may be more affected in people who have certain tumors in the brain that interfere with the pathways from taste or olfactory receptors to processing and routing pathways within the CNS.

Moo and Wityk[154] describe a patient who reported altered sense of taste and smell after his second and again after his third stroke (all strokes were due to infarcts in the middle cerebral artery territory, involving the insula and frontoparietal cortex). They report that these impairments are rare in poststroke patients and may occur only when the insula and frontoparietal areas sustain bilateral lesions, as was true for this patient.

Arousal/Attention System

The clinician monitors heart and respiration rates, blood pressure, and pupil dilation/constriction and refers to the medical team with labile readings or suspected body temperature changes. These signs may indicate severe systemic distress and prevent therapeutic intervention until stability is reestablished.

The clinician observes and measures the client's generalized arousal and readiness to interact with the environment. The clinician examines the effects of imposed and self-initiated movement on the client's arousal and the effects of sensory system input on arousal, noting how long arousal is sustained and how well it is modulated. The clinician examines the ability of the client to attend to relevant/meaningful stimuli, focus and sustain attention, and shift attention between competing relevant stimuli. The clinician notes the stimuli that modulate arousal/attention and which stimuli disrupt arousal/attention. The clinician notes stimuli that increase or decrease motivation.

Generalized arousal is a physiological activity regulated in several sites in the CNS. Pfaff et al[155] define generalized arousal behaviorally, as showing greater responsiveness to sensory stimuli in all sensory modalities, showing increased motor activity, and more emotional reactivity. Arousal includes cortical, endocrine, and autonomic arousal, which underlies motivated behavioral responses.[155]

The general arousal system is controlled in a top-down as well as bottom-up system. The ascending (bottom-up) system includes information received in the CNS by tactile, taste, vestibular, and auditory systems projected through the brainstem (reticular formation) to the posterior cerebral cortex to support sensory alertness, and to the anterior, frontal cortical projections for directed motor acts (**Fig. 7.25**). Projections to the limbic system and hypothalamus control autonomic and emotional arousal, while histamine-producing neurons have widespread projections to increase CNS arousal.[155]

Descending control includes hypothalamic projections to the brainstem and spinal cord to control autonomic arousal and preoptic area neurons that affect sleep and autonomic functions.[155] Both ascending and descending controls have highly redundant functions to protect arousal. (There are more than 120 genes that contribute to regulation of CNS arousal.[155])

Autonomic nervous system arousal includes elevated heart rate, elevated respiratory rate, elevated blood pressure, and elevated temperature. Clients in an intensive care unit with acute TBI who showed autonomic arousal plus muscle overactivity (termed dysautonomia) within the first 7 days post-TBI had significantly more severe injuries and poorer outcomes reported in one study.[156]

Attention is the focused awareness of specific information. Attentional demand includes the ability to respond to a specific stimulus, the ability to sustain attention, selective attention, and the ability to shift attention.[3] Attention, like arousal, involves multiple neuronal pathways. The frontal cortex, parietal cortex, thalamic, and brainstem regions contribute to attention.[157] Resources are allocated to executive functions, selection and direction of attention, and arousal. The insula (a deep structure in the sulcus between the frontal and temporal lobes that is primarily associated with emotional states and homeostasis) is hypothesized to be specifically involved in cognitive control systems.[157] In a study by Mohanty et al,[158] hunger sensitivity was shown to be routed through the visual cortex, limbic system (amygdala and posterior cingulate), and substantia nigra when studied by functional magnetic resonance imaging. The cingulate, posterior parietal cortex, and frontal cortex were involved in spatial orienting and attention shifts during this experiment.

Arousal and attention share neuronal pathways with brain regions known to influence motivation (**Fig. 7.26**). The striatum of the basal ganglia, which

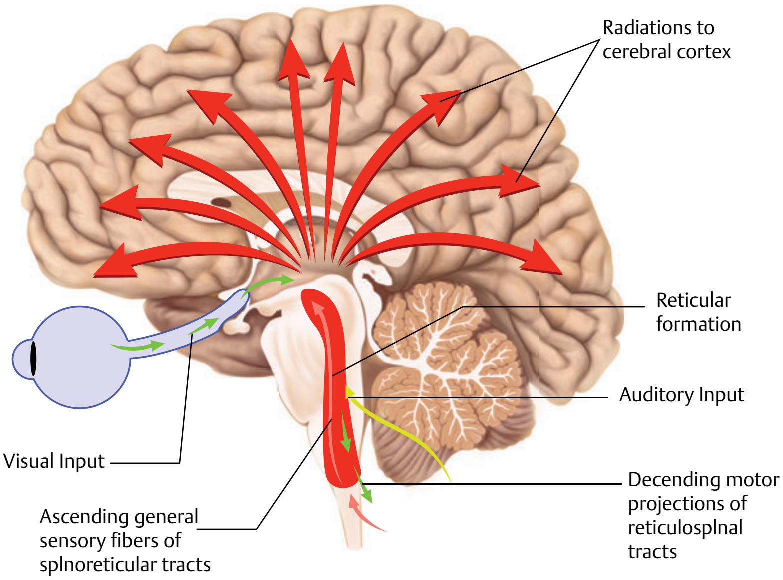

Fig. 7.25 Physiological arousal involves many structures of the central nervous system (CNS). Information from the periphery ascends and projects to many higher centers for alertness and motor responses. Information also travels from the CNS to the autonomic system (not shown in this illustration). Modified from Schuenke, Schulte, Schumacher, *Head, Neck, and Neuroanatomy, 2nd edition* © 2016. Thieme Publishers, New York.

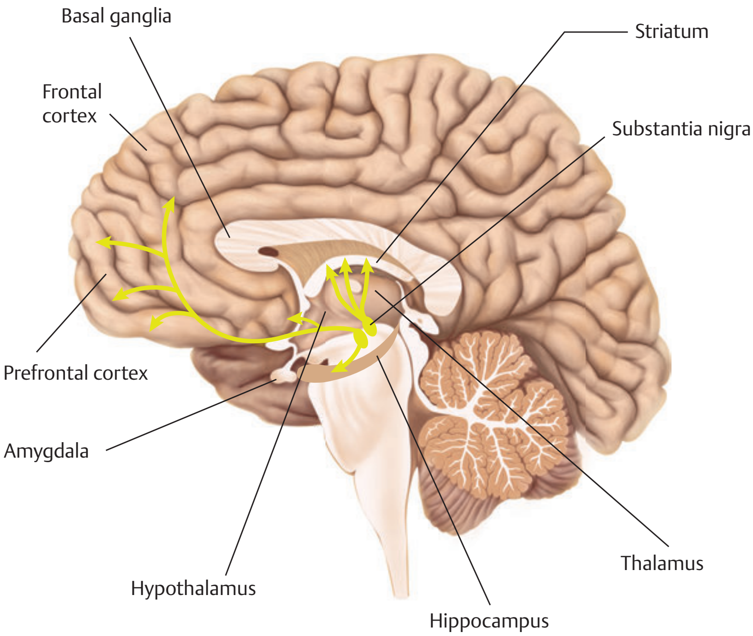

Fig. 7.26 Pathway involved in motivation. The prefrontal cortex and limbic system form a motivation pathway. The limbic system includes the basal ganglia, amygdala, hippocampus, thalamus, hypothalamus, and cingulate gyrus. Modified from Schuenke, Schulte, Schumacher, *Head, Neck, and Neuroanatomy, 2nd edition* © 2016. Thieme Publishers, New York.

relays information from the prefrontal cortex to the limbic system, is involved in motivation. The mesolimbic pathway, which connects the limbic system to the prefrontal cortex, is involved in the anticipation portion of motivation.[159] In addition, attention is a part of motivation.

Cognition

> The clinician tests cognitive/language skills or consults with team members, such as neuropsychologists, who test clients for cognitive function. The clinician examines the ability of the client to express and receive information related to posture and movement intent, decision making, memory, and praxis.

Cognition refers to knowing or understanding and includes processes such as reasoning, intuition, judgment, remembering, problem solving, and abstract thinking. The last two functions are often called executive functions.[160] Cognitive functions and connections are located in several areas of the brain, including the parietotemporal association areas, the prefrontal cortex, and limbic association areas (**Fig. 7.27**).[13] The cerebellum may also play a role in cognition in its connections to the prefrontal cortex and limbic system.[161,162]

People with CP show a wide range of IQ scores.[163] Comparison of classifications of CP may show some general differences in cognitive abilities,[164] and measuring intelligence on standardized testing is difficult for many children with CP who have sensorimotor, perceptual, and expressive language challenges.[163] In addition to impairments in these systems, social affordances or lack of affordances may affect cognitive development.[165]

In clients poststroke over age 70, Claesson et al[166] found in a prospective, randomized study that 72% had cognitive impairments, including memory impairments, aphasia, apraxia, agnosia, and impaired abstract thinking at 18 months poststroke. Lindén et al[167] also found 72% of their elderly patients with stroke had cognitive impairments compared with 36% in the general population matched for sex and age. In a population-based study of adults post–first stroke using a different assessment tool, approximately one-third of the 65 to 75 age group showed cognitive impairments.

In long-term clients with TBI, cognition impairment was greater after increasing years postinjury. In addition, the older the person at the time of TBI, the poorer the cognitive outcome (possibly due to loss of plasticity plus aging).[168] In TBI overall, cognitive and behavioral impairments are more prevalent than physical impairments and affect return to work in adults.[89] Cognitive impairments most frequently include decreased processing speed, attention deficits, memory impairments, and executive function impairments.[89,169]

Perception

> The clinician tests perception with standardized and nonstandardized tests. Some tests of perception are motor free. The clinician observes how the client interacts with the environment and to single-sensory-system and multi-sensory-system stimuli.

Perception refers to the ability to process and assimilate sensory information from the environment and the self through various sensory systems to provide meaningful information about the body in space as it relates to the environment.[3,13,170] Perception of environmental events received through one or multiple sensory systems travels from sensory receptors to the primary and association cortices in various hemispheric lobes where information is analyzed. This route considers a bottom-up pathway only, where sensory information received via the environment, proprioception, and/or interoception is interpreted and routed in the CNS. Perceptual information is then routed to a response, which could be a memory, an emotion, an internal image, an executive function, such a computing a math problem, or an action, such as saying a word, reaching, or running.

Perception also involves integration of attention, motivation, memory, and expectations (goals), and so includes the integrity of many pathways throughout the CNS. Perceptual information intended to influence action is routed to the

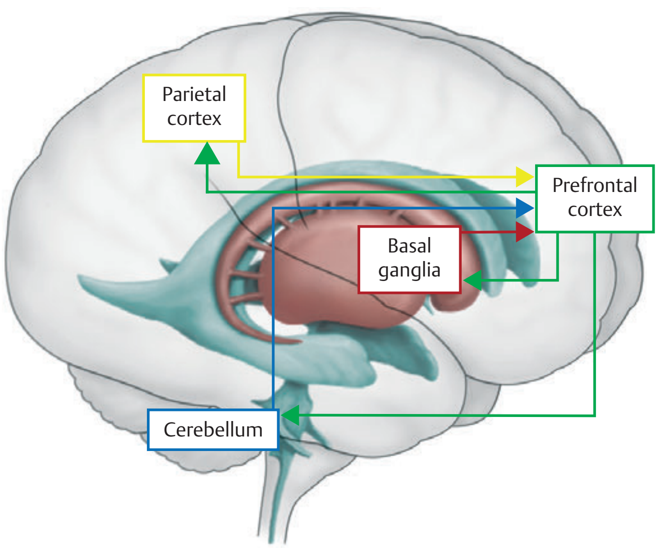

Fig. 7.27 The cognitive system includes intact pathways through the prefrontal cortex, basal ganglia, parietal cortex, and cerebellum. Reproduced from Schuenke, Schulte, Schumacher, *Head, Neck, and Neuroanatomy, 2nd edition* © 2016. Thieme Publishers, New York.

motor planning areas of the supplementary and premotor cortex in the frontal lobe and translated into motor commands in the primary motor cortex for motor execution.[13,76] This relationship of perception to posture and movement action is of great interest to the clinician using the NDT Practice Model because perceptions develop according to sensorimotor experiences, memories, and specific environments within which a person functions. Accurate perceptions help establish accurate motor responses as a person motor plans, whereas abnormal perceptions of the environment and the self may lead to inaccurate and inefficient movements. Because perceptions and motor plans rely on intact multipathway routing, damage to any one part of the CNS may compromise the perception/action couple.

Current research proposes that perceptions are influenced in top-down pathways as well as through the reception of input through multiple bottom-up pathways.[171,172,173] Parallel cortical processing may even be considered a top-top processing of distributed cortical networks.[174] Whether top-down or top-top, processing through various pathways—including the prefrontal cortex, the orbitofrontal area, and parietotemporal association cortices—analyzes, interprets, and alters the meaning of environmental information received through sensory systems based on past experience, context, and social interaction.

Although some perceptions are followed with action, action can in turn influence perception. An example of this influence is how visual flow of a person moving through space affects the development of depth perception.[175] As the eyes work together to focus, the images of a three-dimensional world project onto the two-dimensional retinas of the eyes. These images are slightly different for each retina (binocularity), which produces a static sense of depth and distance in the near environment. However, to perceive depth in the larger environment, motion through space produces a constant change in the “scene,” which allows a person to compare the ever-changing relationship of two or more points in the environment. This visual flow and the changing vestibular and proprioceptive input caused by self-movement, along with movements of the head and eyes in the transverse plane while the body moves in another plane, are interpreted perceptually as visual depth. Self-action has produced depth perception of the wide environment.

Kozeis et al[128] tested 105 children with spastic CP ages 6 to 15 using the Motor-Free Visual Perception Test, which assesses spatial relationships, visual discrimination, figure-ground perception, visual closure, and visual memory. Results showed that 57.14% had visual perceptual skills less than or equal to those of 6-year-olds in the population without disability.

Perceptual impairments are common in clients post-stroke. One discrete impairment is unilateral sensory neglect, defined as the failure to orient, report, or respond to visual, auditory, or tactile stimuli located on the contralateral side of the brain lesion.[75,176] Unilateral personal neglect results in reduced awareness of one side of the body itself as opposed to neglect of external sensory information.[176] Unilateral spatial neglect is the failure to acknowledge stimuli in near (within reach) or far space on one side of the body[176,177] and can be due to impairments in vision, audition, or somatosensory awareness. Research study designs that attempt to distinguish which sensory system impairments cause perceptual impairments are challenging.[12]

Unilateral neglect is most common in clients with right hemisphere lesions.[74,75,177] Agnosia is more common after right posterior lesions and results in clients sensing unfamiliarity in an environment that was previously familiar to them.

Visual perceptual impairments in clients post-TBI have been shown to correlate inversely with independence in self-care.[74] In a convenience sample study of 31 patients post-TBI from a major metropolitan hospital, McKenna et al[74] found unilateral neglect in 45.2% on subscales of the Occupational Therapy Adult Perceptual Screening Test.

Praxis, or motor planning, which consists of idea formation, planning, and motor execution after receiving perceptual information, was described in the section on multisystem influences on participation and activity.

Musculoskeletal System

The musculoskeletal system provides the framework for the nervous system to express action. In CP, stroke, and TBI, primary impairments of this system rarely occur (although primary impairments in the musculoskeletal system are often present in people with genetic syndromes). Musculoskeletal impairments are frequently caused secondarily through internal and external forces applied over time.[178] It is beyond the scope of this text to describe all possible secondary musculoskeletal changes that can occur in neurodisability. Major categories are presented here with some descriptive details.

The clinician using NDT measures morphological characteristics (height, weight, head/chest circumference, limb length and circumference), muscle length, muscle strength, joint mobility, and bony angles and rotation using clinical tools. The clinician bears in mind that the accuracy of these measurements may be complicated by abnormal muscle tone masking isolated muscle control. Some clients lack the ability to cooperate with testing. Therefore, vigilant and repetitive testing along with visual observation, palpation, and handling are used to differentiate neuromuscular from musculoskeletal integrities and impairments as much as possible. The following broad categories of musculoskeletal impairments are likely to be present in many clients with neurodisabilities.

Force Production Mechanics

The clinician tests muscle strength using manual muscle testing when possible, dynamometry, and observation of muscle activity with and against gravity. Muscle activity is observed during isometric, concentric, and eccentric activity and in open and closed kinetic chains.

Muscle force physiology was described as part of the neuromuscular system, but the mechanics of force production (strength) can be considered a musculoskeletal structure and function.[1] Muscle activity moves the joints of the skeletal system using isometric, concentric, and eccentric activity. These movements usually occur across several joints in a body segment in open-chained or close-chained kinetic chains. Open-chained movements occur with the distal segments free in space and are non-weight-bearing movements, such as reaching, which often requires rapid movement. Close-chained movements occur with the distal segment in a weight-bearing situation and can develop power and force. An example of close-chained movement is the translation of the body over the weight-bearing foot in the stance phase of gait.

Force production, or strength, depends on the integrity of many components of the musculoskeletal system. These include the size of the muscle and the architecture of its fibers; the passive structures, such as fascia and muscle cellular structure; the muscle's length–tension relationship; the moment arm of the muscle's length; the speed of the muscle's contraction; the muscle's active tension; and the age and gender of the person.[1,179]

In ambulatory children with CP, impairments in strength correlate to activity limitations.[180,181,182] Children with CP who are ambulatory have been shown to increase their strength during aerobic exercise,[181,183] although, in these children, activities such as walking also show many more impairments than lack of strength.[184] In a systematic review of randomized trials with strength interventions for children with CP, strength training was found not to be clinically effective in increasing scores on the Gross Motor Function Measure.[182] Of interest is that many studies that research the effects of strengthening in children with ambulatory CP test strength using concentric or isometric maximal voluntary exertion only,[185] and they use open-chained progressive exercises as intervention.[183,186,187] Because walking and related activities require complex postural control and many lower-extremity muscles to work in isometric or eccentric activity in close-chained movements, and because walking also requires optimal use of skeletal lever arms and transfer of energy from one body segment to another,[184] strengthening in open-chained movements or even close-chained "exercises" may not be sufficient to change walking efficiency and activity.

Changes in Muscle Length

The clinician measures passive range of motion (PROM) and active range of motion (AROM). The clinician measures in various body positions to note differences in ranges and tests two-joint and multijoint muscles both in classical test positions and with altered positions as necessary to accommodate the client's muscle and bony morphology. The clinician records findings in a detailed manner to convey the variations in muscle length the client demonstrates.

In vivo ultrasound images of muscle have made direct observation possible for researchers.[188,189,190,191] Researchers have measured muscle properties of the medial gastrocnemius in ambulatory children with spastic diplegia and hemiplegia and adults poststroke using ultrasound technology. They challenge the widely held notion that spastic muscles have sarcomere loss similar to that seen in prolonged immobilization. Muscle length changes may be a function of decreased fiber diameter and fascicle length or sarcomere length instead of decreased number of sarcomeres. These investigations are still being refined and explored, but they currently support active intervention to address the resultant decreased muscle volume and increased passive stiffness.

Foran et al[192] reviewed the current literature regarding alterations in spastic skeletal muscle, concluding that there is likely to be altered muscle fiber size and fiber type distribution, proliferation of extracellular matrix material, increased muscle cell stiffness, and inferior mechanical properties of extracellular material in spastic muscle as compared with normal muscle tissue.

Changes in muscle length may be associated with abnormal reflexive muscle tone, excessive cocontraction, and spasm, as well as altered mechanical properties within the muscle and surrounding connective tissues,[6,7] but a cause–effect or "vicious cycle" of increased tone ↔ muscle shortening/joint contracture has not been established.

Some muscle groups tend to become overlengthened in clients with CP and stroke. The rotator cuff in clients with stroke who have flaccid or hypotonic muscle tone may become overlengthened with time.[193] The results include shoulder pain and rotator cuff tears along with shoulder joint subluxation.

Skeletal Changes

The clinician measures joint mobility and bony alignment in all three cardinal planes. The clinician palpates for bony shape. The clinician measures body segment length and circumference.

Delayed skeletal maturation, low bone density, and diminished linear bone growth are often seen in children with moderate to severe CP.[194,195] Common skeletal changes occurring secondarily in CP include scoliosis (**Fig. 7.28**), excessive thoracic kyphosis, spondylolysis, hip dysplasia and arthritis, hip subluxation and dislocation, torsional deformities of the long bones, patella

Fig. 7.28 Scoliosis is common in people with cerebral palsy, and its severity is associated with the severity of the neurological impairments as well as the onset of curve appearance. Scoliosis can progress after skeletal maturation.[30]

alta, and multiple distal limb deformities.[28,29,30,178,196] All of these skeletal changes are studied to determine the factors that cause them, including abnormal neural influences, external (floor reaction, loads on limbs or limb segments, gravity) and internal (muscle length and activity imbalances) repetitive forces on poorly aligned body segments, and poor sensory registration or processing. Many secondary musculoskeletal impairments that develop in people with CP and TBI are described in detailed texts (**Fig. 7.29, Fig. 7.30, Fig. 7.31, Fig. 7.32**).[197,198,199]

Respiratory System

Respiratory drive is controlled centrally in the brain stem (the upper two-thirds of the medulla and in the pons). Respiratory centers control the rhythmic pattern and rate of respirations and can be damaged in some people with stroke.[206] Damage to these areas in CP and TBI is possible as well. The respiratory cycle adjusts and responds to blood levels of carbon dioxide and oxygen through chemoreceptors and sensing extracellular fluid pH.[206] Cortical control can also adjust respiration

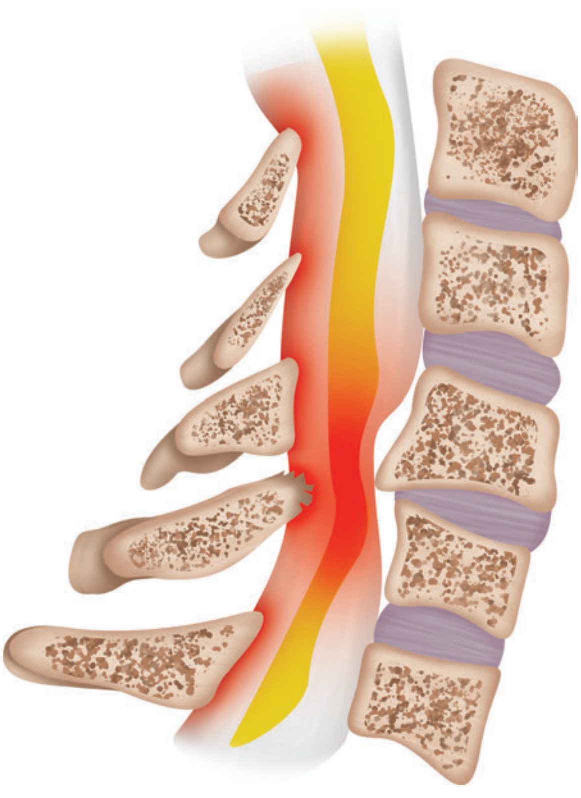

Fig. 7.29 Degenerative cervical spine lesions with compression of the spinal cord and deterioration of neurological status are common in dystonia and athetosis.[178,200,201,202] Their cause is abnormal movement of the cervical spine (people with dystonia or athetosis often use strong, repetitive cervical extension in positions of asymmetry) and strong asymmetrical jaw movements.

Fig. 7.30 Pronation of the foot with weight bearing.

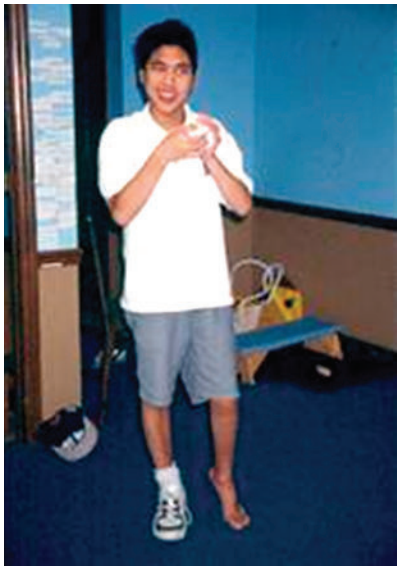

Fig. 7.31 Equinus of the foot.

rates to some degree (limited by blood gas levels) for short periods. Within the lungs, bronchial muscles that control bronchodilatation and constriction are smooth muscles under control of the autonomic nervous system.

Actions of the diaphragm, scalenes, intercostal muscles, abdominals, and accessory muscles adjust the size and shape of the respiratory system, as well as intrathoracic and intra-abdominal pressure (**Fig. 7.33**). The primary muscle of inspiration is the diaphragm, a dome-shaped muscle with a central tendon. As it contracts, the dome descends and compresses the abdominal contents, increasing intra-abdominal pressure. This pressure transmits laterally to the lower rib cage, causing it to expand, while contraction of the abdominal muscles support the viscera against the dome of the diaphragm.[207]

Fig. 7.32 Contractures in clients post-TBI, as seen here in Ernie (see Case Report A4 in Unit V) are associated with muscle overactivity and postinjury muscle structural changes.[6,7,203] Bone remodels across the lifespan,[204,205] and abnormal muscle activity and alignment of body segments can place abnormal mechanical stresses to bones, potentially altering its structure. Some people with TBI show severe hypertonia, which can rapidly alter body segment alignment and possibly bone structure. In addition, TBI can happen at any age, so the long-term effects of abnormal neural influences, abnormal internal and external forces, and altered sensory registration and processing may affect the client post-TBI similarly to effects seen in clients with CP.

Contraction of the diaphragm also causes the lower six ribs to move upward and outward via the origin of the diaphragm's costal fibers. The scalenes and the sternal portion of the intercostals lift and expand the upper and middle portions of the rib cage during inspiration. Tidal expiration is passive as the lungs recoil. Expiration can be controlled by action of the abdominals for activities such as speech.

Decreased muscle activity during respirations causes a decrease in the dome shape of the diaphragm as well as decreased effectiveness of all muscle actions already described. Both stiffening of the chest wall and collapse of the chest with inspiration with outward movement of the abdomen occur.[206,207,208,209] Breath sounds are quiet, with little air movement in the base of the lungs detected on auscultation.[209] Breathing is shallow and may be compensated with increased rate.

Clinicians examine the patient's respiratory sounds using auscultation. The clinician also examines respiratory modulation with position change and with the introduction of upright postures and movements. The clinician notes the results of pulmonary testing performed by medical specialists. Pulse oximetry readings, used with some clients for data on oxygen saturation levels in the blood, are noted with position change and postures and movements performed.

In rehabilitation or habilitation, the clinician examines and measures respiratory rhythm, rate, chest circumference, and muscular pattern used during inspiration and exhalation. These measurements are taken at rest and with activity. The clinician measures the coordination of respirations with swallowing/breathing, voicing/breathing, and moving through the environment/breathing. The clinician examines active airway clearance abilities. The clinician handles the client to feel respiratory rhythm and pattern and to determine how respirations change with posture and movement changes.

Premature infants with bronchopulmonary dysplasia (BPD) show less coordinated patterns of suck–swallow–breathe than premature babies without BPD.[210,211] In addition, babies with BPD may not be able to modulate their respiration rate to a stable pattern of suck–swallow–breathe because a slower rate may decrease their oxygen saturation.[211] Their irregular respirations and increased apnea in turn interfere with much-needed nutritional intake. Babies with BPD and those who have difficulty establishing suckle feedings are often regarded as being at high risk for neurological disabilities.[210,212]

Children with severe CP (Gross Motor Function Classification System [GMFCS] levels IV and V) showed markedly lower forced vital capacities than their age-matched peers without disability in one study.[208] Their upper chests were underdeveloped (X-ray measurements compared with peers without disability), and their breathing patterns were often rapid with chest wall collapse on inspiration. Teens and adults with severe CP (GMFCS levels IV and V) showed abnormal swallow–respiration patterns, especially with thin liquids, in one pilot study.[213] With

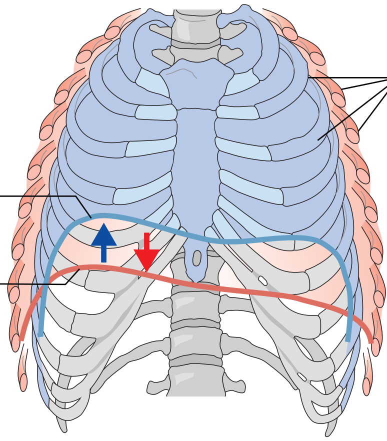

Fig. 7.33 The mechanics of respiration. Reproduced from Gilroy and MacPherson, *Atlas of Anatomy, 3rd edition* © 2016. Thieme Publishers, New York.

thin liquids, the participants showed a greater incidence of postswallow inspiration than a control group, whereas swallow–breathe with thicker liquids or pudding showed expiration after swallow comparable to that of the control group.

Respiratory impairments also affect patients poststroke. Pulmonary complications are common during the acute care phase poststroke.[214] Pulmonary emboli, pneumonia, or pulmonary edema develops in some patients on the first day of hospital admission after stroke and in others within the first few weeks. These life-threatening conditions require careful examination by all team members when interacting with patients poststroke.

Respiratory impairments are estimated to affect between 18 and 88% of clients poststroke, depending on the study cited.[206] In addition to central respiratory dyscontrol, which is managed medically, clients poststroke may demonstrate impairments of musculoskeletal mechanics of respiration as well as dysphagia. Both resting respirations and coordination of respirations with swallowing are significant impairments in some clients poststroke, with a shorter mean cycle length and faster respiration rate.[215] Many clients with dysphagia showed impaired coordination of swallow–breathe patterns in one study, with failure to exhale after swallow.[216]

Cardiovascular System

The cardiovascular system delivers nutrients, gasses, hormones, and blood cells to the body and removes waste products of metabolism through the blood vascular system. The pump for this system is, of course, the heart. The medulla regulates changes in the diameter of the blood vessels (vasomotor activity), receiving input from baroreceptors (**Fig. 7.34**) and chemoreceptors in the vascular system, located in the carotid sinuses and aortic arch. The vasomotor center in the medulla also receives input from the hypothalamus, cerebral cortex, and skin. The cardiovascular system is regulated by the autonomic nervous system (ANS) output via the

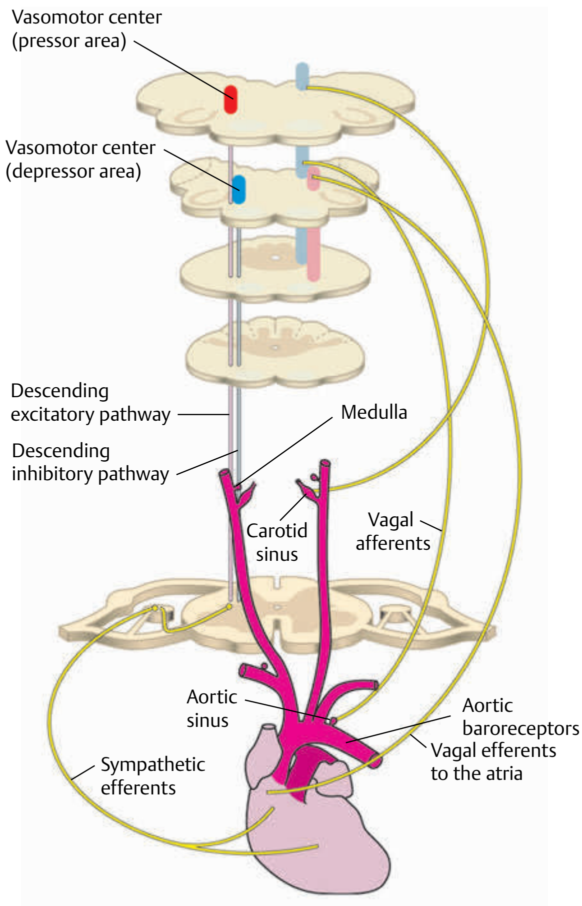

Fig. 7.34 The baroreceptors send information to the medulla, which then regulates the diameter of blood vessels, controlling blood pressure and flow. Reproduced from Michael and Sircar, *Fundamentals of Medical Physiology* © 2010. Thieme Publishers, New York.

medulla. The sympathetic portion of autonomic control has receptors located in the sinus node of the myocardium. Stimulation of these receptors by norepinephrine increases heart rate, increases force of contraction, and dilates the coronary arteries. Sympathetic stimulation in the peripheral blood vessels results in vasoconstriction.[217] The sympathetic portion of the ANS can stimulate the adrenal glands to secrete epinephrine during exercise, which is carried through the bloodstream. The parasympathetic portion of the ANS influences resting heart rate through the vagus nerve (cranial nerve X), decreasing the force of heart contraction.

> The clinician monitors blood pressure and heart rate and rhythm by auscultation or palpation of the pulses. The clinician monitors these vital signs at rest, with position change, and during activity. The clinician monitors vital signs in clients with a history of poor modulation or regulation of the cardiovascular system. The extremities are examined for color and temperature, and the limbs are examined for signs of edema. The clinician monitors vital signs with exercise and activity.

Patent ductus arteriosus (**Fig. 7.35**) can occur in babies born preterm as well as at term, but it is much more common in premature babies, who are also more vulnerable to its effects of decreased oxygen-rich blood flowing to the body and increased pressure in the arteries of the lungs.[218] In babies weighing 1,000 g or less, congestive heart failure can result, and treatment with surgical ligation is required to permit survival.[219]

Children with CP have been shown in research studies to be less active than children without disability, with lower maximum oxygen consumption, muscle endurance, and peak anaerobic power.[220] Physical conditioning programs with cardiopulmonary fitness have shown that many children and adults with CP can train safely at 70 to 85% of maximum heart rate levels. The effects on longevity and health have yet to be studied.

With adult-onset cardiovascular disease, coronary heart disease and stroke share several risk factors, including hypertension, elevated cholesterol, diabetes, and smoking.[221] Atrial fibrillation is associated with increased risk for stroke.[222] People who do experience a stroke may have cardiac impairments, such as ischemic heart damage, cardiac arrhythmias, and decreased heart rate variability (HRV).[223] In addition, hemiparesis and poor motor control after stroke often result in low levels of physical activity, which are risk factors for new cerebrovascular and cardiovascular events. Cardiovascular fitness after stroke may be only 50 to 70% of that of age- and sex-matched sedentary peers.[224]

Researchers evaluated cardiovascular system responses post-TBI to predict neurological injury severity and outcomes.[225,226] In a healthy cardiovascular system, heart rate varies. Loss of this variability in brain injury may indicate

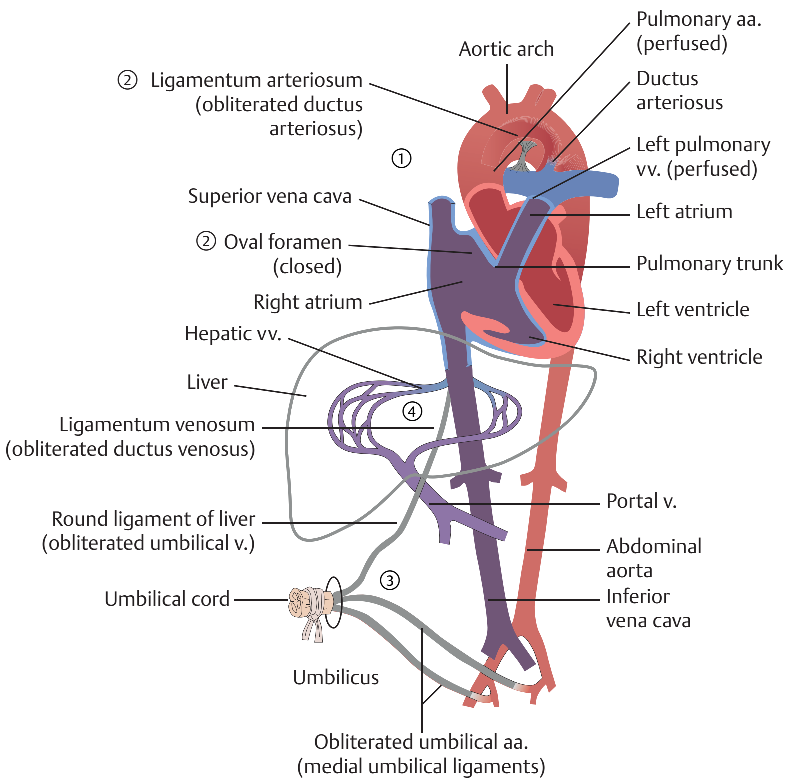

Fig. 7.35 Fetal circulation changes to postnatal circulation as described in the drawing. If the oval foramen and ductus arteriosus fail to close, fetal circulation persists, allowing blood to flow between the aorta and the pulmonary arteries. This strains heart function, as oxygen-rich blood mixes with oxygen-poor blood and can cause increased blood pressure in the arteries of the lungs. Reproduced from Gilroy and MacPherson, *Atlas of Anatomy, 3rd edition* © 2016. Thieme Publishers, New York.

① As pulmonary respiration begins at birth, pulmonary blood pressure falls, causing blood from the right pulmonary trunk to enter the pulmonary arteries.
② The foramen ovale and ductus arteriosus close, eliminating the fetal right-to-left shunts. The pulmonary and systemic circulations in the heart are now separate.
③ As the infant is separated from the placenta, the umbilical arteries occlude (except for the proximal portions), along with the umbilical vein and ductus venosus.
④ Blood to be metabolized now passes through the liver.

loss of autonomic input to the baroreceptors, which are responsible for sensing blood pressure changes and adjusting heart rate accordingly. This loss was correlated to poor survival prognosis in one group of patients studied.[225]

Another cardiovascular event post-TBI that occurs in some patients is a syndrome of persistent paroxysmal sympathetic and motor overactivity to noxious stimuli (suctioning of fluids through a tracheotomy, full bladder, medical procedures, etc.).[226] Although a sympathetic response to adverse stimuli is to be expected, the inability to regain control after the stimulus has been removed may be the cause of this dysautonomia, which is associated with poorer outcomes.

Digestive System

The digestive (gastrointestinal) system is controlled centrally in both the brainstem and the cerebral cortex. Swallowing involves cranial nerves V, VII, IX, X, and XII. These cranial nerves are involved in the control of chewing and in sensory and motor functions of the tongue, pharynx, and larynx. Cranial nerves are peripheral nerves that synapse directly on the brainstem. The initiation of swallowing is voluntary, with central connections to the sensory and motor cortex, cingulate gyrus, and the insula. The cerebellum may also play a role in timing and sequencing of swallow.[227]

The pharynx at the top of the esophagus is controlled by skeletal muscles innervated by cranial nerves. The esophagus has both skeletal and smooth muscle. The upper esophageal sphincter is controlled by skeletal muscle, whereas the lower esophageal sphincter is controlled by smooth muscle. The vagus nerve responds to mechanosensors in the esophagus to control movement of contents to the stomach. The vagus nerve also controls gastric tone and motility. Both the vagus nerve and the spinal afferents supply the small intestine and proximal colon.[227]

Although the diaphragm is considered part of the respiratory system, the esophagus passes through its crural portion (**Fig. 7.36**).[207,228] This portion of the diaphragm must cease contraction briefly to allow food to pass through the esophagus and may be controlled by medullary or spinal neurons or even more peripherally.[228] Excessive relaxation of the crural diaphragm is implicated in gastro-esophageal reflux disease.

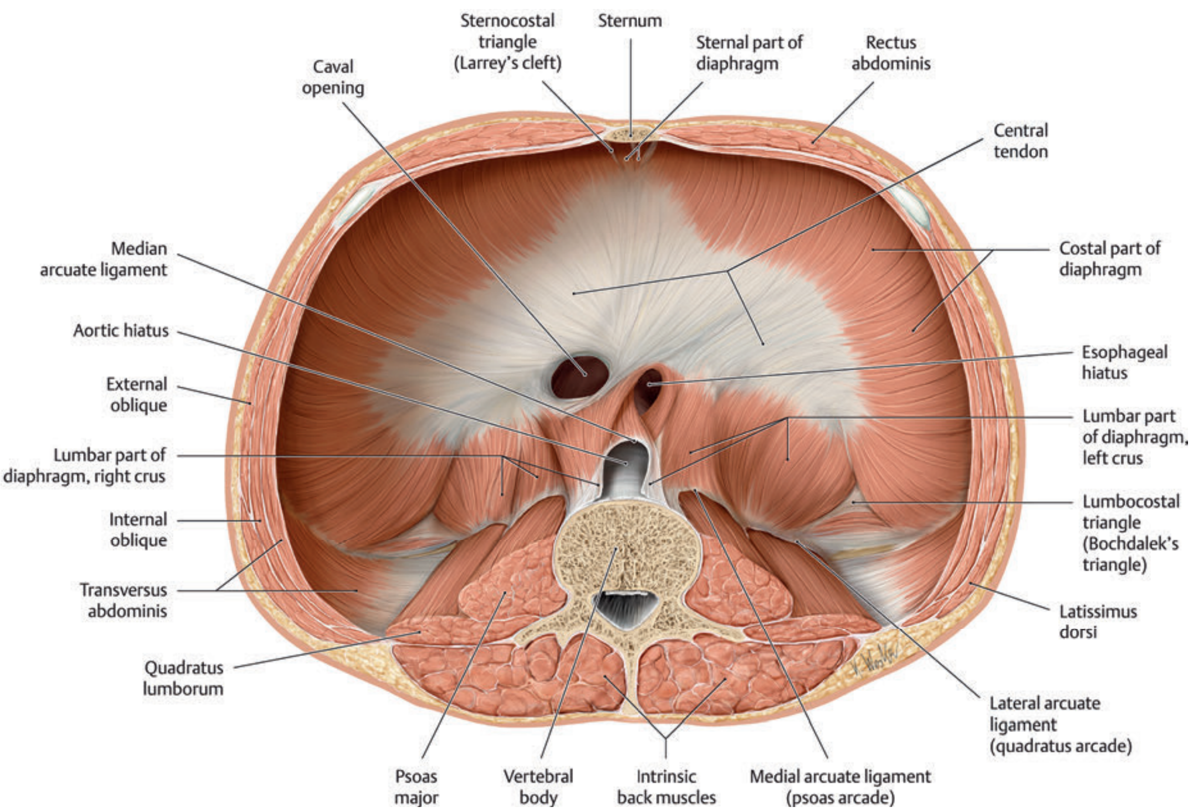

Fig. 7.36 The digestive system includes portions of the diaphragm as it surrounds the esophagus. Diaphragm activity, esophageal sphincter activity, gastric and intestinal motility can be impaired in people post stroke, post TBI, and with CP. Reproduced from Schuenke et al, *General Anatomy and Musculoskeletal System, 2nd edition* © 2014. Thieme Publishers, New York.

The clinician examines sensory and motor functions of the oral area and swallow mechanisms and may be involved in videofluoroscopic testing of swallow. Testing includes eating and drinking within parameters of safety. The clinician palpates muscle activity of the thoracic spine and chest, diaphragm, and abdominal muscles in various postures and movements during eating, drinking, breathing, and voicing. The clinician advocates for referral to specialists in nutrition, swallowing, and gastroenterology when indicated.

Swallowing impairments (dysphagia) are common in children with CP, with both oral control and coordination of swallow–breathe impairments possible.[229] Digestive system impairments are common in children with CP[230] and tend to increase in severity with the severity of CNS damage. The primary impairment is gastrointestinal dismotility[231] seen during videofluoroscopy and ultrasound examinations. Gastroesophageal reflux is common, with prolonged gastric emptying and abnormal esophageal motility. Chronic constipation is also common, with prolonged transit in the proximal colon seen in studies.[231,232] Chronic constipation contributes to increased intra-abdominal pressure and possibly to gastroesophageal reflux disease (GERD).[230] Colonic transit time was longer in children with CP who were nonambulatory in the study by Park et al.[232]

Poor nutrition and weight gain may be related both to feeding difficulties and to GERD. Campanozzi et al[230] suggest that the neck hyperextension posturing in children with CP and GERD may be due not only to posture and movement impairments but also to efforts to find a comfortable position due to GERD.

Clients poststroke also show swallowing and gastrointestinal motility impairments similar to those seen in children with CP. Strokes affecting the brainstem disrupt reflex swallowing, whereas lesions in the precentral gyrus and internal capsule affect voluntary swallow and peristaltic coordination. Clients with combined brainstem and cortical lesions with cranial nerve involvement are at the greatest risk for dysphagia.[227] Brainstem lesions are associated with decreased tone in the lower esophageal sphincter and increased tone of the upper esophageal sphincter. Vagal nerve dysfunction may cause gastrointestinal hemorrhage (stress ulcers). Gastric emptying may be delayed. Colonic transit time may be delayed, especially in the right colon, and colorectal dysfunction may be due to a combination of the CNS pathology as well as immobility and altered dietary habits.[227]

In patients with acute post-TBI, trauma releases cortisol, adrenocorticotropic hormone (ACTH), and gastrin.[233] This hyperadrenergic response increases rapidly within 24 hours of injury and correlates to the severity of injury. Subsequent acid secretion in the digestive system leads to stress bleeding ulcers, which can be fatal.

Integumentary System

The skin (integument) protects the body from environmental toxins and microbes, protects from injury, and prevents loss of water.[234] It is continually shed and replenished, as layers are formed in the bottommost of the five layers of the epidermis, and pushed upward. Skin layers form in utero from 21 days as a single layer, adding layers and complexity until postnatal maturation. Below the epidermis lies the dermis, which consists of fibroblasts, elastin, and collagen. Underneath the dermis lies the subcutaneous fat, then the muscle fascial network (**Fig. 7.37**).

The epidermis and dermis are richly supplied with sensory receptors (**Fig. 7.38**). These include Merckel's disks, free nerve endings, Meissner's corpuscles, Pacinian corpuscles, Ruffini's endings, and hair follicle receptors. Merkel's disks are slowly adapting mechanoreceptors that sense pressure and texture. They are found in hairy and glabrous skin. Free nerve endings are numerous and detect temperature, pressure, touch, stretch, or pain. Different types of free nerve endings adapt to stimuli at various rates. Meissner's corpuscles are mechanoreceptors that sense light touch and are rapidly adapting.

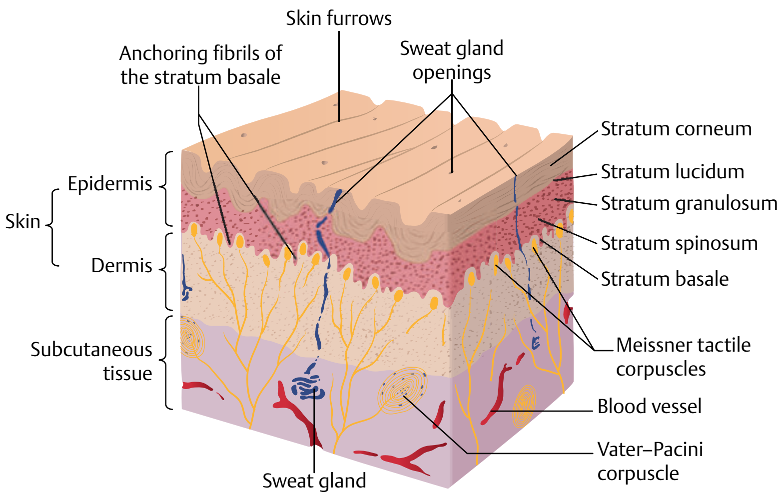

Fig. 7.37 Layers of the skin. Modified from Schuenke et al, *General Anatomy and Musculoskeletal System, 2nd edition* © 2014. Thieme Publishers, New York.

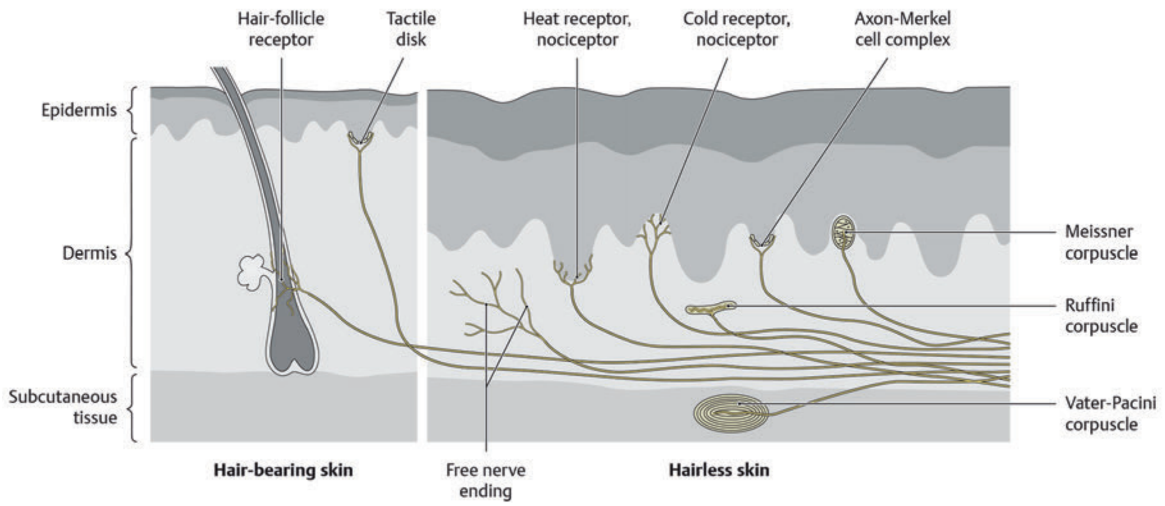

Fig. 7.38 Sensory receptors in the skin. There are a variety of sensory endings in the hairy skin and glabrous (palms of hands, soles of feet, lips, nipples) skin. See section on tactile receptors for details of how this sensory information travels to the central nervous system. Reproduced from Schuenke et al, *General Anatomy and Musculoskeletal System, 2nd edition* © 2014. Thieme Publishers, New York.

They are numerous in glabrous skin. Pacinian corpuscles are mechanoreceptors sensitive to vibration and pressure, such as indenting the skin, but are not sensitive to slow pressure because they are rapidly adapting. They are not as numerous as other receptors. Ruffini's endings are slowly adapting mechanoreceptors that sense stretch in glabrous skin. They contribute to kinesthetic sense of fingertip movements. (Ruffini's endings are also in joints, sensing joint angle changes). Hair follicles have free nerve endings at their roots that sense movement and touch.[235]

The clinician using NDT examines the skin, noting areas of integrity and lesions, and measures the size of any lesions. The clinician examines the suppleness and mobility of the epidermal layers over the layers of fascia and muscle beneath, examining for signs of hydration. The clinician notes general temperature of the skin and examines the client continuously for dermal responses to therapeutic interventions. This includes color and temperature changes, signs of histamine responses, signs of ischemia, and signs of autonomic nervous system modulation impairments. The clinician palpates scar tissue and callouses to examine their texture, depth, and compliance or adherence to deeper layers of epidermis and dermis.

Skin condition is considered a part of physical examination by many professionals concerned with healthy functioning. The skin of premature babies is not as thick and as fully developed as it is in term babies,[234] and aging skin becomes thin and flattened as it loses elastin and collagen.[236] Skin in these two groups is more fragile than skin in other age groups and will therefore require precautions against injury.

Skin integrity can be compromised by mechanical loads causing ischemic pressure and can be a primary source of morbidity when open ulcerations result. People who are elderly, bedridden, or use wheelchairs are particularly vulnerable. Factors such as shear forces, moisture, temperature elevation, friction, and sensory impairments may hasten the development of pressure ulcers.[237]

Scarring of the skin from surgeries can restrict joint mobility. The skin areas surrounding scarring may show anesthesia or paresthesias. Surgical scarring is common in clients with CP due to orthopedic surgeries, ventricular peritoneal shunt placement, gastrostomy placement, and cardiopulmonary surgeries associated with premature birth. Cranial surgeries are common with intracranial hemorrhages causing stroke or due to TBI. Clients with TBI may have multiple injuries over their bodies requiring surgeries. Devices implanted below the skin, such as shunts; pharmaceutical reservoirs for medication delivery, such as pumps and ports; and pacemakers can adhere to skin layers, restricting movement and causing discomfort.

Autonomic responses can cause skin discoloration, skin temperature changes, perception of warmth or coldness in an extremity, and sweating. These symptoms are commonly seen poststroke,[238] and as a part of reflex sympathetic dystrophy or similar autonomic dysfunction, are multisystem in nature. Svedberg et al[239] found that children with CP had significantly lower skin temperature than children without disability in both hands and feet. Children with CP who were nonambulatory had lower skin temperature in the feet than children with CP who were ambulatory.

7.2 NDT Practice Model in Action

The clinician records findings of observations, handling, and testing, which may generate more questions. Questions are part of information gathering, as described in Chapter 6, and the NDT Practice Model shows how all portions of interaction with clients continuously overlap and reinforce each other. Once again, information gathering and examination are not always distinct entities, with one completed prior to moving on to the next phase. Rather, examination may lead any member of the process to further question how the client functions within his or her world or to answer questions generated by the client or family.

For example, a therapist who handles a client as he attempts to step up a curb notes that the client can lift and place the foot up onto the curb. However, once the foot contacts the curb, the client contracts the hip, knee, and ankle extensors near the end range of extension while pushing toward the back of the base of support, causing the weight of the entire body to move dangerously backward, which could easily lead to falling. The client and family note that this same pushing backward movement occurs when the client attempts to transfer to the passenger seat of the car by himself, and they ask the clinician if the two movements may be related. This car transfer had not been previously discussed in information gathering, but it now becomes an addition to the information about the client's daily routine. This example once again shows how interactive the process of NDT practice is, both among all people involved with the client and among the different phases of client interaction.

7.3 Summary

Examination of a client with CP, TBI, stroke, and related neurodisabilities requires knowledge of the relationships of participation, activity, and body structure and function in many systems. Because clients with neurodisabilities almost always have impairments in several body systems, examination requires skilled observation and can be time consuming. Therefore, the clinician using NDT structures examination based on information gathered in the initial interview, outcomes stated by the client and family, initial observations of posture and movement, and information from handling for examination to streamline and customize examination.

Clients examined by the clinician may not be able to fully participate in standardized and nonstandardized testing. This limitation reinforces the clinician's need to develop excellent observation, palpation, and handling skills, as well as careful listening to the client and family, with the willingness to examine, listen, and evaluate during each intervention session.

Although third party payers and employers require written documentation in a timely manner, the clinician realizes that examination is complex and, therefore, ongoing. Examination does not stop when initial documentation is completed. Examination requires vigilant reexamination, which is why the NDT Practice Model shows that examination is always taking place in any interaction with a client and family.

As this chapter and the NDT Practice Model show, the therapist who uses NDT relies on many sources of knowledge to inform practice during examination. These include, but are not limited to, the following:

- Knowledge of function (participation and activity) and its impact on future functioning.
- Knowledge of multisystem body functions, including postural control and movement execution.
- Knowledge of single body system integrities and impairments.
- Knowledge of motor control, motor learning, motor development, and neural plasticity.
- Knowledge of how and why multiple systems develop compensations.
- Knowledge of cognitive/learning theories, communication theories, and psychosocial theories.
- Knowledge of handling skills to examine body systems while noting the effects of handling on function, posture, and movement.
- Knowledge of standardized and nonstandardized tests.

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8 Evaluation and Developing the Plan of Care

Marcia Stamer

This chapter develops and explains the evaluation process of the Neuro-Developmental Treatment (NDT) Practice Model. Its purpose is to make cognitive processes of clinical reasoning explicit. Evaluation involves determining why clients do what they do. On a detailed and interactive level, clinicians using NDT constantly seek to understand the relationships among participation in individual contexts, activity, and body structure and function; prioritize these factors in their analyses of their clients' abilities and disabilities; and use this problem-solving process to set prognoses, measurable functional outcomes, and the plan of care.

The last sections provide information and guidelines for mentoring students and novice clinicians in evaluation processes, and the details of two outcome writing and measurement systems.

Learning Objectives

Upon completing this chapter the reader beginning to learn about NDT will be able to do the following:

- List the sequence of evaluation processes in the NDT Practice Model.
- Write a profession-specific, measurable functional outcome for a client from his or her practice, and identify whether the outcome is an activity or a participation outcome.
- Identify at least two body system integrities and two body system impairments that influence the outcomes listed above.
- List the components of the plan of care important to the NDT Practice Model and describe briefly why each is important.

Upon completing this chapter the reader who is more experienced with NDT will be able to do the following:

- Use the evaluation process in the NDT Practice Model to document evaluation of clients from his or her practice.
- Write functional outcomes, quickly determining how changing contexts (personal and environmental) can lead to additional outcomes and greater activity/participation for clients from his or her practice.
- Describe the interaction of body systems typically evaluated by the profession of the reader, emphasizing how one system may alter, intensify, or create new integrities or impairments in another body system.
- Describe the interactions of body systems, activities, and participation in terms of their mutual influences on a client from his or her practice.
- Write an individualized plan of care for clients from his or her practice, including all components listed in this chapter.

Upon completing this chapter the advanced reader who is experienced with NDT will be able to do the following:

- Write evaluations and plans of care for clients in concise descriptions that can also be used to teach the process to novice clinicians.
- Explain to novice clinicians, team members, clients and family members, and peers the structure and purpose of the NDT Practice Model evaluation and plan of care content in terms applicable to each person's role in the therapeutic process.
- Develop problem-solving templates to explain the relationships among participation/participation restrictions, activity/activity limitations, and body system integrities/impairments to instruct him- or herself and others in the possibilities of these interactions as they relate to client outcomes.

8.1 Evaluation Using the Neuro-Developmental Treatment Practice Model

The evaluation portion of practice (**Fig. 8.1**) asks the question, Why? Why can clients do what they can do, why can't they do what they can't do, and what can the clinician do about it? Evaluation is a complex process dependent on the clinician's knowledge base of pathophysiology, domains of functioning, typical and atypical development throughout the life span, and the lifelong influences on functioning of effective, ineffective, and compensatory postures and movements. Evaluation requires profession-specific abilities to synthesize and analyze examination findings. The process requires cognitive problem-solving skills using analytic (hypothesis-guided inquiry or hypothetico-deductive

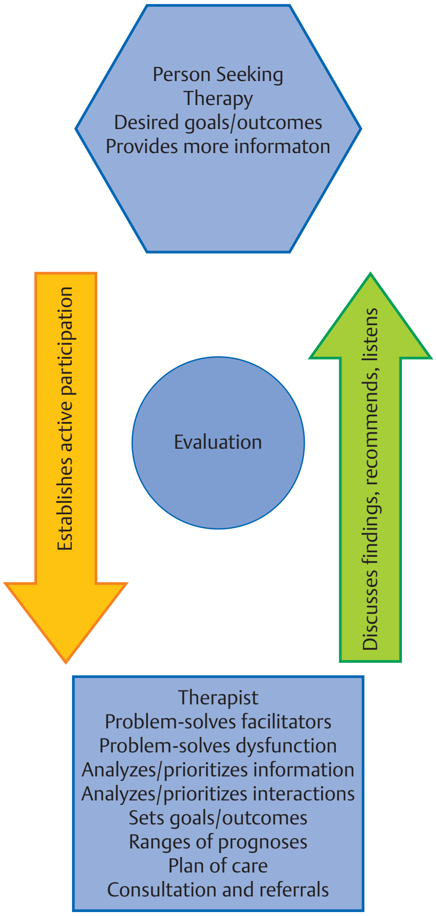

Fig. 8.1 Evaluation is the problem-solving and hypothesizing portion of the Neuro-Developmental Treatment Practice Model.

reasoning) and nonanalytic strategies (forward reasoning or pattern recognition), and understanding the situation from the client's perspective, life story, and context (narrative reasoning).[1,2,3,4,5,6,7]

Evaluation is a process of assigning meaning to all of the information gathered through client/family interviews and discussions, observation of all domains of human functioning (participation, activity, body structure and function), handling for examination, and standardized and nonstandardized testing of all domains of human functioning. Clinicians evaluate this information in accordance with their professional practice acts.

Clinicians also seek information from theoretical sources, such as theories of motor control, motor learning, motor development, neuroplasticity, human behavior, and related areas of inquiry to evaluate their findings. See Unit III for detailed information on motor control, motor learning, motor development, and neuroplasticity theories. In clinical practice, therapists must decide how to synthesize and analyze information from these many fields of inquiry, interpreting theoretical possibilities and research findings to form the rationale for intervention strategies. On a deeper level, the *why* questions lead the clinician to hypothesize about or recognize relationships: Do each of the impairments directly cause activity limitations and participation restrictions, or do combinations of impairments and context have a greater impact and correlation to activity and participation than any one system would have by itself? Are there impairments or combinations of impairments that affect activity and participation more than others do? Are there impairments that influence other impairments, increasing their severity or preventing improvement in structure or function?

For example, in excessive and sustained coactivity of muscles around a joint, joint mobility through its full range is prevented, and muscular strength and endurance cannot fully develop, resulting in secondary impairments of joint soft tissue restrictions, muscle stiffness and morphology changes, weakness, and decreased muscle endurance. This in turn may increase co-activity force and endurance in very small joint ranges in voluntary attempts to control a limb position or to move, further preventing mobility and strength development and resulting in permanent morphology changes within the muscles.

8.1.1 Evaluation Requires a Framework

Describing how clinicians use Neuro-Developmental Treatment (NDT) to analyze and synthesize information is a daunting task. However, it is necessary to describe and explain the problem solving that NDT clinicians use to create a deeper understanding of NDT practice.

Evaluation *requires* a model to structure its tenets—a reference for hypothesis generation and pattern recognition. A set of beliefs about organizing and interpreting information is inherent in evaluation for any clinician practicing with any clinical approach, whether the clinician is able to express these beliefs explicitly or not. In NDT, the NDT assumptions and philosophy describe the beliefs that NDT holds. The NDT Practice Model provides the structure for these beliefs and assumptions upon which evaluation depends. Because of this organizing and interpretive structure, the way an NDT clinician interprets and applies all information to intervention is distinct from other approaches.

8.1.2 What Do We Already Know about How Clinicians Evaluate and Treat?

Given that evaluation assigns meaning to all information gathered and measured, there needs to be a process whereby the clinician recognizes, groups, and prioritizes the information to determine whether intervention is warranted. How do clinicians perform this process in the professions of occupational therapy, physical therapy, and speech-language pathology? A search for literature that explains the evaluation process reveals a great paucity of information, with only a few studies addressing the subject.[2,3,8] These few studies of clinical decision making or clinical reasoning outline an evaluative process that includes prioritizing problems, deciding which problems are the largest barrier to function, and which problems may be most amenable to intervention.

How this process works requires qualitative research methods. The most detailed literature concerning the evaluation process focuses on the difference between novice and expert practitioners, describing their problem-solving processes. Qualitative research methods based on structured and repeated interview analysis and coding are used to understand the cognitive processes that clinicians use during clinical reasoning.[4,5,9,10,11,12,13] Further information about this process is found in the section on Mentoring Students' and Novice Clinicians' Problem-Solving Activities. It is the basis for sample teaching strategies for students and novices.

Gaining expertise in evaluation and intervention appears to be a developmental process for the clinician.[10] Although gaining effective evaluation and intervention skills is unquestionably a highly complex phenomenon, this chapter identifies salient characteristics of the process.

8.1.3 A System for Evaluation Using the NDT Practice Model: The Problem-Solving Process

How can a clinician organize, analyze, and prioritize the vast amount of clinical information using the NDT Practice Model? Let's begin with a general pathway through the evaluation process that can assist clinicians in problem solving, synthesizing, and analyzing information in preparation for intervention.

Evaluation

Summary and Prioritization of Participation /Participation Restrictions and Activities/Activities Limitations with Contextual Factors

↓

Summary and Prioritization of Body System Integrities and Impairments with Contextual Factors as They Affect Participation and Activity

↓

Set Participation and Activity Outcomes

↓

Analysis
(Clinical hypotheses of relationships among all domains)

↓

Analysis
(Potential for change and prognosis based on optimal participation, activity, body structure/function, and contextual resources decreasing function in participation, activity, body structure/function, and lack of contextual resources)

Listing and Prioritizing Information

Throughout the evaluation process, the clinician must realize that no two clinicians will make the exact same lists and priorities, even if they are of the same profession. Each clinician's own contextual factors, educational background, and experiences influence the evaluation. In addition, as the clinician becomes more familiar with the client, the lists of participation, activity, and impairments are refined. As the client changes, these lists also change. Finally, it is likely that clinicians in the different professions (occupational therapy, physical therapy, speech-language pathology) will make different lists and priorities.

After the information gathering and examination, the clinician lists and prioritizes information in each domain and context in order of importance for the client and family.

- The client's participation/participation restrictions within the client's personal, family, and community facilitators and barriers.
- The client's activities/limitations within the client's personal, family, and community facilitators and barriers.

This individualized list is the rationale for detailed information gathering and examination. No two prioritized lists will ever be the same; each client will have a unique list. The therapist using NDT considers this list to be the foundation for further analysis, outcome setting, and intervention planning.

Next, the clinician hypothesizes which body system integrities and impairments influence participation/restrictions and activity/limitations. The list is prioritized based on hypotheses of influence each system has on participation and activity. Therefore, listing and prioritizing single- and multisystem integrities and impairments are highly individualized. For example, let's assume that one client's participation restriction is that she cannot unload her dishwasher at home. We will assume the same restriction for a second client for comparison purposes. The two clients, however, have different integrities and impairments that are hypothesized to cause the restriction. Table 8.1 provides a comparison.

Furthermore, the context of unloading the dishwasher will influence intervention. Perhaps for the first client, unloading the dishwasher has been a daily skill used for many years, and it is important to that client to regain the skill. Perhaps for the second client, the skill is easily taken over by her husband, who frequently performed this task anyway. It may not be so important for the second client to set unloading the dishwasher as an outcome for intervention, and she may choose another outcome that is more important to her.

Setting Outcomes with the Client and Family

Participation and activity outcomes for intervention are set collaboratively between the therapist and the client and family. The client and family often know what they want as outcomes: "I want to walk again," "I just want her to call me 'Mom'," "I want to go back to work," "I want him to eat at the table with us." These outcomes are always respected by the NDT clinician, even if the clinician thinks that the outcomes may not be attainable. Clinicians

Table 8.1 Comparison of two clients with the same desired participation outcome

Client One	Client Two
Integrities (prioritized)	Integrities (prioritized)
• Intact cognition	• Adequate strength in shoulder complex for overhead reach
• Intact motor planning	
• Adequate passive range of motion in UEs	• Ability to use trunk control in all three planes of motion with UEs supported on countertop
• Initiates shoulder motions below 90°	
Impairments (prioritized)	Impairments (prioritized)
• Lacks UE movement against gravity above 90° shoulder flexion	• Poor awareness of body position in space; visual attention to body part improves awareness
• Lacks thoracolumbar extension mobility to assist overhead reach	• Unreliable gradation of muscle force production—uses either too much or too little grip force (visual attention to task helps), therefore grasp of items in dishwasher is unreliable
• Delayed initiation and limited ability to sustain postural extension in LEs, notably hip extension and isometric ankle extension in weight bearing	• Unpredictable timing of muscle activity of LE postural extensors for reliable postural stability during reach down and diagonally to dishwasher, followed by the overhead reach
• Lacks control of eccentric LE extension when reaching down into bottom dishwasher rack	• Delayed eccentric extension in LEs when reaching down to dishwasher
	• Motor planning impairments suspected

Abbreviations: LE, lower extremity; UE, upper extremity.

Note: We can see that, although the task is the same one, the two clients differ vastly in the integrities and impairments that are hypothesized to contribute to the restriction. Therefore, the intervention for each of these clients requires different strategies. The integrities and impairments will also influence participation outcome setting by the client and clinician and will influence the length of time predicted to achieve the selected outcome.

are well aware that setting outcomes with their clients requires compassion, humility, and the ability to express possibilities as knowledgably as possible. Talking with the client and family about what can be accomplished today, this week, this month, and adjusting outcomes, based on the knowledge that the individuals involved gain with time and work as they build a therapeutic relationship, is required. This approach helps both client and clinician to strive for attainable outcomes over time.

Writing Outcomes

Outcomes are the anticipated participation and activities (functions) that are expected under stated contexts. They include the following information:

1. The name of the client. Occasionally the name of the family appears in an outcome.
   a. Mrs. Jones.
   b. Claire's mother.
2. An action verb that is observable.
   a. Mrs. Jones will stand.
   b. Claire's mother will feed.
3. The functional performance itself.
   a. Mrs. Jones will stand up from her bed.
   b. Claire's mother will feed Claire.
4. The contexts (conditions and criteria) of the function.
   a. Mrs. Jones will stand up from her bed every morning next week after placing her feet on the floor while her husband supports the left side of her trunk and shoulder.
   b. Claire's mother will feed Claire pureed fruits from an adaptive spoon (may state brand or type) at lunch tomorrow, completing the entire meal within 20 minutes while Claire sits in her adapted high chair with all straps secured.

Note that the functional participation or activity is stated immediately after the verb. With our clients who change slowly or who are anticipated to achieve a limited number of functions, the supporting contexts (conditions and criteria) are stated in a detailed way so that changes in these details can denote progress.

Take care to separate the function from the conditions under which that function will occur. For example, an outcome may be written "Johnny will sit . . . ." Sitting may be the function the clinician targets or it may be the condition under which Johnny will do something else. "Johnny will eat his dinner while sitting in his booster chair" or "Johnny will write his name on his English paper when sitting at his desk in his wheelchair" may better reflect that sitting is a condition of the function and not the function itself if the clinician is measuring eating or writing as an activity rather than achieving sitting activities.

Contexts (conditions and criteria) describe where, when, for how long, and how well the client performs a particular activity. Johnny may sit in his wheelchair in his classroom to complete his spelling test for 15 minutes with his left hand holding the paper down while using a dynamic tripod grasp on his pencil.

In writing functional outcomes this way, we see that they are measurable and reproducible. Any peer of the clinician will be able to observe and measure the outcome, reproducing the context as stated.

The NDT clinician plans outcomes for each client that reflect more skillful function over time. However, is the progression from session outcome to long-term outcome simply a manipulation of performing a functional skill longer or faster, with more strength or better range of motion? Or does the function itself change over time? Any of these measures may change to reflect progress, and the clinician thinks carefully about what will change and how it will change to influence functional performance as the client moves through each intervention session. A clinician may change the following:

- The participation or activity function itself.
- The conditions and criteria under which the function will be performed. These conditions and criteria include the following:
  - The various environments the client will function in.
  - The range of personal contextual factors, such as personality and family structure and function.
  - The people the client will interact with while functioning.
  - Criteria such as the time of day the function will be performed, the time required to complete the function, how far or how long the function is performed.
  - The posture and movement used to perform the function.

For example, a client who is recovering from a stroke or traumatic brain injury (TBI) or a child with cerebral palsy (CP) after a hip surgery may quickly recover the skill of sitting up again and move on to more challenging activities in standing and walking, or progress from no speech and gesturing to using single words and multiple gestures. The clinicians treating these clients may predict that participation and activity domain functions will progress quickly based on the pathology, medical history of the client, and predictable patterns of recovery. Therefore, outcomes reflect performance changes in several functional skills.

Conversely, a 10-year-old child with CP with Gross Motor Function Classification System (GMFCS),[14] Manual Ability Classification System (MACS),[15] and Communication Function Classification System (CFCS)[16] Level V functioning may achieve a few participation and activity functions only over many years' time. With this child, sensitive measures of the environmental conditions and performance criteria are critical to show progress and, in fact, may show changes in participation *because* the conditions and criteria change. For example, for those caring for this child, there is a clear advantage to the child's ability to eat orally safely when fed by his parents, aides at school, a respite care worker, and an aunt versus only being able to eat when his mother feeds him. The activity remains the same for this child—that of eating when fed by an adult—but his skill in eating safely when fed by less trained and less familiar adults allows him to be cared for at home and at school, and when his parents are out of town. His participation has broadened as a result.

Outcomes may be categorized by length of time to complete. In the initial documentation, clinicians often designate short- and long-term outcomes, but the lengths of time vary for each clinician according to workplace setting. Therefore, it is wise to record a time length for these outcomes. For example, a school-based therapist might write 9-month (long-term outcomes) on the individualized education plan (IEP), with the short-term outcomes designated as 3-month outcomes. In contrast, a therapist working at an inpatient rehabilitation facility with adults may view long-term outcomes as those measured after a 3- to 4-week period, whereas a short-term outcome in an acute setting is set to be measured in 3 to 5 days. As we will see in the next chapter, the therapist also sets a session outcome that is functional.

Progression from session to short-term to long-term outcome does not necessarily have to be a graduated change in criteria and conditions. For example, a long-term outcome may be that a client is able to ascend six steps without a handrail on the outside of his home, and a short-term outcome may be to step up a curb to a sidewalk. A long-term outcome may be that a child dresses himself in the morning for school, whereas a short-term outcome is that he dresses himself on Saturday mornings (when there is more time to complete the task). A long-term outcome may be that a teenager feeds himself lunch in the cafeteria at school, whereas a shorter-term outcome is that he feeds himself a sandwich in the classroom with only adults present. Each of these outcomes is itself a participatory outcome, yet the shorter-term outcomes have fewer postural, movement, and contextual demands.

The NDT clinician is often likely to set outcomes established and valued by the client or family rather than those taken from standardized and nonstandardized test items. These tests have the limitation of offering only selected functions (or postures and movements that are said to be functions) to measure and are often not compatible with the highly individualized care provided by the clinician using the NDT Practice Model.

Finally, the clinician using NDT considers lifetime outcomes. Because stroke, TBI, CP, and related neurodisabilities affect people for their lifetime, the clinician is concerned with the effects of participation restrictions, activity limitations, and body system impairments that are likely to change through the years. The clinician considers possible consequences of the relationships among these domains and the possible effects of practicing ineffective postures and movements on the future in terms of years and decades. These variables expand the knowledge that the clinician seeks—that of life span understanding of skill development and decline, variability in people with and without pathology, and the consequences of functioning with ineffective and compensatory posture and movement.

For further information about outcome writing and measuring, see section on Writing Outcomes for Clinical Practice and Statistical Analysis.

Analyzing Relationships among Domains of Functioning

The clinician analyzes the relationship of all domains of the International Classification of Functioning, Disability and Health (ICF), looking at a big picture of how each item of a domain influences aspects of the same domain and other domains. An example in Fig. 8.2 from the body structure and function domain shows the complexity of influences of body systems on each other over time.

The clinician analyzes how participation and activity affect body systems and how single- and multisystem integrities and impairments influence participation/restrictions and activity/limitations. These relationships are not linear, however, and the problem-solving possibilities are complex. Body system integrities can support participation and activity, as well as support function in other systems. Participation and activity can support body system integrities. Impairments can cause participation restrictions and activity limitations, but the restrictions and limitations can also cause further impairments or new impairments. Impairments in one body system can cause impairments in another, and these influences could potentially continue. The NDT clinician considers all of these current and potential future relationships (Fig. 8.3).

Fig. 8.4 and Fig. 8.5 show examples of positive ICF domain function and negative domain function in a teenager with CP.

A Look at the Literature—Linking Impairments to Function

Inherent to the structure in both the ICF model and the NDT Practice Model is that impairments have a relationship to participation restrictions and activity limitations.[17,18] Researchers are careful to make clear that we do not know if the relationship is causal.[17,18,19,20,21,22,23] However, case reports that include examination of impairments, activity limitations, participation restrictions, and contextual factors generate hypotheses about the relationships of each of these categories. They describe intervention with measured outcomes that may assist in determining how impairments influence function (activity limitations and participation restrictions). In Ling and Fisher's[24] case report of a client 4.5 years poststroke with severe upper extremity impairments and a Fugl–Meyer upper extremity motor score of 18/66, the authors/clinicians examined impairments using standardized tests to quantify impairments and functional abilities/disabilities. They also used detailed posture and movement analysis to evaluate and plan intervention for a specific functional outcome. The outcomes were specific to the client's participation needs. Using posture and movement analysis, the authors generated hypotheses about how single-system and multisystem impairments affected these specific functional tasks. Intervention consisted of 8 weekly 1-hour intervention sessions, and intervention strategies were described in detail.

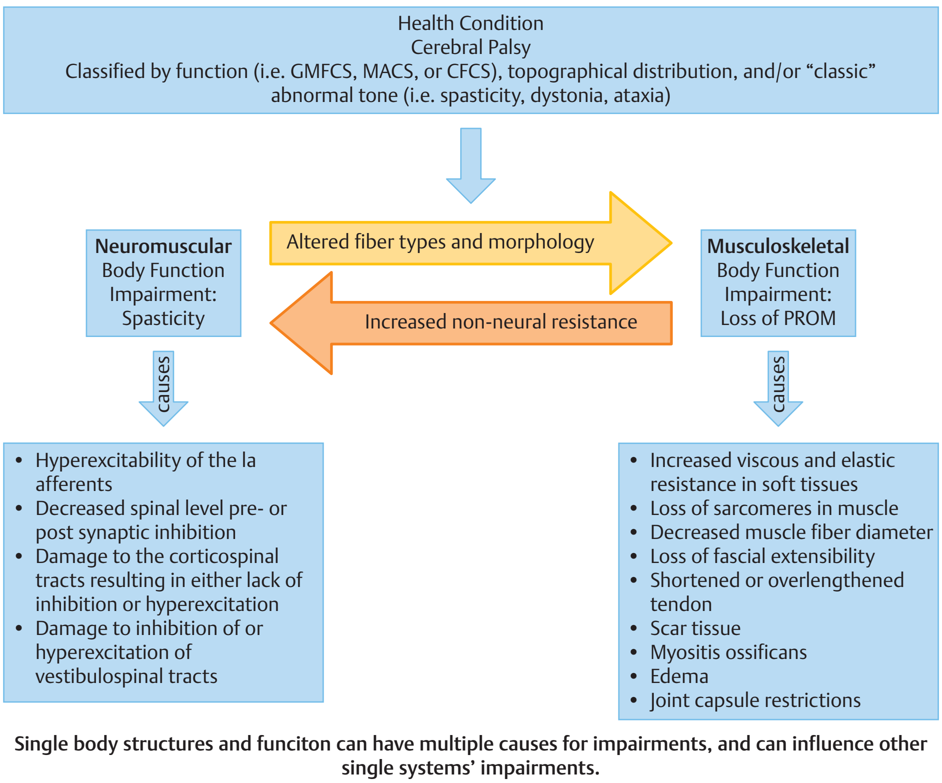

Fig. 8.2 The interrelationship of body structures and functions over time—one example.

The client in Ling and Fisher's case report achieved the task-specific outcomes and maintained these outcomes when measured after 20 weeks with no intervention between week 8 and week 20. Of particular interest is that the Fugl–Meyer score did not change, and individual system impairments showed minimal changes. However, objectively measured *posture and movement strategies specific to the tasks changed, and the client gained participation skills*. The authors suggest that the changes in posture and movement strategies may be critical in improving functional outcomes.

In a study performed by Slusarski,[25] 40 ambulatory children with CP participated in a total of 12 hours of intervention based on NDT principles, with each child working toward individually set functional ambulation goals. In addition, pedographs measured stride and step length, foot angle, and base of support. Cadence and velocity of gait were also measured. Significant positive changes toward age appropriate gait parameters occurred for the group in stride and step length, foot angle, and velocity, with improvements also measured in base of support and cadence. In this study, the intervention strategies were not described in detail in the research report, but they were stated to be individualized for each child. The study showed that pedographs can be sensitive to gait changes in children with CP and that the group improved significantly in four of the six measures of gait toward normal parameters. Keep in mind that "normal parameters" indicate energy efficiency and more normal stresses on joints. *This study linked posture and movement changes to improved gait.*

Arndt et al[26] studied the efficacy of an operationally defined NDT-based trunk intervention protocol on gross motor function (activity) in babies ages 4 to 12 months with posture and movement dysfunction. The protocol for trunk activity was described in the research report. These infants were compared with a group of infants exposed to a structured parent–infant play group on gains on the Gross Motor Function Measure (GMFM) after each group received 10 hours of intervention. An examiner masked to group assignment rated each infant. Both groups of infants improved their GMFM scores, but the NDT trunk protocol group increased their scores significantly ($p = 0.048$) more than the parent–infant play

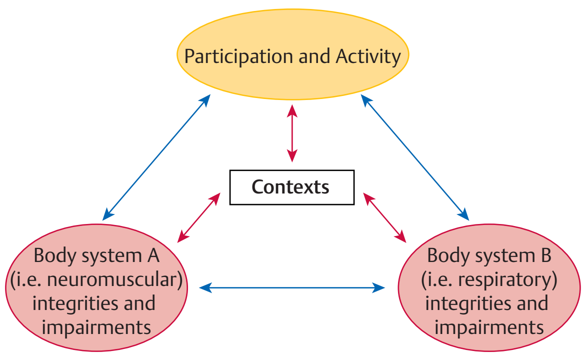

Fig. 8.3 The interrelationships of all domains of the International Classification of Functioning, Disability and Health (ICF). Any number of body systems could be considered in this diagram.

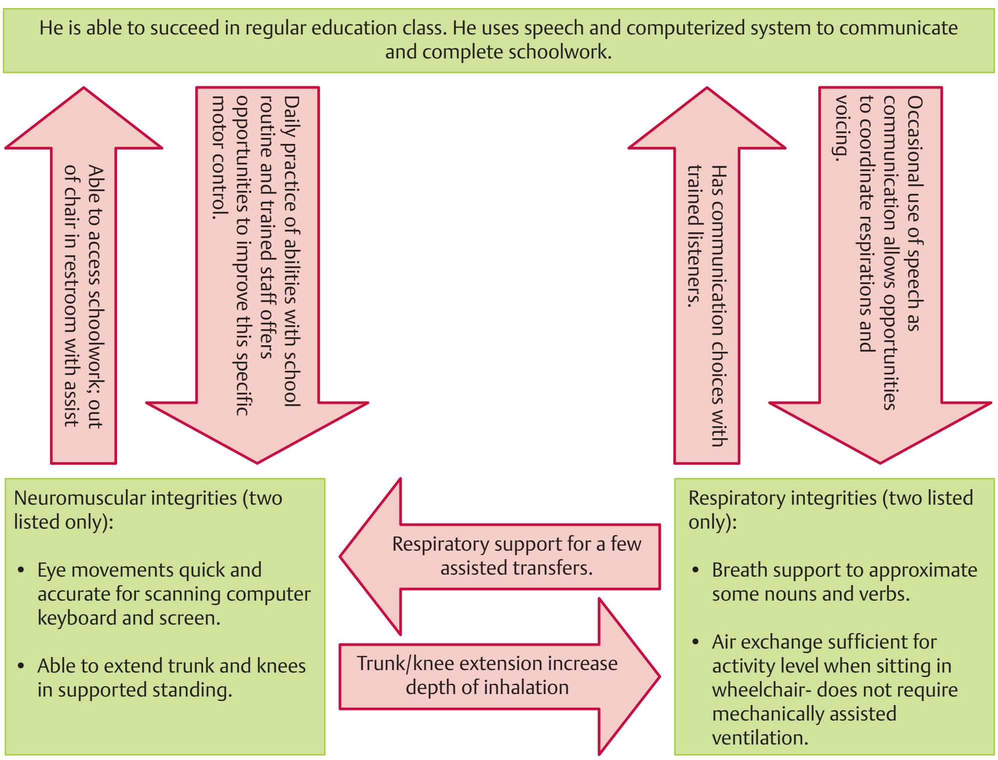

Fig. 8.4 An example of a teenager with severe dystonia using the information in Fig. 8.3 (participation, activity, and body system integrities).

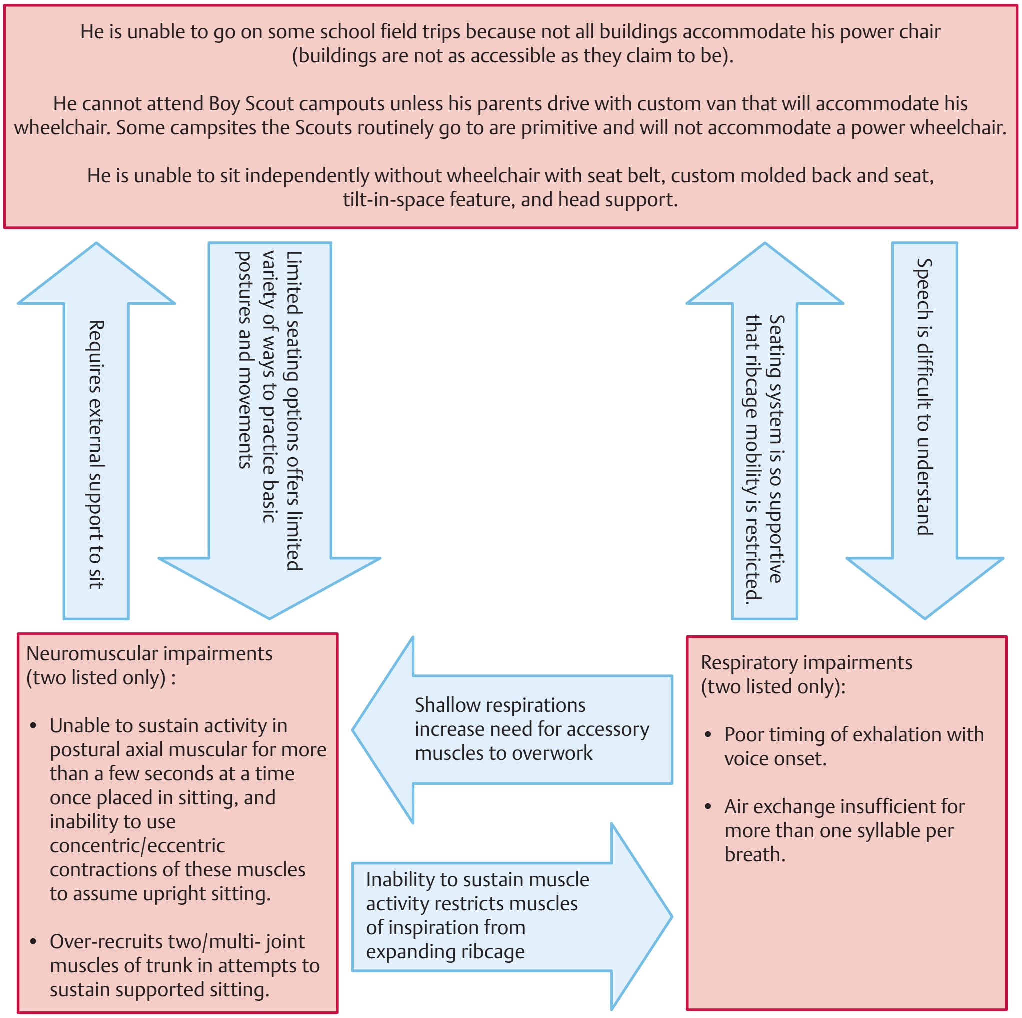

Fig. 8.5 Example of the same teenager with severe dystonia using the information in Fig. 8.3 (participation restriction, activity limitations, and body system impairments).

group, and maintained the skills in a 3-week follow-up. *This study showed posture and movement changes linked to gains made on a standardized test.*

Linking Integrities and Impairments to Activity and Participation Using the NDT Practice Model

Clinicians using NDT have the opportunity each time they evaluate and provide intervention services to a client to hypothesize how impairments may be linked to activity and participation. Each intervention is designed and planned around a functional outcome. This outcome is recorded in the documentation, and then the clinician generates hypotheses as to what is interfering with the attainment of that outcome. Intervention is planned to address the single- and multisystem impairments and contextual factors that are hypothesized to interfere with activity and participation. NDT hypothesizes that system impairments are linked to activity limitations and participation restrictions. Multiple case reports linking or failing to link these hypotheses to function, such as the published reports by Ling and Fisher,[24] Slusarski,[25] and Arndt et al,[26] will continue to shape intervention and refine the NDT Practice Model.

For example, Chris is a 5-year-old kindergartener who loves to play and have fun. He likes music and watching videos. He is social and engaging. He also has CP. His speech-language pathologist (SLP) notes Chris's integrities of the abilities to speak one to two words per breath, his communicative intent in a variety of social contexts, his perseverance in attempting skills that interest him, and his intact language skills. Chris shows impairments in active control of his respiratory cycle, specifically in grading exhalation for speech that requires trunk postural muscle timing and endurance (**Fig. 8.6**). Chris's SLP hypothesizes that the total body extension and laryngeal valving he uses to phonate constitute a compensatory posture and movement

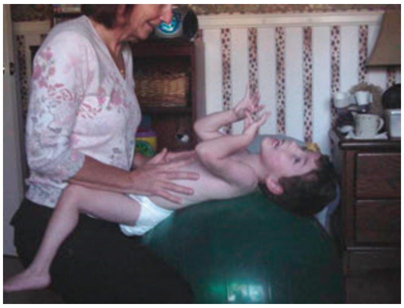

Fig. 8.6 Chris works in intervention with one of his therapists, who is addressing his rib cage position and mobility.

strategy for this respiratory control impairment. She also hypothesizes that this compensatory posture and movement strategy negatively affects alignment of Chris's oral structures (lips, tongue, and jaw) for rapid, connected speech production and decreases his speech intelligibility for most listeners. She hypothesizes that communication in the participatory domain is restricted. She sets a functional outcome about the number of words or syllables that Chris can consistently produce per exhalation in the context of interacting with peers in kindergarten or with his siblings under particular environmental conditions. A range of prognoses from use of verbal communication in a variety of (although perhaps not all) contexts to a poorer prognosis of limited verbal communication only with people familiar with Chris is possible.

The outcome is set, and Chris's SLP hypothesizes that active rib cage expansion with respirations, control of inhalation/exhalation timing and airflow through the larynx, use of postural muscle activity rather than phasic extension movements throughout the body to control airflow, and optimal alignment of oral structures will be necessary to achieve the outcome. She then selects intervention strategies to address selected single- and multisystem impairments, including ineffective postures and movements, while assisting him to practice efficient and functional postures and movements. She constantly monitors if, in fact, the posture and movement changes achieved in intervention result in the desired outcome. Evaluation is constant and ongoing throughout the intervention. Examination, evaluation, and intervention interweave and are essentially inseparable.

Chris's occupational therapist (OT) sets a functional outcome regarding his ability to control a switch to access his computer. He attempts to reach the switch but is unsuccessful. He knows what a computer and switch can do and attempts to reach for the switch. His OT hypothesizes that the posture and movement strategy that Chris uses to reach is ineffective, however, because he is seldom successful in activating the switch, even when it is placed within his range of reach. Chris uses thoracic flexion with head and neck hyperextension, shoulder girdle elevation with scapular abduction and anterior tipping, shoulder internal rotation and adduction, elbow flexion, and forearm pronation to reach. His OT further hypothesizes that this posture and movement strategy is a compensation for impairments in several single and multisystems, notably the following:

1. Difficulty initiating and sustaining postural muscle activity in the synergy of trunk extension while grading small ranges of hip flexion/extension.
2. Lack of development of spinal, rib cage, and shoulder complex alignment to allow the possibility of using scapular stabilizers to move the scapulae out of abduction, elevation, and anterior tipping.
3. Trunk flexion with scapular position as in number 2 places the shoulder joints in a position of internal rotation and adduction, with distal components following.
4. Possible range of motion restrictions in the spine, rib cage, shoulder, elbow, forearm, and hand.
5. Decreased somatosensory awareness of upper extremity position and movement.
6. Impairments of visual perception that may interfere with accuracy of reach.

As the SLP did, Chris's OT will structure a plan of care based on hypotheses that link single- and multisystem impairments to outcomes. She can envision a range of prognoses from little/no successful functional reach to the ability to reach and possibly use limited grasp and release with a variety of objects. As she engages Chris in intervention, she will constantly monitor the success or lack of success of her strategies. Examination, evaluation, and intervention interweave and are essentially inseparable.

Analyzing the Range of Possible Prognoses

The clinician analyzes the range of possible prognoses. Prognosis is based on the following:

1. Severity of participation restrictions, activity limitations, and impairments.
2. Responses to therapeutic intervention to change participation, activity, and impairments.
3. Contextual factors, such as attitude, determination, desire to work to change, and family, community accessibility, and monetary resources.

During each session with a client, the NDT clinician gathers information about responses to intervention and therefore can adjust the prognosis as necessary.

Example of Evaluation Overview Using a Case Report

As an example of the evaluation process, we will look at parts of the case report of Carol (**Fig. 8.7**) found in Unit V (A3), an adult poststroke. Information from her history, interview, and examination is summarized and prioritized in **Table 8.2** and is weighed by her physical therapist (PT) as they work together to determine intervention outcomes.

Table 8.2 Problem-solving and decision-making process during Carol's evaluation portion of clinical practice using the Neuro-Developmental Treatment Practice Model

ICF domains[a]	Prioritization within each domain and explanations[b]
Contextual factors: • Carol's husband is determined to provide care for her in their home. • Carol is a retired nurse; her husband is retired. • The home is one level. • New equipment is needed since the stroke: ramp over outdoor steps into house, bedrail, wheelchair, commode chair. • Her husband provides daily care, including support of Carol's efforts to do activities herself as much as possible.	The contextual factors determine available facilitators and barriers, settings for intervention, and physical, emotional, social, and financial support that affects outcome decisions. Carol's PT may be able to suggest durable medical equipment that results in outcomes for intervention that are different from outcomes if equipment is not available. This is also true for health care services—physical assistance in addition to Carol's husband may allow more difficult postures and movements to be practiced safely and effectively.
• Her husband is emotionally supportive.	Examples: • Carol's husband's decision to care for Carol at home affects every choice of outcome—who will be assisting Carol physically and emotionally (her husband), what settings they participate in, how care will be safely performed.
• Carol is able to participate in partnership with her husband regarding decision making for the house, family, finances, etc.	• The couple is retired, which allows for a daily routine devoted to their personal wants and needs. • The one-level home affects decisions about mobility outcomes and priorities.
• Insurance coverage provides part-time home health care services, therapies, and equipment.	• Carol and her husband view decisions as a joint effort, and Carol's PT will include both of them in decision making throughout the intervention.
• No outpatient services are close to where she lives (or that she's eligible for). • Personal care attendants are not trained/allowed to transfer/practice skills with her because of her low physical abilities (i.e., she's too low level and there are rules about how much they're allowed to "lift"). • Care aides assist with personal care and dressing every morning and evening. • Carol possesses a previous social network in the community at the gym, with friends/family, at work, and through travel.	• The couple has a limited social and family network in place that may serve as resources for physical, emotional, and social support as well as participation choices.
Participation: • Unable to perform any step of sewing for business enterprise. • Unable to grocery shop, garden, attend craft fairs (business and leisure), travel long distances to visit children and grandchildren.	• Carol is currently unable to participate in community involvement, of which physical barriers are the most restrictive, but personal issues (including her self-consciousness about drooling) are also factors. Carol, her husband, and her PT prioritize which community participation choices Carol would like to return to first.
• Unable to participate in community physical exercise/mobility.	• Carol's hobbies and routine family roles have been severely altered. Problem solving revolves around what Carol wants to try to do—what are the most important roles or parts of roles she wants to regain first?
Activity: • Eats at a table; wipes mouth with cloth; reads books/ watches TV—all when set up in a wheelchair or propped in bed by husband.	• Carol is dependent on her husband for all mobility needs, and many of her activities of daily living (ADLs) routines. Carol's PT considers the physical, social, and emotional implications on this drastic change in Carol's daily lifestyle.
• Dependent in all home tasks, where her current activity takes place—husband transports via wheelchair and manages all transfers, including bedside commode; in and out of bed and van; assists care aides with dressing when standing is needed. • Unable to use sewing machine or cut out patterns. • Cannot get in/out of pool or on/off gym equipment.	• Carol, her husband, and the PT prioritize which activities are most important and may be the least difficult for her to work on first in intervention. Activities that affect participation outcomes will be priorities (e.g., will Carol and her husband feel car/van transfers are the first activities to focus on? or getting in/out of the pool?).

(continued)

ICF domains[a]	Prioritization within each domain and explanations[b]
Most significant system integrities: • Cognitively intact • Continence of bowel and bladder • Sensation tests as intact (light touch, pain, proprioception) • Skin intact	Carol's system integrities allow her to make decisions about her intervention and the outcomes she desires. Continence allows a return to pool participation. Intact sensations and skin condition assist relearning of posture and movements.
Most significant multisystem impairments: • Pushes strongly with right arm and leg to the left and backwards with any attempts to shift weight forward and up, i.e., scooting forward, sit to stand, transfers (sensory, graviceptive, perceptual systems could contribute). • Very fearful of coming forward in space (sensory and perceptual systems, and knowledge of loss of postural control and movement with experience could contribute). • Sits in a flexed trunk in all postures (neuromuscular, musculoskeletal, sensory, perceptual systems, and external seating support could all contribute). • Trunk passively elongated on the right in sitting and standing (neuromuscular, sensory, perceptual, musculoskeletal systems, and habitual positioning could contribute). • Left scapula wings and rests in downward rotation, elevation, and abduction compared to right scapula (neuromuscular and musculoskeletal systems plus disuse could contribute). • Left GH joint subluxed approximately three finger widths (neuromuscular, sensory, and musculoskeletal systems, as well as disuse, gravity, and alignment of entire body could contribute). • Muscle atrophy around left scapula and GH joint (not only musculoskeletal, but disuse and lack of full sensation could contribute). • Left hip deviates laterally > posteriorly in standing (neuromuscular, sensory, perceptual, and musculoskeletal systems could contribute). • Hyperextends left knee 100% of the time in standing and stepping (neuromuscular, musculoskeletal, sensory systems along with ground reaction forces could all contribute). • Drools, primarily from left side of mouth (sensory and neuromuscular systems, as well as body alignment could contribute). • Left fingers rest in flexion with slight wrist flexion (neuromuscular, sensory, musculoskeletal systems as well as disuse could contribute). • Holds head/neck to the left rotation and side flexed (neuromuscular, sensory, perceptual, and musculoskeletal systems could contribute). • Never attempts to use left limbs for any task, i.e., no volitionally active movement seen (neuromuscular, sensory, perceptual systems as well as learned disuse could contribute). • Left foot/ankle tends to passively invert and plantar flex, and it is difficult to position with foot flat on floor for transfers and transitions, i.e., scooting, sit to stand (neuromuscular, sensory, and musculoskeletal systems as well as gravity and body positioning could contribute).	This list of Carol's multisystem impairments is significant because the postures, movements, and behaviors observed, measured, and perceived through handling can each have many sources that contribute. In addition to single-system structure and function that could contribute, the clinician must hypothesize about how the contextual factors contribute, and then how all of these possibilities reinforce each other. For example, as Carol sits with a flexed trunk in all postures, how are her sensory receptors adapting to this position? How do any musculoskeletal impairments that contribute to this posture become reinforced and magnified by constant asymmetrical positioning, leading to new perceptions of correct upright posture? How does the posture increase perceptual impairments over time? How do Carol's wheelchair, commode chair, and bed contribute to increasing number or severity of impairments in all of these body systems? How does the way care aides and Carol's husband help her perform transfers and daily care improve or increase the severity of the interaction of all these factors?
Most significant single-system impairments: *Neuromuscular* • Inappropriate over-activity of right lateral trunk and limb extensor muscles (UE > LE). • Decreased ability to sustain activity in spinal extensor muscles (thoracic >> lumbar and L >> R). *Perceptual and Graviceptive Sensory Systems* • Decreased awareness of midline primarily in frontal plane, but also in sagittal plane. *Musculoskeletal* • Weakness in left lateral trunk muscles. • Weakness in left hip abductors, extensors, and quadriceps muscles. • Tightness in:	This list of Carol's single-system impairments is significant because they are hypothesized to interfere with most or all attempts at activity and participation. They are listed in order of the impairment that makes the biggest impact on activity limitations and participation restrictions.

(continued)

Table 8.2 Problem-solving and decision-making process during Carol's evaluation portion of clinical practice using the Neuro-Developmental Treatment Practice Model *(continued)*

ICF domains[a]	Prioritization within each domain and explanations[b]
◦ All neck muscles for side flexion, rotation, and long pivot extension (left > right). ◦ Left > right soleus > gastrocnemius muscles. ◦ Right lateral trunk muscles (rotators included). ◦ Left shoulder (GH) internal rotators and adductors. ◦ Left MCP and PIP flexors (especially digit 4) and long wrist flexors. *Neuromuscular* • Inability to initiate activity throughout left UE and scapular muscles. • Inability to initiate activity in left LE muscles other than hip abductors, extensors, and quadriceps. *Cardiovascular* • General cardiovascular deconditioning. *Regulatory (Arousal/Attention)* • Decreased attention.	

Abbreviations: GH, glenohumeral; ICF, International Classification of Functioning, Disability and Health; PT, physical therapist.

[a] Information in this column would be written in the preferred manner of documentation used by the clinician.
[b] This problem-solving and clinical decision-making process is depicted here for explanation. It would not be a part of written documentation.

Fig. 8.7 Carol, prior to intervention with her physical therapist, who used the Neuro-Developmental Treatment Practice Model as her clinical practice framework.

Setting Carol's Functional Outcomes

Carol, her husband, and her physical therapist might set the following two outcomes for a 1-month period at the initiation of her therapy at home after discharge from the hospital.

- Carol will perform a standing transfer to the toilet with the assistance of her husband by scooting forward to the front edge of her wheelchair with verbal cues and physical cues of one hand on her left posterolateral trunk. She will require his full assistance with positioning of her left foot and hand for the transition.
- Carol will stand to pull her pants up or down in front of her wheelchair with the assistance of her husband for the following:
  - To place and lock wheelchair.
  - To assist Carol to sit erect and stay forward in space over her feet as she rises to stand.
  - To keep Carol's left foot on the ground with the hip and knee aligned over the left foot in the sagittal plane while standing.

These two outcomes address participation and activity for Carol in her current daily routine. They reflect active control of postures with the acknowledgment that alignment will require support for safety and for more efficient muscle activity. They include postures and assisted functions that are paramount to achieving her long-term outcomes.

The Therapist's Analysis

After outcomes are set, the PT analyzes the relationships among all ICF domains, including detailed information about posture and movement. The clinician probably began this process the instant she met the client and family—possibly even prior to this time if historical records, telephone or e-mail information, or written intake information was reviewed prior to the face-to-face interview.

Carol's PT hypothesizes why Carol cannot perform these outcomes when she sets the length of time she thinks it will take to achieve them. Her PT may have used any combination of hypothetico-deductive reasoning, narrative reasoning, and pattern recognition for this analysis. Let's consider a scenario based on clinical reasoning to problem-solve using NDT with Carol's PT as she works to determine a range of prognoses and the subsequent plan of care.

A PT using the NDT Practice Model who is experienced with contraversive pushing and stroke may recognize patterns of Carol's posture and movement that she has previously encountered. She is familiar with the client's perception of an abnormal sensation of verticality and has experience understanding the relationships among impairments in posture and movement seen in stroke and stroke with contraversive pushing, and can quickly comprehend Carol's unique version of posture and movement impairments. This synthesis of relationships among all ICF domains may be implicit in the experienced therapist's problem-solving process. Let's make it explicit here.

In **Table 8.3**, Carol's PT hypothesizes these relationships as she and Carol decide on the outcomes.

Table 8.3 is not all-inclusive. The PT will use clinical reasoning for other aspects of Carol's posture and movement, activities, and participation. This clinician used all types of clinical reasoning in this small sample of clinical reasoning: pattern recognition, hypothetico-deductive reasoning, and narrative reasoning—a finding seen in the study by May et al.[4] See section on Mentoring Students' and Novice Clinicians' Problem-Solving Activities for more information on clinical reasoning.

Carol's PT creates outcomes for intervention that are realistic and accurate because past experience has taught her to analyze similar impairments in contraversive pushing within the individual's contexts, integrities, and all other impairments. A less experienced PT may also be able to create accurate outcomes for Carol based on discussions with mentors and peers, through reading descriptive and research studies, and through development of problem-solving skills. Carol's PT has examined salient systems for integrities and impairments and sees relationships among systems that she has experienced in similar and different ways in other clients. She has skillfully examined Carol with observation and handling, discerning changes in muscle activity, responses to the environment, and responses to imposed and self-initiated postures and movements. As she examined, her questions to Carol and her husband request specific information that assists her understanding of how Carol's integrities and impairments affect her current functioning.

Table 8.3 Setting functional outcomes for Carol based on problem solving

Examination observation/handling/palpation/ testing/interview	Evaluation prioritizing information	Evaluation analysis of relationships/meaning for outcomes
Carol's position in her wheelchair shows marked thoracic flexion, lateral trunk flexion to the left, pushing with the right foot against the floor and right hand against the armrest in a left posterior-lateral direction with attempts to move, an inactive left UE > LE, and almost no adjustments to this posture during the 30-minute interview. As Carol and her husband demonstrate wheelchair to bed or commode transfers, the PT notes amplification of Carol's starting posture and alignment, and of her tendency to push. She asks Carol to prepare to stand up, waiting for Carol's response. Carol pushes more to the left and backward with her right lateral trunk and right limb extensors, and remains flexed in her thoracic spine with attempts to move forward in the chair. The PT asks if Carol's thoracic flexion is a new posture, or if she had it prior to the stroke. She asks Carol to reach with her right UE in various planes. If Carol is unable to reach, the PT takes Carol through the range. She incorporates Carol's left UE and LE into her base of support to test whether Carol can contract any of her left UE and LE muscle groups. As she interacts with Carol, she examines Carol's ability to follow verbal requests and tests her vision in a general way.	The PT notes "classic" posture and pushing behavior in Carol. She hypothesizes (implicitly) that impairment of trunk and limb postural muscle activity combined with overuse of right trunk muscle activity is one of Carol's most profound impairments and wonders if there is loss of interoceptive perception. She hypothesizes that Carol's sense of postural vertical is altered as a direct result of the lesion(s) that caused Carol's stroke. With attempts at changes in postures in her wheelchair, the PT detects no active initiation of Carol's left UE muscles, and unsustained contractions in the upper thoracic extensors with reaching above 90° with her right UE. She notes that Carol can respond appropriately to verbal requests within her current posture and movement repertoire.	Carol's PT hypothesizes that impaired trunk control and inappropriate overuse of the right lateral trunk muscles and limb extensors to "correct" her perception of verticality are the most pervasive impairments that restrict all of Carol's activities and participation. Because she hypothesizes these impairments are severe, she thinks about outcomes that will be measured in small increments of change. She plans outcomes that can have the biggest impact on daily life for Carol and her husband while also stated in ways that are sensitive to small measures of change. Although outcomes will need to be measured in small increments of change, progress may be more rapid for Carol versus other clients the PT has known due to the contextual factors of her husband's support and abilities, Carol's prior health status, time available for attention to Carol's needs, and Carol's intact cognition, communication, and motivational level.

Abbreviations: LE, lower extremity; PT, physical therapist; UE, upper extremity.

This PT has also seen a range of clients, so she can readily state a range of prognoses for Carol (**Table 8.4**). She immediately adjusts outcomes based on each intervention session because she can quickly synthesize the relationship of each domain to the others using a model of human functioning, such as the ICF, and because she uses narrative reasoning to assign meaning of each observation to every aspect of Carol's life.

8.1.4 Developing the Plan of Care

Following evaluation, the clinician writes the plan of care when deciding that a patient/client requires management. Management encompasses the whole system of care and intervention with the patient/client. Management includes direct intervention, periodic assessment, home and community carry-through programming, and patient/client education.

Plans of care for intervention adhere to each profession's practice guidelines. For example, intervention is defined by the American Physical Therapy Association (APTA) as the purposeful interaction of the PT with the patient/client and, when appropriate, with other individuals involved in patient/client care, using various PT procedures and techniques to produce changes in the condition that are consistent with the diagnosis and prognosis.[27] The plan of care is the *action* plan—the plan for intervention that outlines *how* the clinician intends to directly intervene or otherwise manage the client to accomplish the stated outcomes.

So far in the examples in this chapter, the clinician wrote a prioritized list of the range of functioning to disability in all domains that relates to current function/dysfunction, long- and short-term outcomes, and a range of prognoses. Now the clinician documents the following:

- Length of session, frequency of sessions (number of sessions per week or month), and duration (episode of care). Although this determination is made according to outcomes and the client and family's abilities to engage in intervention and other management sessions, often third-party payers and family financial and time resources weigh heavily in determining session length, frequency, and duration.
- A general outline of intervention strategies to address the impairments, activity limitations, and participation restrictions in the context of the client and family when intervention is the choice of client management. This includes time with the clinician and activities recommended outside of intervention sessions to do the following:
    - Practice newly learned portions or entire posture and movement sequences within functional activities and participation.
    - Address impairments, activity limitations, and participation restrictions that require time or place to complete (e.g., night splinting for muscle length, ability to sit for an hour or two at a time, ability to eat a meal in a favorite restaurant).
    - Prepare for the next intervention session.
    - Educate the client and family.
    - Advocate for the client's civil rights and personal needs.
- Referral, discussion, and planning with other team members to address intervention and other management needs of the client and family.
- Anticipated assistive technology and intervention strategies needed to optimize outcomes.
- Date of next formal reexamination and reevaluation with measurement of outcomes.
- Discharge planning.

Table 8.4 A range of prognoses for Carol

Poor prognoses	Good prognoses
Carol could lose function and require total care for all of her mobility in her home and community. This prognosis is based on several factors:	Carol could become ambulatory for indoor and limited outdoor walking with or without a trained adult for assistance and safety. She could return to some of her prestroke participation. This prognosis is based on several factors:
• Carol's lack of spontaneous postural adjustments and inability to sit unsupported. • Carol is doing no standing without total support of another person. • Carol is pushing her body weight to the left and posteriorly, which is both unsafe and inefficient when she is assisted in transfers. • Her husband may decide that her care is too difficult for him physically and emotionally. Others may eventually convince him that the best place for Carol is residential care. • Expectations for Carol's activity and participation by those responsible for her daily care may be limited, resulting in lack of practice of postures, movements, and skills.	• The determination of Carol and her husband to work toward best recovery in their home. • The expectation that Carol can improve. • Carol's husband's ability to manage their daily routine, including total-assist transfers and all setups for ADLs. • Carol's previous health and active community involvement. • Carol's cognitive and communication abilities to be an active part of decision making. • The PT has seen improvements in other clients with similar integrities/impairments and contextual factors.

Abbreviations: ADLs, activities of daily living; PT, physical therapist.

Note: The experienced PT can envision a wide range of prognoses for Carol using knowledge of neuroplasticity poststroke and an understanding of the effects of integrities/impairments on function over time in a wide range of contexts.

Connecting the NDT Practice Model with Intervention Decisions

What can we do as clinicians using the NDT Practice Model to assist in determining the best intervention decisions, length of sessions, frequency, and duration? Before researchers can conduct experimental studies using quantitative and qualitative methods, we need detailed descriptions of intervention, such as the ones found in the case reports of this text, to lay the groundwork for developing further studies. The NDT Practice Model and case reports show clearly that every person brings many variables to intervention, including past and present history, the uncertainty of the future, unique combinations of integrities/impairments, activities/limitations, participation/restrictions, and rich contextual individuality. Determining best practice in intervention frequency and duration will require a deep understanding of all of these variables.

What Do Researchers Conclude about Determining Intervention Session Length, Frequency, and Duration?

The literature concerning intervention frequency and duration often attempts to determine a relationship between either of these two variables and functional outcomes or length of stay in rehabilitation centers.[28,29,30,31,32,33,34,35] In adult patients with stroke or TBI, a higher intensity of intervention (number of hours in therapy per day or per week) has been shown to result in shorter lengths of stay in rehabilitation centers or better outcomes in the United States and United Kingdom.[30,31,35] Two of the three studies were prospective, whereas the other was a retrospective analysis. Other studies in the United Kingdom and the Netherlands have not found that increased intensity results in shorter stays or better outcomes.[29,34]

In children with neurodisabilities, emphasis on determining intensity also includes trials with periods of daily intervention, followed by periods of decreasing intensity or home programming without direct services.[28,32,36,37] Increasing sessions/week (intensity) is correlated with improved outcomes on standardized testing. See Case Report B9 in Unit V as an example of intervention intensity.

The therapy professions are only beginning to try to determine standards for length of session, frequency, and duration.[33] The conflicting results in research studies regarding correlation of intensity and duration to outcomes is likely due to varying populations studied, populations studied at various stages between acute and chronic, different measurements used for outcomes, different intervention approaches, and different intervention strategies used within each session.

Over the past few decades, health care providers worldwide have attempted to determine ideal intervention strategies for patients in acute care and rehabilitation using protocols, guidelines, and care pathways.[38] Care pathways attempt to map out patient management and recommended interventions using evidence-based decision making, allowing for reports of variance from planned to actual care needed.[38,39] Care pathways (also called critical or clinical pathways) may be best suited for conditions in which care varies little from patient to patient.[39]

Rehabilitation is much more variable in application than trials with pharmacological agents or surgical procedures[38] and would require large-scale, randomized, controlled trials to assess effect and validity. Using both quantitative and qualitative studies may give a more complete picture of intervention,[38] and designing assessment forms that prompt clinicians to evaluate and document intervention may assist clinicians in understanding the effects of choices made for health care.[39] At present, the usefulness of care pathways, guidelines, and protocols remains unclear in their abilities to assist in intervention planning at any stage of patient care, from acute care to rehabilitation.[38,39]

Intervention Planning in NDT

Intervention is one type of management that the NDT clinician selects for a patient/client. This process requires that functional outcomes are set first, because intervention is structured around the relationships of restrictions, limitations, and impairments that interfere with the outcomes. As therapists conceptualize a general intervention plan of care to address all of these domains that may interfere with attaining individualized outcomes, they must hypothesize how each domain interacts and influences other domains and factors within the same domain. This process has been completed in the evaluation problem-solving process. Now this information is used to design individualized interventions that will focus on the desired functional outcomes. **Fig. 8.8** summarizes this process.

For example, in Case Report A2 in Unit V, JW is a 51-year-old woman poststroke. After information gathering, examination, and evaluation, her PT and OT focused intervention on outcomes that JW saw as requirements for return to work: putting on a coat, typing speed, walking with or without an assistive device on a large university campus, and negotiating stairs (**Fig. 8.9**).

Home Programs

Clinicians working in habilitation and rehabilitation are familiar with the concept of home programs designed for the perceived benefits of exercise and practice. Variously referred to as home programs, home exercise programs, home therapy programs, exercise recommendations, or conditioning exercises, these programs operate under the premise that performing some prescribed activity compatible with the therapeutic intervention will be beneficial to functional outcomes. The Bobaths taught about the importance of home programs performed by families in their lectures to therapists and wrote about them in articles they authored.[40,41] How does NDT currently view the purposes and implementation of home programs?

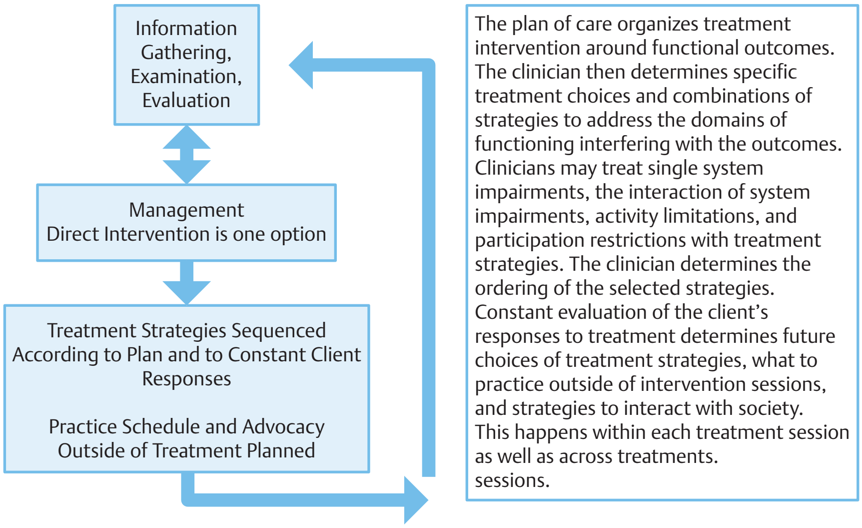

Fig. 8.8 A general intervention plan of care.

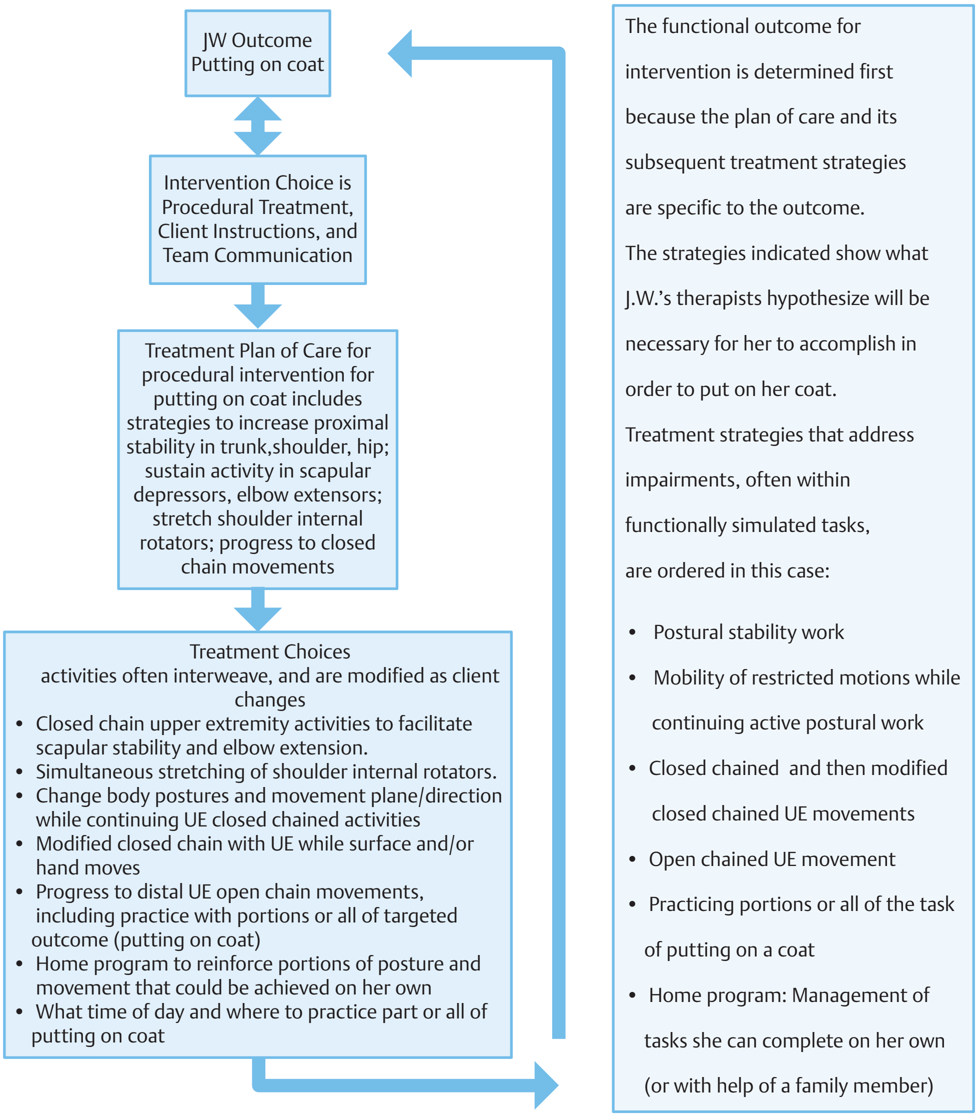

Fig. 8.9 JW's plan of care.

A review of the NDT Practice Model shows that NDT views the collaborative work of client, family, and clinician throughout the entire therapeutic relationship. This applies to home program planning as much as it does to all other portions of the therapeutic relationship. Beginning with initial contact with a client and family, the clinician is interested in determining the contextual factors where participation and activity are performed. One of the many reasons for this inquiry is that the clinician is gathering information that will be used for the collaborative planning of home programs.

With active listening to the client and family's details of their concerns, outcomes desired, and contextual factors affecting participation and activity, the clinician assists the client in planning what may be done at home, school, and work and during leisure times to promote outcome attainment and retention (see Chapter 13 on motor learning for more information about practice). Included in the process of developing a home program in collaboration with the client and family are the following concepts, which are reflected in the NDT assumptions:

- A home program is designed to provide opportunities to practice participation, activity, and effective postures and movements. Mrs. Bobath viewed NDT as addressing life situations, not as exercises.[42]
- When providing ideas for practice, the clinician focuses on the relationship of the client to whomever it is that will assist him or her with the home program. For example, if the client is a child with CP and the home program is the responsibility of the mother, the clinician thinks, "What is the mother's role every day with this child? Now, how can I ask her to practice within that role?" An alternate way to think about this is to ask, "What does the child's mother do each day with her child? Now, how can I design the home program to fit within their daily routine?"

This view differs vastly from thinking of home programs as "doing therapy." Although concerns about health care costs and limited resources may lead therapists to believe that handing off "therapy" as home programs is a solution, family members and friends are not the client's therapists. There is a vast difference between carrying out functional practice sessions and using the moment-by-moment decision-making and procedural skills of therapists. We would never ask a surgeon to teach the mother to perform surgery at home or a teacher to hand over the curriculum for a school year for a home program.

For example, a clinician may find out during information gathering that the child cannot use a spoon to feed himself and his mother wants him to do this. The therapist examines and evaluates the child's abilities, planning and implementing intervention toward this outcome. Therefore, a clinician may say to the child's mother, "I think if he practices eating with this adapted spoon for yogurt, applesauce, and oatmeal while he sits in the high chair, which we adapted for more trunk and foot support, the activity will be functional *and* will help prepare for what I want to do next week with him. Do you think this will work for you this week? Would you like to practice with him now as I watch? Would you like me to write any of this down for you? Is there something you would rather do instead?"

- This home program addresses a function within the role of both the child and the mother and fits in with their daily routine.
- The home program asks for practice of a function that is not stressful in its difficulty level or on the relationship between the child and mother. (If the activity is difficult or stressful, it is still a part of the therapist's responsibility, not the mother's, and this activity is not given as the home program. Something else is chosen.)
- The request for practice asks for the mother's opinions about feasibility and preferences in learning style.

Researchers have currently focused on home program participation in children with disabilities, primarily those with CP. Following through with home programs prescribed by therapists is complex. Although both families and therapists value family-centered models of interaction,[43,44,45] believing in collaborative planning, the implementation of home programs is not always carried through. Having a child with a disability alters family dynamics, expectations, and hopes for the child's future, resulting in a process termed episodic stress response or chronic sorrow and eventually transformed parenting.[46] The diagnosis of a child's CP or other disability is an overwhelming stress for families[45,47,48] and may initially preclude the caregivers' abilities to follow through with therapeutic suggestions for home programming.

In a qualitative study of mothers with children with CP, Piggot et al[45] found that parents initially adjusting to their child's diagnosis and prognosis were unable to participate in home programs at that time. They were coping with survival skills and were unable to see the point of home programs, let alone grasp the purpose of the many professionals who were now a part of their lives. Only after establishing a trusting relationship with therapists and having time to adjust to the demands of an unforeseen life with a child with a disability were parents able to participate in home programs. Now, they could see the progress of their child and hear what the child's therapists had to say. Their effectiveness at setting outcomes for their child improved.

In a study by Hinojosa and Anderson,[48] which also used extensive interviewing techniques, there were similar findings. In addition, mothers developed their own ways to implement suggested home programming into their daily routines in their mothering role. In addition, mothers in this study stated that they selected activities that were enjoyable for their children and for them and that they made decisions about what to do at home more on the basis of watching their therapists interact with their children than by formal instruction. Furthermore, they clearly saw a difference in the roles of the therapists and their roles as mothers.

An informative observation of both studies cited earlier is that, in the initial interactions with parents who were able to attend therapy but could not yet participate in home programming, therapists believed that families were carrying out home programming suggestions. Therapists need to be active listeners of parents' observations regarding a child's progress, making sure to articulate the progress they observe and measure themselves in therapy to assist parents in this awareness. They need to be sensitive to the overwhelming nature of the diagnosis of disability for a family and realize that it may take time and trust building before a parent feels capable of contributing to the therapeutic process.

Current research about family life after stroke and TBI focuses on coping strategies and life satisfaction rather than in carrying out home programs. However, information gleaned from these studies may be useful when planning and discussing home programs and is valuable in referral to other team members. Caregivers of clients who are poststroke report both positive and negative aspects of caregiving.[49] Depression, loss of "self," social isolation, exhaustion, and fear of another stroke are commonly reported in caregivers, both in the acute phases of their family member's poststroke period and long term.[49,50,51] Visser-Meily et al[50] report that the severity of physical impairment is of minor importance in caregiver burden, whereas Haley et al[49] identified mood disturbances and memory impairments in their family member poststroke as highly stressful. In caregivers of clients post-TBI, impairments of cognition, emotions, and behavior were reported as stressful,[52,53] whereas families with strong social support systems reported more satisfaction in their caregiving roles.

NDT clinicians view their clients holistically, encouraging family communication of any aspect of daily life functioning. Clinicians are therefore prepared to design and alter home programs based not only on the client's motoric participation and activity, but on psychosocial integrities and impairments as well. In addition, the NDT clinician values referral to other team members, including psychologists, social workers, and others who are well versed in the psychosocial aspects of chronic disability.

Referral, Discussion, and Planning with Team Members

Another early tenet of NDT was the value placed on services provided by speech, occupational, and physical therapies; nursing care; and families in treating children with CP and adults poststroke.[40,41,54] Mrs. Bobath recognized that CP affects the person's learning in many body systems.[55]

Speech-language pathology, occupational therapy, and physical therapy professions all have statements of professional commitment to referral to other health professionals based on professional judgment.[27,56,57] Referral requires some level of collaboration or information sharing. This collaboration may result in formal or informal teamwork. In the habilitation of children and rehabilitation of acquired central nervous system injuries in children and adults, team collaboration has existed for decades in various organizational structures.

NDT emphasizes the role of the team in the NDT Practice Model for several reasons.

- NDT recognizes that stroke, TBI, CP, and related neurodisabilities affect all domains of human functioning and the many contexts under which people function. Participation restrictions, activity limitations, ineffective posture and movement, and impaired body system structure and function interfere not only with motor functions but with all aspects of life. No one professional is schooled or licensed to meet these needs, although schooling and licensure vary from country to country.

For example, the inability to sit independently and safely in a chair can restrict communication with family and peers through speech and nonspeech communication efforts, can restrict social mealtimes, can restrict attending a play in an auditorium, or can restrict transferring into a car.

- Clinicians are schooled and licensed to practice in their disciplines. Each discipline requires rigorous and lengthy academic preparation for practice. This preparation is viewed as necessary because of the complexity of human functioning. SLPs are therefore prepared to work in the previous example with communication. They may also be trained to address feeding issues, as may OTs, who are schooled to address the various occupations people engage in throughout the life span. PTs are prepared to assist their clients to achieve functional mobility and safety in postures and transitional movements. Then, there are the medical and surgical specialties, psychologists, social workers, nurses, orthotists, biomedical engineers, teachers, aides, and vocational counselors who all contribute to the needs of the client and family at various times throughout the person's life span. This overwhelming number of people requires a focused and coordinated plan of care that is well communicated to all members. NDT recognizes that all members of this team are valuable and that there will be times in a client's life when some team members are needed while others assume a lesser role.
- Teamwork results in desired outcomes for our clients. Teamwork in rehabilitation with patients poststroke has been shown to decrease length of stay, improve functional outcomes, decrease mortality rates, and increase the rate of discharge to home.[58,59,60]

What constitutes effective teamwork? This question is the focus of several research studies that describe both processes and outcomes of teamwork.[58,61,62,63] Team processes are constructed in several ways.

- Multidisciplinary teams comprise various professionals who independently assess and provide intervention to clients in isolation from each other. They report to each other and collaborate as needed.[59,61]

- Interdisciplinary teams have shared outcomes for their clients and may share intervention time and decision making among members.[59,61]
- Transdisciplinary teams work together during assessment, and often a single team member is assigned to implement the intervention plan with clients.[59]

Research has not established superiority of one type of teamwork model over another. Whichever team approach is used (and there are likely to be variations on all three of these types of teams), NDT advocates for sharing problem solving among team members. NDT recognizes that intervention in clients poststroke, post-TBI, and with CP benefits from collaborative and creative problem solving. No one profession is more important than another. What is important is what the client needs in the current episode of care. Each professional must have knowledge of the roles of other team members to recommend referral for participation restrictions, activity limitations, and system impairments that are addressed by that profession.[59] NDT advocates for this base knowledge and the process of referral and collaboration in its practice model.

Assistive Technology

Assistive technology refers to products, devices, or equipment that is used to maintain, increase, or improve function of people with disabilities.[64,65] The use of assistive technology is intended to increase independence in life roles, such as wheelchairs to provide a means of mobility for participation. Some assistive technology is used to address impairments, such as splints and orthoses designed to address joint range of motion, or prism glasses made to improve visual reception, which can lead to increased activity and participation. Assistive technology ranges from communication aids, self-care equipment and devices, feeding and eating equipment and devices, and mobility devices, to low- and high-tech environmental home equipment and controls.[64,65,66,67,68,69,70,71,72,73] Henderson et al[67] found an overwhelmingly positive effect on activity, participation, and personal contextual factors with the use of assistive technology for children with disabilities. In a policy study of assistive technology use by Medicare recipients in the United States, Wolff et al[66] suggest that assistive mobility devices may reduce the need for unpaid and paid help.

In the ICF model, assistive technology is considered a contextual factor listed under the model's environmental factor category.[64] OTs, PTs, and SLPs are often the clinicians directly responsible for assistive technology assessment, acquisition, training, and follow-up.[68]

NDT considers assistive technology a facilitator to participation and activity. As with other needs for clients, assistive technology needs are individualized according to functional outcomes identified by the client, family, and clinician. These needs take into consideration possible future participation and contexts of participation to maximize use and minimize cost. The clinician considers the effects of assistive technology in terms of minimizing energy expenditure, minimizing the adverse effects of body system impairments on further impairment development and on function, assisting with caregiver health and ease of care, and empowering the client's ability to control choices and interaction with the world.

For example, a child with dystonic CP is seen by an SLP who uses the NDT Practice Model for problem solving in selection of intervention strategies to address posture and movement for augmentative communication. Augmentative communication is a facilitator to communication for a child who is nonverbal, expanding her activity and participation choices through effective communication.

Although constrained by cost, the clinician may recommend more than one type of assistive technology in an activity category because people participate in various ways within activities. This is true for people with and without disabilities. For example, a person without a mobility limitation uses walking, bicycling, driving an automobile, and community transportation, such as trains, buses, and airplanes, for different levels of participation. A person with a mobility limitation may use some of the same modes of mobility but may use a walker and a wheelchair for home, school, and community mobility depending on the distance that person must travel. Although two mobility devices (the wheelchair and the walker) may not be paid for by a third party payer at the same time, this does not mean that both are not needed and used. Similarly, a person with a communication disability may use natural speech for family and close friends, a high-tech communication device with voice output for less trained listeners, and an interface of that device with a computer for messaging and Internet access.

Reexamination and Reevaluation

Reexamination is a process of retesting and remeasuring selected domains of functioning to guide intervention. It is performed during episodes of care and, for some patients, over the life span.[27] The plan of care is reviewed to assess if outcomes are met or need to be modified, and this information determines if intervention should be continued with new or modified outcomes or if the episode of care will end.[56] Each profession follows its guidelines for reexamination and reevaluation, and each facility that provides services in speech-language pathology, occupational therapy, and physical therapy has a structure for formal reexamination and reevaluation that must be followed. This formal structure is determined in part by the payment system for reimbursement of services.

The NDT Practice Model views reexamination and reevaluation as ongoing, continuous processes that are practiced in every intervention session. These intervention session examinations and evaluations involve a process of assessing the effects of intervention moment by moment. They also involve a formal documented process of setting an outcome for each intervention session and measuring that outcome, which will be described in detail in Chapter 9 on intervention sessions. NDT views constant assessments of intervention and documented sessions and short-term, long-term, and life span outcomes as the critical organizational components of intervention.

Discharge Planning

Discharge planning from intervention and other management is based on anticipated completion of outcomes. Portions of discharge decisions are often determined by facility protocols and third party payer requirements.[27] The widespread acceptance and use of the ICF model has assisted all involved in the care of clients with lifelong disabilities to see that intervention and other management needs vary throughout the life span according to the effects of participation and activity contextual changes over time and because of the interaction of body system integrities and impairments on each other and on participation and activity over time.

For example, a child with spastic and dystonic CP may be able to walk household distances with a reverse walker and platform arm attachments with supervision of his family and school staff when he is 6 years old, but many changes occur in this child's lifetime. By age 12, walking has become more difficult because of added height and weight without the commensurate growth of strength and motor control to accommodate these changes, and his school is bigger, requiring a longer distance to walk from class to class. He and his family continue to assist him with walking under these new contexts, but they also choose a power wheelchair for some mobility needs. In addition, the child's motor control impairments have made some of his joint mobility and muscle length impairments more severe, and he has developed hip joint and ankle–foot deformities with time.

However, this child has also learned to use his computer efficiently with the help of his parents and teachers and has developed better visual perceptual skills as he does his schoolwork using his computer after an episode of care with an OT, allowing him to stay at grade level with his schoolwork. He is able to use speech in phrases instead of only single words because coordinating respirations with voicing has improved with episodes of care with his SLP, and he can operate his power wheelchair, negotiating school and home barriers and obstacles efficiently. After another episode of care with a PT, he can ascend the stairs at his grandmother's new condominium with assistance from his mother or father, whereas earlier in his life he had no need to manage stairs.

With each episode of care, the child's therapists used the NDT Practice Model for intervention, including planning for discharge from the beginning. Outcomes are set collaboratively, and intervention is focused on outcomes. In addition to setting outcomes for each episode of care, the child and his parents discuss expectations for the future with his clinicians, including the following:

- The anticipated effects of spastic and dystonic CP throughout the life span.
- Potential future contexts that this child may need to contend with, whether they require more episodes of care or not.
- Ongoing management of participation, activity, and body system functioning to maximize prognosis.
- Education to assist the family in identifying potential problems as they first arise to minimize their effects.

Both the NDT Practice Model and the ICF model support the life span effects that neurodisabilities have that often necessitate multiple episodes of care. Discharge is planned for each episode of care, therefore, with the anticipation that there are likely to be future episodes of care with various clinicians to maximize health and function.

A Plan of Care Example

Recall the example of Carol. Her physical therapist set the following two outcomes for a 1-month period at the initiation of her therapy at home after discharge from the hospital:

- Carol will perform a standing transfer to the toilet with assistance from her husband by scooting forward to the front edge of her wheelchair with verbal cues and physical cues of one hand on her left posterolateral trunk. She will require his full assistance with positioning of her left foot and hand for the transition.
- Carol will stand to pull her pants up or down in front of her wheelchair with the assistance of her husband for the following:
  - To place and lock wheelchair.
  - To assist Carol to sit erect and stay forward in space over her feet as she rises to stand.
  - To keep Carol's left foot on the ground with the hip and knee aligned over the left foot in the sagittal plane while standing.

Episode of Care (Session Frequency and Length)

Carol will be scheduled for home-based physical therapy intervention twice weekly for 6 months. She will then be formally reexamined and reevaluated. Sessions will average 1 hour for the 6-month period.

General Intervention Strategies

Intervention will address functional practice, ineffective postures and movements, and system impairments that interfere with the stated outcomes, which will be revised monthly. Activities will focus on facilitation of liftoff from a high sitting position from various chairs (**Fig. 8.10**) used functionally, with and without reaching activities; active small-range movements from a midsquat posture while engaged in a task (clients who are "pushers" perform better with movement vs. holding/isometric work); scooting forward in chairs and low (i.e., semisitting) pivot transfers; gait training with an assistive device; lower extremity orthotics/splints/shoe modifications as needed with maximal assistance from the PT.

Home Program

Carol and her husband will be asked to practice strategies that will safely and effectively recondition muscular and cardiovascular endurance, such as recumbent cycling; moving within her wheelchair using reaching activities; and posting written cues to orient to vertical environmental structures within the home.

Referral, Discussion, and Planning with Team Members

Carol, her husband, and her PT will make up the team during this home care phase of Carol's rehabilitation.

Assistive Technology/Equipment

Carol and her husband will try a wheelchair with support and pressure relief cushions, a commode chair, and a rail on the side of the bed. Her husband built a ramp on the outside of the home for wheelchair access.

Reexamination and Reevaluation

Reexamination and reevaluation will be formally performed every 6 months.

Fig. 8.10 Carol working with her physical therapist.

Discharge Planning

Discharge planning will involve predicting the time required for Carol and her husband to perform and manage daily activities that are functional in a way that will allow Carol to continue to improve. (During the course of intervention, the following information guided her PT's decision making: At first, the only way Carol could transfer, walk, and scoot in her chair was with assistance of the PT. Her husband was performing safe transfers using compensatory postures and movements with Carol that would not allow her to increase her skill level.) Once Carol and her husband can practice sit-to-stand transfers, walking, and other postures and movements in a way that will allow Carol to improve her skill level, intervention sessions can be reduced in frequency.

Periodic increases in session frequency will be scheduled when Carol improves to a level where she would benefit from more intensive work, such as when Carol and her husband began practicing transfers in and out of the shower.

Episodes of care may continue throughout Carol's life, because people may improve function poststroke for the remainder of their life. These episodes of care also help to manage and minimize secondary impairments as well.

8.2 Mentoring Students' and Novice Clinicians' Problem-Solving Activities

How does a new graduate in occupational therapy, physical therapy, or speech-language pathology gain the expertise that his or her mentor has? How does the novice clinician learning about NDT problem solve and perform intervention with clients as effectively as the experienced clinician? Can the process be taught?

Although expert therapists are able to explain their thinking processes more thoroughly than novices can,[74] they may not always be able to fully explain all that is occurring in an intervention session to others. However, studying the differences between experts' and novices' problem-solving processes may help our professions understand how expertise develops. This huge task begins in a professional's entry-level education and continues through lifelong learning. It is the purpose of mentorships, residencies, and continuing education, such as the NDT certificate and advanced courses, taken throughout a therapist's career.

Embrey and Hylton[74] listened to and studied the retrospective explanations that expert and novice pediatric PTs gave as they viewed their own videotaped intervention sessions. They found that PTs used problem-solving strategies they termed movement scripts to organize the vast amount of clinical information into intervention decisions. Novice therapists used these movement scripts primarily to describe characteristics of the children, whereas experienced therapists used the scripts to organize clinical information and compare the current situation with past situations. Of interest in this research is that NDT principles constituted the basis for much of the decision making throughout intervention. Although this research may appear to apply more to intervention itself, it is an example of the continuous cognitive problem solving that clinicians perform in all aspects of practice. Recall that, in the NDT Practice Model, all aspects of interaction with a client are interwoven, which means in this case that evaluation and intervention occur simultaneously, just as information gathering, examination observation, and evaluation often occur simultaneously.

Carrier et al[3] focused their study on OTs who provide services within community settings. They found cognitive problem-solving processes involved hypothetico-deductive (analytic) reasoning used mainly by novice therapists and pattern recognition (nonanalytic) used mainly by experienced therapists to understand a client's needs for services. The OTs in this study used many categories of information to evaluate potential solutions for intervention. They used scientific information for occupational diagnosis and intervention, narrative information (client's personal story) to understand the personal significance of the situation requiring OT services, pragmatic information to understand the practical and logistical aspects the situation, ethical considerations of practice, the interaction of the OT with the client and other people involved, and the conditions (context) of the client's situation.

Research about clinical reasoning consistently shows that novice therapists use hypothetico-deductive reasoning to select strategies of activities for intervention[5] and benefit from external structure provided by assessment forms.[7,75] Novices also tend to focus on tasks to structure intervention strategies.[75] Expert therapists (expertise does not equate with years of experience[11]) are much more likely to use narrative reasoning and pattern recognition to evaluate a client's needs for intervention and focus on a larger picture of the client–family interaction while focusing on salient features of a task in flexible and creative ways.[4,5,10,74]

Therefore, one of the mentoring skills clinical instructors focus on in NDT education courses is teaching course participants how to use tasks and intervention strategies to serve client/family outcomes. Practice sessions with clients during NDT courses allow for this focus and create mentored practice for participants to build a larger repertoire of problem-solving and creative solutions to individual situations. Although course participants in NDT courses often state that they are taking the course to increase the number of intervention techniques for their repertoire, what they gain is much greater; the NDT courses are designed to assist novices in how to think and problem solve with greater expertise.

The following forms may be used as guidelines to develop problem-solving skills with students and novice clinicians. They build in complexity. Use them, adapt them, or make your own to guide students and novice clinicians to greater expertise.

Form 1 Listing Participation and Activity

Listing Participation/Participation Restrictions and Activities/Activity Limitations
Refer to Chapter 3.
Make a list of the participation functions the client can perform (participation is defined in the International Classification of Functioning, Disability and Health [ICF] model as functional involvement in a life situation performed within a specific relevant environment or within a specific societal context). These will be highly individualized and contextual.
Make a list of the participation restrictions the client has (participation restrictions are defined as problems that an individual may encounter in life situations no matter what the cause).
Make a list of the functional activities the client can perform (activity is the positive performance of a task). Examples are eating, reaching, speaking, communicating, sitting, walking, climbing stairs.
Make a list of the activity limitations the client has (limitations are the difficulties that the individual may have in executing those tasks).

Form 2 Observations of Alignment

Observations—Alignment
Choose a functional (activity or participation) skill that your client wants to achieve during intervention. Make sure you have chosen a function, not a posture or movement. Ask yourself, "What does this client want to be able to *do* in his or her daily life?" Write the outcome.
Does the outcome you wrote have the client's name, an action verb that is observable, the functional skill, and the context(s) that the client will perform the skill within? Is it written in a way that others in the profession could observe the client and know that the outcome has been achieved or not achieved?
Observe the client in positions and postures that are similar to the desired outcome (e.g., if the outcome is eating at a dining room table, observe sitting and eating or a similar sitting and fine motor task).
How is the client's entire body positioned? You may want to draw a picture.
What is the base of support for this position (the portions of the body that contact a support surface)? Draw or diagram the base of support.
What happens to the client's alignment when the client is relatively still? Does the alignment stay the same? Does it change, and if so, how does it change?
What happens with alignment when the client moves? Here, you may need to describe various body segments—the trunk, the head, the mouth, the eyes, the arms and legs (and each joint of the extremities).
Find an isolated place in the facility where no one (except peers and mentors) can observe you, or do this next task at home. Assume the alignment of your client as closely as you can (the purpose of doing this in an isolated place is so that the client and others will not think you are making fun of or being disrespectful to the client in any way). Try to move the way your client moved. This can give you additional information through your own sensory systems, deepening your understanding of your client.
Write two to four clinical hypotheses about why you think the client postures or moves the body and body segments in a particular way during the function you chose to observe.

Form 3 Observations of Posture

Observations—Posture
Choose a functional (activity or participation) skill that your client wants to achieve during intervention. Make sure you have chosen a function, not a posture or movement. Ask yourself, "What does this client want to be able to *do* in his or her daily life?" Write the outcome.
Does the outcome you wrote have the client's name, an action verb that is observable, the functional skill, and the context(s) that the client will perform the skill within? Is it written in a way that others in the profession could observe the client and know that the outcome has been achieved or not achieved?
Look at a posture within the context of the outcome you have chosen. Choose the posture that the client most frequently assumes. You may want to use this form repeatedly for other postures the client frequently assumes. Focus your first observations of posture on the trunk and head. Describe how (if) the client controls stability of the posture. Is stability controlled through muscle activity, skeletal alignment, external supports, or a combination of these three? Describe the muscle activity, skeletal alignment, and external supports used: Muscle activity:
Alignment of body segments:
External supports used:
Review your descriptions above. Which of them allow the client to actively control posture that is efficient (energy conservative and nonstressful)?
In what ways is the client inefficient in controlling postural stability?
If the client continues to control posture within the functional activity or participation exactly like she or he is controlling it now, will the control allow more complex skills to be developed? If not, generate several clinical hypotheses of what could happen over time if the client continues to control posture the way she or he currently controls it.

Form 4 Observations of Movement

Observations—Movement
Choose a functional (activity or participation) skill that your client wants to achieve during intervention. Make sure you have chosen a function, not a posture or movement. Ask yourself, "What does this client want to be able to *do* in his or her daily life?" Write the outcome.
Does the outcome you wrote have the client's name, an action verb that is observable, the functional skill, and the context(s) that the client will perform the skill within? Is it written in a way that others in the profession could observe the client and know that the outcome has been achieved or not achieved?
Choose a movement that the client makes or attempts to make within the context of the outcome you have chosen. You may want to use this form repeatedly for other movements your client often uses. Focus on control of that movement. What are the ways the client uses postural stability or lacks postural stability to support the movement?
How does the client initiate the movement? (Initiation may occur in other parts of the body as either postural stability strategies and/or attempts to weight shift, as well as movement in other body segments).
What muscles contract to initiate and control trajectory and speed of the movement?
Is the movement successful (i.e., is it accurate, does it have sufficient speed, does it result in the desired outcome)? If not, hypothesize why the movement is inefficient and/or ineffective.
If the client continues to move this way, will the client be able to build more complex movements that result in greater activity and participation functions? If not, how will the movements interfere with skill development and/or cause deterioration of skills over time?

Form 5 Listing Body System Integrities and Impairments and Hypothesizing Their Relationships to Function

Listing Body System Integrities and Impairments and Hypothesizing Relationships to Function
Select a participation restriction or activity limitation that you wrote on Forms 1–4. List the body system integrities and impairments that contribute to this function (refer to Chapter 7 on examination for a detailed list of body system functions and structures). Try to list single-system impairments, but you will work in the next assignment to distinguish between multisystem and single-system impairments.

(continued)

(continued)

Listing Body System Integrities and Impairments and Hypothesizing Relationships to Function
Body system integrities:
Body system impairments:
In relation to the restriction or limitation that you selected, prioritize, in order of influence on that function, the integrities and impairments you listed above. Be specific to that client and the function you selected. These are your hypotheses of why the client is restricted or limited. Ask yourself, "If I could make this body system function well, how would that affect the restriction or limitation?" You may find that, for one person, decreased joint mobility is most impaired; for another, it is a poor ability to recruit postural muscles when needed; for another person, the cognition is most impaired; for yet another it is visual impairments; and so on.
Hypothesize how body systems might influence each other over time. For example, how could respirations affect posture? How could sustained muscle activity on one side of a joint affect joint range and mechanics? How could lack of proprioceptive processing affect muscle control?
Hypothesize how participation and activity with repetitive postures and movements now used by the client could influence body systems over time. For example, how could repetitive speaking using eye, cervical, lumbar, and knee/ankle extension to initiate voicing influence muscle length? How could the same activity influence another activity such as walking? Another example is the following: How could eating by moving the mouth to the hand using extreme ranges of thoracic flexion influence rib cage and spinal mobility? How could it affect muscle length and strength? How could it affect respirations?

Form 6 Alignment, Posture, and Movement As Multisystem Expressions

Alignment, Posture, and Movement As Multisystem Expressions
Choose one of your observations about alignment, posture, and movement impairments from Forms 2–4. Alignment, posture, and movement impairments are considered multisystem impairments because many single systems contribute to their expression. Examples would be poor head or trunk control, posterior pelvic tilt in sitting, inability to bring the hand to the mouth, poor articulation, crouching gait, or toe walking.
For the client you chose to write your observations about, choose an alignment, posture, or movement impairment. Analyze the single body systems you hypothesize to contribute to this multisystem impairment. Prioritize this list in order of most to least influential. Remember to keep this list individualized for the client you are writing about—this is not a generic list.
Also consider how participation and activity influence the multisystem impairment you chose. For example, how does eating a meal by bringing the mouth down to the hand affect sitting in a chair? How does it affect the client and family's decision to eat at a restaurant?

Form 7 Pattern Recognition and Past and Future Functioning

Pattern Recognition and Past and Future Functioning
Document an intervention session with your client. Then answer the following questions. How did my client function differently today than she or he did yesterday or last week or last month?
Why did my client function differently (think about all domain levels—participation, activity, and body systems and their interactions)?
Have I seen this type of change in other clients (pattern recognition)? If so, what were the varieties of outcomes (this begins to give you an idea of the range of prognoses for your clients)?
What would be the most effective intervention to do today in order to give my client the best outcome for the future today, next week, next month, and 10 years from now?
Can I think of a new and creative way to accomplish intervention strategies for this session that would be meaningful and useful for my client today?

8.3 Writing Outcomes for Clinical Practice and Statistical Analysis

Clinicians use a variety of ways to measure outcome achievement for clients. Outcome measures should allow clinicians to document the effectiveness of an intervention.[76] NDT has advocated writing individualized, personally meaningful outcomes for many years[41] because intervention in NDT is highly individualized, and clinicians find that outcomes written this way are much more sensitive to change. However, many times clinicians may feel discouraged about writing individualized outcomes because research methodology, third party payers, and facility protocols often value (pay for) outcome measures on standardized tests only.

Standardized tests are used in research studies to compare outcomes across clients and between different interventions.[77] They may be mandated by facility protocols and third party payers.[76] However, they are often not sensitive to individual client changes.[76,77,78,79,80] They often do not aid the clinician with decision making or problem solving about intervention choices, and they do not measure individualized responsiveness (the ability to detect meaningful change over time).[79,81]

Recently, clinicians in the rehabilitation field have adopted or developed ways to set individualized outcomes that have meaning for clients that can also be studied in various research designs. Goal attainment scaling (GAS) allows highly individualized outcomes to be set and measured.[78,79,80,82,83,84] GAS was originally developed by Kirusek and Sherman in the 1960s to measure outcomes in the field of mental health.[80,84] Clinicians and clients collaborate to set meaningful intervention outcomes, and the clinician then develops a scale to reflect criteria for success on a discriminative scale. Several outcomes (called goals in this scale) are usually set for a client, and these can be rated or weighed in importance to the client. The scaling and weighting of outcomes can be mathematically transformed into standardized measures or T-scores, if desired, for statistical analysis.[78] The original GAS rated outcomes on a 5-point scale, but researchers have experimented with 3-, 6-, and 7-point scales as well. Reliability studies need to be performed for all of these scales and to determine if one scale is superior to another in measuring client outcomes and determining if intervention is effective.[80]

The original 5-point scale is most commonly cited in research studies. A score of 0 represents the expected level of functioning after a predetermined period of intervention.[78,80] Baseline (current) functioning is described as a −1 or −2 score on the scale. A Likert scale defines −2,

−1, 0, +1, and +2. Likert scales are also used to weight the goals in terms of importance for clients. GAS outcomes follow the SMART principle—specific, measurable, attainable, realistic, and timely.[78,84]

Let's try an example as seen in **Table 8.5** using 5-point GAS with −1 representing current functioning and 0 representing the expected outcome for a 1-week period. Imagine that this is a client beginning inpatient rehabilitation after a TBI or stroke.

The example in **Table 8.5** could also be shortened, eliminating the repetitions of phrases to save time, as seen in **Table 8.6**.

Turner-Stokes[78] suggests that three to five outcomes are sufficient for rehabilitation in routine clinical practice, with clinicians measuring outcomes only at the beginning and end of an episode of care. Outcome difficulty would need to be set for the length of time anticipated for the episode of care.

The Canadian Occupational Performance Measure (COPM) is another individualized outcome scale developed by OTs to assist clients in assessing their self-perception of change in occupational performance.[77,81,85] The OT conducts a semistructured interview concerning a client's problems with self-care, productivity, or leisure activities. The client is asked to rate the importance of the problems on a scale of 1 to 10 (1 = not important at all; 10 = extremely important). Clients are also asked to rate their performance on these activities on a 10-point scale from "not able to do it" to "able to do it very well." Reassessment by the client occurs after a period of intervention.

Research studies have focused on the sensitivity of GAS and the COPM, their responsiveness compared with standardized measures of outcomes, and their discriminant validity compared with standardized measures, such as the Functional Independence Measure, Barthel Index, the Pediatric Evaluation of Disability Index, and the Gross Motor Function Measure. Client populations studied include stroke, TBI, and CP. Both scales show promising responsiveness and sensitivity,[79,81,83] and discriminative validity has been confirmed in the study by Cup et al.[85] However, no research study has yet shown that the effects of adding either GAS or the COPM to standardized testing improve functional outcomes, as reported in a preliminary study by Colquhoun et al.[76]

Table 8.5 Using goal attainment scaling with a 5-point Likert scale

Score	Goal
−2	Mr. B will stand up from his wheelchair with right arm pushing on armrest only and left arm inactive, requiring PT's assistance to shift weight forward and up, standing with weight on both feet, left knee hyperextended.
−1	Mr. B will stand up from his wheelchair with right arm pushing on armrest while left hand stays on armrest after being placed there for initial push, requiring PT's assistance to shift forward and up, standing with weight on both feet, left knee hyperextended. (This is his baseline measure.)
0	Mr. B will stand up from his wheelchair by first placing both hands on the armrests, standing with weight on both feet, requiring PT's assistance to shift forward and up, allowing left knee hyperextension (This is the targeted outcome.)
+1	Mr. B will stand up from his wheelchair by placing both hands on the armrests and pushing on the armrests with both hands, standing with weight on both feet, requiring PT's assistance to shift forward and up, allowing left knee hyperextension.
+2	Mr. B will stand up from his wheelchair by placing both hands on the armrests and pushing on the armrests with both hands initially and releasing with both hands while rising to stand, standing with weight on both feet, requiring PT's assistance to shift forward and up, allowing left knee hyperextension.

Abbreviation: PT, physical therapist.

Table 8.6 A shortened version of Table 8.5

Score	Goal
−2	. . . with right arm pushing on armrest only and left arm inactive . . .
−1	Mr. B will stand up from his wheelchair with right arm pushing on armrest while left hand stays on armrest after being placed there for initial push, requiring PT's assistance to shift forward and up, standing with weight on both feet, left knee hyperextended. (This is his baseline measure.)
0	. . . by first placing both hands on the armrests . . . (This is the targeted outcome.)
+1	. . . by pushing on the armrests with both hands . . .
+2	. . . by placing both hands on the armrests and pushing on the armrests with both hands initially and releasing with both hands while rising to stand . . .

8.4 Summary

As this chapter and the NDT Practice Model show, the therapist who uses NDT relies on many sources of knowledge to inform practice during evaluation and in writing the plan of care. These include, but are not limited to, the following:

- Analytic skills, including the ability to see relationships among participation, activity, and posture/movement multi- and single-body system integrities under a variety of contexts using basic and applied sciences, experience, and expertise.
- Nonanalytic skills of pattern recognition.
- Narrative reasoning skills.
- The ability to prioritize effects on all influences of future functioning.
- The ability to determine a range of prognoses, taking all factors into account and correlating to outcomes.
- The ability to set functional and measurable outcomes for intervention.
- The ability to plan general intervention strategies that will address participation restrictions, activity limitations, and body system impairments.
- The ability to determine a realistic episode of care to meet the outcomes.
- The ability to design a home program to reinforce and practice effective posture and movements within daily routines.
- Knowledge of assistive technology that facilitates participation and activity.
- The ability to work on a team and value the opinions and priorities of others.
- The ability to plan reexamination, reevaluation, and discharge.

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9 Neuro-Developmental Treatment Intervention—A Session View

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This chapter describes the process of designing and implementing a single intervention session from the perspective of the client, family, and therapist within the context of the Neuro-Developmental Treatment (NDT) Practice Model. The rationale for setting a session outcome, performing a pre- and posttest, and implementing intervention that includes preparation, simulation, progression, and practice of meaningful tasks is described in a way that the reader can identify a problem-solving process that is continuous and interweaving in design. In addition to engagement of the client with the therapist, client and family education, assistive technology, therapy equipment, and home programming are also described as they are integrated within and between sessions. Clinical examples are given throughout the chapter to illustrate the concepts. The chapter concludes with planning for the following intervention session. Throughout the chapter, examples of real-life intervention sessions illustrate the topic descriptions.

Learning Objectives

Upon completing this chapter the reader will be able to do the following:

- Delineate among the roles of the client, therapist, family members, and other team members in the NDT intervention process.
- Recognize the continuous decision-making process of setting the session outcome among client, family, and therapist, and the integration of relevant and meaningful functional activities throughout the session.
- Describe the integration of contextual factors, including environmental and personal factors throughout the intervention process, both in the planning and in the session itself.
- Discuss the process and purposes of the pretest, preparation, simulation, practice, home programs, education, and posttest within the intervention session.
- Analyze the role, gradation, timing, and weaning of therapeutic handling, including key points of control (KPCs), facilitation, and inhibition within the context of a single intervention session.
- Define the role of assistive technology and therapeutic equipment within a session and in the home, school, or community environments.

9.1 Intervention Using the Neuro-Developmental Treatment Practice Model

Intervention is the action piece of the integrative process of decision making within the Neuro-Developmental Treatment (NDT) Practice Model that brings the client and clinician together to make logical choices toward successful outcomes (**Fig. 9.1**). In previous chapters, information gathering, examination, evaluation, and the plan of care were described in detail. These components continue to be important parts of intervention because the clinician must continually be gathering information, examining, evaluating, and altering the plan of care in the moment throughout the intervention session as needed. This constant listening, observing, examining, and responding to changing information is critical to the NDT Practice Model and can be observed and heard in each intervention session.

Intervention is the part of the plan of care that the clinician puts into action as strategies to address the restrictions in participation, limitations in activity, and impairments in body systems. During the intervention session, the clinician applies procedural knowledge to achieve functional outcomes that have been written in the plan of care, with problem solving in the moment to address the therapeutic needs of the client in all International Classification of Functioning, Disability and Health (ICF) domains: participation, activity, and body systems, in functional contexts. All domains are addressed within each intervention session.

This chapter describes the development of a session plan, the individualized therapeutic process for the session, options for modulating or progressing within a session, as well as specific intervention strategies that represent the NDT Practice Model. In addition, a collection of potential frameworks or principles for developing intervention strategies is presented toward the end of the chapter.

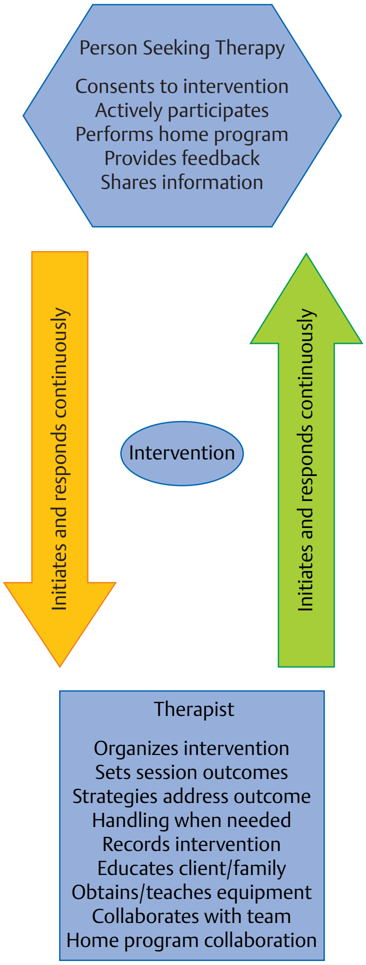

Fig. 9.1 Intervention using the Neuro-Developmental Treatment Practice Model.

9.1.1 Components of an Intervention Session

Each intervention session is an expression of all of the core philosophical tenets, assumptions, and key principles of the NDT Practice Model presented in Unit I. As such, it should be clear that the individual seeking therapy is the focus and heart of each session. The client is viewed as the center or leader of the intervention team who works together with others to reach outlined outcomes. The team can include the individual, his or her family or caregivers, and the extended social, medical, and educational team. The person seeking therapy, however, and his or her family, identify the functional goals that are to be the focus of the intervention. Those identified desired participations and activities become the outcomes around which the long-term intervention process is designed, as well as becoming the focus of each individual session. Each individual has many ways to participate and a variety of activities that she or he wants to regain or improve upon. All of these choices drive intervention decisions. Each session is therefore designed considering this *one individual* with all her individual integrities and impairments, *one specific outcome* of an activity or a participation role, and *one unique blend of contextual factors*, including both environmental and personal facilitators and barriers for that activity. Each session is organized around this specific session outcome. The individual is an active participant in every aspect of each session, and the therapist works to build on the individual's strengths while addressing the individual's impairments and activity limitations. Intervention itself includes a hands-on aspect within the examination, evaluation, and intervention process within the session. The intervention session is individualized based on the ongoing synthesis of information gained from the examination and intervention process and therefore includes continual examination and evaluation. The session includes education with the client and family or caregivers and a plan for active practice throughout daily life, a critical component for permanent integration into postural and movement control.

The Client, Family, and Therapist Roles in Intervention

Each person who comes to an intervention session is a unique being. This person brings not only specific diagnoses, impairments, and limitations but also unique strengths, hopes, and goals. Each person has a different history or varying life experiences with different family and community influences. In some sessions, the therapist may meet and only know the client as an individual if no family members are present. In other cases, the entire family may be active participants in intervention sessions and may be instrumental throughout the intervention process. For example, if one considers an early intervention session with an infant who was born prematurely, the parent–child team may be viewed jointly as the client.

At the beginning of the intervention planning process, the client, the family/caregivers, and the therapist create a therapeutic relationship. This relationship may be new, having been forged a few minutes earlier during the examination and evaluation process, may be ongoing, when the client is continuing within an existing plan of care, or may be decades old, when beginning a new episode of care. The therapeutic relationship will continue to evolve and change during the intervention, and the relationship among them will have an influence on the intervention process.

People who seek occupational therapy, physical therapy, and/or speech-language therapy from a therapist who practices within an NDT framework can anticipate that they will have an active presence in the planning of their intervention program and that they will be actively engaged in each step of the process. They expect that their goals, needs, wants, and dreams will drive the development of the plan of care and will frame the focus of each and every intervention session. Their responsibility is to share with the therapist the participation and activities they value. They will need to describe their home life and the key environments in which they currently function or would like to return to and changes in their lives as they occur so that therapeutic intervention can be adapted accordingly. Also, they need to reveal information concerning their body systems, including both integrities and impairments. They anticipate that therapy will be active and that they will work hard during an intervention session. They also know that part of the intervention requires them to provide honest feedback during and between sessions as to the effect of strategies experienced during a session. They understand they are expected to continue the therapeutic process outside of the session through active participation in their home program.

As stated previously in this chapter, there is a constant interaction between the therapist and the client (and family/caregiver if involved). The plan evolves based on the needs, desires, and outcomes of the client. When clients and families are unfamiliar with NDT's philosophy of care, the NDT practitioner assumes the added responsibility of education about the intervention process. Consumers develop an appreciation for their expected active involvement and the different roles and responsibilities they will assume.

The therapist understands that for the session to have meaning, the outcomes of the session must be grounded in real-life function, and this function must have meaning to the individual now and in the future. A therapist using an NDT practice framework understands that care will be provided within a discipline-specific scope of practice. A practitioner of NDT understands that current evidence informs practice decisions when developing and implementing a plan of care with the client and also understands that principles of best practice include consideration of client preference, clinician skill, and expertise. This expertise includes previous therapeutic relationship experiences with this client and other clients that will influence the decision-making process during both the planning and the implementation phases of intervention.

The therapist gathers information during the examination of the individual from all domains within the ICF model, but during intervention sessions, this information is enhanced and enriched as time allows more detailed information sharing in a less structured and informal format. For example, during information gathering, it may be reported that an adult client is unable to cook her own meals or meals for her husband. The improvement of this participation restriction may be perceived as an appropriate outcome toward which the therapist will work. However, as intervention progresses, this client might reveal that she never has cooked and that role has always been performed by her husband or that she cooked prior to her stroke but never really enjoyed it. What she did enjoy though was gardening. Her personal goal would be to return to her hobby as a gardener and to have the intervention focus on this activity/participation. The specific impairments that are limiting her ability to return to gardening become the focus of the intervention.

What is true, however, and critical to note for therapists who feel constrained by the standard list of outcome activities used in many health care facilities, such as bed mobility, bed and wheelchair transfers, toileting, feeding/eating (and which are often dictated by the reimbursement schedule), is that an individual possesses only one set of impairments. This one set of impairments interferes with all the individual's activities and participations. The influence or weighting of impairments may vary from one activity to another, but there is not a different set of impairments for each activity limitation. In this example, if the intervention focus is on the impairments interfering with the tasks and subtasks of the activity of gardening (and the other activities this individual has identified as meaningful to her), as these impairments are reduced or eliminated, this improvement will also influence her ability to perform many of her other daily activities and participations, such as dressing for work, walking in the community, transfers, and cooking for her family if she is so inclined (**Fig. 9.2**).

Fig. 9.2 Working on a client's impairments within a motivating task.

Setting Session Outcomes

Laurence J. Peter and Raymond Hull of the *Peter Principle*[1] wrote, "If you don't know where you are going, you will probably end up somewhere else." Lewis Carroll,[2] from *Alice's Adventures in Wonderland*, is often paraphrased as writing, "If you don't know where you are going, any road will get you there." These are two wise statements to heed in the intervention process with clients. Helping clients achieve sustainable, meaningful, functional outcomes is the end goal of the therapeutic process of the NDT Practice Model. Every choice that is made before, during, and after a session has the potential to either lead the client and therapist toward this outcome or, when in a random direction, away from this outcome.

A session outcome is determined for each intervention session. Just as the long- and short-term outcomes described in the previous chapter include specific, measurable functional outcomes, so too does this session outcome. The paraphrase by Lewis Carroll, "If you don't know where you are going, any road will get you there,"[2] is as applicable to a single session as it is when discussing intervention as a long-term process. ***The session outcome forms the foundation from which the session is planned, designed, implemented, and evaluated.*** It is an independent, stand-alone measure of performance for the client. The session outcome provides a frame of reference, an expectation of what is to be achieved during the therapy session. Work within an intervention session sets the stage for motor learning. The reader is directed to Chapters 12 and 13 on motor learning and motor control for further discussion.

Session outcomes are generally linked to short-term outcomes (STOs) and long-term outcomes (LTOs). However, the relationship of the session outcome to the STO and LTO is more complex than a simple scaling up of a task or a change in the context of the task. Session outcomes represent desired functions or reflect unique, individual task specific skills, which, when combined, achieve a change in functional capabilities that is consistent with achievement of an STO or LTO. Generally, the relationship of session outcomes to STOs and LTOs is not simply incremental or proportionate. Therefore, a session outcome is not simply written as 25% or 50% of the desired task or linked STO. It is also not constructed as an approximation or extension of the last session's outcome or linked STO, such as a progression of functional mobility from 5 feet to 10 feet. Again, the session outcome is a stand-alone performance measure of a task. The session outcome is often a subtask or a sister task of an activity that is meaningful to the individual and offers the client and therapist a focused target to address some specific impairments within that session. A sister task is a task that requires the integration of many of the same body systems and/or movement components for task completion. For example, in Case Report A1 in Unit V, the client wanted to return to golf. One of the subtasks of golf is bending down to place the tee in the ground for the ball. A sister task to this task would be bending down to tie his shoes or pick up his towel from the bathroom floor.

As discussed in Chapter 8 on the evaluation and plan of care, the session outcome is developed from collaboration among the client, family/caregivers, and therapist. When session outcomes are collectively viewed during an episode of care, they should reveal a sequential pathway for progress toward the STOs and LTOs. When this pathway is established, the client and therapist anticipate that the session outcome will be achieved within the session—that the new task or function is realistic and possible.

In the case report on Mark in Unit V, examples of STOs for the occupational therapy and physical therapy sessions show a progression toward the client's long-term goals of returning to golf and participating in a cross-country move. His individual session outcomes were subtasks or sister tasks of the many activities required for these participations. For example, one session outcome may have been related to how Mark moved into a squat position while reaching for an empty moving box on a lower shelf as seen in **Fig. 9.3**. Another might be related to how Mark reached back and up behind him with his right hand to get his golf hat from a shelf, a movement similar to what he would use in a golf back swing. For a child who has a long-term outcome of putting on his own jacket at recess time, a session outcome may be how he puts on an art smock for finger painting or how he reaches to select particular toys from shelves to his right and left at shoulder heights.

Once a session outcome begins to take shape (it may still be refined), the therapist identifies the constraints and facilitators of the environment and other contexts

Fig. 9.3 One of Mark's session outcomes—bending down for a box in preparation for his cross-country move.

under which the function will be performed. This identification may occur through discussion with the client and family. For example, the therapist might ask the client to describe the location of the dishwasher relative to the storage area for dishes, cups, and silverware or where his favorite toys are in his room to determine the setup required for practice. This environmental information allows the therapist to make calculated choices about how the intervention practice can be set up. What postures or transitions will be chosen? What will the role of the more involved limbs be in the task practice? Where does the therapist need to be in relation to the client and the tools of the task? What handling should be used to both encourage (facilitate) the efficient movement components that need to be practiced and to limit (inhibit) the inefficient postures and/or movements that are interfering with function?

Questions may be more affective or psychomotor in nature. An example would be asking the client to describe how it feels to sit on a particular chair. Does it feel safe, supportive, too soft or firm? Information gained at the affective, cognitive, and psychomotor domains of learning will help to shape the session outcome and influence decisions for the remainder of the NDT-based intervention planning process. For the therapist who practices within the context of the NDT framework, an appreciation for and an understanding of the barriers and facilitators are believed to increase the likelihood of the development of a successful plan of care.

Establishing a meaningful and achievable session outcome can be motivating and empowering to clients and families because it validates their efforts within and between intervention sessions and provides a definable structure for all to remain focused on. This task practice within the functional context, in the meaningful activity within the intervention session(s), demonstrates to the individual that positive change and success are possible for new and regained skills and that further contextual practice is necessary for this success. A child who practices climbing into the family vehicle after an outpatient session that included stepping up a variety of high steps within the session is not only more likely to be able to get into the family car but also more likely to try the steps of the school bus and perhaps the steps on the slide on the school playground.

If an individual is loading or unloading the clothes dryer within the intervention session, as seen in **Fig. 9.4**, she develops the motor habit, confidence, and skill to repeat this practice at home. The NDT assumption is that, if practice in the session only includes working to increase lower extremity strength and mobility, trunk rotation, and visual scanning, all outside the context of functional activity, the long-term benefit is diminished. The reader is directed to Chapters 12 and 13 on motor control and motor learning for further discussion of these concepts.

A common question of novice clinicians is often, “How do I help my clients achieve carryover?” When an individual is practicing functional tasks or subtasks in therapy, the motor and sensory memories and habit of this practice are more likely to carry over into everyday life practice when compared with the performance of movement activities that are more exercise-like and nonfunctionally

Fig. 9.4 As this woman practices loading and unloading the clothes dryer, she incorporates her right upper extremity (UE) into the base of support for her posture and movement. This activity is practiced in context with the therapist monitoring her entire body’s posture and movement skills, working to gain right UE function in context. The outcome may be her ability to do her laundry, whereas the intervention includes increased activity in the right UE in her best alignment.

contextual in nature. Carryover outside of therapy is seldom achieved if the individual is only performing noncontextual exercises in therapy, even if these may be addressing the impairments that interfere with skills, such as unloading the clothes dryer or climbing into the family vehicle. In addition, when immediate suggestions are provided to the individual on how to integrate skills introduced in therapy into the daily routine, the opportunities for direct carryover are increased.

For some individuals, progress is rapid, and significant changes are apparent. For others, progress is slow, and change may be difficult to detect. For clients with progressive, degenerative, or complex and long-term disabilities, success may be measured by little or no loss of function. As discussed in Chapter 15 on neuroplasticity and recovery, an individual’s rate of change may be variable. As discussed in Chapter 8 on evaluation and plan of care, it is of critical importance that the therapist considers all factors that may influence an individual’s potential for change. The session outcome is therefore developed based on the individual’s prognosis and potential for change.

The therapist integrates all information obtained about and from the client to set a session outcome that challenges the client yet does not create impossible demands. As the intervention session begins and progresses, the therapist constantly asks, "Is my client working in ways that promote change and progress in all domains of function? Are the demands on all body systems too easy, sufficient, or too demanding? Am I encountering difficulties that I did not originally anticipate? How can I adjust the work we are doing to create challenges that promote progress?" The most successful plan is one that is expected to change constantly.

Activity Analysis

The first part of the session plan includes selecting an activity that can be used as meaningful and motivating practice throughout the session. In some cases, this activity is the client's outcome activity, and in other cases, it is a simulation or therapeutic activity for the session. For a child, the activity might include pretending to be a princess getting ready to go to a party. For an adult, the selected activity may be working in the woodworking shop to make a gift for a grandchild. The individual may still be functioning at a very low level, and the full task of dressing like a princess or building a wooden toy for a grandchild may not be even remotely possible. However, working within the context of these activities, even at a basic level, will inherently motivate the client. Even if the client is still in an acute care setting after her stroke, having a piece of wood available at the bedside to sand, measure, or examine for defects in the grain will engage her in a way that working with cones or pegs never will.

Through activity analysis, the therapist next needs to choose the appropriate subtask or task components of this activity to be practiced within the session that best address the individual's impairments. Activity analysis includes task analysis, determining the subtasks that make up a task, as well as movement analysis and determining the movement components (sensory, motor, visual, etc.) of the tasks and subtasks.

The clinician refers to the plan of care for information regarding STOs, LTOs, and the general plan of care. However, for each session, the clinician creates a plan specific to the session outcome. The clinician identifies the body system integrities, contextual facilitators, and engaging activities that will assist the client in reaching the session outcome. In addition, the clinician identifies and prioritizes which impairments or barriers prevent the achievement of the outcome. For example, if the desired outcome is for the child to put on a sweater while seated on the edge of the bed, it may not be critical that the child has limited hip extension range. For this session, the focus will be on the achievement of this one outcome and the integrities, impairments, facilitators, and barriers that will influence achievement in this one session.

An expert clinician may be able to complete this process during the pretest process, whereas a student or novice clinician may need to analyze the task prior to a session and write a plan that outlines the intervention session with specific prioritized impairments that will be addressed in the chosen activities. Eventually, this type of problem solving must be an ongoing and automatic process for effective intervention. An example of this type of analysis and problem solving is developed in the case report about Mark in Unit V. The first table in that case report outlines the standard performance criteria and compares this with Mark's baseline performance criteria for the task of stooping to pick up a lightweight box off the floor with both upper extremities (UEs), carrying it to a nearby counter top, and placing it on that surface. From this analysis, Mark's therapist was able to identify his system integrities (facilitators) and prioritize his system impairments interfering with his ability to perform this task. This analysis allowed her to develop a sequence of activities in a single session and sessions over time to address Mark's impairments in intervention and to move toward a more standard performance of this task.

When the therapist identifies the highest priority impairments that interfere with outcome achievement, a list of objectives for changes in the impairments may be generated. These objectives must also be prioritized as to the impairments that must be addressed first in the session and the ones that may be less significant to that session's outcome. The clinician develops this list but must be willing to constantly reevaluate the decisions and shift intervention based on the changing needs of the client. For the previous examples, the subtask chosen for the session outcome for the child pretending to be a princess might be reaching for the tiara, jewelry, wand, and boa that are in front and slightly above the child. For the adult interested in making a gift for a grandchild in her woodworking shop, the subtask chosen on a given day may be sanding the wood that will be used for the toy baby cradle. When a child or adult is asked at the end of a successful session to report what was done in therapy, the answer may include a description of play activities, task activities, therapeutic activities, or contextual factors, whereas the therapist may answer with the list of impairments addressed and outcomes achieved. Regardless of the perceptions, the appropriate selection of the activity is necessary for a successful session.

The Intervention Session

Once the analysis and planning for the session have been completed, the therapist is ready for the session itself. The structure of sessions may vary depending on the needs of the client, but the following actions occur in most intervention sessions.

Pretest of Functional Outcome

The session outcome may have been partially established at the close of the previous session because this is when the therapist has the best image of the client and the interaction of all the domains of functioning. It is also then that the therapist or client may know what would be best to do next. The outcome may need to be modified at the start of the session, however, because there may have been changes in the client's status between sessions. Once the session outcome has been determined and refined, it is important to start each session with a pretest of this outcome. It is possible that an outcome which was thought to be challenging is easily achieved at the start of the session or that the outcome is out of reach on the day of the intervention session. An outcome that seemed ideal at the end of one session may be inappropriate on another day due to changes in family dynamics, an unexpected illness, or faster improvement than predicted. Therefore, it may be necessary to completely rethink an outcome or modify the measurement of the outcome based on this pretest.

The Interaction of the Client, Family, Therapist, and Environment during the Session

The following concepts are all critical aspects of NDT intervention and incorporated to reach the stated outcome. These concepts include environmental setup, preparation, simulation, and practice, as well as achieving carryover. These concepts are not meant to be presented as a linear sequence for intervention and do not reflect completely separate concepts within the intervention process. At times, the concepts overlap or repeat, whereas at other times they flow from one to another.

Initial Environmental Setup

Once the outcome has been established and the plan for the session is determined, it is necessary to set up the environment for maximal success. The options for setup vary with different clients and in different settings. If the session will occur at a clinic or in a hospital, the decision may include issues such as whether the session occurs in the individual's quiet room or in a department with many other people present. The decision is based on factors such as whether a small private space is required for increased focus or concentration or if a large space is necessary for the activities that are to be practiced. If the session is in the client's home, similar considerations are made. Will the living room be an appropriate space where there is more room but there is added confusion with the extended family watching a loud TV program? Or could the session occur in the client's bedroom if it is considered appropriate for nonfamily members to be in it?

The therapist must also consider what tools/toys may be necessary to complete the task. These items not only include those needed for the activity identified as the outcome but all of the items that may be used throughout the session in both preparatory practice and task practice. For example, it may be necessary to have the appropriate walker close by for an individual if the outcome is related to walking across the room and the individual requires an assistive device, or to have several differently shaped items available, such as a hair brush, toy bat, or cylindrical musical instrument, if grasp is being addressed in therapy with a child. Although each of these items may differ from the exact grasp size required for the outcome task, they can aid in the progression to achievement of the outcome. All of the tools/toys are considered carefully as to the affordances of the object and are not introduced simply because one is readily available in the therapy cupboard or the child really likes a particular toy.

For example, if the outcome with a child is to walk with a suspension walker in the home from his bedroom to the kitchen, introducing a new set of tiny Legos that can only be played with in sitting and with pieces that require a pincer grasp is not a wise choice. The toy in this case is a distraction to the achievement of the outcome. Instead, the child may be given a basketball to throw into a hoop while standing with the support of the walker. The therapist (or parent) can encourage the child to walk to the basketball hoop to throw the ball. The ball game is an integral part of the walking experience, as seen in **Fig. 9.5**.

Likewise, a speech-language pathologist (SLP) may have a long-term outcome that an individual will use an augmentative device for communicating at school or in the community. The device may be integrated in each session as the individual makes choices and communicates with the therapist for decision making and conversation *and* as the therapist and client work together to increase accuracy in icon selection and learning to use the device more effectively. The device is not used as a distraction from the tasks being practiced but is integrated throughout the session. The device may also be incorporated into the occupational therapy and physical therapy sessions as appropriate.

The session outcome dictates the furniture, floor surfaces, presence of distractions, and task tools that will be used. Thought and planning must be given to the environmental setup to optimize outcomes. As seen in **Fig. 9.6**, setting up the environment for an individual who

Fig. 9.5 This child walks toward the basketball net to throw the ball into the hoop.

Fig. 9.6 Making choices for an optimal setup of the environment for an individual interested in painting.

Fig. 9.7 Choosing the subtask and environmental setup to match impairments and optimize outcomes.

is interested in painting must consider his impairments as choices are made about the posture he is in for the task, where the paint brushes and paint are located, and where he will do the painting. Similarly, as seen in **Fig. 9.7**, if the individual is a carpenter, choosing the tools, posture, and subtasks to match the impairments will optimize outcomes.

In addition to real-life objects, furniture, and tools, therapeutic equipment may also be integrated into the session. The therapist might decide to use a partial body-weight-bearing (PBWB) support device. This decision may be made to allow walking practice in upright alignment with support to free up the therapist's hands to address impairments such as range limitations or impaired sequencing of muscle activation during the gait process. The therapy equipment must be specifically selected to meet the contextual factors, the outcome, and the impairments. A therapist working in a hospital setting may include the PBWB device because it is readily available while the home-based clinician may not have the same options. A more detailed discussion of the use of therapeutic equipment and assistive technology during intervention and as it relates to home programming is included later in this chapter.

Handling

An important role of the therapist is to integrate or weave together the preparation of all of the different body structures and functions with activities to keep the client engaged and actively learning. When the therapist is addressing these issues or progressing through the session, the role of handling becomes evident. Handling is an important element of NDT practice that can be used to address any of the domains of the ICF model. The therapist can choose to assist, to resist, to guide, to reinforce, or to limit all or any part of a participation or activity. In addition, any of the single body system impairments or functions can be affected through the handling. The therapist may contact the client with the intent of changing, altering, or modulating one or multiple elements of a task, how the task is being performed, and the impairments in the body system(s) the therapist thinks are contributing to the activity limitation. This process of planning not only involves deciding if therapeutic handling should be used but extends to the questions of when, for what purpose, how, where, and for how long. Within the NDT framework of practice, where the therapist places his hands is referred to as a key point of control (KPC). The key points can include the therapist's hands on the individual but can also include any avenue of contact. A baby sitting on the therapist's lap can be given input from the therapist's thighs underneath her or the arm that the upper body is resting on. Another example is demonstrated in **Fig. 9.8**. In this case, the therapist uses her leg to provide input to the child's hip to help the child have confidence to shift weight to the right as the clinician uses her hands to facilitate trunk rotation.

The concept of KPCs can be expanded to include concepts such as the visual input of the therapist's body. KPCs can be unilateral or bilateral, proximal or distal, symmetrical or asymmetrical. Equally important to the consideration of the KPC is the therapist's rationale for what she believes her hands will provide for the client relative to the learning process. The therapist's hands should be viewed as a clinical tool; a piece of therapeutic equipment. Their use should be purposeful and judicious. The therapist's hands can provide minimal tactile cues to guide a movement or can provide deeper proprioceptive information relative to the individual's alignment, base of support, or need for postural stability or active movement. The input from the therapist's hands can facilitate stability or movement or can inhibit stability or movement. Often, the therapist's hands provide both facilitory and inhibitory input simultaneously. Examples of how a clinician may provide handling include assisting the individual to sit up straighter when attempting to put on a T-shirt, assisting an individual who had a stroke with the third rocker action of the more involved stance foot, as seen in **Fig. 9.9**, or stopping the hand and arm from pulling into flexion when transitioning from sit to stand by facilitating the elbow extensors to actively recruit with the hand placed on a table.

The clinician has an anticipated outcome with an anticipated motor performance. Based on the examination

Fig. 9.8 The therapist uses her hands on the child's trunk as a key point of control to facilitate trunk rotation, but her leg becomes the point of contact for the child's change in weight bearing.

Fig. 9.9 The therapist uses her hands to facilitate the third rocker of the foot for preswing.

and evaluation, there is an expectation of what is going to happen both positively and negatively as the client engages in postures and movements while involved in an activity. Therefore, the therapist introduces specific handling strategies to encourage the desired aspects of the movement needed and to minimize the negative ones. A frequent analogy is made to watching a couple dancing across the floor. The couple interacts through touch and *handling* to suggest directions or moves to each other. Input may be given to prevent the couple from bumping into another couple (inhibition) or to suggest (facilitate) a more eloquent move when space and time allows. With a client who is experienced in active intervention such as NDT and an experienced clinician, it is possible for the individual to achieve better alignment, posture, balance, and control and coordination of movement for functional outcomes. The effective use of handling requires developing a rapport with a client with the judicious use of facilitation and inhibition, as well as knowing when to grade the client's withdrawal. Handling should always be temporary and always be given with the intent to give less with each repetition and movement within a session and across sessions over time.

Preparation

Preparation is the process of addressing the impairments in body system structures and functions. Impairments in the individual systems may be addressed one by one or together within multisystem structures and functions, such as posture and movement. An analogy of preparation during intervention is the process of baking a cake. In baking a cake, one must retrieve from the pantry and refrigerator all the ingredients—the flour, the sugar, the chocolate, the eggs, the butter—and mix them together. When working with a client to achieve a desired activity, the therapist needs to help the client access or retrieve the range of motion, the sustained or graded control, the strength, the perceptual awareness of midline, and so on, and blend them cohesively to facilitate an activity.

A difference in the two processes is that when the flour is mixed into the cake batter, it stays mixed in. However, the therapist may prepare a system, such as somatosensory awareness in the hand, for transitioning to standing using support of the hands on a support surface. Early in the session, the therapist may have the client use the hand as part of the base of support (BOS) on a coffee table or small stool while squatting to pick an object or toy up from the floor. However, when the transitional task of sit to stand is introduced, the hand may slide off the surface without the client apparently taking notice. The therapist would need to add sensory input during the transition. Therefore, it is often necessary to prepare the body systems throughout the session and even to suggest activities to the client or family that will prepare a system for future sessions. Thus preparation occurs not only at the beginning of the session but throughout the session as the need arises to increase range, reinforce dynamic control in a segment, realign the center of mass (COM) over the base, and so forth. Whenever possible, preparation occurs within functional activities and, at minimum, within functional contexts: movement is organized around the task.

Single-System Preparation

Preparation of the following systems within an NDT framework will be discussed: regulatory, sensory, musculoskeletal, neuromuscular, respiratory, cardiovascular, gastrointestinal, and integumentary. There are certain body systems that may require preparation before others. The order in which the systems are presented here reflects this sequence. In addition, there are clear recommendations from an NDT perspective for how to most effectively prepare a system for achievement of a participation or functional activity outcome. Following the discussion of single-system impairments and intervention, the multisystem impairments are presented.

- *Regulatory system*: If the client has impairment(s) in the regulatory system, it may be necessary to address this system first. If the client is agitated, fearful, or angry, the likelihood that the intervention strategies will have a beneficial outcome is reduced. Quinton[3] taught that it is important to respect an infant's crying and to work to "win" the baby to therapy. If a client is anxious or fearful, it may be necessary to reassure or calm the individual before proceeding. Handling options, such as steady touch or deep pressure, to calm and specific vestibular input to modify the level of alertness may be effective.

  Environmental modifications, such as lighting, temperature, or noise, are examples of strategies that can be used in intervention to prepare the regulatory system. Life participation usually requires that an individual be able to function in a wide range of contextual factors, such as visual stimulation, noise and other distractions, or an extremely challenging task. Activities in life sometimes need to occur when the individual is nervous or exceedingly excited. Working only in limited or narrow ranges of regulatory control may not lead to maximal change in participation. Thus the individual is gradually exposed to more within and across intervention sessions.

- *Sensory systems*: The second group of impairments to consider addressing early on in intervention is those of the sensory systems. The sensory system is the primary avenue a therapist has to influence a client's body systems. We access and influence the central nervous system (CNS) and many other body systems via the sensory systems. All of the sensory modalities must be considered as both contributors to activity limitations and facilitators to achieving positive outcomes.

  Individuals usually have a preferred system that allows them to learn more effectively. It is not uncommon to hear a person report that she is a visual learner or that she needs to feel something before she can perform the activity. The therapist should have a clear idea of the integrity of the individual's sensory systems as well as impairments in specific sensory modalities. This begins with the examination and evaluation process. The therapist can then choose to use the sensory system integrities in intervention and to address the individual's impairments. For example, it may be helpful to play classical music in the background for one client, while another may find it irritating. For an individual with an auditory processing impairment, any background music may make it more difficult to attend to verbal directions or feedback.

  During NDT intervention, it is optimal to provide sensory input in functional contexts rather than out of context. For example, if a therapist wants to improve an individual's sensory awareness on the sole of the foot, the therapist is more likely to have success with the client standing barefooted on an indoor/outdoor carpeting surface or on a sandy beach than to suggest rubbing an assortment of different textures across the bottom of the foot each day.

  Intervention for the sensory systems may include addressing the single systems individually such as the visual, auditory, gustatory, or somatosensory systems, or it can include addressing the more complex multisystem phenomena. The therapist must consider the specific roles of the sensory systems on posture and movement. For example, although postural control is influenced by all systems, the visual, vestibular, and somatosensory systems are of prime importance. There is a growing literature that demonstrates, especially in young children, a heavy reliance on the visual system for upright orientation.[4,5,6] The influence of the perception of the visual horizon and ambient vision may dramatically influence the performance of the individual as related to head and trunk control and therefore of a task. If the client has an outcome that is impaired because of poor postural control, it is important to address any sensory system impairments that influence the poor postural control for a task.

We know that the body structures and systems do not work in isolation but function as a cohesive whole. We also know that most, if not all, activities have a sensory component. Thus it is the responsibility of all clinicians to examine and integrate intervention for multiple systems into the plan of care within their scope of practice, addressing impairments that contribute to clients' activity limitations. For a more detailed discussion of the sensory and perceptual systems, see Chapter 7 on examination. For intervention strategies for impairments in these systems, the reader is directed to Chapter 16 on occupational therapy as well as the case reports in Unit V.

- *Musculoskeletal system*: The third system to consider addressing initially is the musculoskeletal system and, specifically, that of joint mobility and soft tissue extensibility. If an individual does not have the range to open his mouth more than one finger width, it is unlikely he will be able to bite through a hamburger, or if an individual does not have the range to dorsiflex the ankle to 90° with the knee fully extended, it is unlikely that she will walk with the foot flat and the knee extended at normal speeds.

Within the NDT approach, there are specific assumptions concerning how best to achieve functional range of motion for activities. First, it is necessary to understand exactly which body structures are contributing to the lack of mobility. Is it the length of the muscle, tendon, ligaments, or fascia, or is it a bony deformity limiting free motion? Then, just as with all systems, it is optimal to address the impairment within functional contexts. For example, if it is determined that the limitation is in the gastrocnemius/soleus muscle group, the therapist may position the individual in sitting with the foot stabilized at the talus or calcaneus and facilitate a transition from sit to stand with a forward weight shift, thus moving the ankle into greater dorsiflexion, at first with knee flexion for liftoff, followed by knee extension to continue to standing. The individual's body weight and active muscle contractions aid in the elongation of the shortened muscle group. In **Fig. 9.10**, the therapists use the individual's body weight to gain length.

In addition, the client and family are instructed in how to position the foot during transfers at home to provide this type of active stretch throughout the day. The therapist may also suggest that the client wear a brace or splint to align the joint at specific times during the day or a device during sleep rather than having the ankle remain in a position of plantar flexion. Active elongation or active stretching is preferred rather than passively moving the targeted joint through the range.

Strength or force production is a second component of the musculoskeletal system. The Bobaths[7] initially claimed that the primary impairment in stroke and cerebral palsy is not weakness but atypical tone. However, working with children post–selective rhizotomy, which alters muscle tone, has taught us that muscle weakness is a factor that can indeed limit activity and participation. When an individual has impairments in force production in muscle(s), the therapist incorporates strengthening strategies into the intervention sessions within functional contexts and activities to reach the desired outcomes. For example, the young child may be unable to drink from her favorite 8 oz glass bottle compared with a 4 oz plastic bottle secondary to weakness in her trunk or arm muscles. Rather than using a standardized exercise, such as a strengthening protocol by adding weights (resistance) to the child's arm, the therapist would progress functional tasks that gradually demand and build greater strength. Practicing within functional tasks also allows for more efficient strengthening of the postural stabilizers while allowing the mover muscles to do their job and work through the available range that will also actively elongate them when needed.[8,9] For play, the child could be presented toys that gradually have increased weight while the clinician ensures that body segment alignment is optimal and postural musculature is optimally active. Play may be progressed from playing with bubbles or light-weight plastic keys on a ring, to playing with toys that are heavier, such as the metal Tonka trucks. The parent may be able to graduate the amount of milk in a bottle (i.e., first the 4 oz bottle and then the 8 oz bottle) to strengthen the child's trunk and arm muscles. The parent may be encouraged to play tug of war games with the child's favorite toys and grade the challenge.

Fig. 9.10 The therapist holds a more optimal alignment while the client actively loads his body weight over the foot to gain length in the gastrocnemius–soleus muscle group.

The therapist must also carefully monitor the individual during the strengthening activities for their influence on the individual's other impairments. If the baby holds the bottle only with the less involved hand and begins to demonstrate both increased tension into flexion of the more involved UE with fisting of that hand and more frequent gagging, the therapist has a decision to make. Is this strengthening strategy the best choice, or is it making the child worse? Most of these decisions are a cost–benefit ratio decision. For an adult, a similar decision might be necessary. For example, if the strategies and activities used to strengthen the glenohumeral flexors in the arm contribute to overrecruitment of the scapular elevators and lead to a painful impingement syndrome, what is the cost–benefit ratio of this strengthening strategy? Is it important enough to the child to gain strength in the UEs to allow independent drinking of larger volumes with her favorite bottle and for other UE tasks? or to allow greater ranges of forward reach for the adult client to continue using these strategies? Or will this process have devastating effects on the more involved body segments, and thus on the potential for future development, that the strategy must be rethought? NDT intervention must consider the past, present, and future simultaneously.

- *Neuromuscular system*: The Bobaths[10] began the NDT approach based on their belief and experience that it was possible to change muscle tone. Mrs. Bobath[10] stated that "the distribution of spasticity is not permanently restricted to certain muscle groups, but influenced, among other factors, by the position of the body in space, the relative position of the head to the body and by the position of the limbs in relation to the body."[10] As discussed in the chapter on examination, the *words tone, muscle tone*, and *postural tone* have all been defined and used in a wide variety of fashions. *Postural tone* is the term being used in this text to refer to a multisystem characteristic, whereas *muscle tone* refers to the neuromuscular components at the level of the muscle. Strategies to address the impairments of the neuromuscular components of tone will be outlined. Descriptions of each component and the underlying rationales for these strategies are included in Chapter 4 on a model for posture and movement, in Chapter 7 on examination, in Chapters 10 and 11 on cerebral palsy and stroke, and in Chapter 12 on motor control.
  - *Motor unit recruitment*: The simplest functional unit of the peripheral nervous system is the motor unit.[11] The motor unit includes an α motor neuron and the muscle fibers it innervates. The basic law of operation of a motor unit is an all or none principle; the motor unit either reaches the threshold, and the neuron fires and the muscle fibers contract, or the threshold is not reached, and there is no muscle contraction. These basic descriptions of neural recruitment form the foundation to describe neuromuscular impairments and to develop intervention strategies. Studies have documented that, following a cortical lesion, the CNS lesion loses its ability to modulate firing frequencies during voluntary movement.[12,13] The clinician knows from a foundation in neurophysiology that to increase the likelihood of any motor neuron reaching its threshold, two neural mechanisms can be incorporated. Those mechanisms are spatial and temporal summation. In temporal summation, depolarization occurs and the motor neuron fires because synaptic potentials occur close together in time; a single input is not sufficient. Likewise, a motor neuron may receive excitatory inputs from different interneurons at approximately the same time that can lead to spatial summation. A therapist, therefore, can theoretically influence the types or intensities of sensory inputs to increase the likelihood of firing through handling. These inputs include using tension and/or directional information over muscles and joints through skin and/or adding compression or approximation through optimally aligned joints. To decrease the likelihood of firing, the clinician can increase the types, intensity, and frequency of inhibitory inputs with handling strategies, such as by providing firm, sustaining, deep pressures into the muscle belly or at its origin or insertion or through manual vibration.

    Another dimension to consider in motor unit recruitment is the ability to sustain a muscle contraction across time. An individual may be able to contract a muscle for a brief moment but is unable to sustain the contraction for sufficient periods of time as may be required for a particular task. If the clinician is attempting to facilitate a sustained motor output, the sensory input is more likely to be lower in intensity, the input is sustained for longer periods of time, and the task choices for practice require a longer duration of muscle recruitment. For example, the therapist may, in a soft steady voice, ask the child to c-a-r-e-f-u-l-l-y hold the cup of juice rather than loudly and abruptly encourage the child to hit a toy drum, or the therapist may ask an adult client to pour the entire watering can into the planter versus just touching the plant leaf. As seen in **Fig. 9.11**, the child is asked to wipe the whole mirror rather than taking quick swipes with the paper towel. This task requires the shoulder girdle and arm to sustain the pattern of coactivation.

    As discussed in Chapter 4 on the model of posture and movement and the chapters on motor control and examination, individuals with neuromuscular impairments may have selected impairments of recruitment of either the postural or the phasic motor units. Almost all clients with CNS dysfunction go through a period of decreased ability to recruit the postural motor

Fig. 9.11 The child is encouraged to clean the entire mirror while maintaining the step position to work on sustained contraction of both the upper and the lower extremities.

units. This episode may last for a short time or may extend for years. It may be evident in one body segment, such as the trunk, while being less obvious in the extremities. If a client is unable to recruit the postural motor units, an effective intervention strategy is to facilitate isometric holding of the impaired muscle(s) in a shortened range and to sustain this contraction for as long as is required for the activity. Because α motor neurons that innervate muscles with primarily slow twitch (postural) fibers are recruited first in muscle contractions in many human postures and movements, lower intensity input is suggested.[14] It is more important to sustain this isometric contraction during an activity rather than having the individual repeat repetitions of shorter burst contractions. A child could be facilitated to sit tall to draw a picture on an easel in front and slightly above him rather than sitting and reaching to the floor and returning to sitting 10 times in a row. An adult client may be positioned in a high sitting position in the bathroom in front of a mirror that is at least at shoulder height or slightly higher while she combs her long hair versus doing situps.

If the client has an impaired ability to recruit the phasic motor units, it is recommended to start with the muscle in a lengthened position and challenge it concentrically through the entire range followed by movements that require the muscles to recruit fast and alternate between the agonist and antagonist activity. The child could throw a Nerf football at a target across the room or an adult could swing a golf club through a full back and foreswing arc.

If the client is compensating for a postural deficit with overrecruitment of the phasic motor units, the postural motor units must be strengthened while the therapist engages the phasic motor units in activities. For example, the child may be holding a toy with both hands that, when shaken, makes a musical sound. Holding this object, even if it is relatively light in weight, requires sustained postural muscle activation while the phasic motor units in the limbs are recruited in a fast and reciprocating way as he shakes the toy. The challenge is that every task has elements that require postural holding and elements that require quick or phasic movement.[15] The clinician must weave these elements together at the right time and in the right place for the client to achieve the desired outcome. The principles for selective recruitment of postural, sustaining motor units versus the phasic, movement motor units are presented in greater depth in the chapter on the posture and movement model by Stockmeyer. Clinical examples are presented in the case reports in Unit V.

- *Concentric, isometric, or eccentric muscle contractions*: It is not sufficient to determine only if a muscle is able to contract. To understand the control or coordination of muscles, one must also consider the type of muscle contraction required for the task since every task requires a specific series of muscle contractions. Task analysis should identify not only what muscles need to be active or inactive at a particular time but also how that activity should occur—concentrically, isometrically, or eccentrically. Activities in the intervention session should specifically be chosen to target these contractions: the right type at the right time in the activity/movement. For example, if a child has difficulty controlling eccentric lower extremity (LE) extensor muscle activity, working on descending stairs or getting to the floor to play with his toys will be chosen over climbing the stairs or hopping and jumping to music. If a client has a Trendelenburg gait secondary to impaired isometric control of the hip abductors, working on sustained isometric holding on the stance leg in standing activities, such as stepping up on a step or the ledge of the bathtub with the other leg, will be chosen over strengthening the muscle concentrically with lateral leg lifts in standing or with leg lifts in side lying.
- *Gradation*: There are also impairments in motor unit recruitment that affect the ability of

muscles to grade activity; within a muscle, between agonist and antagonist, and/or among multiple muscles in a limb or between body segments. As discussed in Chapter 7 on examination, this gradation relies on the interplay between reciprocal activation and coactivation. For example, if an individual is unable to effectively grade the recruitment of quadriceps and hamstring activity in his leg for stability in stance, the therapist could choose a task such as reciprocally ascending and descending stairs as opposed to sustaining a standing posture while brushing his teeth. Handling is also used to limit errors in performance, such as facilitating eccentric hip and knee extensor activity to prevent dropping to the lower step in an uncontrolled way while descending or by facilitating hip extension to neutral before the knee extends fully to prevent a hyperextending knee while ascending stairs. If the need is for stability with greater coactivation, the therapist can provide approximation through an optimally aligned knee during stance in a standing task. If the greater impairment is thought to be diminished reciprocal activation of the quadriceps and hamstrings, the therapist could provide light resistance to the trailing leg as it begins to lift up to the higher tread. What makes any of these strategies NDT-based is not the specific technique (many clinicians use compressions or approximation during intervention without it being NDT), it is the ongoing examination with the clinical problem solving that relates impairments to the individual's activity and participation domains, the decisions to incorporate any specific strategy into the functional activity context, and the active participation of the client in the problem-solving process.

For these impairments, the clinician may choose practice activities and tools/objects that facilitate grading of muscle recruitment rather than requiring maximal contractions or sustained coactivation of muscles. For example, if an individual is unable to effectively grade the recruitment of quadriceps and hamstring activity in his legs, choosing a task such as that shown in **Fig. 9.12a, b** would be preferred over sustaining a standing posture while writing on a chalkboard.

Handling strategies that facilitate motor recruitment in one muscle or body segment and inhibit it in others are also used. To change the functional use of a limb or the trunk, the individual must contract and coordinate muscles across many joints of the body. This control and coordination requires precise timing and sequencing of muscle activation as well as the synergistic coordination of multiple muscles. Consider the relationship between the agonist and antagonist at a single joint. The two muscles may need to contract simultaneously in a task to have greater stability, such as is needed to hold a heavy item overhead or to maintain balance when standing on a bus or train as it begins to move. Conversely, it may be necessary for one of the muscles to generate a large amount of force

Fig. 9.12 **(a, b)** As this 3-year-old moves from sitting with hands on the floor, to lifting hips off the bench and then returning to sitting, he must grade the quadriceps and hamstrings in midranges using reciprocal combinations of concentric and eccentric patterns as he raises and lowers his hips from the bench.

while the other is relatively quiet, such as when swatting a mosquito or throwing a dart.

Clients demonstrate difficulties in establishing recruitment options. A common impairment in some individuals poststroke or with cerebral palsy is a diminished ability to coactivate agonist and antagonist muscles or muscle groups within a limb or connecting body segments for stability.[16,17] Clinicians can use handling strategies such as compression or approximation through optimally aligned joints to facilitate greater coactivation and stability as well as choosing tasks and environmental setups/conditions that facilitate this coactivation and coordination. Conversely, in individuals with impairments of increased cocontraction of agonist and antagonist muscles throughout the body or in a single limb, asking for quick alternating movements may diminish the degree of coactivation and allow more full-range, fast, and efficient movements.

- *Timing, sequencing, and muscle synergies*: In function, individuals must contract and coordinate muscles across many joints of the body. Synergies are defined as those groups of muscles that work together across many joints to complete specific tasks. As described in the motor control chapter, synergies are not viewed as hard-wired entities but as constantly changing groupings of muscles (and changing types of muscle contractions), based on the specific requirements of that individual at that one moment in time doing that one specific task. Chapters 10 and 11 on cerebral palsy and stroke discuss alterations in synergies that include a limited repertoire of synergies in contrast to age-matched peers without disability, increased activity in muscles not typically recruited for a particular task, or overflow of muscle recruitment (in that limb or elsewhere in the body) indicating impaired isolated recruitment or control. The clinician intervenes with handling by choosing a specific task or by manipulating the environmental setup to alter the recruitment pattern.

  A common gait pattern seen is decreased isolated control such that hip flexion on one side is coupled with hip flexion on the opposite side. Or, the individual may demonstrate decreased isolated control such that extension at the hip is coupled with extension at the knee, and plantar flexion at the ankle and flexion of the hip are coupled with flexion at the knee and dorsiflexion at the ankle. In young children, the therapist can return to information learned from the study of typical development and observe that infants develop isolated hip movement with increased lateral weight shifting. In young infants, this is performed in prone or rolling activities. However, with young children, lateral and diagonal weight shifting may be introduced in supported standing or other functionally relevant contexts, such as cruising and stair climbing. In older children and adults, activities in upright postures that demand a coordinated reciprocation of left and right leg muscle activation, such as in cross country skiing or stepping into a pair of jeans in standing, could be chosen.

- *Stiffness*: As described and discussed in Chapters 10 and 11 on CP and stroke, *stiffness* is a term that refers to the resistance a muscle or ligament offers to lengthening. It can be considered to be a ratio of the relative change in force/change in length.[18] When applied to humans, stiffness is viewed as having both active or neural components as well as passive or myoplastic components. Some of the neural characteristics of motor unit impairments already mentioned in this section clearly contribute to the neural components of stiffness. Examples include instances when the motor unit(s) cannot terminate activity such that a muscle or muscle group is constantly contracting, and when there is excessive cocontraction in muscles or muscle groups. This phenomenon is referred to as hyperstiffness.[19] The first choice in intervention for hyperstiffness is movement, multidirectional movement (that is, movement in all three planes, including the transverse/rotational plane). When any of us feel stiff, we weight shift and stretch the muscles that feel tight. Thus, if a child arrives for therapy in a wheelchair and is hyperstiff, the therapist helps the child out of the chair and introduces movement through the fullest range feasible in functional contexts and activities. If the impairment is an inability to terminate motor unit activity, other strategies to reduce hyperstiffness include quick alternating movement, manual vibration, and multidirectional, big range movements. The client should be as active as possible while the therapist protects the alignment.

- *Respiratory system*: Many individuals diagnosed with cerebral palsy or those who have had a stroke or traumatic brain injury (TBI) may have associated disorders of the respiratory system. For example, an infant born prematurely may have bronchial pulmonary dysplasia (BPD) and an adult may have preexisting chronic obstructive pulmonary disease (COPD). The therapist must be aware of these conditions and follow the necessary precautions during intervention. All three disciplines (physical therapy, occupational therapy, and speech-language pathology) may have special contributions to the management of the respiratory impairments based on the educational foundation of the disciplines. The reader is referred to Chapter 7 on examination and the chapters in Unit IV for more detailed information.

There are also secondary respiratory impairments that emerge based on the posture and movement disorders of cerebral palsy and stroke and secondary to periods of bed rest and/or inactivity in these individuals. Respiratory complications remain a frequent cause of early death for individuals with cerebral palsy and adults poststroke. For example, if one considers an individual who sits with a rounded back due to the inability to sustain activity of the postural extensors of the trunk, decreased range of motion into thoracic extension, shortened pectoral muscles, and weakness of the abdominals, it becomes obvious that the respiratory pattern will also likely be altered. The individual's ability to achieve optimal thoracic and rib cage expansion for full inspiration is impaired. The individual may rely on abdominal or belly breathing or may gain chest expansion by using accessory respiratory muscles, or with the use of the UEs to stabilize the rib cage. The neuromuscular, musculoskeletal, and respiratory impairments reinforce each other and lead to additional limitations in activity and perhaps other pathologies. The NDT clinician considers the ongoing relationships of the system integrities and impairments in terms of activity and participation implications and also in terms of future health issues.

Clinicians need to monitor an individual's respiratory status, analyze which impairments contribute to the poor respiratory support for function, and then treat the involved systems within the context of functional activities, whether these impairments are in the musculoskeletal, cardiovascular, neuromuscular, or another system. For these reasons, a therapist must consider the impairments contributing to an individual's respiratory status while working with the individual in therapy. For example, the therapist could be focusing on increasing overhead reach for an upper body dressing activity with a long sleeve pullover shirt and note that immobility in the rib cage is one factor that limits the reach. The client may also expand the chest by increasing the diameter posteriorly or by using increased thoracic flexion. As the therapist continues to work on overhead reach in the upper body dressing task and other similar activities, the therapist is able to address the decreased mobility of the rib cage as well as work to introduce a different breathing pattern or synergy for the client. When the pectorals are elongated and the anterior chest expands while the thoracic spine moves into and sustains extension, the ribs will move more freely. Each breath can lead to improved rib mobility and therefore a better performance of the dressing task. If the impaired respiratory pattern is not addressed, the client may begin to breath-hold during the dressing and other tasks, becoming less successful in these tasks. The individual who pulls into trunk flexion to breathe also usually demonstrates associated increased flexion of the UEs, potentially leading to their limited use. With impaired respiratory effort, the individual is also less able to produce an effective cough, which may lead to additional respiratory complications.

- *Cardiovascular system*: Just as it is common for individuals to have concomitant respiratory disease or disorders, it is common to observe cardiovascular disease or disorders, particularly in adults poststroke, since many individuals have strokes secondary to cardiovascular disease. When the individual is limited in his mobility in the early phases after the stroke, cardiovascular fitness becomes further compromised. There is also an ever-increasing preponderance of obesity in our society affecting pediatric, adolescent, and adult populations. This occurrence is associated with poor diet as well as a more sedentary lifestyle. When a physical disability increases this sedentary lifestyle, cardiovascular disease becomes a further complication. The therapist must be knowledgeable in the management of these associated impairments. The contribution of the NDT Practice Model demonstrates how the impairments are managed within each session in relationship to the other impairments and how the impairments in a body system influence activity and participation of the individual both during the immediate session and across time. If an individual's overall cardiovascular endurance is impaired, intervention needs to include activities to address this endurance. For example, many clients benefit from practice aimed at increasing the heart rate and blood flow and building increased cardiorespiratory capacity. This practice may include stationary bike riding, treadmill training, brisk walks in the community, circuit training, and others.

Another example of cardiovascular compromise may be seen as the therapist examines distal circulation in individuals with severe involvement in a limb. For example, if an individual demonstrates hyperstiffness in the upper extremity with a fisted hand that has very limited active and passive range of motion, the hand often demonstrates signs of decreased vascular supply, such as appearing reddish-purple or being cool to the touch. Similarly, if an individual post stroke demonstrates absent or decreased force production throughout a UE, it is not uncommon to see a swollen, painful, mottled wrist and hand. There is a clear relationship between active contractions of the muscles throughout a limb and blood flow in that limb.[20] In addition, the efficiency of muscles is partially based on the oxygenation provided by the circulatory system.[20] The therapist must treat the impairments in this system with the other body systems through their relationship to activities and participation. The therapist may start with analyzing the relationship to the client's posture and movement. For example, are there musculoskeletal impairments limiting distal range of motion and interfering with the use of this limb as an active part of the base of support? Can changing the alignment improve the perfusion of and thus the color of the limb? Does increasing the movement of the body part improve the distal circulation? Are the changes in circulation consistent with changes in sensation in the limb? Does the circulation change with increasing stress, either posturally or in terms of an activity or contextual factor? Each impairment is viewed in context with the other body system integrities and impairments, the environmental constraints, and the client's desired outcome.

- *Gastrointestinal (GI) system*: There are many examples of primary and secondary GI impairments that are associated with the neuromuscular disorders. Some of the associated problems include swallowing disorders, gastroesophageal reflux disease (GERD), aspirations with swallowing, and constipation. These disorders or impairments are related to issues of neuromuscular control and coordination, such as impaired timing and sequencing of muscle activity in swallowing to coordinate the swallow or to prevent aspiration during the swallow. Constipation may be related to the impaired activation of the abdominal musculature, particularly of the obliques and transversus abdominis muscles as well as to the overall decreased activity level of the individual. An infant who has severe GERD may push with the head, neck, and trunk into strong extension to lessen the pain in the esophagus from the reflux of stomach acids. If the infant also has cerebral palsy, this strong extensor activity may be confusing for the clinician. Should strategies be employed to focus on the neuromuscular impairments? or should the focus be on management of the GI system disorder? Are the GI impairments contributing to and reinforcing the atypical extension? Each session presents a unique situation that requires an examination and evaluation to determine which system(s) require intervention and the sequence in which to address them. The therapist may also need to carefully time intervention sessions in relationship to meals in the presence of GI system dysfunction. The reader is directed to Chapter 18 on the practice of speech-language pathology for further discussion of GI impairments and intervention strategies as well as to the case reports in Unit V.
- *Integumentary system*: The integumentary system, which includes the skin, connective tissue, and fascia, should perhaps be listed first in the list of systems needing to be addressed in intervention because it is a system that is influenced every time the therapist touches the client. It is one of the most responsive systems to input or stresses.[21] Skin changes its characteristics based on the types of input it receives or from weight bearing. Connective tissue responds to changes in stresses, such as those from sustained postural stresses, surgery, or an injury. These changes may result in scarring and thickening of the skin and connective tissue that may limit mobility. Thicker, denser fascia can also lead to restricted motion. Losses in mobility in the integumentary structures can influence activity limitations as well as overall participation. When integumentary system mobility restrictions are present, the clinician must examine and determine which structures of the system are causing the restrictions, including shortened fascia, shortened connective tissue, or decreased skin mobility. These impairments are also considered with the other systems' impairments. Different intervention strategies may be required for different body system impairments and, again, will be implemented within functional contexts as much as possible. See the chapter on examination for further information about impairments in the integumentary system.

Multisystem Preparation

Within an NDT framework, the therapist considers multisystem components related to posture and movement. For the purposes of discussion, it is beneficial to break the multisystem impairments into components to streamline the planning process and to make intervention strategies more specific and effective.

- Postural control, postural orientation, postural tone, praxis, and motor planning are concepts that reflect multisystem integrities or impairments related to posture and movement. The reader is referred to the discussion on these terms found in Chapter 7 on examination and additional discussion on praxis and motor planning in Chapter 16 on occupational therapy. When parents of a child report that their child's arms and legs are floppy, or that the child lacks trunk or head control, they do not know what specific body system(s) contribute to the multisystem impairment in postural tone. They are describing a global picture of their child: a gestalt. Similarly, a therapist may talk with a colleague asking for advice about a client who has increased postural tone. The description given is to provide a broad picture of the individual. Before intervention can be planned, however, the therapist must hypothesize and determine which of the single systems contribute to the hypertonia, including the neuromuscular, musculoskeletal, regulatory, visual, and other sensory systems. The therapist must also determine what contextual factors influence postural tone in the performance of desired functional tasks. For each individual, the strategies developed must match the contributing single system impairments at the time and in the context of that task.

  In addition to the consideration of postural tone, orientation, and control, it is also useful to consider kinesiological factors that contribute to these multisystem impairments. To understand intervention strategies, it may be beneficial for the clinician to think through the ABCs of posture and movement.

  - **A** is the *alignment* of the body and specific body parts that are key to outcome achievement. If the session outcome is to reach overhead for an item while sitting on a chair and the client is observed to be sitting with a very rounded back, the pelvis tilted backward, and the feet far out in front of the chair, the first step in intervention may be to align the pelvis more upright or perpendicular to the chair surface with a more extended spine and position the feet directly under the knees so the individual has a dynamically stable base to move efficiently over while reaching up. An individual's alignment may be more impaired distally, such as at the ankle, or proximally in the trunk, or both. To achieve this more efficient alignment, it will be necessary to address the underlying single-system impairments in the impaired body systems, such as hip joint mobility; recruitment of the postural muscles, especially in the thoracic spine; the ability to visually scan the environment; and the strength of the lower extremities to provide a stable part of the base of support. The preparatory work likely includes simultaneous and interactive loops of strategies for both the single- and multisystem impairments.

- **B** refers to *base of support* (BOS), which is defined as the points of contact of the person's body with support surfaces and all of the area circumscribed by these points. The BOS is both a biomechanical concept and a perceptual concept. For sitting, the feet, posterior thighs, and ischial tuberosities are typically the primary BOS.

  An individual may be sitting in a chair with both feet resting on the floor with the hips positioned in abduction and external rotation, the length of both thighs in contact with the chair surface, the entire back against the chair back, and the UEs on the arm rests, yet still perceive that the security in her BOS is coming from the UEs rather than all the other points of contact and the overall size of the BOS. This perception, and then the use of the UEs as the primary point of stability/BOS, precludes their use for other tasks in sitting. A large BOS provides external stability, decreasing the need for postural activity. Thus, the larger the BOS, the more difficult it may be to recruit the postural activity required to move in or out of a posture. Choosing a small BOS in intervention may result in increased postural activity. The less involved body parts are also often playing too large a role in the individual's BOS.

  Choosing an environmental setup that provides a smaller BOS and an activity that engages the overstabilizing limbs is a strategy used with both children and adults. For example, if a child is sitting on the floor and using the support of both UEs to hold the sitting position, the therapist may alter the sitting alignment by providing a small bench for the child to sit on and suspend play items in front of the child for the UEs, achieving both a smaller BOS and a reason for the UEs not to be part of the base. An adult poststroke who is overstabilizing with his less involved arm and/or leg and tends to sit far back on surfaces may be seated closer to the edge of a higher surface that aligns his hips above his knees and engaged in an activity that gives the less involved limb(s) a job, such as playing the drums.

- **C** refers to the *center of mass* (COM), a hypothetical point that represents the focal point of the individual's entire body mass based on the immediate posture and alignment of his body parts over the BOS. It is an ever changing point, shifting with every movement, with every breath, and even with every heartbeat. To maintain balance or have efficient, effective postures and movement, the COM must be controlled over the BOS. Individuals must be able to stabilize and move their COM (i.e., the COM moving smoothly within and at times outside the BOS) for function.

  To fully understand what creates efficiency and coordination in the ABCs of posture and movement, clinicians also require an understanding of the multisystem components of symmetry, balance, and weight shifting.

  - Symmetry in the body can occur in all three planes: left to right (frontal plane), front to back (sagittal plane), and in the transverse, rotational plane. Midline is the point around which the body moves in these three planes. We don't always "live" on the midline, but we balance and organize our movement around this midline. The concept of midline includes both a motor ability to be on and move around the midline and the sensoriperceptual awareness of the midline.

    The therapist and client, through active movement with consistent sensory input, establish the perceptual and motor midlines for functional tasks. For example, the therapist must decide if a slight asymmetry observed in a young child, due primarily to impaired isolated control on one side of the body and impaired somatosensory awareness, will escalate into a true scoliosis with the associated secondary musculoskeletal impairments and visual and vestibular impairments when the child enters the teen growth spurt. The clinician addresses the impairments relevant to the session outcome and thinks to the future and addresses the impairments that may contribute to further impairments and conditions over time. The therapist must intervene to minimize the secondary impairments associated with asymmetry. Extreme asymmetry may lead to impairments in the respiratory and digestive systems. Sensory disregard also contributes to asymmetry.[22] The therapist must continuously analyze the relationship between the multisystem impairment(s) and the single-system impairments that contribute to them.

- Balance is also a multisystem phenomenon. A person's balance in a posture or during movement results from a synthesis of multiple body systems, including, as a minimum, any or all of the sensory systems, as well as the neuromuscular and musculoskeletal systems. For this reason, intervention aimed at improved balance for any task requires complex problem solving on an ongoing basis to determine the contributing single-system impairments. For example, an adult with hemiplegia who wants to be able to walk without a cane in the crowded mall without loss of balance may need to practice activities that address many system impairments. That person might have a hemianopia and have decreased somatosensory awareness in the lower extremity on the more involved side. There also could be a vestibular impairment. The ankle joint may have decreased active and passive range of motion on the more involved side. The limited mobility is made more problematic by weakness of the plantar flexors so that the foot does not adapt to the surface well and does not control the body moving forward over the foot when that foot and leg become the stance leg. The therapist must sort through the underlying single-system impairments and develop intervention strategies that address each of these impairments within functional contexts that are meaningful to the individual.
- Weight shifting also contributes to the issues of symmetry and balance as well being a component of every task that is performed. Weight shifting occurs throughout the entire body, as when shifting the body weight forward and up when rising from sit to stand, and also occurs within a single part of the body, as when weight shifts in the foot from the heel during initial contact toward the lateral border of the foot and then diagonally across the foot toward the base of the great toe for terminal stance and preswing. It occurs across the palm of the hand from the ulnar to the radial border of the hand when pushing up from side lying toward sitting and occurs within the mouth with the weight of the food being transferred from the front of the tongue toward the sides of the mouth and teeth for chewing and then to the back of the tongue for the swallow. The direction and magnitude of the required weight shift are based on the desired outcome(s), the contextual functional activities in which the individual is engaged, and the environmental conditions. For example, if an individual is sitting in a car for a long ride, the weight shifts that occur to relieve pressure are small shifts in varying directions. In contrast, if a child is sitting in a desk at school and drops a pencil, the weight shift required to reach with one hand to the floor and remain seated in the chair requires bigger range movements. The individual must have the soft tissue mobility and strength for the weight shift to occur. Each movement requires selection of the appropriate postural *and* phasic motor units for effective weight shifting. There must be a balance of agonist *and* antagonist activity at individual joints as well as across multiple joints. The individual must also sense the body alignment through the integration of multiple sensory systems, including the visual, vestibular, and somatosensory systems.

  Weight shift can occur in the sagittal plane controlled by flexion and extension, in the frontal plane with abduction/adduction, or in the transverse plane with rotation. Most tasks require combinations of these directions of weight shifts. In addition, weight shifting can be initiated from different parts of the body and with different combinations of muscle synergies. This variety can be seen by reviewing the photos of babies between the ages of 3 and 5 months. The child in **Fig. 9.13a** is 3 months old and demonstrates weight shift with the head and upper body by actively pushing against the support surface with the upper extremities with more weight shifted to the right elbow and with the pelvic girdle remaining relatively symmetrical. In this situation, the trunk shortens on the weight-bearing side so that the baby is more likely to fall into a roll if the lateral weight shifting is of large magnitude. However, in the second set of photos (**Fig. 9.13b, c**), a 5-month-old baby demonstrates even more caudal weight shifting such that weight is born primarily across the pelvis and thighs rather than across the abdominal area, as in the first two pictures, and the weight-bearing side is elongated. The head remains more central over the BOS. This weight shift provides greater balance in prone on elbows and even on the hands with a more graded roll to the side. It also leads to greater dissociation between the lower extremities. It lays the foundation for creeping forward on the belly. Both forms of weight shifting—initiated from the arms or upper body or initiated from the lower body—are necessary in different functional activities.

  When learning a task, the individual may self-limit weight shifting to a single plane. For example, when learning downhill

Fig. 9.13 **(a)** The first photo demonstrates a weight shift while prone on elbows with the head and upper body leading the weight shifting. **(b, c)** The second two photos show a 5-month-old in prone actively lateral weight shifting with elongation on the weight-bearing side with greater dissociation between the upper and lower extremities. This baby would be able to control rolling toward supine.

skiing, the individual may create a wide BOS with the skis and snowplow down a gentle, smooth slope. The control is achieved with simpler patterns of primarily trunk extension balanced with flexion. Any lateral weight shifting that occurs is movement of the upper body over a more fixed lower body resulting in lateral shortening on the weight-bearing side. The expert skier keeps the skis closer together with well graded and timed weight shifts in all directions to permit skiing down rougher terrain at higher speeds.

An individual with a hemiplegia may keep weight shifted over either the more involved or the less involved side based on his unique blend of impairments. An individual with ataxia may not demonstrate a consistent or predictable pattern of weight shifting. During intervention, the therapist must determine which directions of weight shift are required for the task and select the key point(s) of control to assist in the magnitude, timing, and direction of the weight shift or to suggest where in the body the weight shift should occur. The therapist anticipates atypical weight shifting and facilitates the required weight shifting. In addition, the therapist anticipates future impairments by inhibiting ineffective and inefficient weight shifting that may lead to the development of additional secondary impairments or greater activity limitations or participation restrictions.

- The multisystem impairments related to control and coordination are also considered. The therapist incorporates the concepts of control and coordination into the problem solving and development of intervention strategies. Scholtz[23] defines these two terms specifically; *control* refers to the gradation or scaling of a factor, and *coordination* refers to the timing or sequencing of the factors. For example, the client may demonstrate decreased midrange control in a limb or in the trunk that may be caused by a combination of neuromuscular, musculoskeletal, and sensory impairments. For this individual, the clinician may decide to support the client in one body segment or at one point in time to minimize the control that is required in part of the body, allowing the focus of movement control to be on another body segment. This support may be offered through the use of a piece of equipment or by handling, providing precise, modifiable, and graded assistance.

  The therapist may also need to prepare a single body system more specifically during a task or transition if it is thought to be the highest-priority system that is interfering with the desired graded response. For example, if the therapist hypothesizes that impaired proprioception of the elbow joint receptors most interferes with the graded reach for a watering can, the therapist may provide compression and slight resistance throughout the range to increase the feedback during the movement or decide how much water will be in the watering can to provide the right amount of resistance to the joint from the weight of the object. However, if another client's most significant impairment interfering with graded reach was weakness of a muscle(s), the therapist might alter the relationship of the limb to gravity to decrease the strength requirement initially and then gradually increase the gravitational demands for the limb movement within and across sessions.

Impairments affecting coordination are also consistently monitored and addressed by the therapist. For example, the therapist may facilitate a weight shift to train or retrain the timing and sequencing of an activity. If an individual pushes into leg extension too soon in the transition of sit to stand causing a loss of balance backward, the therapist may use handling to facilitate a weight shift far enough forward for the individual to be balanced over his feet before allowing an upward weight shift to come to standing. The clinician may also engage the individual in a task such as reaching forward to place a cup on a stool a short distance in front of the individual to facilitate this forward weight shift as the client is moving from sit to stand. As shown in **Fig. 9.14**, the clinician encourages a child to shift his weight forward by asking him to place a book on a bench in front of him. The therapist facilitates this forward weight shift as the child moves from sit to stand.

Simulation

Simulation is the use of an activity or series of activities that are similar to the functional outcomes yet different in some aspect to make performance easier or more motivating initially. The difference between simulation and the real task may be from a contextual factor or due to alterations of any one of the ICF domains. For example, the short-term outcome for a teenager may be to put on a designer sweater independently. The individual may have tried repeatedly through the week with repeated failure and increasing frustration. A simulation activity could include putting on bangle bracelets or a favorite watch. The task of putting on a bangle bracelet requires many of the same postural and movement components as putting one hand through the sleeve of the sweater. However, it is easier to achieve because the bracelet is shorter than the sleeve and the bracelet remains the same shape compared with the conforming sweater sleeve. Putting on bracelets is also not connected to the frustration of trying to put on the sweater.

It is possible to build successes in this fashion, progressing to other simulation tasks that are successively slightly more difficult. For example, the next progression may be putting on a wrist sweat band. This task is more difficult than the bangle bracelet because of the softness and conformity of the material. However, it is still perhaps less problematic than the sweater.

Children frequently engage in simulation activities in play or in sport in therapy to increase the likelihood of outcome achievement and speed progress in nonplay life activities. Choosing tasks in intervention that the child may be more interested in, such as playing with toys or playing a sport to address his impairments versus working within a basic activity of daily living (ADL) task that the child needs to improve in but is not interested in practicing provides the right match between engagement in a motivating activity yet still addressing the high-priority impairments (**Fig. 9.15**). Adults may not need this same strategy since they are able to understand and appreciate the relevance of the real-life simulation activity.

The individual needs to be engaged in the simulation task if it is to be of benefit. Some individuals do not respond well to simulation, even if it offers opportunities to address their impairments. For example, if a child has significant sensory impairments, the child may not be able to perceive that putting on a bracelet is anything like putting on a sweater, or sitting on a green 8-inch bench is the same as sitting on a blue 8-inch bench. If the individual cannot generalize motor learning, simulation is not effective. For these individuals, the link from the simulated practice to the real task is obscure, and therefore, simulation is not the right choice.

Fig. 9.14 Forward weight shift is encouraged by the selection of the activity, setting up the environment, and hands-on facilitation.

Fig. 9.15 Taking off shoes is a difficult and unmotivating task for this 3-year-old boy. However, he is motivated to reach forward to push a toy. This position and play simulates the movements he needs to untie and remove his shoes and ankle foot orthosis (AFOs).

Achieving the Outcome

Because the desired outcome of intervention is a change in activity or participation, it is critical to reach and perform the outcome in each session. Thus, when the therapist is planning for the session, preparation and simulation tasks should be performed with the client actively engaged in functional activities that he or she values, and these should be chosen to be within or related to the outcome task of that session. It is not acceptable to structure sessions such that preparation and simulation activities are planned to be completed in one session and the performance and practice of the functional outcome at the next. If a client is scheduled for only 30-minute sessions, the outcome that is set may be less ambitious than if an hour session is scheduled. The performance of the outcome task should be well before the end of the session to allow time to *practice* the skill under different conditions. We know that, for permanent learning to occur, individuals need many repetitions, repetitions that include an appropriate combination of blocked, random, and novel task practice as described in Chapter 13 on motor learning.[24,25]

Progressive Challenge

As discussed in Chapter 13 on motor learning, practice to induce motor learning must be somewhat effortful and varied to achieve optimal carryover into life tasks. The choices available to add successive challenge within an intervention session are many and are dependent on many factors, including the client's needs and impairments, individual preferences and motivations, the environmental options, and the task characteristics. For intervention strategies to incorporate successive progression within and across intervention sessions, the reader is directed to the examples in the last section of this chapter.

Other Considerations for Organizing and Problem Solving in the Intervention Session

As has been discussed in previous chapters in this book, movement is organized around the task. An experienced NDT clinician will wisely choose activities that are meaningful to the individual to structure the active practice in the task both within and across intervention sessions. From a holistic evaluation, garnered through examination in functional activities and contexts chosen with consideration of the individual's participation domain, clinicians will be better able to develop an intervention plan that leads to effective outcomes for each individual. The activities are selected from the participation roles the individual wishes to return to or improve in. However, simply practicing tasks over and over again does not ensure improved outcomes. Engagement in the task, harnessing the parameters of the environment, and the clinician's handling to guide the individual's posture and movement combine to give the desired result. This paradigm and the interaction of the environment, handling, and the activity are underlying principles of NDT and are critical to the success of each intervention session and ultimately to the individual's outcome success.

It may be helpful to the clinician to think of this paradigm as a triad with the client in the middle. The role of the client in the process as well as each individual component of the triad have been discussed previously in this text as separate entities: the importance of working in functional tasks, choosing a contextual and challenging environmental setup, and when and how to use handling to effect better outcomes. The three components of the triad will be explored in greater depth in the following paragraphs.

The Functional Task

The individual client ultimately chooses the tasks that are to be practiced. These are the activities that are meaningful and motivating for the client. The client expresses this information to the clinician or the family, and caregivers guide these choices when the client is unable to. But how does the clinician choose from this often large list of activities when deciding which task(s) should be practiced within the intervention session(s), especially during the earlier sessions? The choice should not be random or linear from the top of the listed possibilities. The specific tasks and subtasks chosen by the therapist to be used during the intervention sessions from within this list of activities need to also match the individual's impairments. That is, the clinician needs to choose the tasks and subtasks that allow practice to specifically address the individual's significant or high-priority impairments that are interfering with his or her activities and participation. The therapist needs to be able to understand the normal task components of all the activities that the client wants and needs to perform. From this analysis, the clinician can then make a select choice for the tasks and subtasks that match the individual's impairment needs.

The list of desired activities our clients want to improve or participate in is often long, offering many options for variety in practice, ensuring neither the client nor the therapist will become bored by working on the same movement and component of a task or activity in a repetitive and boring way. For example, if we think of our previous example with the client who was an avid gardener, if one of her most significant impairments is the inability to sustain thoracic extensor muscle activity against gravity, choosing an activity such as reaching up and slightly forward to prune her roses from a position of high sitting or standing to water her hanging baskets, an activity that requires sustained trunk extension in vertical postures, would be a better choice than having her bending over a pot on a low table to replant her geraniums while sitting on a low stool.

For a child who is interested in playing soccer with his older brothers who play competitively, but who ambulates short distances with difficulty with the assistance of a walker and relies on a wheelchair for most household and community ambulation, his interest in playing soccer can be incorporated in his sessions as the functional context. He may be more motivated to dribble a soccer ball toward a goal post to develop more endurance for walking and to increase the precision for navigating through the house than to simply practice walking from one location to another. He might be a more active participant in therapy learning to lift and place his foot on the soccer ball rather than lifting his foot to place it on a bench for a caregiver to tie his shoes (unless they are his soccer shoes). The soccer ball activity may be considered a simulation activity for an outcome, such as stepping up a curb. It can successfully address his high-priority impairments, such as decreased isolated control within and between the LEs, decreased ability to scan the environment when in motion, and decreased impulse control. In addition to working toward activities and participation that are important to the child, the improved soccer skills are based on similar impairments that interfere with his ADLs, functional ambulation, and cooperative interaction with peers for play and school. Once again, neither the therapist nor the child becomes bored or uninterested in the therapeutic activities.

The Environmental Setup

The environmental setup for the task/subtask practice includes choices for the following (**Fig. 9.16**):

- *The tool objects*: Can the real task tools be used (optimal) or do objects that have similar shape and characteristics to the real task tools need to be used initially to simulate the activity? For a child, the tool may be a toy or for an adult, a guitar, if the client was a musician.
- *The contextual environment*: Can practice occur in the real environment (optimal) or is an environment that matches *some* of the demands of the real environment better initially?
- *The setup of the client*: Is the client in a squat posture and shifting over both feet as he would in the real task (optimal) or does he need to start in high sitting initially? Are the more involved limbs the primary support limbs while the less involved limbs perform the action of the task? or can the more involved arm be an action arm?

Fig. 9.16 This child practices toothbrushing while standing in a partial body-weight-bearing walker in front of a mirror to eliminate the need to balance and maintain alignment for this task.

- *The setup of the therapist*: Does the therapist need to be sitting beside the client, standing in front of him, positioned higher or lower than the client, stabilizing the tools/toys of the task, providing resistance to the movement, and so forth?

Once the decision is made about which task or subtask is to be practiced, the tools/toys and contextual environment choices are clear. If the client needs to practice walking in a busy environment or climbing the stairs with the laundry basket or the school backpack on, then the practice needs to occur where there are many people moving about or on a real set of stairs with a laundry basket in her hands or a backpack on her back. If this can't be achieved initially, it should be the goal as soon as possible. Remember, movement is organized around the task; this organization includes the task tools/toys and environment. The movement components of climbing stairs, right foot up followed by left foot up, and so forth, are only one part of being able to climb a flight of stairs with a specific object that requires a specific grasp, cognitive attention to the environment and task, and the ability to do this in an efficient and timely way. It is not always possible to practice the task in such a real manner and environment in the intervention session, but every effort should be made to simulate the environment with respect to the tools, the contextual environment, and the postural and movement demands (including the cognitive, perceptual, sensory, etc., demands) of the task.

Working within the actual task context offers the individual the ability to problem-solve movement (subcortically), just as he would if he were to perform the activity outside of the intervention session. Working in functional contexts in functional tasks also offers the client challenge in a way that exercise may not. Having to manage all the environmental demands of the task while moving or controlling within a posture or transition, during the task performance, provides an inherent level of challenge to the individual that drives improvements in activity and participation outcomes.

The Handling

The therapist makes choices for handling based on the following:

- *The client's impairments*: This directs the therapist's choices for where his hands and other contacts go.
- *The client's movement tendencies*: Do the therapist's contacts need to be proximal on the trunk or limbs? or distal? Does the input need to be for facilitation (encouraging movement that is desired)? or for inhibition (stopping or limiting movement that is not helpful)?

Examples of how this triad is used for decision choices within an intervention session for successful client outcomes are outlined in the case reports in Unit V.

Posttest of the Functional Outcomes

At the close of the session, the therapist conducts a posttest with the client in the session outcome activity.

This allows a careful comparison to the task performance that was observed at the start of the session (**Fig. 9.17a, b**) and leads the therapist and client in the planning stages of the next session, analyzing whether the session outcome was achieved and why, identifying the impairments that will be targeted to further improve activity, choosing the functional task and context for the next intervention session, identifying what needs to happen between sessions for the individual to continue to improve, and exploring if there is a role for assistive devices or technology to enhance the outcomes. The therapist and client develop a plan that outlines how the positive changes achieved in this session will be carried over to the next session, including through a home program, and how problems encountered in this session may be avoided in the next.

9.1.2 Bridges to the Next Intervention Session—Achievement or Failure to Achieve the Session Outcome

Achievement or failure to achieve the session outcome offers both the client and the therapist a rich opportunity for learning. Analysis of the factors leading to achievement or lack thereof can enrich the cognitive, psychomotor, and affective domains of learning. It is important for the therapist to identify and analyze the factors that led to successful achievement of the session outcome. Luck did not create success. Understanding which factors most directly contributed to achievement of the session outcome will help to guide the planning process for future sessions. If the outcome was achieved, was it too easy? Could the challenge have been greater?

Similarly, failure to achieve an outcome is an opportunity to evaluate the causes of lack of achievement. It is important for the collaborative partnership of client and therapist that they together analyze the factors that led to a failure and that they approach the lack of outcome achievement as a learning experience. Was the wrong subtask chosen to specifically match and therefore address the individual's impairments? Was the setup of the environment and task tools not ideal? Was the challenge too small or too great? Were the handling choices the wrong ones?

Fig. 9.17 **(a)** At the beginning of the session, C's attempt to reach for a toy on the floor. **(b)** The same activity at the end of the session showing changes in pelvic/trunk alignment, freer arm and hand movements, ability to control balance over a narrower base (note: hand on bench vs. hand on thigh) and improved symmetry in the frontal plane. These skills will lead to greater independence in dressing and rising to stand.

9.1.3 Additional Responsibilities in and between Intervention Sessions

Client and Family Education

One of the professional roles of all occupational therapists (OTs), physical therapists (PTs), and speech-language pathologists (SLPs) is education of clients and their families and caregivers. As professionals, we value the power of knowledge that assists clients in understanding and decision making in regard to their health and health care. Professionals who practice using NDT value the entire process of engagement with clients from initial information gathering through episodes of care. Educational opportunities exist the moment we begin a dialogue with our clients and families.

Each intervention session provides opportunities to enhance client and family knowledge through education as well as the therapist's knowledge about the client, a two-way exchange. Clients and family members are encouraged to take an active role throughout each intervention session. This active role is encouraged from the moment the clinician meets the client and family, asking them to describe their understanding of why participation is restricted, what activities are limited, and which impairments interfere with the client's function.

The clinician offers evaluation information to the client and family that becomes more specific as the clinician becomes more familiar with the individual. As the clinician shares information in a nonjudgmental manner, the client and family are more likely to develop trust with the clinician. Trust allows a mutual exchange of information and therefore education. Each intervention session allows education to begin, continue, repeat as needed, and modify. Clinicians working within an NDT framework therefore value and encourage the presence of family and caregivers throughout the intervention session. Educational opportunities exist in each session in the following ways:

- To discuss the health condition itself—pathophysiology, expected changes over time in participation, activity, and impairments; prognoses.
- To explore how all domains of health interact—body structure and function, activity, participation.
- To demonstrate that the purpose of intervention is to gain and/or preserve participation and activity unique to the individual client and to discuss why this purpose is important.
- To explore together alterations to the home, school, work, and leisure environments; assistive technology options; referrals to other team members with rationale for these referrals; and alternate options/adaptations for scenarios for outcomes desired.

For example, in the case report about Dennis in Unit V (A6), he and his wife participated in initial information gathering, examination, and evaluation with a PT who uses the NDT Practice Model. Education prior to intervention began with information exchanged among the three people involved. Part of the general and philosophical information that Dennis and his wife learned about in this interaction was that the PT believes it is possible to achieve functional outcomes with people who are many months poststroke. As they worked together in episodes of care over a 5-year period, Dennis and his wife learned that Dennis could indeed achieve new outcomes. They learned that the PT was interested in Dennis's participation and participation restrictions and that the purpose of intervention was to address the restrictions. They learned to pay attention to what Dennis could do each day at home and in the community and were taught to generate their own hypotheses as to what influenced his abilities as they learned more about how posture and movement and contextual factors influence function. The couple learned that the PT wanted to know of successes, failures, or changes in function at home because that was how she determined what needed to happen next in therapy. This educational process teaches clients and families advocacy skills and shows during each intervention session how NDT is a problem-solving process of creating solutions to addressing participation restrictions, activity limitations, and body system impairments.

During examination and intervention, Dennis's PT educated him about how he moved and asked him to focus his attention and sensory awareness on movements to learn how to differentiate an efficient from an inefficient movement. She educated Dennis about the negative effects of overstretching muscles and corrected his posture and alignment of any errors he made while he demonstrated for the PT what he was doing at home. This education led directly to Dennis and his wife's increasing management of Dennis's function outside of therapy with the result that episodes of care over time could be reduced.

In the case report about Jamie in Unit V (B5), a 10-year-old with cerebral palsy, he was educated by his PT that his work in intervention correlated to the participation outcomes that he and his family set. Because he understood this relationship, he was motivated to work hard, even when tasks were difficult. It is quite possible that this education contributed to the success of intervention.

In the case report about Jagraj in Unit V (B6), an infant with impairments in oral feeding, the SLP first gathers information so that she is aware of the distress that his family suffers in relation to the disruption in their roles of nurturing their infant. As she examines and evaluates Jagraj's impairments related to oral feeding, she develops an intervention plan of care. She is highly sensitive to the family's desire to protect their infant from distress and discomfort. Through inclusion of his family in decision making and in handling him, the SLP educates them about why Jagraj experiences limitations in oral feeding, how to handle and support him to intervene, and how to present food and liquids to him in a way that is safe and comfortable as well as therapeutic. In return, the SLP is educated about how Jagraj's family views his needs and learns what is acceptable and unacceptable in her advice to them. As the family and Jagraj develop a trusting relationship with the SLP, education and shared problem solving are likely to effect functional outcomes for Jagraj's oral feeding skills during each intervention session.

Through client and family education and the learning that occurs for all involved, including the therapist, the clinician modifies anticipated session outcomes or creates a new session outcome for future sessions.

Therapy Equipment

Equipment designed for use in therapy sessions may be used by OTs, PTs, and SLPs. Within the NDT Practice Model, therapy equipment provides clinicians with options that may assist in intervention strategies. Therapy equipment and assistive technology, such as partial body-weight-supported walking equipment, augmentative and alternative communication (AAC) devices, splinting, and orthoses, are not "NDT equipment." These devices are used within NDT intervention sessions incorporating problem solving and are seen as contextual facilitators.

Equipment is used to assist the clinician with addressing single- and multisystem impairments while working toward a session outcome. It can be commercially made and distributed, or it can be designed and made by the clinician, such as by fashioning a bolster support from heavy blankets and packaging tape. Equipment can be adapted from ordinary objects, such as using a toy that has sound, moving lights, and vibration to increase sensory arousal and attention for outcomes using functional reach and grasp, attention and response to the voice of a family member, or direction of movement of the head and trunk in preparation for an assisted bed-to-sitting transition with a child.

For example, in the case report about Makayla in Unit V (B4), the PT uses therapeutic equipment to address body system impairments and to facilitate efficient posture and movement. She selects a bench that is adjusted for height so that Makayla can sit upright with feet flat on the floor. The bench allows Makayla's PT to work toward an outcome of sitting with hands free for play and allows access to Makayla physically from any direction and plane. The height, incline, and Makayla's position along the long or short side of the bench can be altered according to the PT's problem solving of Makayla's needs for posture and movement and for the task they are engaged in. The bench is chosen for its sensory properties too. It is flat and firm so that when the PT provides hands-on strategies that assist Makayla to sit upright, she is able to feel the bench against her bottom and thighs, recruiting muscle activity in response. Makayla's PT also uses a ball as a piece of therapy equipment to provide a sitting surface that is firm yet mobile in all three planes. She uses these properties to enhance sensory awareness of the seating surface, to enhance upright postural control, and to guide movements. The size and the firmness of the ball are selected for the specific postures and movements that her PT wants to elicit.

In the case report about Mark in Unit V (A1), the PT chooses a long wooden pole to provide a "bridge" for the UE movements required to regain his golf swing and to bring his hand toward his head for putting his golf hat on. The pole provided a surface for the hand and arm to activate and organize on in a modified chain setup (see the last section of this chapter for a discussion of modified chain setup). Initially, Mark's impairments of weakness in his shoulder girdle and humeral muscles could not efficiently manage the required open kinetic chain movement against gravity for these two tasks. The pole provided a surface that supported some of the weight of his arm, gave him sensory feedback about the movement required for the task, and could be angled to accommodate the trajectory of the reach. The bottom of the pole on the ground provided stability, but the multiple degrees of freedom that the pole could be moved into from this stable base allowed his therapists to selectively challenge various ranges in the shoulder girdle and humeral joints and could be moved to simulate his golf swing. Mark's hand could either be stable in one spot on the pole while he moved the pole through various ranges as is needed for a golf swing or his hand could slide along the pole either up or down from his head as is required to put on or take off his golf hat. The series of photos in Fig. **9.18a–e** demonstrate the use of a pole for Mark as he works toward his return to golf.

Fig. 9.18 **(a–e)** Mark uses a pole as a therapeutic piece of equipment as he works on his golf swing. *(continued)*

Fig. 9.18 *(continued)* **(a–e)** Mark uses a pole as a therapeutic piece of equipment as he works on his golf swing.

Assistive Technology

The previous chapter on evaluation and the plan of care defined assistive technology as a facilitator to participation, activity, and body system impairments. Its uses may increase independence in life roles. Because use of assistive technology requires a clinician's understanding of its operational features, how it is intended to interact with the client, safety features, and how to teach clients and families its role in their lives, clinicians spend time during intervention sessions in all of these activities. Sometimes, this instruction consumes only part of one session, such as teaching a person how to use a cane on level surfaces or using a rocker knife for cutting meat. However, teaching use of assistive technology and customizing its features to a client may require multiple sessions and require periodic adjustments and upgrades (sometimes throughout life). The skill set of a clinician may include specialized knowledge in specific areas of assistive technology, such as wheelchair prescription, AAC devices, and adaptations for computer access.

Assistive technology fits into the NDT Practice Model just as the ICF describes it, as a facilitator. The clinician bears in mind that the piece of technology, no matter how low tech or high tech it is, is useful if it serves the session, short-term, and long-term outcomes. Therefore, the outcome is not that Mrs. Baker will get a manual wheelchair or that Hannah's AAC device needs an upgrade. The outcomes measure the participation and activity outcomes that the assistive technology facilitates.

For example, Mrs. Baker's wheelchair, once fitted properly, subserves the outcome of family community mobility. With a wheelchair, Mrs. Baker now has a means of mobility to go to the doctor's office, grocery store, and her grandson's eighth grade graduation with her family's assistance. The outcome is measured in the expansion of her home and community mobility abilities. The clinician may educate the family about the benefits and drawbacks of a power wheelchair versus a manual wheelchair, work on fitting the wheelchair to Mrs. Baker with the equipment provider, and teach Mrs. Baker and her family how to care for the chair—how to collapse it and open it, how to help her position correctly in it, and troubleshooting. They work together on ascending and descending curbs and uneven sidewalks. However, the clinician is also spending time in these same sessions working with Mrs. Baker on postural control with graded movement for sit to stand transitions, squat pivot transitions from various surfaces, taking steps forward and backward, and walking in indoor environments on smooth surfaces like she has in her condominium. There may be some session outcomes that are related to her use of the manual wheelchair such as the following:

- Mrs. Baker will move from the manual wheelchair to the toilet in her bathroom with the assistance of her husband and her daughter together. Mrs. Baker will move forward in the chair from the back of the seat to the front third prior to the transfer with verbal cues only.
- Mrs. Baker will perform a squat pivot transfer from her manual wheelchair to the front passenger seat of her daughter's car with assistance of either her husband or her daughter. She will move to the front of her chair (as in previous outcome) and initiate weight shifting to her feet as her family member asks her to stand up.

These session outcomes help Mrs. Baker expand her mobility options in her home and community with the use of her manual wheelchair. The assistive technology supports session outcomes. Obtaining the wheelchair is not the outcome; what Mrs. Baker and her family can do with the wheelchair is the outcome. Sessions may therefore be designed around learning to use the assistive technology in participation and activity roles.

In Case Report B8, assistive technology is integrated into a comprehensive plan of care and plays roles in all domains in the ICF as well as being an important contextual factor. Brandon was a child with cerebral palsy who also suffered from frequent seizures. His condition affected many of his basic life body functions, such as his arousal level or state of alertness; cardiovascular and respiratory regulation; as well as his neuromuscular and musculoskeletal systems. His PT and mother chose several pieces of assistive technology (adaptive equipment) for the purpose of increasing family participation in the home and in the community for him.

Brandon's family obtained multiple pieces of adaptive equipment, including a wheelchair, an activity chair, and a stander through consultation with his PT. His PT taught the family how to position Brandon in the equipment, adjusted its fit, and made frequent modifications based on his changing medical status as well as changes in the manifestations of his impairments. It was important that the family be able to effectively manage Brandon during his seizures in all pieces of equipment. His O_2 monitors provided constant information on his heart rate, blood pressure, and oxygenation level. His family also regularly watched for signs of reflux or gastrointestinal (GI) discomfort. Standing in the stander and using the PBWB at therapy were designed to address the impairment of low bone mineral density in his lower extremities and to assist in maintaining full range of motion into extension at his hips and knees. However, this work was only a small part of how the stander and PBWB device served the outcomes of family participation. He could play his bells best in standing, and he could walk in the PBWB device at therapy because of the effects of his stander at home and could thus be like the other boys in the family.

His PT asked for feedback constantly from Brandon's family, not only about his comfort, his ability to regulate his state of alertness, and cardiovascular and respiratory body functions but also his participation abilities that resulted from the use of the assistive technology. The wheelchair as well as the associated activity chair at home, with many of the same accessories as the wheelchair, provided him opportunities to join in family activities such as meals and movie time, to play independently and with his brothers, and to learn from his teacher. The wheelchair also provided transportation for Brandon and all of his required medical equipment and supplies around his house and in the community. Finally, the PT also used Brandon's adaptive equipment in intervention sessions to assist body segment alignment, to assist arousal and attention, and to monitor heart rate and respirations while she provided therapeutic handling to achieve session outcomes.

Home Programming

One of the many reasons clinicians ask clients about the details of daily life during their initial information gathering is to direct choices for home programming. As noted in the previous chapter on evaluation and establishing a plan of care, the NDT-educated clinician who knows the details of a client's daily routine will be able to customize a home program specifically to that client's needs. During an intervention session, the clinician is problem solving many facets of his or her interaction with the client as noted previously in this chapter. In addition, the clinician is thinking the following:

- What parts of the session outcome are safe and reliable enough that the client and family can practice them at home to achieve motor learning? What type of practice and instructions work best for this client learning this skill?
- Who should be responsible to supervise, monitor, or assist with this practice if required (the client, spouse, parents, grandparents, siblings, school aide, other caregivers)? The clinician designs home programs directed to the skill level and role responsibilities of each person who is likely to assist the client with the home program.
- If the client is able to successfully practice part or the entire session outcome within the daily routine, what will the client be prepared to do next session?
- How often and/or how long can the client reasonably be expected to practice each day? Time available to devote to a home program is one reason that the clinician asks detailed questions about the client's typical daily routine.
- How can the home program be as stress-free for the client and caregiver as possible? Can the home program be made enjoyable and fun?

As clients and their families and friends participate in an intervention session, the clinician also thinks about when in the session the home program should be discussed, whether it is written down, and when it is shown to and practiced with the caregiver. It may seem logical that this work is done at the end of the session so as not to disrupt the flow of interaction between the client and therapist. Sometimes, this sequence works well. At other times, however, waiting until the end of a session can result in unanticipated difficulties. The following situations can alter the decision as to when in the session it is best to discuss home programs.

- Many clients become fatigued physically and emotionally by the end of an intervention session. Their performance may then be less than ideal, and if family or caregivers are involved, poor performance may be perceived as not trying or not cooperating. As clients and caregivers practice a skill that is new to them, therapists should ask them to demonstrate the practice and talk about practicing outside of therapy before fatigue becomes a factor. Stopping to practice a portion of the outcome or give related tasks as home programs during the portion of the session that the client is performing well may be a better option than waiting until performance is deteriorating for some clients.
- Clients and family members may remember what to do and how to do the skill at the moment it is performed within the session rather than waiting until the end of the session when the therapist says something like, "Remember 30 minutes ago when you were able to scoop the applesauce up with your spoon so easily? That's what I want you to do at home." By this time, the client and family may not recall how or why that particular performance worked well.
- Opportunities to instruct clients and families and deciding on the best method of remembering what to do and how to do it vary from client to client and with each family. As with all people, there are different learning styles from client to client and family to family. Some learn best with physically guided practice, remembering what to do easily with this type of instruction. Therefore, the therapist may show and practice with a client or caregiver several different times during the intervention session. Perhaps another individual or family is more comfortable watching and writing down instructions in their own words. Another may prefer digital photos or videos to help them know what to do and how to do it. Each variation may alter when in the session the home program is explained, demonstrated, and recorded.

For clinicians practicing within the NDT Practice Model, home programs encompass learning opportunities as described. Home programs are carefully designed practice sessions meant to assist motor performance become motor learning within the context of each client's daily life. In general, a home program does not include more than one to three key practice strategies.

It must also be remembered what home programs are *not*:

- A home program is *not* a list of preprinted exercises. Generic exercises do not fulfill the requirements of individualized outcomes designed specifically for each client. They do not assist in practice of participation and activity skills specific to that person. They rarely provide motivation necessary for motor learning.
- A home program is *not* an attempt to mimic the intervention session that the therapist completed while making professional procedural decisions constantly throughout the session. Home programs are *not* intervention sessions or substitutes for them.
- Home programs are *not* added assignments for caregivers to give therapy a certain amount of time each day. A home program is *not* an opportunity for therapists to expect caregivers to perform skilled manual strategies, complicated handling strategies,

and sensory modulation strategies or try new skills that require constant professional monitoring for safety and effectiveness.

- For example, it is often not safe for a family member to passively stretch a client's tight hamstrings; it could be extremely painful and dangerous if the family member performs the stretch incorrectly. The therapist must appreciate that hamstring stretching is not a typical family member or school/work aide role. However, standing as upright as possible during assisted transfers to and from the toilet may be the role of these caregivers. Providing instructions as to how to safely assist the client's best upright position in standing done several times each day may certainly assist in hamstring muscle group extensibility and be the right task for that individual's home program.
- For example, it may not be safe for the babysitter to feed a child who does not chew food efficiently or sufficiently a fast food burger with eight different textures in it while the child is also running and laughing at the playground. The therapist and family may want the child to enjoy the playground and a snack with her siblings while under the babysitter's care. In this situation, the therapist and parent plan carefully what the snack will be, and the therapist or parent may decide to watch the babysitter feed the child a few times prior to the trip to the playground.

The clinician using NDT is committed to asking prior to the next intervention session how the home program is working. Depending on the level of trust and self-examination, the client and family should feel free to report honestly. The therapist will need to decide over time if the home program is too difficult or too lengthy, and/or whether the client is not willing or able to take much opportunity to practice. Sometimes, home programs are not performed with any consistency or dedication, but the client does attend intervention without fail. Therapists need to consider that dedication to attendance at therapy is a significant investment and that perhaps this is the extent of what the client and family can handle at this time.

In any case, whether the home program is practiced or not and whether it worked well or not, the therapist needs to hear about it so that future session outcomes, future home programs, scheduling of therapy frequency and duration, and the plan of care can be altered accordingly.

In Case Report A2 in Unit V, JW is able to assist her therapists in problem solving for home program recommendations. JW made modifications within her home to practice some of the postures and movements within her daily activities as recommended by her therapists. One such modification in the early phases of intervention was in the furniture and stable support placement in her kitchen and at her computer table so that her left arm might actively support as she adjusted her postures and movements in a variety of movement planes during functional activities. This home program, adjusted weekly, allowed the collaboration that JW was capable of to maximize carryover of therapeutic strategies used in each intervention session.

In Case Report A5 in Unit V, PW is given activities to perform at home. Reaching activities and visual motor activities were performed independently or supervised by family and directed toward daily life tasks. Because PW's therapists were unsure that opportunities for expanding PW's skills were being practiced in a variety of environments, they scheduled a formal meeting to establish the importance and commitment to programming follow-through. Family members committed to community outings but were unable to follow through. The lack of follow-through was reported to be a major factor in the decision for PW to live with another family member.

In the case report about the twin babies Mya and Maddison in Unit V (B1), they both require controlled environments and assistance with optimal positioning for feeding. Because their mother has a full schedule in managing the twins' additional needs for safety and nutrition when eating, and a 3-year-old sibling to manage as well, the home program must consider how to assist the mother in ease of management, reducing stress as much as possible for all. Early management included designing additions to typical baby seating equipment so that one baby could be optimally positioned while the other was fed. Environmental modifications to assist active engagement of each baby's attention needed to be included within the feeding schedule. Unless one has managed three children under the age of 3 with two of them needing additional assistance at mealtimes, it is difficult to understand that the feeding schedule is likely to consume a major portion of the mother's day. From a background knowledge of motor development, deviations from typical development, and system impairments; experience in feeding skills for babies high-risk for disabilities; and in listening to the concerns of families in this situation; therapists could recommend home programming to accommodate both the specialized needs of the babies while streamlining daily care to minimize the mother's workload. During subsequent intervention sessions, Mya and Maddison's therapists listen to the mother's description of daily feeding and work continuously to meet the needs of everyone in the family.

Finally, the clinician and caregivers may decide that, for a given or multiple intervention session(s), it would be best if the caregiver is not present. With the caregiver not present, home programming may be altered in scope and will need to be discussed and shown after a session is completed. The decision of whether a caregiver is not present during one or multiple sessions may not be a consistent practice but can be deemed the best choice or necessary for some sessions. Rationales for this decision may include the following:

- The caregiver may be physically and emotionally exhausted. The decision to stay out of the session for rest and regrouping may be the best way to assist the caregiver that day. The therapist reassures the caregiver of this choice.
- The client may perform better for the clinician without the caregiver present. This performance is not limited to children. Our relationships with people close to us are complex, and at times, anyone's

behavior and performance may not be ideal when this relationship is foremost in our thoughts. If the caregiver is not present in the session for this reason, client education and home programming will alter significantly. The clinician may choose to ask that nothing new be attempted after this session and may in fact decrease the time devoted to practicing new skills if other portions of life are deemed more critical. Or the clinician may show the caregiver one idea for practice when the caregiver returns at the end of the session.

9.2 Summary

Each intervention session includes many components as outlined in this chapter. The therapist must determine how to organize all of the components and how to progress through them. There will be loops through the various individual aspects, rather than a progression that is more linear in organization, with the emphasis changing along the way as required. Helping clients achieve sustainable, meaningful, functional outcomes is the end goal of the therapeutic process of NDT practice. The NDT Practice Model guides clinicians to evaluate in an ongoing manner during and between sessions so that optimal choices can be made for intervention and the plan of care. If you know where you are going, there *is* a logical road to take you there.

9.3 A Collection of Intervention Strategies and Frameworks

The following frameworks are meant as guidelines or examples of progression to use during intervention. They are not firm rules *and* are not meant to be used in a dogmatic and sequential manner. Each individual is unique and thus deserves a unique plan of care for intervention. These intervention strategies and frameworks are offered here simply to provide the clinician with a starting point and some ideas for progression and challenge. Clinical reasoning and problem solving must still be the cornerstone of a successful intervention plan in a single intervention session and in sessions over time. Some of these frameworks are more appropriate with adult clients and others for children. At times, the emphasis is noted in the text.

The ideas contained in these frameworks are a collection of strategies that have been developed and refined over time. The Bobaths[7] and their early collaborators made keen observations in the examination and evaluation of clients with CNS dysfunction. From the observations of abnormal posture and movement in these individuals, they developed hypotheses about the causes of the dysfunctional postural and movement control that then led them to develop ideas for intervention.[7] As the collective knowledge base progressed over the decades since the 1940s, these first ideas for intervention were expanded and refined, and they stimulated new and more successful strategies. The instructors and clinicians who have worked within the NDT Practice Model over the past 80 years are all the originators of these ideas. Intervention strategies will continue to change going forward—out of necessity from the scientific discoveries yet to be made, from the efforts of master clinicians' continuing to challenge what we know, and mostly from the need for our clients to get their lives back—faster and better.

9.3.1 Considerations for Progression of Limb Control in Adult Clients Post–Acquired Brain Injury

Cathy M. Hazzard

Closed kinetic chain (CC) → Modified chain (MC) → Open chain (OC)

When the neuromuscular and musculoskeletal impairments in the proximal trunk and more involved limbs are such that the limb function and control are absent or minimal (e.g., the proximal shoulder girdle and arm muscles are unable to initiate activity and/or are profoundly weak), the progression from CC → MC → OC demands offers a logical sequence to support recovery of function. It is not logical or helpful to expect control to return in an antigravity, long lever, OC movement when the muscles in the proximal arm are unable to activate consistently and with adequate force to support the weight of the arm against gravity. The sequence from CC to MC to OC can be used for both the lower and upper limbs but is particularly helpful for the UE, thus most of the following explanations and examples will be given for the UE.

Closed Kinetic Chain Movement

CC movement refers to movement of the body on the limb when the distal segment of the limb is on a stable surface.

- The distal segment of the limb, the hand or foot, remains in contact on a stable surface as the individual moves his body over and around on this stable limb. Depending on the specific control and movement demands that are then placed on the other body segments (and in particular, movement demands out of the BOS), the CC arm may be facilitated to automatically actively assist as a supporting part of the BOS.

  Examples include the following:

  - When the individual is in high sitting on the forward edge of a stable kitchen stool and the hand of the non- to low-functioning upper extremity is open and on a table at the side of the hip with the elbow slightly flexed, the clinician asks him to take a small step forward with the less involved foot while reaching forward and slightly up for a full glass of water with the less involved hand. This activity may result in an automatic support response (i.e., activation) of the scapular stabilizers, depressors, and elbow extensors of the low-functioning upper extremity as part of the BOS.

- ◦ When the individual is in standing facing a counter with the hand of the non- to low-functioning upper extremity open and on the counter in front of him at a height such that the elbow is slightly flexed, the clinician asks him to reach up into the cupboard with the other hand. This activity may result in an automatic support response (i.e., activation) of the scapular stabilizers, depressors, and elbow extensors as part of the BOS.

Note: In both of the foregoing examples, as one part of the BOS is removed to be the action limb, the remaining parts of the BOS need to become more active (this happens in a feedforward way) to maintain stability for the action. Thus, in the first example, the more involved leg may also become more active during the step and reach with the less involved limbs, and in the second example, both LEs will become more active for stability.

- In this same setup of CC with active support, body on arm strategies can also be used to actively lengthen shortened muscles/tissues.

  Examples include the following:

  - ◦ If the individual rotates in the trunk on midline to look away from the supporting arm at the clock on the wall behind him, this results in movement toward scapular adduction and external rotation at the glenohumeral (GH) joint. If the therapist uses handling to *hold* the proximal shoulder girdle toward scapular adduction and GH external rotation *before and during* the client's trunk rotation (i.e., limiting the movement of the scapula and humerus), this may result in a lengthening of the muscles that pull the scapula into abduction and humeral internal rotation (**Fig. 9.19**).
  - ◦ If the individual has the more involved hand open and on a surface in front of him while he shifts his weight forward over his BOS (including over this hand) to reach for an object with the less involved hand, the shift results in movement at the wrist and fingers into extension (**Fig. 9.20**). If the therapist uses handling to maintain the hand open and in contact with the surface while the client shifts forward, an active lengthening is achieved of the muscles and soft tissues that may be shortened (i.e., long finger and wrist flexors).

Modified Chain

MC can be defined as the distal segment of the limb (i.e., the hand) maintains contact with a surface and either the hand moves on that surface or the hand and surface move together (**Fig. 9.21** and **Fig. 9.22**). Thus this movement may be either with the body moving on the limb or with the limb moving on the body. Arm on body movements occur when the arm is moving but the body is stable.

Fig. 9.19 Gaining glenohumeral external rotation range through body on arm movements.

Fig. 9.20 Gaining wrist and finger extension range through body on arm movements.

Fig. 9.21 Opening a door; a modified chain movement for the upper extremity.

Fig. 9.22 Rolling a ball; a modified chain movement for the lower extremity.

Some examples include the following:

- Walking while pushing a wheelbarrow (see **Fig. 9.2**).
- Walking while carrying a laundry basket with both hands.
- In standing, sliding the hand up an inclined surface toward the cupboard.
- In standing, opening and closing a door.
- Riding a bike or rollerblading (examples for MC for the LE).

Rationale and Benefits of Using CC and MC Setups before OC Demands

- Part or all of the weight of the limb can be supported on the contact surface, even if the surface is slanted or vertical.
- The degrees of freedom can be selectively controlled.
- Sensory information is received through the contact points, which may help to organize activity throughout the arm.
- Distal demand facilitates proximal activity and vice versa.[26]
- The effects of gravity can be mitigated (i.e., eliminated or minimized initially and then gradually reintroduced).
- Most importantly, the activity involved in CC and MC is how we use our limbs functionally for a significant number of activities. This activity is easy to think of for the LE (stance phase of gait) but it is also true for the UE. The only two truly OC activities we perform with our UEs are gestures and the reach phase of moving our hand in space until we make contact with the target object.

Open Chain

Opening the chain or part of the chain places increased demands on the limb because it is now moving selectively, free in space. Controlling movement with an OC limb is more difficult from a neuromuscular and biomechanical perspective.

The following conditions may present:

- Increased demands for muscle activation (isometrically if just holding the limb in place, as well as from a concentric and eccentric perspective if the limb is moving in space).
- Increased strength and range of motion demands.
- Increased gravitational demands.
- Increased demand for trunk control.

When first working in an OC setup, clinicians can make the task easier by initially using shorter lever arms to open only part of the chain in the UE. For example, in Case Report A2, as JW gained more range of motion and strength around her shoulder girdle, the therapists had JW slide her arm up an inclined surface and over its end so that her forearm or elbow remained *lightly* (not propping through this contact) in contact as a distal point of stability while her wrist and hand moved off the surface to reach for objects. This resulted in the wrist and hand link of the UE chain to be open (a short lever) while the rest of the limb was still in active support. They used a similar strategy with JW at her wrist and forearm when she began using her computer keyboard.

Other points about OC include the following:

- Initially the movement demands in an OC should be in small ranges and using smaller levers.
- Depending on the task and the setup, the challenge can selectively be increased in different UE movements by opening the chain at the elbow, forearm, or wrist or finger links.
- This same rationale and sequence can be used for the LE to work on swing phase impairments. For example, selectively opening the chain to target knee flexion with short levers allows for more focused work on the hamstrings but without the individual having to hold the entire weight of the leg in space.
- Throughout CC, MC, and OC work, it is useful to incorporate objects in the hand earlier rather than later in functional tasks. This work allows the proximal impairments to be addressed while also addressing the distal impairments. Using different sizes and shapes of objects as well as different textures of objects in the more involved hand (contextual objects for the specific tasks being practiced) allows for improving graded grasp, active radial wrist extension, improved subcortical sensory awareness in the hand, and movement of supination and pronation of the forearm. It is important to focus on both proximal and distal impairments in the UE because efficient UE function requires both proximal and distal control.

The sequence of photos in **Fig. 9.23a–k** demonstrates a progression from CC to MC to OC for an individual who

Fig. 9.23 **(a–k)** A sequence demonstrating a progression from closed chain to modified chain to open chain practice activities for an individual working toward a return to golf and planning a cross-country move. *(continued)*

Fig. 9.23 *(continued)* **(a–k)** A sequence demonstrating a progression from closed chain to modified chain to open chain practice activities for an individual working toward a return to golf and planning a cross-country move.

Fig. 9.23 *(continued)* **(a–k)** A sequence demonstrating a progression from closed chain to modified chain to open chain practice activities for an individual working toward a return to golf and planning a cross-country move.

was working toward returning to golf and planning a cross country move.

9.3.2 Pediatric Considerations for Progression of Limb Control

Jane Styer Acevedo

There are several instances when closed chain activities are used purposefully in pediatrics. The first is in infant and toddler development. Creeping on hands and knees with the tummy off the floor is very helpful, and some would say essential, to the proper development and strengthening of the shoulder girdle to prepare the arm and hand both for use in space and for fine motor manipulation. Some children will walk without creeping and have no ill effects within the realm of typical development. However, when the child is faced with developmental challenges, such as cerebral palsy, quadruped is typically used to strengthen the shoulder girdle, arms and hands, as well as the core in preparation for self-care and fine motor activities.

When quadruped is not possible due to range of motion, strength, or postural tone limitations, or when it is no longer developmentally appropriate, it is helpful to find another way to promote closed kinetic chain activities of the shoulders and arms. It may be in a modified vertical position, in sitting with weight bearing through the arms and hands, or perhaps in supported prone or side-lying positions. The choice of task/activity and the presentation of the child will guide the therapist in how to promote closed chain activities for range, strength, and functional skill use.

9.3.3 Mitigating the Demands of Gravity

Cathy M. Hazzard

As in the reasoning described in Section 9.3.1, when the neuromuscular and musculoskeletal impairments in the proximal trunk and more involved limbs are such that the limb function and control are absent or minimal (e.g., the proximal shoulder girdle and arm muscles are unable to initiate activity and/or are profoundly weak), it is not logical or helpful to expect control to return in an antigravity, long-lever, OC movement when the muscles in the proximal arm are unable to activate consistently and with adequate force to support the weight of the arm against gravity. Thus having ideas of how to minimize or eliminate gravity initially will help the clinician assist clients in building muscle strength in a graded manner. Of the two limbs, the UE and LE, the UE is the one that primarily functions as a lever against gravity. Thus again, the following explanations and ideas will be described for the UE. All of the following points are in either a CC or an MC setup until the last point.

- Keeping the limb *down* in line with gravity (e.g., the arm is aligned vertically down such that the hand is below a slightly flexed elbow) requires less strength/force production than an arm that is held in a horizontal alignment relative to gravity.
- When progressively increasing the gravity demands for the limb, use slanted surfaces first before working with a horizontally aligned limb with the hand on a vertical surface. When clinicians introduce an inclined or vertical surface, initially the muscle work demand may need to revert back to CC to place isometric holds on the muscles in the extremity. The added challenge of gravity is typically enough to challenge the system initially without also asking for eccentric or concentric muscle contractions. The elbow joint should not be allowed to be in full extension; it should remain between softly flexed and more flexed.
- When the arm has adequate control to isometrically hold the arm/hand on a steep slope or a vertical surface, there is less force demand on the limb if the arm is aligned vertically in line with gravity with the hand high up above the head. That is, in ranges of glenohumeral (GH) flexion and/or abduction of 130 to 180° versus at 70 to 110°.
- As strength in the arm muscles to manage the weight of the arm against gravity is improving, the final ranges to work on are between 70 and 110° degrees of GH flexion and/or abduction.
- When first beginning to open the chain in the UE, use shorter levers initially versus a fully extended arm (i.e., at the elbow joint even if only softly extended). See the discussion in Section 9.3.1 for OC movements. There are two reasons for this choice:
  - The weight of the arm is less with a shorter lever compared with a longer lever.
  - Functionally, even if the target is in front and at shoulder height, normal reach trajectory involves a folding arm before it is extended toward the final destination.

9.3.4 Ideas to Address the Variations of Weakness Impairments in Muscles

Cathy M. Hazzard

Individuals with weakness, an impairment of the neuromuscular and/or musculoskeletal systems, require intervention strategies for strengthening the weak muscles and muscle groups. As discussed throughout this text, muscle weakness may manifest in different ways. Clinicians need strategies to address each of these variations of weakness. The strategies used for each of these forms of muscle weakness vary slightly. Thus greater success will be achieved if the following principles are used.

- *Inability to initiate activity in the muscle*: The activity demand needs to be such that the muscle automatically contracts in response to a significant demand placed on it (e.g., as part of the base of support [BOS] or because an object may be tipping and the limb needs to hold it up or away).
- *Inability to sustain activity in the muscle*: The duration of the muscle activation should be longer. For example, when the individual steps up onto a high surface with the less involved leg, the more involved leg muscles (and arm/hand if part of the BOS) need to sustain activity during the movement of the other leg up to this high surface and down again, especially if the moving foot is only touching the surface versus landing and loading onto it (**Fig. 9.24**).
- *Inability to generate sufficient force production in the muscle*: The activity demand needs to be for a greater weight (and this can be either body weight or object weight or both).

For each of the preceding variations of weakness, it is also important to think about the planes of movement that are weak and to choose movements in these planes for better outcomes. For example, if the muscles that are weak typically contract and control in the frontal plane, the intervention activities should be biased in this plane, and if the muscles that are weak typically contract in the sagittal plane, intervention activities should be biased in this plane, and so forth. It is true that, normally, muscles contract and provide control in multiple planes. However, the strengthening strategies for weak hip extensors will be more successful if the movement demands are in the sagittal plane, for weak hip abductors in the frontal and transverse plane, and so on.

As discussed earlier in this chapter, the type of muscle contraction—isometric, eccentric, or concentric—must also be considered and selectively targeted in intervention. The reader is also referred to the principles outlined by Stockmeyer in Chapter 4 on a posture and movement model.

Fig. 9.24 Stepping to a higher chair requires a longer duration of muscle activation on the stance leg.

9.3.5 Dimensions for Modulating and Varying the Level of Challenge

Cathy M. Hazzard and Jane Styer Acevedo

There are many options for varying the challenge in an intervention session. The dimension(s) of challenge chosen depend on several factors, including, but not limited to, the individual client, the impairments being addressed, and the task characteristics of the activity the client is interested in (i.e., task specificity considerations). The following list is not exhaustive and is not meant to be used in the order given, nor is each dimension meant to be used in isolation. *Specific suggestions for the pediatric population are presented in italics.* Clinicians are encouraged to choose strategies for varying the level of challenge with individuals that address multiple impairments at the same time and that include movement and postural control demands of multiple body segments and body linkages at the same time. As the challenge is increased in one dimension, it may be necessary to modulate down the challenge in another dimension(s).

- Postures → transitions (i.e., high sitting → higher sitting → liftoff → squat).

With the pediatric population, other transitions are also appropriate, including floor-sitting ↔ quadruped, floor sitting or quadruped ↔ standing via bear stance and squat and cruising. In some specific situations in pediatrics, such as when working with children with at*axia, it is necessary to avoid more static postures and begin with multiple transitions to avoid compensations.*

- Fewer degrees of freedom challenged → multiple degrees of freedom challenged.
- CC → MC → OC movements.
- Gravity assisted → gravity neutral → against gravity.
- Larger BOS → smaller BOS.
- Stable BOS → unstable BOS.
- No hand demand → gross grasp → fine motor grasp.

In pediatrics this concept may be broadened to include beginning with gross motor skills and then moving toward fine motor control. This progression can also include the transition toward more refined oral motor control. This progression is not an absolute. For example, at times the child's drive to use the hands for reach and grasp can drive the more proximal or gross motor control for sitting.

- Short distance/duration→ long distance/duration.
- Short levers → long levers.
- Familiar task → novel task.
- No precision required → accuracy required.
- Quiet, simple environment → noisy, complex environment.
- High error tolerance → low error tolerance.

- Low consequence to mistakes → high consequence to mistakes (e.g., full cup of hot water to spill).
- Other considerations, such as object/surface characteristics (friction, shapes, diameter, size, firmness).

In pediatrics, sensory stimulation may shift from registration of different body parts to increased body awareness or to develop body image. Body image and protective responses are followed by activities to increase discrimination and modulation of sensory inputs. Each system can be addressed in isolation and then integrated with the other systems (e.g., vision with vestibular and somatosensory input) to increase complex awareness, such as body in space and visual flow. The reader is encouraged to refer to Chapter 16, on occupational therapy, for further information.

9.3.6 Changes to the Base of Support to Increase Challenge

Cathy M. Hazzard and Jane Styer Acevedo

1. Manipulate the BOS.
   a. Movements of the least important part of the base → more important part of the base (i.e., of the less involved extremities).
   b. Ask for work as in a., then work for MC movements → OC movements.
   c. The movements of a. are small initially rather than large.
   d. More body segments compose the base → fewer segments compose the base.
   e. One body segment of the base → multiple segments of the base are manipulated at the same time (e.g., moving the less involved arm and leg at the same time).
   f. The surface that the less involved extremities are going to change from should progress from stable → less stable → mobile.
   g. The less involved extremities spend greater time not actively supporting and can be manipulating objects (i.e., to require the muscles to sustain activity).
2. Decrease the BOS (i.e., move the COM over a smaller space). Examples of decreasing the BOS include the following:

   High sitting
   ↓ > and with forward bend and with liftoff
   Higher sitting
   ↓
   Squatting/standing

   Additional examples from early development include shifting from ring-sitting → bench-sitting → standing, or shifting from quadruped → kneeling → half-kneel → standing.
3. Add transitions/superimpose movement. Examples of transitional and superimposed movement are:

   Sit to stand.
   Stand to sit.
   Up and down in squats.
   Loading/terminal stance weight shifts in standing.
   Additional pediatric examples:
   Ring-sitting → bench-sitting → standing.
   Quadruped → kneeling → half-kneel → standing.
   Side-sitting → quadruped.
   Prone ↔ prone prop and reaching.
   Prone ↔ sitting.
   Floor → pulling to stand,
   Cruising → reaching across space toward a stable object.
   Standing to balance → taking a step → multiplesteps independently.
4. Combine movements.

   Examples:
   Sit to stand with stepping.
   Sit to stand holding an object.
   Walking and stooping to pick an object up.
   Walking and carrying an object.
   Walking and changing directions.
   Getting dressed and listening to an iPod.

With all the foregoing combinations, incorporate a task and start at the level of challenge where the client begins to show postural and movement control impairment in function.

9.3.7 Gaining Soft Tissue Length

Cathy M. Hazzard

Observing and Measuring Muscle Length

When the clinician observes and measures or hypothesizes that some muscles or segments are shortened, these impairments will need to be addressed first before much success can be expected in activating the inactive or weak antagonist muscles.

It is important to first assess *if* the client requires these active elongations by doing the following:

- Observing the client moving in an activity that requires the range.
- Asking for the movement in an activity that requires the range.
- Facilitating the movement in an activity that requires the range.
- Taking the individual through the movement.

If at the end of this sequence, you have observed and felt that the passive range of motion/length is impaired, then an active elongation stretch may be indicated. We need enough range of motion in any muscle or segment to allow us to function more in our midranges. It is too difficult and fatiguing to function at our end ranges for long periods of time.

Guidelines to *Actively* Lengthen Soft Tissue

Attempt to make the elongation as active as possible.

- Position your client in an active posture (vs. supine).
- Have the client incorporate an active body movement to assist with the lengthening (e.g., to lengthen the shoulder internal rotators, have the client turn away from the CC tight arm on the midline to elongate the muscles by activating the antagonist and the synergistic muscles). It is important to pay attention to the overall body alignment though as the client moves to stretch the muscles.

A pediatric example is to have a child standing in front of a low stool where the frame for a puzzle is placed. Place the puzzle pieces on the floor around the stool and encourage the child to reach down to retrieve the puzzle pieces while the therapist supports the legs in soft knee extension. This will elongate the hamstrings while activating the antagonists, the quadriceps.

Note: Because the client is controlling the lengthening, these strategies are possible to do with individuals with osteoporosis or osteopenia. However, always err on the lighter side of pressures and let the client's responses (verbal and body) guide you.

- Choose a slightly more stable BOS when elongating tissue as compared with when facilitating movement. For example, the client may still be in high sitting (the hips are still higher than the knees) but the individual is not in extreme high sitting/high perch. The client's feet are still hip joint distance apart but they may be slightly forward compared with where they would be if the client were getting ready to lift off the surface to stand.
- Stabilize the body segment above and below the body segment/part being lengthened as much as is possible.
- Think about supporting or offloading the weight of the arms when lengthening structures in the trunk. Heavy, dependent arms will pull the upper trunk into flexion.
- The therapist takes the muscle/body segment into as much range as possible (i.e., as is comfortably allowed by the client) and then just holds while the client does the active movement.
- Grade pressures slowly; there will be more active resistance and thus a potentially negative effect on the alignment if pressures are built too quickly.
- Aim to gain a little range at a time (i.e., each session). It is then important to use this new range within that session to build stability.
- Both the therapist and the client need to keep breathing!
- Very shortened muscles/segments may need to be initially lengthened in mid or inner ranges. Often, these muscles may need to be lengthened again in different ranges and postures and activities as these are required functionally (e.g., the latissimus dorsi muscle and other shoulder internal rotators may need to be lengthened with the arm in shoulder flexion when the client's active movement and progress make this necessary and safe to do).
- Active lengthening or elongation in an intervention session should only take up ~ 5 to 10 minutes total. These specific strategies may be used at various times during the session if required in different ranges.

9.3.8 Concepts in Pediatric Core Stability

Jan McElroy

Individuals who experience CNS insults as young children, adolescents, or adults have had appropriate previous sensorimotor and postural experiences that they might benefit from or draw upon during intervention tasks within participation activities. Children who experience movement dysfunction from birth or early infancy (e.g., children with cerebral palsy, developmental delay, or genetic disorders) never experienced activity, appropriate postural sets, or postural control of the trunk (core stability) and limbs. They have no past motor or mental experience against which they can compare their performance in a task. Hence interventions with this group of children should include additional focus and handling to help them experience and then apply appropriate trunk postural sets or control to create dynamic core stability during functional intervention activities.

Typical Movements of the Trunk

Children developing typically who use dynamic core stability during functional activities are observed to move their trunk within all planes—sagittal, frontal, and transverse. They demonstrate the following:

- A dynamic balance between the trunk flexors and extensors in the sagittal plane needs to be achieved. Trunk flexors and extensors are active simultaneously but may be slightly biased toward flexion or extension depending on the postural requirements of the task. Within an NDT framework, this is described as an active trunk or a balance between flexors and extensors in the trunk.
- Frontal plane movements require simultaneous activation of trunk flexors (oblique abdominals) and trunk extensors on the same side with eccentric elongation of trunk flexors and extensors on the opposite side. Within an NDT framework, this is described as elongation on the weight-bearing side. This is identifiable by looking at the trunk—one side of the trunk between the pelvis and armpit will look longer than the other. This is the weight-bearing side. The other side of the trunk between the pelvis and armpit will appear shorter,

and skin wrinkles will often be observed on that side. The shortened side is the non-weight-bearing side.

- Transverse plane movements of the trunk are rotational movements around the spine. During functional tasks, transverse plane movements require a complex combination of movements. Within an NDT framework, functional transverse plane movements are described as dynamic rotation with weight shift.

Summary of Trunk Movements for Trunk Control

- *Sagittal plane*: A dynamic balance between trunk flexors and extensors.
- *Frontal plane*: The ability of trunk flexors and extensors to switch from bilateral to unilateral activation (as described in the second bulleted item in the preceding list).
- *Transverse plane*: Activation of the small rotators of the spine and increased activation of the external oblique abdominis on one side with the internal oblique abdominis on the other side.

Atypical Movements of the Trunk

Trunk movements of children with movement dysfunction are often described as *moving only in the sagittal plane, being stereotypical,* and *using limited synergies*. These descriptors all indicate a lack of variable and appropriate dynamic core stability. Children with movement dysfunction rarely demonstrate a dynamic balance between trunk flexors and extensors. When they move, they either turn on the trunk flexors (typically the rectus abdominis) and turn off the trunk extensors or turn on the trunk extensors and turn off the trunk flexors.

Observation of an individual's posture and movement during functional activities, such as using the rectus abdominis only during sitting, substituting flexion for rotation and/or lateral flexion, and using trunk extension, can alert the clinician to trunk control impairments.

Intervention and Handling with Atypical Trunk Movements

Therapists should address core stability within the context as previously described for task, environment, alignment/BOS/COM, and progression. Be sure the child is interested and motivated by the task. Key points will vary depending on the individual needs of the child. The focus then turns to the trunk.

Prior to the child beginning the task, the therapist will do the following:

- Check to be sure environmental and task selection require movement in the frontal and transverse planes in addition to the sagittal plane.
- Check to be sure that the BOS is appropriate for the task. Is the base so wide it is too stable for movement? Is the base so narrow that the child will not feel stable during movement?
- Check trunk alignment. Sometimes task-appropriate trunk alignment alone will activate a balance between flexors and extensors in the sagittal plane.
- Check for appropriate arousal.
- If handling is needed, select the key points of control appropriate for the child.

The following will occur in a very quick sequence (sometimes appearing simultaneous) during each task:

- *Sagittal plane*: Activate a balance between trunk flexors and extensors.
- *Frontal plane*: Begin weight shift (does not have to be a large weight shift).
- *Transverse plane*: Begin rotation (does not have to be a large excursion).

It is important to remember that trunk transverse plane movements (rotation with weight shift) cannot occur without trunk frontal plane movements. Trunk frontal plane movements cannot occur without sagittal plane dynamic balance of trunk flexors and extensors. Hence every movement task should begin with activation of a balance of trunk flexors and extensors.

A balance between trunk flexors and extensors may be activated in a variety of ways. Following are a few strategies that may be used singly or in combination:

- Task-appropriate alignment may activate the balance between flexors and extensors. For example, if the task requires standing on one leg, setting the environment such that the foot of the non-weight-bearing leg is high enough to create a more neutral position of the pelvis (vs. an anteriorly tilted pelvis), then the alignment itself may create a bias toward more active trunk flexors. The lower the foot is, the more it may create a bias toward activation of the trunk extensors.
- When the child's trunk is aligned, if the COM is still anterior to the center of the BOS, a small movement of the COM in a posterior direction may create a bias toward activation of the trunk flexors. If the COM is posterior to the center of the BOS, movement of the COM in an anterior direction may create a bias toward activation of the trunk extensors. It is important to note that these activations will not occur with a poorly aligned trunk.
- A key point of control with the therapist's hands on the muscles on the sides of the child's trunk may activate both flexors and extensors if the direction of handling intent is slightly in toward the center of the body and then very gently directed down toward the center of the BOS.

Focus on the sagittal, frontal, transverse trunk activations can increase core stability during tasks. It is not a stand-alone activity but occurs within the selected task and is repeated as often as necessary with the child independently maintaining the dynamic activation as much as possible.

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10 Cerebral Palsy

Marcia Stamer

This chapter provides essential information about postures and movements expressed in people with cerebral palsy (CP). Neuro-Developmental Treatment (NDT) recognizes that each person participates and chooses activities because of complex and interacting factors and that each person will have a unique combination of abilities and disabilities as well as effective and ineffective postures and movements. This chapter describes common postures and movements observed in many people with CP and provides core knowledge needed for examining and evaluating their effects on activity and participation.

Learning Objectives

Upon completing this chapter the reader will be able to do the following:

- Define CP according to the consensus definition from the international definition of 2004.
- State the three primary classifications of CP, describing their identifying positive and negative impairments.
- Identify the typical sites of lesions for the three primary classifications of CP.
- Describe posture and movement impairments that are typically seen in children with the following:
  - Spastic quadriplegia.
  - Spastic diplegia.
  - Spastic hemiplegia.
  - Dyskinetic dystonia.
  - Dyskinetic athetosis.
  - Dyskinetic chorea.
  - Ataxia.
  - Mixed spastic dystonia.
  - Mixed ataxia diplegia.
- Describe at least three unique impairments that an adult with CP is likely to contend with, relating these impairments to the need for advocacy for lifetime episodes of care.

10.1 What Is Cerebral Palsy?

Cerebral palsy (CP) has been recognized as a central nervous system (CNS) pathology since at least the 19th century.[1,2] *Cerebral* refers to the brain and *palsy* to a general paralysis. These terms can be misleading because *palsy* in *cerebral palsy* refers to impaired voluntary posture and movement control rather than complete loss of muscle activity. Authors describing CP have considered revising the name of this disability to reflect a more accurate description[3,4] but state that the term is well established in the literature and culture and so recommend that the term not be changed.

In the 20th century, two definitions of CP dominated the literature. The first was Bax's definition: "a disorder of *movement and posture* due to a defect or lesion of the immature brain"[5] (italics added). A second, oft-quoted definition by Mutch et al[6] defined CP as "an umbrella term covering a group of non-progressive, but often changing, motor impairment syndromes secondary to lesions or anomalies of the brain arising in the early stages of development." Recently, researchers felt a need to update the definition in light of the complexity and breadth of the disorders grouped as CP. An executive committee meeting for the definition of CP[3] in an international workshop held in Bethesda, Maryland, in 2004, wrote and revised this definition:

Cerebral palsy (CP) describes a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication, and behavior; by epilepsy, and by secondary musculoskeletal problems.[3]

This definition emphasizes many important points about CP. First, CP is a heterogeneous group of disorders. Blair and Watson[7] emphasize that CP is a description, not a diagnosis, whereas Shevell et al[8] describe CP as a "symptom complex" to denote the wide range of presentations, etiologies, impairments, and functional implications possible. Palisano et al[9] created the Gross Motor Function Classification System (GMFCS), Eliasson et al[10] created the Manual Ability Classification System (MACS), and Hidecker et al[11] created the Communication Function Classification System (CFCS) to classify CP according to the range of functional abilities and limitations, which emphasizes their wide variation. Classifying people with CP according to activity rather than type of tone and its limb distribution may be a more valid and reliable method of classifying for research and epidemiological consistency.[8]

This newer definition continues to emphasize the central characteristic common to all children and adults with CP—that it is a group of disorders of posture and movement. This is particularly relevant to clinicians who practice using Neuro-Developmental Treatment (NDT) because the NDT Practice Model emphasizes knowledge and careful analysis and treatment of posture and movement.

The definition of CP also emphasizes that, although the anomalies and lesions that cause CP are nonprogressive, the effects on a young and developing brain cause an ever-changing posture and movement disorder.[8,12] These effects persist throughout the life span, which approaches a typical length in those who are not severely involved.[13,14,15,16,17,18,19]

10.1.1 Types and Timing of Pathologies That Can Cause Cerebral Palsy

Researchers are interested in linking pathology of brain anomalies and lesions and the timing of them to particular types of CP, if possible. Researchers state that the causal links from pathology to type of CP are currently weak, although magnetic resonance imaging (MRI) shows lesions and anomalies in over three-fourths of people with CP,[2,20,21,22] and estimating the timing of lesions is becoming more exact. The following information is tentative and will likely change as studies with more powerful diagnostics become available. However, we should begin to study this information and follow its evolution closely.

Advances in neuroradiology have made defining and differentiating pathologies that can cause CP more possible. In the CNS, the many developing structures and pathways are more vulnerable to injury at different stages of development. Identifying *when* an insult occurs or a structure malforms is of great importance.[20] The effects of the insult or anomaly will also be shaped by its severity and duration (e.g., asphyxia will have a more profound effect than transient hypoxia).

Some researchers question the usefulness of the current classifications of CP by distribution and posture/movement because the timing and type of insults that cause CP result in differing clinical presentations. Rosenbloom[23] notes that there are huge differences among children classified as quadriplegic due to differing pathologies (e.g., extensive white matter damage vs. ischemic infarction vs. extensive neuronal migration abnormalities). He calls for better clinical descriptions of the classification of CP to develop appropriate services and prognoses.

Congenital malformations usually indicate injury to CNS development during the first half of pregnancy.[20] Malformations are usually the result of interruptions of migrating neurons during the developmental process of forming layers of the cortex and synaptic connections (**Fig. 10.1**). If malformations result in the posture and movement disorders defined as CP, they are included with this diagnostic category (as opposed to malformations such as neural tube defects that may cause disorders such as spina bifida and anencephaly).[2]

Kułak et al[25] noted congenital brain anomalies as a frequent cause of spastic quadriplegia (other causes in their study were white matter damage and cerebral atrophy), whereas Feys et al[26] found malformations as one cause of hemiplegic CP (**Fig. 10.2**).

Focal malformations in the supra- and infratentorial regions (**Fig. 10.3**) and extensive cerebellar malformations have been implicated in ataxic CP.[27] Minor structural anomalies in the mouth, hands, feet, and trunk of some children with ataxia suggest that these congenital malformations occur in the early prenatal period.[28]

Primary white matter damage is often seen in children with spastic forms of CP.[2] Malformations of the corpus callosum are one type of white matter damage; myelin abnormalities are another.

White matter damage of immaturity results from insults between 24 and 34 weeks' gestation and often results in preterm birth.[20,29,30] Bax et al[31] state that 71% of children with spastic diplegia show evidence of white matter damage of immaturity, including periventricular leukomalacia (PVL) and periventricular hemorrhage (**Fig. 10.4**). PVL is likely to be caused by both vascular and metabolic lesions.[25] Some children with spastic quadriplegia also show white matter damage (to a greater extent than those with diplegia).

Focal lesions close to term are often in the territory of the middle cerebral artery, often resulting in hemiplegia.[20] Bax et al report that 27% of children with hemiplegia in their studies had strokes. Some children with hemiplegia show asymmetrical PVL[31] (**Fig. 10.5**). Feys et al[26] state that many children in their study of hemiplegic CP had a combination of white matter damage and basal ganglia/thalamic involvement. Reduced thalamic volume was seen in preterm children with moderate to severe white matter damage in a study by Lin et al.[32] When the infant's brain is close to gestational maturity, the gray matter is more sensitive to injury than the white matter,[20] and damage is often associated with various levels of hypoxia and anoxia. Gray matter is present in the cerebral cortex and the subcortical nuclei, including the basal ganglia and thalamus.

Koman et al[30] note that the basal ganglia have unique metabolic needs at 38 to 40 weeks' gestation, creating selective vulnerability that may result in dystonic movement disorders with insults at this time (**Fig. 10.6**). Bax et al[31] state that many children with dystonic or athetoid CP have basal ganglia lesions, and Towsley et al[33] found lesions in this subcortical gray matter are often associated with severe CP.

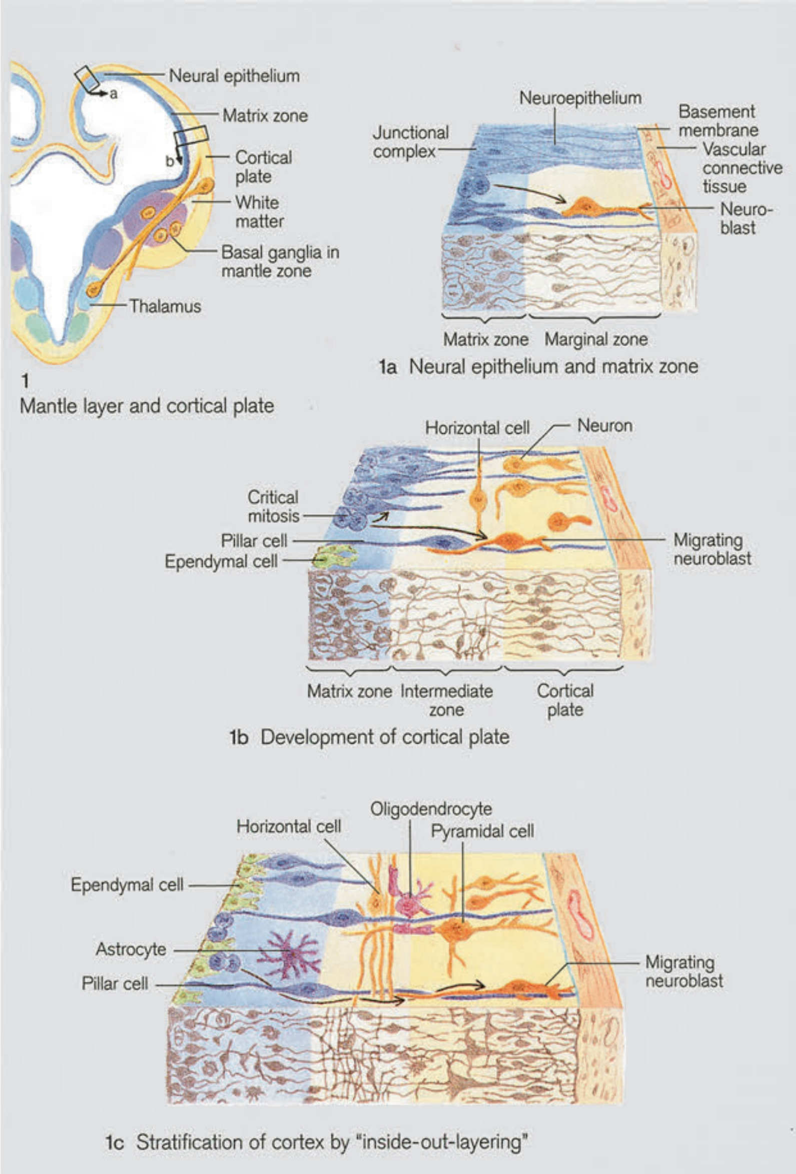

Fig. 10.1 Neuronal migration begins in the fifth week of gestation and continues until at least the fifth month of gestation.[24] This drawing shows examples of neural migration in the central nervous system. Errors of neuronal migration include lissencephaly, heterotopia, polymicrogyria, and schizencephaly.[24] Reproduced from Drews, *Color Atlas of Embryology, 4th edition* © 1995. Thieme Publishers, Stuttgart.

10.1.2 Classification of Cerebral Palsy by Body Distribution and Characteristics of Posture and Movement

The purpose of classifying CP into distinct posture and movement disorders resulting from early brain lesions and anomalies is to encourage a more standardized terminology for diagnostics, research, and epidemiology studies. Rosenbaum et al,[3] Cans et al,[34] the Surveillance of Cerebral Palsy in Europe,[35] and Sanger et al[36,37] have all worked to classify CP in terms of muscle tone and posture and movement characteristics.

Researchers such as Nashner et al,[38] Rose and McGill,[39] van der Heide et al,[40] van der Heide and Hadders-Algra,[41] Brogren et al,[42] van Roon et al,[43] Woollacott and Shumway-Cook,[44] Hadders-Algra et al,[45] and de Graaf-Peters et al[46] have focused their studies on postural control of people with and without CP. All state that research about the specifics of postural control variations among the classifications of people with CP is only beginning, and many more studies need to be done to corroborate or challenge their findings.

Researchers such as Eliasson et al,[47,48,49] Yokochi et al,[50] Hadders-Algra et al,[51] Hallett and Alvarez,[52] O'Dwyer and Neilson,[53] Fowler et al,[54,55] Fowler and Goldberg,[56] Stackhouse et al,[57] Tedroff et al,[58] Leonard et al,[59] and Hirschfeld[60] focused their studies on movement disorders

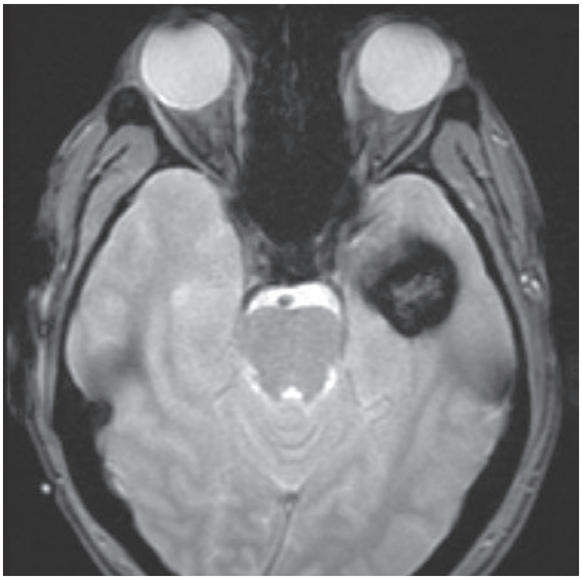

Fig. 10.2 This image depicts a cavernous malformation, a vascular malformation that can cause focal neurological impairments and seizure activity. Reproduced from Tsiouas et al, *Case-Based Brain Imaging, 2nd edition* © 2013. Thieme Publishers, New York.

in children with CP. Again, these studies are pioneering insights into the particular movement disorders that accompany various classifications of CP.

Table 10.1 summarizes posture and movement characteristics of people with CP. **Fig. 10.7** diagrams the motor types of CP with characteristics of pathophysiology, muscle tone, and movement.

10.1.3 Classification of Cerebral Palsy for the Clinician

While research contributes more and more information about the impairments observed and measured in the defined classifications of CP, it does not describe posture and movement in detail. Recall in Chapter 3 about NDT and the International Classification of Functioning, Disability and Health (ICF) model that the foundation of problem solving in NDT is generating hypotheses about the relationships of pathology to impairments, impairments to posture and movement, and all of these domains of functioning to contextual activities and participation. Hypothesis generation is difficult, especially if the clinician does not have a detailed understanding of the common postures and movements that people with CP use and why they are there. Describing and defining postures and movements in detail are also necessary for interpreting effectiveness of interventions aimed at improving activity and participation outcomes. Because CP is a heterogeneous group of posture

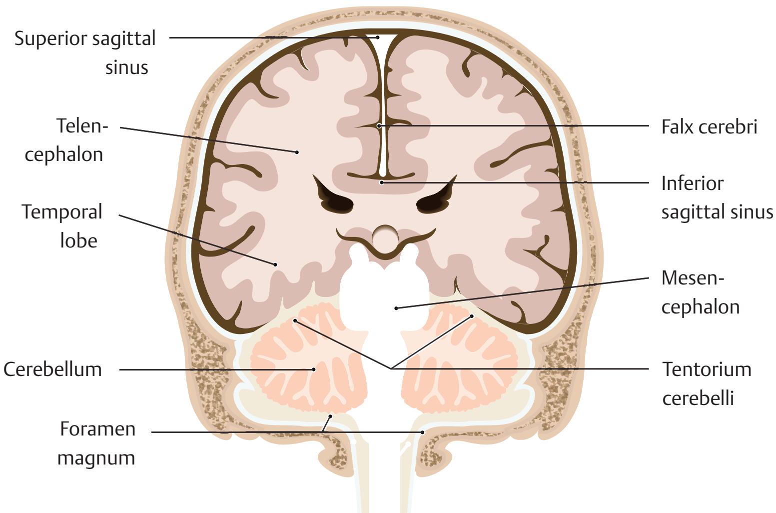

Fig. 10.3 Malformations in the area of the tentorium, the dural covering of the cerebellum, may cause ataxic cerebral palsy. Modified from Schuenke, Schulte, Schumacher, *Head, Neck, and Neuroanatomy, 2nd edition* © 2016. Thieme Publishers, New York.

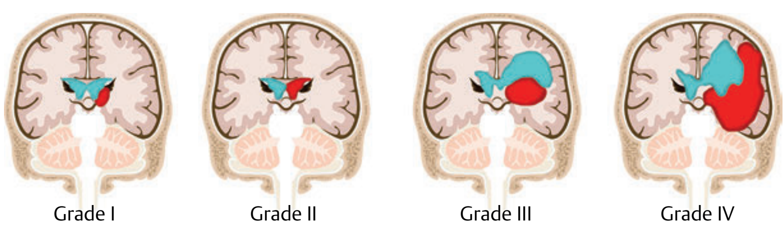

Fig. 10.4 Periventricular hemorrhages of grades III and IV with resultant ventricular enlargement are a frequent finding in children with spastic quadriplegia.[25]

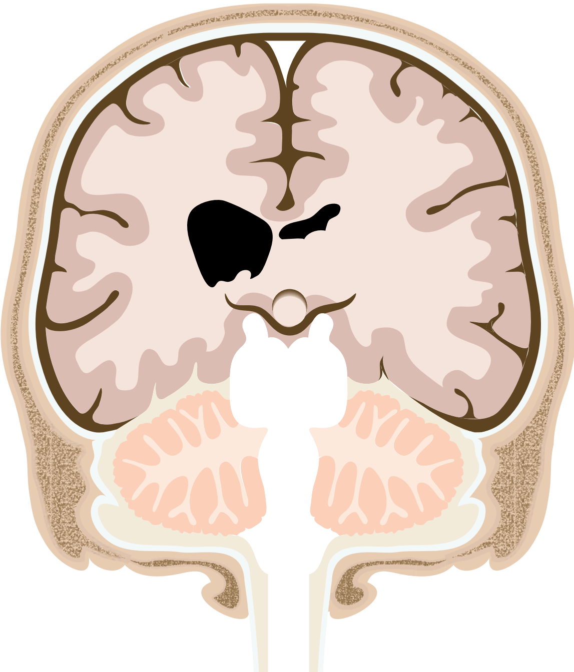

Fig. 10.5 Unilateral lesions in the cerebral cortex can cause hemiplegia. Modified from Schuenke, Schulte, Schumacher, *Head, Neck, and Neuroanatomy, 2nd edition* © 2016. Thieme Publishers, New York.

and movement disorders, intervention strategies that are effective for one person with CP may be inappropriate for another person with very different impairments, activities, participation, and the context in which all of these interact. The clinician uses research to guide and inform decision making, not as a recipe for intervention for individuals.

The clinician using NDT must always remember that any description of CP is a description of commonly observed and measured phenomena. The following information will be useful only insofar as it allows clinicians to improve observation skills and deepen their understanding of posture and movement. *The most important skill a clinician using NDT can develop is the ability to observe and measure each individual's functioning and then create hypotheses about possible causes and relationships of findings.*

10.1.4 A General Description of Children with Spastic Cerebral Palsy

Primary Pathology

Children with spastic forms of CP make up ~ 80 to 86% of people who have CP where CP registers are kept.[35,61,62] Lesions that cause spastic CP are located in the cerebral cortex and the subcortical white matter. These lesions may be the results of errors of neuronal migration, hypoxic/anoxic events, bleeding of the cerebral blood vessels into the brain and ventricles, cerebral atrophy, and other structural malformations. The resultant damage may be focal or diffuse, causing a person to develop quadriplegia (total body involvement), diplegia (lower body more involved than upper body), or hemiplegia (one side of the body involved). Clinically, this clear-cut division of distribution is rarely seen. Many children present asymmetrically in addition to the described distribution or have three limbs involved with one limb relatively spared (often an upper extremity). In addition, the extent of the damage will initially determine the severity of the posture and movement disorder. For example, a person could have quadriplegic distribution and attain motor goals, such as walking, speech, and many independent activities of daily living, whereas others may not be able to achieve these skills at all, even with excellent intervention and care.

The lesions that result in spasticity damage the corticospinal tracts and other descending tracts that transmit direct posture and movement commands, which carry motor commands from the cerebral cortex through the subcortical internal capsule, crossing at the medulla to travel down the spinal cord. The corticospinal tracts carry information for motor commands and are the largest motor tracts that descend through the spinal cord and synapse with spinal afferents and efferents.

The tracts synapse with α motor neurons at all spinal levels to give commands to muscles. Positive primary impairments that result from damage to these upper motor neurons result in abnormal responses to velocity-dependent stretch, which defines spasticity.

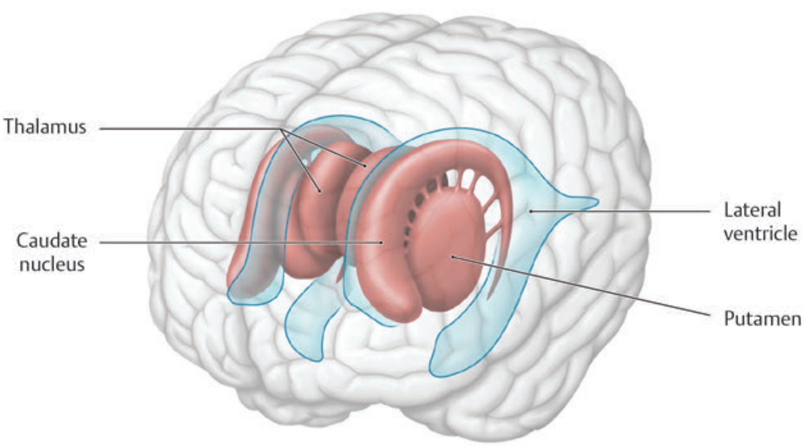

Fig. 10.6 Damage to the basal ganglia in babies at term birth is thought to occur primarily in the putamen and caudate nucleus. Damage to the thalamus may also result in dystonic cerebral palsy. Reproduced from Schuenke, Schulte, Schumacher, *Head, Neck, and Neuroanatomy, 2nd edition* © 2016. Thieme Publishers, New York.

Table 10.1 Classifications of cerebral palsy according to body distribution and characteristics of posture and movement

Type	Subtype or distribution	Tone	Common postures	Common movements
Spastic	Quadriplegic (also called tetraplegic or bilateral)	Spasticity (velocity-dependent resistance to externally applied forces) Hypertonia Hyperreflexia in upper and lower limbs	Delayed onset of anticipatory posture in standing LEs when reaching; delayed termination of posture; sustained hip adduction/internal rotation; equinus foot; severely involved may not develop direction specific postural adjustments to perturbations—those with direction-specific postural adjustments often show top-down recruitment order	
	Diplegic	Spasticity Hypertonia Hyperreflexia lower limbs greater than upper limbs	Delayed onset of anticipatory posture in LEs in standing when reaching; delayed termination of posture in lower limbs; sustained hip adduction/internal rotation; equinus foot; often shows direction-specific postural adjustments, but may use top-down recruitment strategies; difficulty with fine tuning to task demand; may show excessive coactivation in standing postural sway	Decreased force production in distal muscles, possibly due to decreased motor unit recruitment and decreased firing rates; loss of modulation of reciprocal inhibition during maximal contraction of the anterior tibialis; excessive coactivation of antagonists at ankle with attempted maximal contraction of tibialis anterior; excessive grip force when lifting using isometric fingertip grasp
	Hemiplegic	Spasticity Hypertonia Hyperreflexia right or left limbs	Delayed termination of posture in hemiplegic limbs; sustained hip adduction/internal rotation; equinus foot on hemiplegic side; almost always develop direction-specific postural sway control, but do not always modulate postural activity to meet specific movement tasks within the posture; may recruit top-down in standing postural sway	Decreased force production in distal muscles, possibly due to decreased motor unit recruitment and decreased firing rates; excessive coactivation of antagonists at ankle with attempted maximal contraction of tibialis anterior (although less than diplegic); weakness due to decreased force production, decreased recruitment and timing of motor units, and increased antagonist coactivation; excessive grip force when lifting using isometric fingertip grasp
Dyskinetic	Dystonic	Varies from hypotonia to hypertonia; resistance to passive, externally applied resistance varies and is not velocity dependent	Repeated postures characteristic for individual child, often triggered by attempts at voluntary posture and movement; sustained for variable length of time; cocontraction may or may not be used to sustain the abnormal postures; often see foot inversion, wrist ulnar deviation, lordotic trunk	Hypokinesia–involuntary sustained or intermittent muscle contractions cause twisting and repetitive movements, but fewer movements; some people with dystonia are hyperkinetic, with more frequent twisting, repetitive movements
	Athetoid	Hypotonic	Continuously changing; unsustained	Hyperkinesia–slow, continuous, repetitious, involuntary writhing that prevents maintenance of stable posture; often worsens with voluntary movement, but can also occur at rest: overflow into synergist and antagonist muscles, often with antagonist firing before agonist, or excessive coactivation, sometimes followed by excessive agonist activity; dysarthria seems to be related more to abnormal temporal spatial patterns of muscle activity than to involuntary movements
	Chorea	Hypotonic	Unsustained	Hyperkinesia–ongoing random-appearing discrete involuntary movements or movement fragments that appear to flow randomly from one muscle group to another and can involve any part of the body; unpredictable and continuously ongoing, although each movement is brief and jerky; not voluntarily suppressible
Ataxic		Hypotonic	Recruitment of lower limb muscles in standing postural sway may show correct order, but latent onset of muscle activity	Abnormal force, rhythm, accuracy; over- or undershooting; intention tremor (tends to increase as a target is approached)

Abbreviation: LE, lower extremity.

Note: Information taken from cited studies.[3,34-60] Lack of information reflects lack of finding research studies addressing posture and movement in specific classifications.

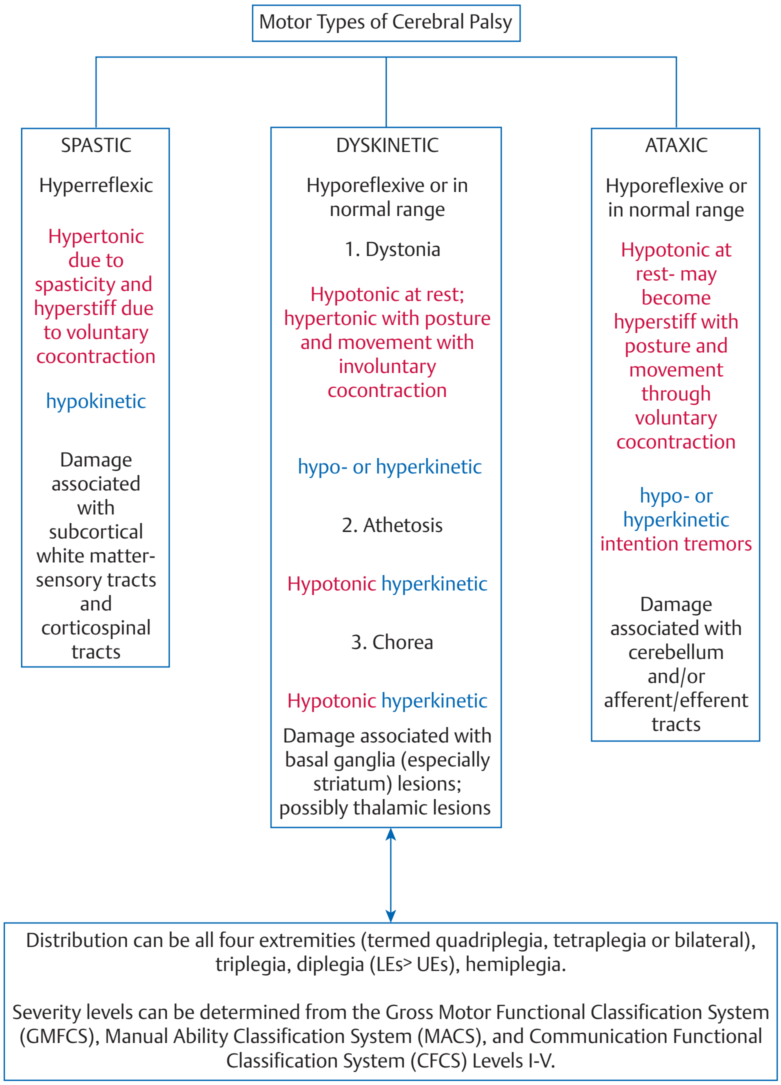

Fig. 10.7 This chart was created by the author and is based on the definitions published by the American Academy for Cerebral Palsy and Developmental Medicine, which were agreed with by the Surveillance of Cerebral Palsy in Europe.

Spasticity is often not immediately apparent in the infant. The typical presentation of an infant who will later express spasticity and other primary impairments is that of generalized hypotonia.[63] This hypotonia could be a systemic response to trauma or an expression of the immaturity of the motor system.

Spasticity is examined by responses to externally imposed *passive* joint ranging at increasing speeds.[36] Increasing speed causes increased resistance to joint mobility through excessive muscle activity, and often, a spastic catch abruptly halts movement that may indicate the threshold of the stretch reflex. Deep tendon reflexes are hyperreflexive. Spasticity continues to be a poorly understood mechanism; however, lack of cortical inhibition and hypersensitivity to stretch originating in the muscles themselves are often implicated as possible causes of the abnormal velocity-dependent responses. Supraspinal lesions may disrupt presynaptic inhibition, reciprocal inhibition, and recurrent inhibition.[64] These lesions may disrupt the balance of excitatory and inhibitory pathways. Spasticity, therefore, may not be only one phenomenon since there may be more than one source as its cause. Research is needed to explain if and how spasticity disrupts voluntary movement.

Negative primary impairments that result from upper motor neuron lesions include the loss of selective motor control. This loss is expressed as errors in timing and ordering of muscle contraction, errors in the ability to select some motor units while others remain inactive, errors in the ability to recruit sufficient motor units for the task,[39] and errors in the ability to terminate a muscle contraction (errors in the ability to inhibit motor units once activated). The result is often overrecruitment of muscles (usually superficial, two-joint muscles), overrecruitment of muscles not needed for efficient movement (*mirroring* and *overflow* are terms often used to describe this error), and underrecruitment of muscle activity responsible for joint stability and postural control. When the lateral corticospinal tract is involved, loss of fractionated movement in the distal upper extremity results.

Other negative primary impairments that are often seen in children with spasticity are visual processing impairments due to lesions affecting the optic tracts as they travel from the optic chiasm to the occipital cortex, somatosensory impairments due to damage of the primary sensory strip and association areas in the parietal lobe, central vestibular impairments, and impairments of conscious proprioception processing. The parietal lobes of the cerebrum receive, process, and route somatosensory information.

Early Development in Children with Spastic Cerebral Palsy

Babies who develop spastic CP may or may not be born prematurely, depending on the timing of the lesion and its cause, as well as the health of the mother and external environmental conditions. Many children with spastic diplegia and subcortical white matter damage are born prematurely; others are born at term.

Initially, caregivers and professionals frequently note generalized hypotonia, or occasionally hypertonia, with poverty of movement in infants who will later be diagnosed with CP.[63] Detailed examination may show abnormal general movements over time predictive of CP and lack of development of fidgety general movements typically seen from ~ 6 weeks postterm to 4 months postterm.[65,66] Spontaneous movements of preterm and term babies can be assessed using the General Movements Assessment (GMsA), which measures qualitative movements over time.[67] Other tests quantify and qualify posture and movement performance.

One test, the Test of Infant Motor Performance (TIMP),[68] specifically identifies postures and movements in infants. Research using the TIMP has shown that infants later diagnosed with CP showed delayed postural control as early as 7 days of age on items related to head control, antigravity arm movements, and facilitated rolling.[69] In addition, several TIMP items are particularly effective in documenting early regression of postural control. In a group of 10 infants later diagnosed with CP, TIMP scores on antigravity items, such as bilateral hip and knee flexion, reciprocal kicking, and selective control of ankle movements, regressed when tested longitudinally at neonatal intensive care unit discharge and 4 months post–conceptual age.

Assessments of infants serve different purposes. Whereas the GMsA is used to help identify infants who are at high risk for the development of CP, other assessments, such as the TIMP and the Alberta Infant Motor Scales (AIMS), assess posture and selective movement.[67] The TIMP can be used to assess progress with intervention as well.

NDT-educated clinicians select different tests and assessments to identify, predict, and measure functional skills in people with CP throughout their life span, ensuring the measure selected is validated to test the desired clinical outcome. Test results can then be accurately interpreted within the confines of the outcomes the test is able to assess. Care is taken not to interpret the meaning of test outcomes in ways they are not intended; for example, the Bayley Scales of Infant Development are designed as normative scales of development that can be used to determine eligibility for programs for children with disabilities.[70] The Bayley Scales are not designed to measure the effectiveness of treatment and are therefore not valid for measuring outcomes of intervention.

In NDT, we hypothesize that the primary positive and negative impairments immediately affect posture and movement, as well as influence each other as the baby attempts to move against gravity and interact with caregivers and the environment. Damage to the sensory systems, depending on which ones are damaged and how severely, can affect the baby's awareness of body position (proprioception), stability and movement of the head (vision, vestibular, and proprioception), and perception of environment (vision, hearing, tactile, vibration). Spasticity, although tested passively, causes excessive resistance to actively generated movements, restricting range of joint mobility and length of muscle. Spasticity may also contribute to abnormal sensory feedback about internal and external events relative to the body. Muscles responsible for antigravity postures and joint stability may be difficult to contract with sufficient force or force that can be sustained long enough to control body position. The baby is often restricted to muscle contractions in the sagittal plane and may rely on flexion or extension of many joints of the body at the same time to produce movement (lack of selective control).

The following initial postures and movements are typical of babies and young children with spastic CP due to the interaction of impairments:

- A compromised ability to initiate and sustain antigravity postures. Recall that, in CP, muscles responsible for posture and stability are difficult to contract. This initially affects head and trunk postures against gravity in those who have total body involvement or moderate to severe diplegia. Babies and young children developing with hemiplegia will most likely develop asymmetrical postures due to asymmetrical muscle activity. Sensory losses and/or abnormal sensory processing usually add to the degree of postural inefficiency.
- Babies and children will attempt to interact with caregivers and the environment despite poor abilities to control antigravity postures. This interaction means that the baby and child must use compensations for the ineffective antigravity postures. These compensations are variable and dependent on the context of the family environment and family dynamics, as well as the extent, number, and severity of posture and movement impairments present in the baby and young child. Children with spasticity can frequently increase joint stiffness through cocontraction or by sustaining one or more superficial muscles in contraction (active stiffness). Often, many muscles are recruited. Abnormal muscle activity is imposed on poor alignment of body segments because the muscles are used in the shortened positions often retained from infancy. Joint and bone structure, different in infants than in older children, and normally molded by normal muscle pull, normal muscle tension, and active and passive joint stability, not only retains infant structure, but deforms

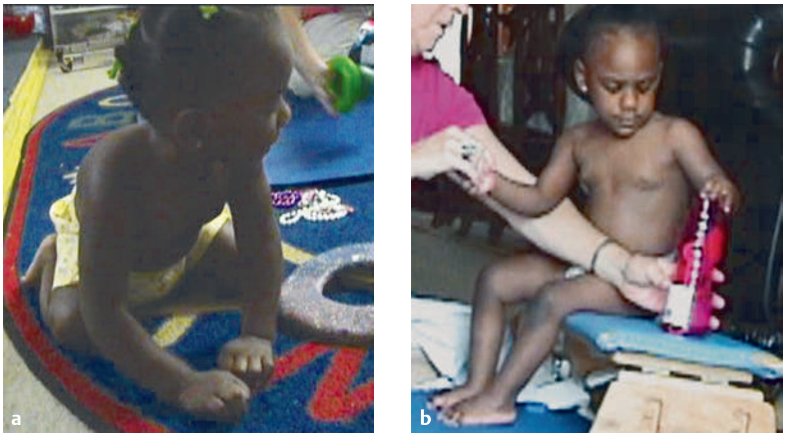

Fig. 10.8 **(a)** Makayla moves around the floor with fisted hands. **(b)** When Makayla feels safe in her position against gravity and the demands on her postural control include the muscles that provide stability to the spine, rib cage, and pelvis, she is able to easily open her hands to play with toys, indicating that the fisting of her hands on all fours is not the result of spasticity only, and in fact, may not be due to spasticity at all.

in response to abnormal and prolonged muscle activity. Secondary impairments in the musculoskeletal system can appear even in young children as a result, and the person with spastic CP is vulnerable to these impairments over the life span. One difficulty this stiffness presents for the clinician is that the resistance when the child is held, carried, dressed, fed, and assisted to move is often attributed to spasticity only, when it may, in reality, be due to both spasticity and compensatory voluntary contraction of muscles designed for movements. Superficial, two-joint muscles are designed for large-range movements rather than the way children with spastic CP must use them in attempts to initiate and sustain antigravity postures. The child learns that this contraction must be sustained to prevent falling and to attempt any control of posture and movement at all. For example, as described in the case report about Makayla in Unit V (B4) (**Fig. 10.8a, b**), she moves across the floor on all fours with her hands fisted. Her stiff movements on all fours with fisted hands may be incorrectly evaluated as spasticity only. Most likely, however, a more complex interaction of spasticity, voluntary cocontraction and excessively sustained muscle contractions in select muscles, and insufficient muscle length or joint mobility in some body segments results in the posture and movement she uses. The clinician using NDT carefully examines and evaluates the person with spastic CP, asking the caregivers how the child initiates postures and movements, responds to postures and movements imposed on him or her, and performs activities. The clinician begins to formulate hypotheses to explain the child's particular posture and movement repertoire. Through observation, handling for examination, and assisting postures and alignment to see how the child responds, the clinician hypothesizes about the interaction of impairments and the compensations developed to allow function, predicting how these may affect future postures and movements. For example, Makayla uses upper extremity and chin support at times when she is standing at furniture to widen her base of support (**Fig. 10.9**). Her physical therapist generates the following hypotheses as to why Makayla must use this posture:

- She has not developed control of her trunk in extension.
- She has not developed control of hip and knee extension with a plantigrade foot in standing.
- She cannot effectively initiate and terminate any lower extremity (LE) muscle groups to adjust hip, knee, and ankle joint position in supported standing.
- She is not able to use or has not developed the ability to use the anterior trunk and hip, knee, and ankle muscles to recover balance if her

Fig. 10.9 When Makayla stands supported, she is unable to extend her trunk, hips, and knees. With her flexed posture and center of mass shifted anteriorly, she rises onto her toes.

center of mass is displaced toward the back of her base of support when sitting or standing with support.

- Children with spastic CP follow logical constraints of their musculoskeletal systems as they develop. These constraints become apparent to the clinician once the primary positive and negative impairments and early developing secondary impairments are understood. They are imposed on the body proportions of an infant initially, so the clinician must keep in mind that an infant's head is large and heavy in proportion to the trunk and limbs. Therefore, children with spastic CP develop according to their morphological characteristics as well as the constraints imposed by their impairments in any of their body systems.

In infants born full term without neurological insults, the rib cage sits in the upper third of the length of the trunk and the thoracic and lumbar spine is in flexion. The shoulder complex is elevated with the scapulae elevated and abducted. The hips are flexed, abducted, and externally rotated, although the femur itself has internal torsion along its long axis. The acetabulum is shallow. The infant's elbows and knees do not fully extend due to soft tissue limitations of the two joint flexors, and the hands are loosely fisted. The fingers and toes extend and abduct briefly with general body movements **(Fig. 10.10)**. Refer to Chapter 14 on motor development for a more detailed description.

Makayla may retain some of these morphological characteristics seen in infants if she does not use antigravity postures and movements that would change structure in the manner that typically developing children change their structure. Her structure could also change in atypical ways based on the common postures and movements she uses (**Fig. 10.11**).

Fig. 10.10 This infant, who is 10 days old and full-term, demonstrates the physical proportions and positions described in the text. Her morphological characteristics limit movements, such as cervical extension with capital flexion; full thoracic, lumbar, and hip extension; costovertebral mobility with respirations; and hand movements toward midline.

Fig. 10.11 Makayla's shoulder complex is almost always in a position of elevation, similar to the position seen in young infants. Active muscle contractions of the thoracic and lumbar superficial and deep extensors, abdominals, and scapular stabilizers change the shoulder complex position in children developing without neuromuscular impairments. Makayla has not been able to establish this neuromuscular control yet, and may be actively using shoulder complex elevation to assist with her antigravity postures and movements. She is not able to free her arms for play in supported standing, however, using this strategy.

Typical Postures and Movements in Children with Spastic Quadriplegia

The constraints imposed on people with spastic quadriplegia due to their impairments include the following:

- Muscles used for postural control and joint stability against gravity are difficult to recruit throughout the body (this difficulty varies with the severity of CP).
- When muscles are recruited, superficial, two-joint muscles are likely to be recruited first (and sometimes exclusively) and/or without the stabilizing effect of postural muscles that work in synergy with two-joint muscles in people without neurodisability. Recruitment is ungraded, often with overflow into unnecessary and often antagonistic muscles. As a result, inefficient cocontraction and/or overflow results and persists, increasing active joint stiffness. Another result is that the two-joint muscles work in small ranges only, sustaining activity longer than functional demands require, and eventually shortening.
- Over the life span, muscles that are recruited and sustained in short ranges tend to alter the proportion of fiber types, alter in extracellular structure, and may be infiltrated by collagen.[39,71,72] Therefore, muscle tissue and surrounding soft tissues shorten and change in structure and function. Altered muscle activity alters the pull on bones, as do lack of weight bearing and movement. All result in a process of secondary impairments of increasing bone and joint deformities.
- Perception of the self and the environment is altered due to altered body segment alignment,

limited successful antigravity postures, and poverty of movement, as well as due to any primary sensory system impairments that alter the development of perception.

Infants and young children with spastic quadriplegia are usually capable of generating simple synergies of flexion or extension in the axial muscles.[45] Muscle contractions are often initiated from the infant position of head asymmetry with an immobile and elevated rib cage. Because postural activity does not develop well to stabilize joints and body segments against gravity, the child uses what she or he has: the ability to sustain contractions in two-joint muscles to assume and sustain antigravity postures. This strategy is often partially successful, allowing some function. The child is stiff, moving in small ranges. Stiffness increases with effort and is often interpreted incorrectly as *increased spasticity* (**Fig. 10.12**).

Muscles of the trunk that work hard to attempt antigravity postures and movements include the pectorals, latissimus dorsi, scapular elevators, and erector spinae (most effective in the cervical and lumbar spine; they are often overstretched and ineffective in the kyphotic and rigid thoracic spine). The person with spastic quadriplegia often uses breath holding to increase trunk stability at the price of developing controlled exhalation for vocalizing and voicing. Breathing is shallow otherwise, as the thoracic spine remains in flexion and the rib cage remains in its infantile elevated position, limiting lung expansion. The rib cage becomes increasingly rigid as the child matures, and bone replaces the cartilage present in infant rib cages. Often, the rib cage becomes barrel shaped because the child must work hard with the superficial muscles to attempt active stability and sustain respirations (**Fig. 10.13**).

Because the child's trunk is limited by structure and function as described, the child often attempts to use the limbs to substitute for trunk control. The upper extremities are constrained by pectoral and latissimus action as they insert on the humerus and are used as a part of antigravity control. The price paid is lack of most functions for which the human arm was designed: body weight support, reach, grasp, manipulation, and nonverbal communication. The upper extremities tend to increase their original infantile position of shoulder complex elevation and shoulder extension, becoming ever more internally rotated with the constant activity of the pectorals and latissimus. Because the upper extremities are being used to attempt and augment trunk stability, any attempts to move the child's arms away from the trunk result in attempts by the child to resist. The child's resistance is for a good reason—the person attempting to move the arms away from the trunk is taking away the child's system of antigravity control. The child's resistance is again misinterpreted as *increased spasticity*, when, in reality, it is increased voluntary contraction, primarily with two-joint muscles, resulting in increased stiffness or hyperstiffness (**Fig. 10.14**).

Likewise, the hips attempt to substitute for lack of postural control in the trunk. The hips of children with spastic quadriplegia are biased toward flexion, adduction, and internal rotation using the medial hamstrings (long, large muscles). When the child attempts functional activities that require postural control of the trunk and hips, she

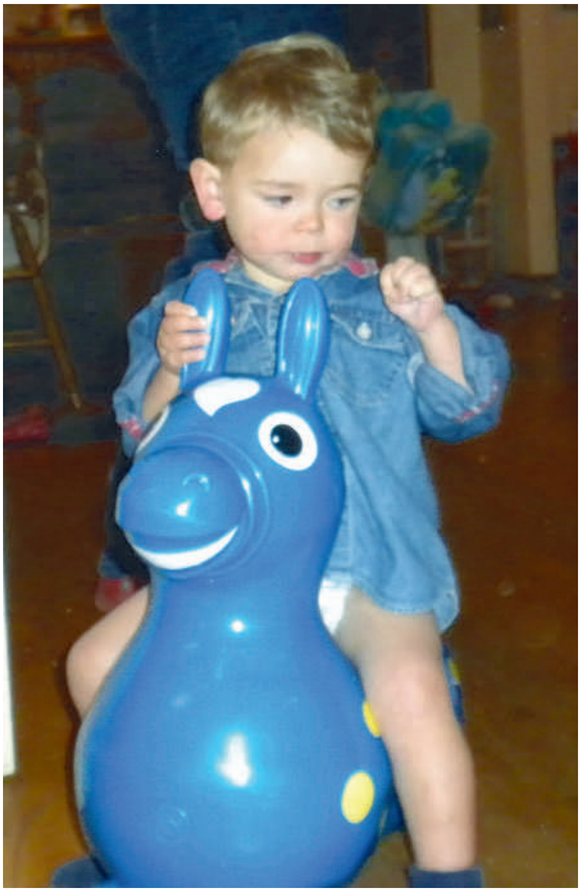

Fig. 10.12 This young child with congenital left hemiplegia shows stiffness in his left upper extremity. Is this stiffness entirely attributable to spasticity? Or are additional neural and nonneural impairments in the neuromuscular system contributing to his stiffness? Is his upper extremity postured this way to assist trunk extension? Or is his posture protective of his arm because his sensory reception or processing of sensation is different between left and right arms? There may be other explanations for his left upper extremity posture too.

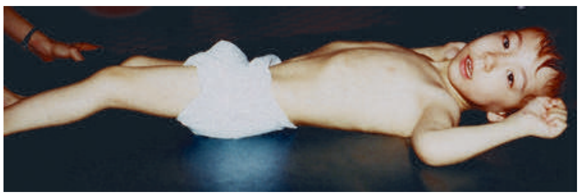

Fig. 10.13 This child has developed a barrel-shaped rib cage.

Fig. 10.14 The effort to roll produces contraction in most of the superficial muscles of the body in this child.

or he is often unable to generate sufficient activity in the trunk extensors (including the deeper extensors that lie close to the facet joints), the pectorals as horizontal adductors, the intercostals and oblique abdominals, and the gluteal muscles. So the child uses muscles that are easiest to recruit: hip flexors, adductors, and medial hamstrings. The gastrocnemius, a large two-joint muscle, is also recruited and sustained in a shortened range (**Fig. 10.15**).

Typical Postures and Movements in Children with Spastic Diplegia

In people with diplegic CP, the lower body is more impaired than the upper body. This distribution of impairment is often due to lesions in the cortex and subcortical white matter closer to the midline of the brain. Recall that the lower extremities are represented on both the primary motor and sensory strips of the cortex closer to midline than the upper extremities. Lesions near the midline of the cerebrum affect the functioning of tracts to sensory areas and from motor areas that supply the lower body. In addition, the optic chiasm and other portions of the visual pathways are located near midline. A common finding in people with diplegia is impairments in the control of the lower body as well as in visual processing. In addition, people with diplegia often have impairments in extraocular movements. The cranial nerves that innervate these muscles originate in the brainstem and travel anteromedially to the eyes. Therefore, it is possible for a person to have impairments in extraocular control and visual processing if lesions affect all of these pathways.

Fig. 10.15 This child shows the typical lower extremity (LE) position seen in spastic cerebral palsy. Note also the slight asymmetry in both the LE position and the position of the pelvis.

The infant and young child with spastic diplegia is likely to exhibit most of the postures and movements described for the child with spastic quadriplegia, especially as it affects the lower trunk and lower extremities. The severity of the impairments is initially related to the severity of the pathology, with a wide range seen in diplegia.

Initially, an infant with diplegia may not appear to have a posture and movement disorder and is often not diagnosed with CP until antigravity trunk control and LE postures are recognized as atypical. The baby's head, upper trunk control, and upper extremity control may allow typical or close to typical postures, movements, and beginning motor milestones. Caregivers begin to notice difficulties at various times, often beginning when the baby's lower extremities become stiff with hip adduction or an internal-rotation-predominating posture. With this posture, it is difficult for the baby to be placed in sitting, a position often practiced with caregivers months prior to the sitting alone achieved by 6- to 7-month-olds who are developing without motor impairments. The baby may appear to be a strong stander when held upright, but caregivers notice the persistent LE stiffness, crossed legs, and plantar-flexed ankles. In addition, some babies will persist in fisted-hand positions, or they may demonstrate extraocular muscle imbalance that caregivers notice as one or both crossed eyes (esotropia) or exotropia (one or both eyes turning outward). More complex eye movement disorders or visual perceptual impairments may be noted early or may become apparent as the child grows and attempts skills that require more complexity in the use of the visual system.

Many children with spastic diplegia are able to sit, stand with support, and walk with or without assistive devices. Caregivers and clinicians will naturally focus on the impairments that affect these skills. Clinicians using NDT will focus on the interaction of impairments as they affect activity and participation in the context of that child's life, keeping in mind that the postures and movements a child uses in the present will have effects on the future. Practicing postures and movements that are inefficient and ultimately damaging to body systems will eventually result in decreasing activity and participation. Although the negative effects of impairments cannot be fully eliminated, the clinician using NDT considers their effects on present functioning, on the interaction with other impairments, and on the future development of impairments, activity limitations, and participation restrictions when making intervention decisions.

In addition, the clinician using NDT is aware that children with spastic diplegia often have complex impairments in the visual system that influence activity and participation choices. The child is also likely to have more mild impairments that directly affect upper body and upper extremity activity and participation. Impairments, compensatory postures and movements, and secondary impairments developing in the lower body and visual system *will* affect the upper body too. Skills that were developed with the upper body can easily deteriorate as visual and lower body postures and movements influence the upper body.

Putting all of this information together, we can imagine the following common example. A 4-year-old child with diplegia is an only child. He attends a local church preschool with children without disabilities. The program made allowances for his lack of toilet training. He is social and is able to communicate with age-level expressive speech. He is able to feed himself with age-level skills, dress with upper body clothing, color with crayons, and play with toys on the floor. He likes to play with model cars and trucks, building sets, and a set of toy golf clubs. He moves about on the floor on all fours with in-phase extremity movements (bunny hopping). He W-sits (**Fig. 10.16**) or sits with his legs in front of him in hip adduction/internal rotation and severe trunk kyphosis, when adults tell him not to W-sit (at which point he can no longer use his arms to play, as they must now support him in this sitting position). He can move from the floor to sitting on a chair at preschool by himself. He can pull himself to stand at furniture and walk along furniture that is heavy and stable. He can take a few steps in a reverse wheeled walker if helped by an adult, but he uses this only in therapy sessions. He becomes toilet trained by age 5.

With his cognitive and verbal skills allowing him to attend regular education, he attends kindergarten and first grade. His teachers enjoy his outgoing personality and hard work, but they are concerned that he cannot see the Smart Board (Smart Technology) well at the front of the room. He holds his head laterally flexed to stabilize his gaze, increasing his thoracic lateral flexion and sagittal plane flexion. Over time, his head becomes more forward in the sagittal plane as he struggles to see the computer screen and his paperwork. He develops a scoliosis and walks with his walker with his head in a forward and laterally tilted position. As he walks within his school and short distances in the community, his overuse of two joint muscles to control his lower body causes increasing loss of hip, knee, and ankle joint mobility. He grows, which adds to the energy cost of his already energy costly gait and joint immobility. He uses his forward head position and increased thoracic flexion, shoulder complex elevation, and shoulder extension to walk with his walker. He also uses breath holding to assist trunk stability when walking.

Now his speech becomes more labored as his trunk position increases in scoliosis and kyphosis, and he uses breath holding for walking (he stops frequently to catch his breath when using his walker). People complain that they can't hear him when he speaks and that he speaks too slowly. He is increasingly ignored in peer interactions, as he cannot initiate speech fast enough to enter most conversations.

His fine motor skills deteriorate too, as his trunk posture worsens. His keyboarding slows, and he must spend longer hours with homework. After puberty and a large height and weight gain, he finds walking so laborious that he usually chooses his wheelchair, except for within his home. His family finds shopping trips, visits to friends and relatives, and vacations more difficult, therefore decreasing their community activities to accommodate their child's difficulty with car and van transfers, walking distances, and lack of an ability to use stairs.

This scenario is one that clinicians using NDT anticipate years before it unfolds, because they understand how impairments, compensatory postures and movements, the contextual activities and participation, and growth are likely to interact. Although the clinician understands that not all deterioration is preventable, the knowledge of the interaction of impairments, growth, activities, participation, and the context for each assists in intervention choices at all times.

The clinician using NDT would examine and evaluate this child when he is 4 years old and, knowing the likelihood of a natural progression as just described, implement intervention that addresses his future now. The clinician would focus vigilantly on developing and ensuring the best possible postural control possible, facilitate active movement transitions that involve control in all three planes, and practice postures and movements that use postural muscles for posture and long, multijoint muscles for full-range movement (full range for that person at that time). The clinician would address the complex needs of the child's visual system, intervening for gaze stability and gaze shift, stability and controlled mobility of the head and trunk to support eye control, while referring to other professionals for eye health care. Controlled and lengthy speech would be practiced in ever-increasing movement transition and environmental complexity.

The clinician would evaluate postures and movements for their effects on future postures and movements. In

Fig. 10.16 Playing in a W-sit position.

the past, some clinicians in the therapeutic community as a whole separated *quality* of movement (i.e., the use of particular muscles in particular synergies with timing, strength, and alignment) from the functional activity itself, believing that quality and function were unrelated components of skill. The reality is that quality affects the parameters of a current functional activity (e.g., speed, kinetics, accuracy, perception) *and* the possibility of attaining higher-level skills. A child with diplegia who practices keyboarding with limited visual scanning and slow accommodation during gaze shift, thoracic kyphosis and lateral flexion, increased stiffness in the lower body, and the need to stiffen the body to prevent falling will be limited in using the computer for lengthy writing assignments required in high school and college, despite normal cognitive skills. In addition, the effort to use the keyboard will require focus and concentration that detract from the person's focus on the higher cognitive skills needed for the writing assignment. *How* the person uses the keyboard affects the scope of functional complexity possible for him.

Typical Postures and Movements in Children with Spastic Hemiplegia

Babies and young children with spastic hemiplegia often have a focal cerebral insult. The insult can originate from any of the sources described in the earlier section on primary pathology in spastic CP. The positive and negative impairments that result as previously described are imposed on the child asymmetrically, with either the right or left side of the body much more impaired. (A person with hemiplegia does not have an "uninvolved side"—the corticospinal fibers do not all cross at the medulla; some travel ipsilaterally to target muscles. In addition, one side of the body cannot have impaired posture and movement without affecting the posture and movement of the other side.)

The child with hemiplegia will experience differences on the right and left sides of the body with primary sensory reception and motor control capabilities, resulting in a distorted perception of midline. The clinician practicing NDT uses this knowledge of asymmetry in sensation, posture and movement, and perception when designing intervention. Alignment toward a more correct midline and practice of postures and movements toward and away from the correct midline are paramount in intervention sessions with this child.

Without intervention, children with hemiplegia often achieve a repertoire of functional skills that may seem adequate. They often walk and talk, and although they often don't use one arm for very much, they figure out how to compensate. This apparent functional compensation can be deceiving to inexperienced clinicians. However, with careful examination and evaluation in the context of the environment the child functions within, the clinician may find that the child needs intervention. In addition, the clinician using NDT thinks about future impairments and function for this child. How will practice using asymmetrical posture and movements affect higher-level skill acquisition and retention of those skills with growth and maturation?

Fig. 10.17 A child with left hemiplegia.

Let's consider an example. A 9-year-old child with left hemiplegia (**Fig. 10.17**) is able to walk and talk and has the cognitive skills to attend regular education. She is able to write with her right hand, and her teachers know to tape her papers to her desk as she writes or orient the computer keyboard and screen to accommodate her body position and vision. Her visual impairments have made reading slow, and she has difficulty scanning a line of text without skipping to another line, but her reading teacher helps restrict how much text is visible on the page with a small handheld screen that she moves across the page to view only a few words at a time. She runs on the playground and likes kickball and soccer. She participates in physical education with a teacher who skillfully adapts games to her needs.

However, her mother and classroom teacher state that there are many things she cannot do, and they are concerned not only that she can't perform some functions but that her limitations and restrictions prevent her from full inclusion. They say that she is unable to use or manipulate many items used on a daily basis: shoelaces, snaps, buttons, and zipper. She is also unable to hold a piece of paper while cutting with scissors, open milk cartons, hold a heavy container while filling or emptying it, pour cereal with milk into a bowl, dress quickly in the morning, or carry her lunch tray. She cannot swing a baseball bat to hit a softball, catch any type of ball, ride a bicycle, run as fast as her peers, and walk community distances for school field trips and family outings without forcing others to stop and wait for her.

The clinician using NDT recognizes that, although this child can perform many functions, she is unable to participate as completely as she potentially could. In addition, the clinician considers the influence of asymmetrical posture and movements on physical growth and perception. As a child, she will be expected to increase her speed, accuracy, and complexity of posture and movement to accomplish the skills associated with older children, teens, and adults as she grows and matures.

The clinician using NDT determines the relationship among the sensory reception and processing integrities and impairments this child has, the motor control integrities and impairments, and the learned perceptions of internal representation of the body as well as the external relationship of the body to the environment. The clinician understands that the sensory, motor, and perceptual systems' growth and changes are interwoven and will therefore address all of these systems (others too, if needed, such as respiration, musculoskeletal, and behavioral) in terms of their interaction affecting posture and movement. This interweaving of influence means, for example, that a shortened heel cord is not simply stretched while admonishing the child to hold still for 10 to 20 minutes; rather, the ankle range is addressed through proper alignment and support of the calcaneus against a weight-bearing surface, with active movement encouraged within an engaging game that requires whole-body orientation around a correct midline.

For this same child in **Fig. 10.18**, a bimanual task is structured through an activity the child enjoys and is motivated by (**Fig. 10.19**). Her occupational therapist (OT) does not simply stretch and strengthen various muscles or provide sensory input to her arm without a context. She may lengthen muscles or stabilize joints and assist posture and movement of the child's body segments while adding sensory information to prepare the child's arm to hold the wooden spoon, but she engages the child with the activity as quickly as possible. The child's sensory needs, motor control, muscle length and strength, and perception are all challenged together while her OT assists body segment alignment, asks her to add an ingredient to the cooking task with one hand while stabilizing the bowl with the other, monitors her entire body position and adjusts as needed through active assisted movement, and increases the difficulty through any of these systems, all while helping the child to enjoy the task.

Fig. 10.18 Therapy involves playing a game that requires active trunk and hip control in all three planes while the game net is held by both hands at midline. The only handling portion during this part of the intervention strategy is to ensure that movement occurs in a well-aligned ankle joint as she reaches to catch the ball.

Fig. 10.19 A fun activity using bimanual skills.

10.1.5 A General Description of Children with Dyskinetic Cerebral Palsy

Primary Pathology

Children with dyskinetic CP often show lesions in the basal ganglia and thalamus. Because these subcortical nuclei are especially vulnerable to hypoxic/anoxic insults near full-term gestation, infants with a pure form of dyskinetic CP may have a birth history of term birth with some type of complications causing decreased oxygen supply to the brain.[20,30] Hypoxia/anoxia can cause initial hypermetabolism and excitotoxicity to the basal ganglia and thalamus, followed by hypometabolism of these structures.[73] Other children with dyskinesia show nonspecific cerebral abnormalities.[33]

The basal ganglia are a group of subcortical nuclei that receive information from the entire cerebral cortex. The basal ganglia processes cortical commands, sending excitatory or inhibitory information to other areas of the CNS through the thalamus, superior colliculus, and pedunculopontine nucleus.[74] Information processed through the thalamus influences motor, sensory, and cognitive information processing; information through the superior colliculus influences head and eye movements; whereas information processed through the pedunculopontine nucleus influences postural control and locomotion. Current research proposes that some basal ganglia circuits facilitate or select appropriate movements, whereas other circuits inhibit unwanted or inappropriate movements.[75]

Because the basal ganglia receive information from the entire cerebral cortex and, after processing this information, can send it to various CNS structures, lesions in the basal ganglia can cause a wide range of complex negative impairments, including impairments in motor control, sensory processing, and cognitive impairments.[76]

Early Development in Children with Dyskinetic Cerebral Palsy

This section considers dyskinetic CP in its pure form. Einspieler et al[77] and Straub and Obrzut[29] state that dyskinetic types of CP occur in ~ 10 to 15% of children with CP. However, the incidence of dyskinesia may be underreported due to difficulties identifying the dyskinetic component in a mixed type of CP[37,78,79] and due to the lack of consistent terminology used worldwide in describing the posture and movement disorders of children with CP.[35] In addition, recent groups defining CP have recommended reporting classifications by the predominant type only,[4] which may result in an underreporting of dyskinesia when mixed with spasticity. Dyskinesia can be mixed with spasticity and/or ataxia, and it will be considered later in this chapter.

The hallmark of infants who later develop with dyskinetic CP is hypotonia at rest[50,77] with varying muscle tone when moving.[34] With movement, hypokinesis or hyperkinesis is present.[34,37] Because there is a marked difference between the muscle tone at rest and the tone with movement, clinicians have traditionally described people with dyskinetic CP as having the following:

- Fluctuating tone.
- Low tone with rest and high tone with movement.
- Low tone proximally and high tone distally.

This text uses more descriptive terms consistent with research findings. Infants with dyskinesia often show little to no antigravity movement in the first months of life and passively conform their body to the support surface (**Fig. 10.20**). Children who will develop dyskinesia show a poor repertoire of general movements in the first few months of life, just as children who will develop spastic CP do. However, Einspieler et al[77] found distinguishing differences between infants who later developed dyskinesia and those who developed spasticity. Infants who later developed dyskinesia showed a coexistence of a poor repertoire of general movements; arm movements in slow, monotonous forward rotation at the shoulders; lack of movements toward midline; and excessive finger spreading.

With attempts at antigravity movement imposed on a body with an extremely asymmetrically positioned head and flattened trunk anterior-posteriorly with wide-based limbs, asymmetry in movement of the head is reinforced. This asymmetry differs from that seen in children with hemiplegia who have asymmetrical motor control. The asymmetry demonstrated by children with dyskinesia is influenced by the end range asymmetrical

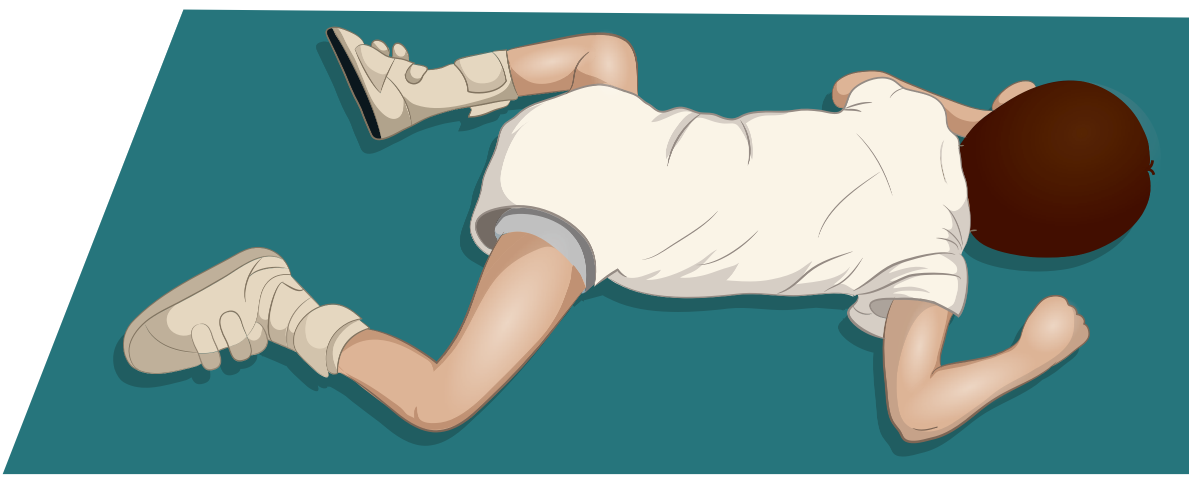

Fig. 10.20 This 6-year-old with the athetoid subtype of dyskinesia is severely hypotonic. Most points of the ventral surface of his body are in contact with the support surface.

starting position of the head in cervical rotation. Movement is often characterized by forceful bursts of activity through uncontrolled, recurring, and stereotyped movements throughout the body.[34] Postural muscles that stabilize joints and provide the ability to initiate and sustain an antigravity position are often poorly recruited in the movements of children with dyskinesia, just as they are in children with spasticity.

Typical Postures and Movements in Children with Dystonia

Dystonia, a subtype of dyskinesia, is defined as a disorder of movement characterized by sustained muscle contraction with frequent twisting, repetitive movements, and abnormal postures.[37,78,80,81,82] Often, cocontraction and overflow into extraneous muscles occur, *and this characteristic makes dystonia resemble spasticity*. When a person uses sustained cocontraction to attempt control of voluntary movement, the body segment increases in stiffness.[83] Hypertonicity is not the same as spasticity, however, and this is critical to understand.[84] Hypertonicity defines an increase in resistance that can have several sources; changes in the length and structure of soft tissues, involuntary overflow of muscle activity, and spasticity are common causes of hypertonicity. In addition, voluntary cocontraction that increases active stiffness can be perceived as spasticity.

Dystonic postures are repeated, but the rate of that repetition is highly individual. Some people with dystonic CP show few repetitions with marked hypertonia (often mistaken as spasticity). Their movement is characterized by hypokinesia, often with sustained abnormal posturing.[79] Infrequently, others show a higher rate of repetitious movements with the movements less sustained and can therefore be described as hyperkinetic.

People with dystonic CP often show low resistance to passive movement at rest, which is the reason dystonia is often referred to as varying tone or fluctuating tone. The limb at rest often assumes extremes of joint range,[81] and there is sometimes antagonist firing prior to agonist firing when movement is attempted.[37,52]

Many people with dystonic CP are moderately to severely involved.[33,62] Therefore, oftentimes the clinician observes and assists someone with dystonic CP in basic postures and movements. The telling difference between those with spasticity and those with dystonia (we will consider mixed spasticity and dystonia later) is the variability in body segment position and movement in those with dystonia, whereas those with spasticity maintain a similar body segment alignment no matter what position they are in. Whereas a child with dystonia often assumes an LE position of hip flexion, adduction, internal rotation, and plantar flexion when supported in standing (**Fig. 10.21**), belly crawling, or reaching when seated, during times of little effort to move the LEs the child assumes a position of hip flexion, abduction, and external rotation, which is not seen in those who have spasticity only (**Fig. 10.22**). Likewise, strong shoulder complex and rib cage elevation, shoulder internal rotation, elbow hyperextension, forearm pronation, and wrist flexion with variable finger positions constitute a common movement strategy in people with dystonic CP and are often sustained with effort in posture and movement that

Fig. 10.21 When standing, which requires a great deal of effort for this child with dystonia, all four limbs become stiff, and she assumes strong hip adduction and shoulder internal rotation.

Fig. 10.22 When sitting with no movement requirements, her hips abduct and externally rotate.

Fig. 10.23 This child assumes a posture of shoulder complex elevation and relative extension of the elbow with the effort of supported standing. Jaw extension with eye extension is another common movement that may be unsustained and repetitive or sustained with voluntary movement. When the child stops voluntary movement from this position, his head is likely to fall forward, with most of the mobility for this movement at the lower cervical and upper thoracic vertebrae. His movement is likely to appear to be an all or nothing phenomenon; he is either sustaining his head up with all the extension he can generate, or everything appears to terminate at once, with his head falling forward hard and fast as far as the length of his cervical extensors allows and a collapse from standing.

may assume variable positions when the person is not attempting postural control and movement (**Fig. 10.23**).

Case Report B9 in Unit V describes Sam as a child with mixed spastic and dystonic CP who shows decreased activity in his postural muscles and difficulty terminating muscle activity in some of his superficial, two-joint muscles (**Fig. 10.24**). He shows overflow with movement attempts and increased body segment stiffness in his LEs and left upper extremity (UE). As a 6-year-old child, he now shows decreased muscle extensibility in the muscles he sustains on excessively and overlengthening in some of the postural muscles he is unable to use effectively. What will happen to these shortened soft tissues when Sam goes through a growth spurt? How will the changes to Sam's body during a growth spurt affect his strength and endurance?

Sam's respiratory excursion is decreased, and he has endured lengthy respiratory illnesses that prevent him from participating in school for long periods. Sam uses augmentative communication to interact with trained adults (**Fig. 10.25**), which allows communication with select people. How will the impairments in his respiratory system, the limitations of options for hand use, and the limitations on safe antigravity postures affect his ability to develop a variety of communication skills throughout his life? What might his therapists and family emphasize today to help him be the most effective communicator now, 5 years from now, and 20 years from now?

Fig. 10.24 Sam's limbs increase in stiffness when he attempts movement. He has difficulty recruiting postural muscle activity to control his trunk position.

Fig. 10.25 Sam works to isolate finger control to access his communication device.

Sam is hypersensitive to sound and tactile information, which may restrict full participation of his entire family in the community. Have these impairments influenced Sam's choices in play preferences? Have they affected community participation for Sam and his entire family? If the family liked baseball, could Sam enjoy a day at a ballpark?

Sam's neuromuscular impairments lead not only to soft tissue restrictions and possibly to bony changes with growth, but are also correlated to activity limitations. He is able to walk with assistive devices with adult supervision only, and his family is moving to a home with wheelchair accessibility. He has limited choices for safe sitting positions. How will his neuromuscular impairments affect his preferences for books and music, the activities he enjoys most, as he grows and matures? How will limited mobility affect choices for school placement, community recreation, and vacation options for his family? How will inefficient alignment and/or abnormal stresses on joints affect bony and joint growth and health? Are there postures and movements he uses now, which if practiced and repeated will limit choices for more complex postures and movements required for more skillful activities?

Typical Postures and Movements in Children with Athetosis

Athetosis is another subtype of dyskinetic CP. The word *athetosis* means "without fixed posture."[52] Athetoid movements are slow, continuous, and writhing, preventing maintenance of stable or sustained posture.[37] The movements appear random and repetitious in body segments particular to the individual. With voluntary effort, the random movements often increase in frequency and intensity, causing hyperkinesis.

At rest, a person with athetosis shows hypotonia and rotation of the cervical spine.[50] Antigravity postures of the head and trunk are difficult, with attempts to move often resulting in strong, unsustained bursts of cervical, lumbar, and sometimes elbow and knee extension. In a study done by Hallett and Alvarez,[52] 14 adults with mixed dystonic and athetoid CP were asked to rapidly flex their elbows while electromyography (EMG) recorded muscle activity. Hallett and Alvarez noted that voluntary effort increased the overflow of activity. In addition, several different EMG patterns were documented in the 14 people as they attempted to flex an elbow. One of the most common was initiation of activity with the antagonist prior to the agonist; another was alternation of agonist and antagonist in a rhythmic pattern. Excessive cocontraction was a third pattern, oftentimes with increased antagonistic activity with increased effort. In addition to these inefficient patterns, the researchers also recorded increased duration of agonist firing once the agonist contracted.

Children developing with athetosis often show excessive and continuous activity in jaw, facial, and tongue muscles. They often use strong and repetitive asymmetrical cervical extension to attempt head control and to control movement initiation of the arms (therefore, eye/head/ arm disassociation is severely impaired). If the child is supported upright, strong thoracic flexion and shoulder internal rotation are used to counterbalance cervical and lumbar extension.

Respirations and voicing reflect the disordered timing and sequencing of athetosis, and many children have severely dysarthric speech, if they are able to generate speech at all. Speech is, of course, a motor function and is separate from cognition and language. Children with athetosis are often unable to produce speech,[85] yet they often possess milder impairments in cognitive skills than children with spasticity.[62] These children are often prime candidates for high-tech augmentative communication devices. This can be true for some children with dystonia too, who do not have significant damage to cognitive processing and their association areas of the CNS.

Although many people with athetosis are severely involved and cannot assume or sustain antigravity postures without assistance and external support, some people with athetosis are ambulatory, able to use speech to communicate, and can develop a variety of fine motor skills.

As a common example of athetoid CP, a teenager who attends middle school uses a power wheelchair for mobility and an augmentative communication device for communication. She uses the middle finger of each hand to access the keyboard of her communication system and drives her chair with a joystick attached to the left armrest of her chair. She enjoys interacting on Facebook, downloading music, and collecting antiques with her father (they frequently go to flea markets and estate sales together).

This 13-year-old girl grew 4 inches taller in the past year, gained 20 lb, and began her menstrual periods. She began experiencing increased difficulties with eating foods that she had always enjoyed, finding that she choked more frequently and experienced severe heartburn after meals. These difficulties resulted in her refusal to eat the foods that bothered her, and people who did not know her very well thought she might be trying to gain attention by not eating or by dieting. During this year, she also began having difficulty performing skills that she had been able to perform for several years, including driving her power chair safely (safely for herself and others) and accessing her communication system with her fingers.

Growth and hormonal changes may affect integrities and impairments, as well as effective and ineffective postures and movements. Teens may experience a loss of skills once stable for them and may experience new system impairments that affect activity and participation, such as the digestive impairments this teen is experiencing. Perhaps growth of the digestive tract itself, along with hormonal changes and other factors not yet described by clinicians or the research literature, combine to cause the new difficulties with eating.

This teen likely required considerable time and commitment to achieve her skills with her augmentative and computer devices and with driving her wheelchair. Separating head, eye, and arm movements from each other is particularly difficult for people with athetoid CP. This was initially explained in hierarchical motor control theory as a reflex called the asymmetrical tonic neck reflex. Changes in the understanding of the possible causes and relationships of lesion timing and location, development of limited movement repertoires with extension imposed on an asymmetrically positioned head, practice of simple patterns of movement control only, difficulty using antigravity postures, and neuronal circuit preference for the limited patterns of movement may change our understanding of the causes of her difficulties with head/eye/ arm movements (see Chapters 12, 13, and 14 on motor control, motor learning, and motor development). This teen's NDT-educated clinicians may have considered options other than a primitive reflex as possible causes of her limited movement and treated her to systematically build more complexity and variety into her postures and movements, thus allowing her to function with her power wheelchair and communication system.

Skills achieved in the presence of many system impairments may deteriorate with growth and maturation. This is a situation well known to experienced NDT clinicians, and it is beginning to appear in the literature on adolescent and adult function in people with CP.[13,16,19,86,87] This teen's clinicians will examine and evaluate the changes in single-system integrities and impairments and in posture and movement integrities and impairments to assist her in regaining deteriorating function, adjusting outcome measures to reflect her current activity and participation needs. It is imperative that NDT clinicians document changes in all domains (of the ICF model) to show how CP affects the life span to advocate for intervention for teens and adults.

A Brief Definition and Description of Chorea

Chorea is another subtype of dyskinetic CP. Chorea differs from athetosis in the duration and continuity of movements. Whereas athetosis is characterized by sinuous and continually flowing random muscle contractions, chorea appears as brief, jerky random movements.[37] Chorea, which means "dance," is not voluntarily suppressible.

Children with chorea are also hypotonic at rest. Their movements are classified as hyperkinetic. On EMG, these movements appear as bursts of activity, rather than the normal waxing and waning of muscle activity.[51] Chorea in CP is almost never seen in isolation.[34,37] Often, the diagnosis of choreoathetosis denotes a subtype of dyskinetic CP with constant, random movements and a lack of stable posture.

10.1.6 A General Description of Children with Ataxic Cerebral Palsy

Primary Pathology

Ataxia is estimated to be the primary classification in 5 to 10% of children with CP.[27,88,89] Although the lesions causing ataxia have traditionally implicated cerebellar damage, the causes appear more complex and more heterogeneous.[27] Cerebellar lesions, including malformations and hypoplasia, have been shown in some children with ataxia,[89,90] but there are also reports of cortical dysplasias, neuronal migration errors, and maldevelopment—some throughout the CNS and some more local to the posterior fossa of the brain.[27] Lesions in the parietal lobe where the primary sensory strip is located and where sensory association areas for vision, vestibular information, and spatial perceptions are processed have been implicated in some children with congenital ataxia; therefore, these children may show sensory ataxia rather than cerebellar ataxia.[91] Genetic disorders have also been diagnosed in some cases.[88,90]

People with congenital cerebellar ataxia show several distinct motor control impairments. The classically identified impairments include the negative impairment of loss of coordination, including abnormal force, rhythm, and accuracy of movement.[34] This loss of coordination is expressed as variable timing of muscle activity, dysmetria (under- or overshooting), and dysarthria. The positive impairment of tremor is often present and is usually characterized by a low-frequency, slow intention tremor. Nashner et al[38] noted that, in children with ataxia who were able to respond to external perturbations of stance stability, there was normal ordering of muscle contractions. Nashner et al[38] noted that children with ataxia in their study performed poorly compared to children with typical development and children with spastic CP under altered sensory conditions. They concluded that children with ataxia appeared to have impairments in central sensory feedback mechanisms.

In children with cerebellar damage, loss of feedforward information for motor commands and/or the pathway for the vestibular–ocular reflex may be disrupted,[92,93] contributing to the negative motor impairments and visual perceptual impairments in some children with ataxia. The spinocerebellar and trigeminocerebellar tracts deliver unconscious proprioception directly to the cerebellum,[94] so damage in the cerebellum or these tracts could potentially alter kinesthetic information received from the entire body, including the face and head. Damage to the parietal lobe or frontal lobe, and their connections to the cerebellum, could alter somatosensory reception and processing, some cognitive functions, and certain types of memory.[94,95]

Early Development in Children with Ataxia

Many children who develop ataxia are born at term[27,88,89] (this does not include those who develop with ataxic diplegia, which will be consider later in this chapter). Babies who later develop with ataxia are usually noted to have varying severity of hypotonia[34,89,90] and delayed motor milestones, especially delayed onset of walking, poor fine motor skills, and delayed speech.[90]

Typical Postures and Movements in Children with Ataxia

Clinicians who examine and evaluate infants and young children with cerebellar ataxia often note some degree of hypotonia, which can vary from mild to severe from child to child. These children often use the integrity of their musculoskeletal systems to support some of their postures rather than controlled gradations of posture and movement to compensate for the poor ability to initiate and sustain muscle activity. The therapist is therefore likely to see infants and young children supporting their head upright by extending the cervical spine until the occiput lies on the elevated and rounded upper thoracic spine, at least some of the time. Other common substitutions of musculoskeletal integrity for graded motor control include

Fig. 10.26 This child with ataxia walks with a wide base of support with his arms held stiffly in a position to assist trunk extension. His trunk stays in a position of excessive thoracic flexion, and he uses very little transverse plane movement (rotation) of his trunk and hips during gait. His impairments include poor timing of muscle activity, including delayed onset of muscle contraction for balance reactions, and visual impairments, including poor tracking and nystagmus.

assuming and moving within a wide base of support in any position, using end range joint positions to support body weight ("locked" elbows and knees are common), and refusal to shift weight, despite being motorically capable of doing so (**Fig. 10.26**).

In children with ataxia, however, a more complex posture and movement disorder than hypotonia usually becomes apparent during the first few years of life. The posture and movement disorder is often more complex than that caused by impaired timing, impaired force production, impaired multijoint coordination, dysmetria, and intention tremor.[96] Children with ataxia are often profoundly impaired in their abilities to process sensory information from one or more sensory systems or learn well through their sensory systems and some cognitive/attention pathways.

Sensory impairments can be difficult to evaluate because sensory processing cannot be observed directly nor tested easily (the Sensory Profile may be a good assessment tool because it measures behavior[97,98,99]). Poor awareness probably results from disrupted processing of unconscious proprioception.[100] In addition, the child may have impairments in vestibular and visual processing.[101,102]

Children with cerebellar ataxia engage in what seems like odd behaviors as a result of impairments in sensory processing: excessive and developmentally prolonged mouthing, biting, or licking objects in their environment; banging toys without stopping to visually examine or softly touch and rotate the toys; stuffing food into their mouth and pocketing food between the teeth and cheek; becoming repeatedly stuck under furniture without learning how to manage the body in relation to the environment; and excessive falling. Caregivers describe them as either excessively cautious, preferring to remain immobile in whatever position they are placed, or dangerous because they move without graded control headlong through the environment. They are also often described by caregivers as intolerant of change in routine; intolerant of noise or other environmental stimuli; fearful of large, open spaces; fearful when a caregiver changes their position; clumsy; and impervious to pain. All of these descriptions suggest to the NDT-educated therapist poor processing of sensory information, and they require vigilant examination, evaluation, and hypothesizing in regard to causative impairments. Often, therapists find themselves advocating for children with ataxia who are exhibiting uncontrolled behavior due to poor sensory processing as opposed to other reasons. For example, they may not be able to learn that they cannot bite people because it hurts others; they have to learn that biting is something they are simply not allowed to do to people and animals but may do on something appropriate, such as food, gum, or a toy.

Let's look at a young girl with ataxia who attends a self-contained classroom at her elementary school. She is 7 years old. She likes her teacher and going to school, and her teacher reports she is a favorite among her peers and the adult staff because she is friendly and social. The child is able to move about the classroom with a reverse wheeled walker. She can safely get up and down to the walker from the floor or a chair. She uses a kindergarten-type wooden chair with a base that has been made larger and heavier with plywood attached under it. She is able to read at a kindergarten level, but her teacher reports that this is highly inconsistent; there are days she reads well and fluently, and there are days when she is unable to identify simple sight words.

Her inconsistency in performance includes both cognitive and motor skills. There are days when she can stand alone after letting go of heavy furniture, and there are days she falls off a bench she is sitting on. There are days she can feed herself finger foods at lunch, and there are days when she drops or smashes the food with a grip that is too firm. Writing individual education plan (IEP) goals has always been a challenge for her teacher and therapists because of her inconsistent performance.

Experienced clinicians who treat people with central sensory processing disorders and motor impairments that cause inconsistent timing of muscle activity are familiar with inconsistent performance. It seems that the ability to process sensory information varies from time to time in some people (poor modulation), and the NDT-educated clinician takes this into consideration when planning and providing intervention.

Clinicians recognize the need for making this child's world as consistent as possible, and they adjust intervention to meet this challenge. Intervention sessions may be more rigid than intervention with children without sensory processing disorders and motor inconsistencies. The NDT clinician recognizes the need for play and fun in the balance but also ensures that part of intervention is consistency and repetition. This often means that the child must practice and repeat the exact personal and environmental contexts when learning new skills much longer than other children who do not have the sensory and motor impairments this child does.

Because the impairment of inconsistent timing in muscle activity is a part of this child's movement, and because fear of movement increases the intention tremor she has, her therapist works methodically and predictably with her. This child is much less likely to develop moderate to severe musculoskeletal impairments than other children with different types of CP, but she is likely to use a limited repertoire of postures and movements to feel secure, which in turn limits her activity and participation.

Knowing the child's likes and dislikes, her goals at school, and her family's preferences for activities and participation is necessary for the diligent work that must be practiced and repeated to become a functional part of this child's new abilities. The NDT clinician understands how sensory processing impairments and inconsistent muscle timing can make new postures and movements frightening for a child and works to practice new postures and movements within boundaries that gently push the child to learn without instilling fear. The clinician works from simple synergies of posture and movement with external support that enhances posture, adding complexity to posture and movement slowly and predictably. The clinician may work to increase visual gaze stability with head stability, smoother eye pursuits with gaze shift or tracking, and visual monitoring of movement. Oftentimes, the child's visual system can partially compensate for the poor proprioceptive (and possibly tactile and vestibular) processing needed to learn skilled posture and movement.

10.1.7 Children with Mixed Types of Cerebral Palsy

The NDT-educated clinician is familiar with children who have mixed classifications of CP. The current consensus definitions, CP registries, and expert panels advocate diagnosing with the primary classification type, however, and this practice may lead to underrepresentation of dyskinesia and ataxia in epidemiology reports[3,35,61,103] and in a failure to address the unique characteristics and life span needs of people with mixed types of CP. Lebiedowska et al[81] state that most children with hypertonic CP have components of spasticity and dystonia. Gordon et al[104] found that, although 12 of 13 children who participated in their research study were diagnosed as spastic, many of the children showed both spasticity and dystonia.

As clinicians, our examination, evaluation, and hypotheses about the relationships of impairments and their effects on a child's growth, activity, and participation are built on careful listening, observation, palpation, and team problem solving. We observe, measure, evaluate, and hypothesize according to our clinical findings, not according to preconceived notions about what people with CP are like or what they need. Rather, knowledge about possible impairments, future impairments, and the interaction of impairments, activities, and participation helps guide the direction of examination of each person with CP.

It is difficult enough to find descriptions of posture and movement in the named classifications of CP in the literature. As a therapist attempts to understand children with mixed types of CP, literature to assist with description is rare. This section looks briefly at two clinically common mixed types of CP, describing observations from clinical experience and relating these to the literature whenever possible. Keep in mind that mixed CP can represent a combination of any two or more classifications. Therefore, spastic athetosis, dystonia and ataxia, hemiplegia and dystonia, or any other combination of the types of CP discussed in this chapter may occur together in a person with CP.

Spastic/Dystonic

It is common for children to have a mixed spastic and dystonic type of CP[4,36,105] (**Fig. 10.27**); such a combination is sometimes referred to as mixed hypertonia.[81] Spasticity and dystonia may be distinguishable, with a person showing both velocity-dependent resistance to passive movement as well as twisting, repetitive postures with some joints assuming end-range positions. The difference between a spastic catch in passive movement and early cocontraction with voluntary movement may be difficult to separate, however,[83] especially in young children who may not be able to respond to requests for imposed movements without their assistance, as is required for passive movement testing.

Infants could possibly present with lesions in cortical and corticospinal tracts that would cause spasticity as well as lesions in the basal ganglia and thalamus. Grade III and IV ventricular bleeds and other causes of periventricular leukomalacia could damage all of these areas, as could perinatal anoxia and diffuse errors of neuronal migration.[32,106]

Children with spastic dystonic CP are often severely involved and may lack basic direction-specific postural activity.[45] Despite this severity, clinicians may note that this mixed type of CP reduces the effects of some impairments. The dystonic component may help reduce

Fig. 10.27 This teenager has a mixed spastic dystonic type of cerebral palsy. He uses strong asymmetrical axial extension to move his head and also to speak. As he pushes out his voice, his limbs become extremely stiff. In addition, he has velocity-dependent resistance to passive movements and clonus with exertion and fatigue. Over time, his distal extremities have become contracted. Note that his feet are positioned in dorsiflexion.

the development of severe joint contractures and bony deformities commonly seen in children with severe spasticity. The larger range and more repetitive movements may be the reason this can occur. On the other hand, the presence of spasticity in a child with dystonia may restrict the large range of uncontrolled movements and support basic antigravity positions without sudden loss of postural control.

Ataxic/Diplegic

With the increase in survival of babies born preterm, including extremely premature infants (23–25 weeks of gestation), therapists may find that some children with spastic diplegia show additional impairments when compared with those who typically present with this diagnosis. These children present with lower body spasticity and loss of selective motor control greater than loss in the upper body, commonly with visual and/or visual perceptual impairments, consistent with diplegia. In addition, the child is often fearful of movement, seeking a crouch stance long before muscle shortening and overlengthening, weakness, and loss of selective control would cause this position. The child also shows additional impairments more consistent with ataxia: poor proprioceptive awareness, difficulty learning some new motor and cognitive skills, and/or poor spatial relationship perception. An intention tremor may become apparent as well, affecting gross and fine motor skills and speech. Respirations for voicing may be poorly timed, and scanning, unaccented speech may be present.

Achievement of function may be a slow process with this mixed type of CP. For example, this child may develop hamstring contractures early in life, not only because of the muscle imbalance, loss of selective control, and compensatory substitution of the hamstrings for postural muscles in standing and gait, but also because of strong voluntary contraction to prevent movement in an effort to compensate for poor muscle timing and lack of kinesthetic awareness. A crouch gait may develop very early as a result, leading to limited activity and participation.

With advances in brain imaging, researchers have only recently noted the catastrophic effects of prematurity on the development of the cerebellum.[107,108,109,110] The cerebellum typically grows rapidly between gestational age 28 weeks and term.[107] With premature birth, all studies cited showed a high incidence of hypoplasia of the cerebellum. In addition, when cerebral lesions accompanied the cerebellar lesions, the cerebellar growth was even more restricted, and some of the infants were later diagnosed with mixed CP, including spasticity, dystonia, and ataxia.[107,108]

10.1.8 Neuro-Developmental Treatment Practice and Classification of Cerebral Palsy

This chapter gives a brief overview of the pathology and impairments that alter posture and movement in children with CP, adhering to current topographical, tone, and limb distribution descriptions. The clinician using NDT becomes familiar with these descriptions to document and communicate with colleagues. Learning about the typical impairments contributing to efficient and inefficient posture and movement in each classification provides only a starting place for observation and description.

A far more important task is for therapists to examine and evaluate each child's integrities and impairments as they interact to affect posture and movement and, ultimately, activity and participation. The client and family's concerns and observations as well as the clinician's observations, examination, evaluation, and hypotheses regarding the client's function are by far the most important skills in NDT. NDT cannot offer an intervention plan or plans for the various classifications of people with CP. Individuals with CP are all unique and must constantly be listened to, examined, and evaluated for their needs to be met. This is what we do in NDT practice.

In Unit V, case reports of people with CP illustrate individualized NDT intervention. Read each one carefully to note how the clinicians examined and evaluated the individual's integrities and impairments, hypothesized how these affected posture and movement, and determined how the person's contextual factors affected posture and movement, as well as how context affected integrities and impairments in turn. Note how individual outcomes are set for each person according to all of these factors. Intervention is not chosen because the child falls into a particular tone and limb or severity classification; rather, intervention is chosen with all domains and contextual factors constantly assessed.

Fig. 10.28 **(a, b)** Nancy A. Jaekle, an adult with cerebral palsy, worked as a journalist for 24 years after earning a master's degree. The devastating effects of cervical spinal cord compression due to athetoid movements changed her function from Gross Motor Function Classification System levels II to IV. She is no longer able to walk independently and is dependent for most activities of daily living. She is still able to speak but requires others to transcribe her words into written text. Options for living with the physical assistance she requires that also allow her to express her intelligence and creativity are severely limited.

10.1.9 Cerebral Palsy across the Life Span

Infants and children with CP grow up to become adults with CP (**Fig. 10.28a, b**). Over 60% of people with CP living in the United States are over the age of 15,[87] with estimates approaching a half million adults.[17] However, specialization in caring for adults with CP is basically nonexistent.[17] CP is a lifelong disability, and disabilities require management. This does not mean that people with CP require constant, ongoing intervention, but it does mean that all individuals with CP will require intermittent episodes of care throughout their life span. Although the lesions that cause CP are presumed to be unchanging, the impairments, interaction of impairments, and changing environment (both internal and external) throughout a person's lifetime constantly affect functioning in new ways.

The unique needs of adolescents and adults with CP and other disabilities have recently gained attention in various professional associations[17,111] that have interest in lifelong health care. Along with this interest is the acknowledgment that teens and adults with CP often develop additional or worsening impairments.[13,87] Fatigue, pain, and new or changing musculoskeletal impairments[13,18,112,113] may contribute to premature loss of mobility,[13] limitations and restrictions in workplace and leisure activities,[16,86] and increasing severity of scores on the Gross Motor Function Measure[19] over time.

Adults with CP may show age-related changes earlier than people without disabilities.[87] Secondary impairments, such as soft tissue contractures, pain, chronic fatigue, diminished bone mineral density, and gastroesophageal reflux,[13,18,112,113] probably result from the interaction of primary impairments and attempts to function in various environments with compromised posture and movement. Ineffective postures and movements eventually lead to a high energy cost of activities and can lead to loss of previous functional abilities.[18,114] Thorpe[87] reports that CP is the fifth leading cause of activity limitation in the United States. Loss of walking ability, which is only one activity to consider, is only beginning to be researched in adults with CP.[114]

Impairments, including ineffective posture and movements, can lead to new pathologies as well. Common pathologies that develop over time, manifesting in adolescence and adulthood in people with CP, are arthritis associated with abnormal joint stresses,[18] osteoporosis and bony deformities, spondylolysis, scoliosis, and cervical stenosis.[13,14,18,] Cervical stenosis and degenerative changes are well documented in adults with CP, especially affecting those with dystonia or athetosis (the forceful, constant cervical extension used over the years is most likely the cause).[14,18,115,116] Symptoms include new spasticity, new weakness, paresthesias, and urinary incontinence. Progression of cervical degeneration can be devastating to loss of function as a result.

Clinicians who treat people of all ages with CP *must* understand the lifelong changes associated with the various types of CP. This is a part of NDT education that is considered crucial in the management of people with CP at any age. Through understanding the possible lifelong consequences of repetitive effective and ineffective postures and movements, clinicians are best prepared for managing at any time in a person's life span. Clinicians who use the NDT Practice Model evaluate and set outcomes with both the present and future in mind. Knowing how impairments can affect a toddler when she is 40 years old assists clinicians in setting priorities for emphasis in intervention and other management strategies in the present.

Convincing health care policy makers that a lifelong disability requires lifelong management is another huge undertaking that clinicians must be willing to take on. As Tosi et al state, "The medical and research communities have helped [people with CP] survive. It is now our responsibility to help them thrive and live productive lives, as uninhibited as possible by the chronic pain and secondary conditions associated with CP."[13]

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11 Neuro-Developmental Treatment Assumptions of Motor Dysfunction: Stroke and Adult-Onset Hemiplegia

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This chapter provides core knowledge for the examination, evaluation, and intervention planning for individuals who have suffered a stroke or traumatic brain injury (TBI). Common clinical presentations seen in individuals poststroke are explored. The underlying single- and multisystem impairments contributing to these clinical presentations are discussed as well as their influence on the International Classification of Functioning, Disability and Health (ICF) activity and participation domains of functioning.

Learning Objectives

Upon completing this chapter the reader will be able to do the following:

- Recognize four common clinical presentations and subcategorizations within these presentations that are frequently
- seen in individuals following stroke.
- List primary and secondary impairments that contribute to these common clinical presentations.
- Identify intervention principles specific to each clinical presentation that would enhance clinical outcomes.

11.1 Introduction

Within the Neuro-Developmental Treatment (NDT) Practice Model, it is accepted that individuals are unique in their participation roles and thus perform activities to fulfill these personal and societal roles. This occurs because of a complexity of interacting contextual factors (environmental, cultural, genetic, etc.), which leads to a unique combination of abilities and then disabilities postinjury, after stroke or TBI.

In an effort to assist clinicians who work with this population of individuals, a categorization based on these common clinical presentations is proposed. Within each of these categorizations, the collection of system impairments (i.e., impairment groupings) is discussed. Intervention strategies to effectively manage these impairment groupings and, thus, ultimately influence activity and participation on an individual basis are also briefly discussed.

11.2 What Is Stroke?

Stroke is the leading cause of disability in adults in Canada and the United States. In 2014 alone, 795,000 individuals in the United States and 50,000 individuals in Canada will have suffered a stroke.[1,2,3] Statistics show 20 to 32% of these individuals will die from their stroke, and 43% of the survivors will be left with some form of permanent disability.[1,2,3]

A stroke interrupts the blood flow to the brain, often leading to damage in some brain functions. This brain damage can cause paralysis of some parts of the body and/or difficulties with affected body structures and functions, for example, somatosensory, visual, cognitive, perceptual, and language function. There are two mechanisms for stroke: ischemic infarction and hemorrhage. Statistics vary but ~ 70 to 85% of strokes are from ischemic events and 10 to 30% are from hemorrhages.[2,3,4] An ischemic stroke occurs when a blood clot stops the blood flow to an area of the brain. A hemorrhagic stroke occurs when a weakened or diseased blood vessel ruptures, causing blood to leak into brain tissue. Hemorrhagic strokes typically occur from aneurysms and arteriovenous malformations (AVMs). There may be other causes of strokes, such as tumors or infections.[2,4]

11.2.1 Classification of Stroke

Strokes are most often classified according to mechanism (ischemic or hemorrhagic) and the location of the lesion (e.g., right brain, left brain, cortical, cerebellar, thalamic, brainstem, middle cerebral artery [MCA] involvement, etc.).[4] It is not the intent of this chapter to repeat what is well documented in the neurology texts. The reader is encouraged to refer to well researched resources and expert knowledge for this type of information.[3,4,5,6]

The clinical presentations, the multisystem posture and movement impairments, and the single-system impairments observed in the population of individuals with traumatic brain injury (TBI) can be similar in many ways to those found in the population of individuals poststroke. The more global term of *acquired brain injury* includes the subcategories of stroke and TBI. Thus the diagnosis and clinical presentation of brain injury are not specifically and separately addressed in this chapter.

It is true that damage to a certain area of the brain may result in certain functional losses, at least temporarily.

For example, individuals with damage to the posterior inferior frontal gyrus (Broca's area) often demonstrate expressive aphasia.[4] However, what is also true is that the brain is a highly integrated organ with complex interconnections among its parts (structures) and with the rest of the body systems. Older beliefs and knowledge about the brain structures and functions led health care professionals and researchers to have a somewhat narrow and limited perspective of the clinical pictures seen as a result of damage to a particular area of the brain; it was thought that all individuals with damage to the same area of the brain would present clinically with discreet impairments depending on the central nervous system (CNS) site of the lesion, as described previously in the example of Broca's area and expressive aphasia. However, it is now known that the brain is not rigid in its functional organization or in its response to injury and subsequent recovery process.

The brain's organization and its response to injury (and its ability to recover) is variable and based on personal factors, contextual factors, environmental factors, age, degree of damage/impairment, and so on. Thus the clinical picture from one individual to another with damage in the same brain location may be quite different.[6] As discussed in Chapter 12 about motor control and Chapter 15 about neuroplasticity and recovery, each individual's brain organization is unique. Clinicians may limit themselves in evaluation and intervention, as well as prognostic expectations for their clients who have had a stroke, when they hold preconceived beliefs and expectations of an individual's clinical presentation based solely upon damage to a particular area of the brain.

There is some benefit to knowing what impairments to expect with an individual who has had damage in a particular area of the brain (right cortex, cerebellum, thalamus, brain stem, MCA distribution, etc.). This knowledge provides useful general information to clinicians to predict the systems likely to be impaired. **Table 11.1** outlines these global functional areas for the various brain structures/regions. However, as Berta Bobath said, "It is important to see what you see, not what you think you see."[7]

Damage from a stroke typically occurs in focal areas of the brain—the infarcted area. Even in most individuals with TBI, there is often greater damage in one area of the brain. This focal damage explains why individuals poststroke typically present with more profound impairments on one side of the body leading to asymmetry in postural alignments and sensory and movement abilities. However, because of the brain's integrated organization, damage to an area in the right cortex of the brain, for example, will influence functional performance on the left side of the trunk and in the left limbs, *and* also on the right side of the body and bilaterally in the trunk. Similarly, focal damage in other areas of the cortex, cerebellum, and brain stem can contribute to posture and movement dysfunction on both sides of the body and bilaterally in the trunk. Thus it is best to think of a more affected side and a less affected side of the body (in the trunk and limbs) after a stroke versus there being a good or spared side and a bad or damaged side. Commonly used terms to describe the more affected side poststroke are *hemiplegia* and *hemiparesis*, meaning total paralysis of one side of the body (i.e., more severe) and weakness of one side of the body (less severe), respectively.[4]

The possible impairments resulting from a stroke, as listed in **Table 11.1**, can be numerous, and the influence on activity and participation domains of function can be wide ranging.[1] An understanding of the posture and movement impairments caused by stroke is particularly relevant to therapists who practice Neuro-Developmental Treatment (NDT). The NDT Practice Model emphasizes the careful examination of all body systems, the interactions of systems in posture and movement, and the influence of these systems and interactions on the activity and participation domains of individuals after CNS damage. Based on observing and analyzing the posture and movement dysfunction, the specific system impairments (primary and secondary) that influence the individual's activity and participation domains can be better identified, understood, and predicted. Intervention strategies are then developed to address the specific impairments within relevant activities and contexts. Section A in Unit V provides specific clinical examples of this evaluation → intervention process.

The NDT Practice Model offers clinicians a framework within which to examine, evaluate, and develop intervention strategies for individuals with CNS pathology. In particular, clinicians working within an NDT framework develop a focused understanding of how the neuromuscular, sensory, perceptual, musculoskeletal, cardiovascular, and respiratory systems' roles in effective and ineffective postures and movements may contribute to either efficient or inefficient function, respectively, at both the Activity and Participation domains of the International Classification of Functioning, Disability and Health (ICF). Clinicians have used the NDT Practice Model to evaluate many clients poststroke or with TBI. Their observations have led to four categories of commonly seen clinical presentations in individuals poststroke and with TBI:

- *Absent or decreased force production:* Individuals who demonstrate an overall low tone base.
- *Hypertonicity or motor overactivity:* Individuals who demonstrate an overall high tone base.
- *Ataxic:* Individuals who demonstrate impairments with the grading/scaling of muscle recruitment.
- *Pushing behavior or contraversive pushing:* Individuals who demonstrate contraversive pushing behavior.

Scheets et al[8] documented the use of movement system diagnoses in the management of individuals with neuromuscular conditions poststroke. The authors state that the medical diagnosis of stroke results in several different clinical presentations and is not sufficient to direct the therapeutic intervention. Scheets et al[9] initially proposed their movement diagnoses or classification based "largely on . . . systematic clinical observations for many years." They propose that movement system diagnoses, at the level of the impairment, provide a rational basis for treatment selection. Thus, similarly, this chapter proposes that the four commonly seen clinical presentations listed will provide clinicians with a useful categorization for evaluation and intervention management of these individuals.

Table 11.1 Clinical presentations related to involvement of arterial supply and/or damage to brain structures

Artery involved	Brain structure potentially affected	Potential impairments/effects
	Right hemisphere	• Left sensorimotor deficits
		• Visual deficits leading to inattention
		• Perceptual (visual, spatial) deficits
		• Motor perseveration
		• Cognitive deficits—memory loss
		• Behavioral changes—quick, impulsive behavioral style
	Left hemisphere	• Right sensorimotor deficits
		• Communication deficits (speech and language)
		• Apraxia (difficulty initiating, sequencing, processing a task)
		• Cognitive deficits—memory loss
		• Behavioral changes—slow, cautious behavioral style
Anterior cerebral artery	Superior border of the frontal and parietal lobes	• Contralateral sensory and motor deficits affecting lower extremity more than upper
		• Speech/language deficits
		• Apraxia
		• Neglect/inattention
		• Memory and behavioral deficits
		• Incontinence
Middle cerebral artery	Surface of the cerebral hemispheres and deep frontal and parietal lobes	• Contralateral sensory and motor deficits of the face, upper and lower extremities
		• Speech/language deficits (Broca's or Wernicke's aphasia)
		• Perceptual deficits (spatial)
		• Visual deficits—homonymous hemianopsia (HH)
Vertebrobasilar artery	Brainstem and cerebellum Cranial nerves	• Diplopia, nystagmus, dysphagia, dysarthria
		• Ataxia
		• Incoordination and equilibrium deficits
		• Headaches
		• Dizziness
Posterior cerebral artery	Occipital and temporal lobes, thalamus, upper brainstem	• Contralateral sensory loss
		• Thalamic pain syndrome
		• Visual deficit—homonymous hemianopsia, visual agnosia, cortical blindness

Note: This table summarizes information from the cited references.[3–6]

Absent or Decreased Force Production

A common clinical presentation seen following stroke and TBI is that of the individual who presents with little or no muscle activation. Commonly, this individual may be referred to clinically as flaccid, hypotonic, or weak. These individuals typically possess a common grouping of impairments. The complexity of dealing with this clinical presentation of absent or decreased muscle activation becomes more manageable if the underlying system impairments are determined and understood. From here, clinicians are able to make appropriate intervention choices.

This clinical presentation is observable in all postures but becomes particularly evident when the individual is first brought to a sitting position at the bedside. This individual often sits with overall flexion in the trunk and asymmetry in the frontal plane, which can fluctuate between a passive elongation or shortening of the more affected side of the trunk, depending on where the weight is concentrated. The more affected limbs fall into alignments that gravity and the location of the center of mass (COM) will dictate—abduction or adduction at the hip/lower extremity (LE) and into glenohumeral (GH) flexion, internal rotation, and adduction (**Fig. 11.1**).

In supine lying, this asymmetry may also be observable, but because of the large supportive base in supine, asymmetrical alignments are not always as obvious as when the individual is brought vertical to gravity. The individual's balance into all vertical postures is poor.

This poor posture can be accompanied by the additional issue of lack of or impaired head control. Many impairments may contribute to this poor postural control and activity level, including visual, perceptual, and sensory impairments. However, research demonstrates that reduced ability to recruit, modulate, and control muscles of the trunk and affected limbs poststroke is a major contributing factor to impaired postural control in sitting and standing. As they relate to impaired postural control and instability, these studies have revealed that individuals poststroke demonstrate greater movement of the upper trunk, with little anterior tilt of the pelvis during performance of sitting activities[10] with the following:

- Reduced force production as well as delayed recruitment of trunk muscle activity on the paretic side compared with the less affected side.[11]
- Deficits in strength, control, and the coordination of limb segments as the primary motor control impairments post stroke.[12,13,14]

Fig. 11.1 Carol, a client poststroke, through her sitting posture and limb alignments, demonstrates a clinical presentation frequently observed in individuals with *absent or decreased force production.*

- Lack of activation of leg muscles for support and balance during reaching activities in comparison to healthy counterparts.[15,16]

Historically, NDT education has taught about the importance of the role of trunk motor control and range of motion to enhance an individual's ability to control the center of mass over the base of support (BOS) and superimpose head and limb function on this stable base.[17,18] Di Monaco et al[19] in 2010 and Hsieh et al in 2002[20] demonstrated the importance of trunk and proximal limb control and independent sitting to the performance of activities of daily living and gross motor functions. As identified previously, many individuals poststroke will move their upper trunk (head, neck, and thoracic spine) but have limited ability to move in the lower trunk (lumbar spine and pelvis). There may also be asymmetry in the trunk movement (right and left sides) if the stroke is moderate to severe. Examination of trunk and limb control through functional activities relevant for that individual, initially emphasizing anterior pelvic tilt with lumbar extension, posterior tilt with lumbar flexion, as well as lumbar lateral flexion to both the more affected and the less affected side, allows the clinician to hypothesize if the underlying impairment is a motor recruitment issue or whether an underlying range of motion restriction contributes to movement inefficiency.

Other secondary impairments can develop over time depending on the individual's initial clinical presentation and impairments, personal and contextual factors, and the interventions received since the infarct. Examples include respiratory system compromise from range of motion restrictions and muscle activation impairments of the thorax/rib cage, impaired cardiovascular endurance from inactivity, further weakness from inactivity in the more involved and less involved sides of the body, cognitive inattention, and lethargy from decreased social interactions and stimulation.

Visual, sensory, perceptual, and other system impairments are definitely important and will influence the specific clinical picture seen in an individual poststroke, but it is paramount to understand the role motor impairments play in interfering with postural control.

Smidt and Rogers,[21] in 1982, defined strength as the ability to generate sufficient tension in a muscle for the purposes of posture and movement. Gracies,[22] in 2005, defined weakness as the inability to recruit or modulate motor neurons secondary to a lesion of descending motor pathways. Thus, force production in muscle can be influenced by both musculoskeletal and neural properties.

The impaired neural aspects influencing force production are related to the following:

- A delay in initiation and termination of muscle contraction, which may be due to the lesion and results in impairments in motor processing and efferent mechanisms.[23]
- The number of motor units recruited, the frequency of firing of these units, or a combination of these factors.[24,25,26]

The impaired musculoskeletal aspects influencing decreased muscle strength (weakness) are related to the following:

- The number and type of motor units recruited, the frequency of firing of these units, or a combination of these factors.[24,25,26]

Weakness can be further characterized by the inability to (1) initiate a muscle contraction, (2) increase muscle force to meet the requirements of the task (strength), or (3) sustain muscle force for the time necessary to complete the task (endurance). Following an upper motor neuron lesion, weakness may vary in severity from paralysis to paresis.

Muscle atrophy (typically from disuse) refers to a reduction in muscle fiber size. Muscle strength, or the ability of the muscle to generate force, is directly proportional to the cross-sectional area of the muscle.[27]

Many physiological changes occur in muscles poststroke.[6] Some of the changes result from the stroke itself, but changes also occur as a result of immobility and disuse and the natural process of aging. These changes occur on *both* sides of the body (greater on the more involved side) and include the following:

- A conversion of fiber types from type IIB (very fast twitch, high power, and fast fatigable) to type IIA (moderately fast, medium power, and fatigue resistant) and type I (slow, fatigue resistant) with disuse and aging changes.[28,29]
- A loss of both types of fibers (type I and type II) poststroke[24,30] and with aging.[29,31]
- A reduction in muscle mass (sarcopenia) occurs as a result of both aging (30–40%), affecting the LE muscles more than the upper extremity (UE) muscles[32,33] and as a result of stroke.[34]
- A loss of 10% strength per week (a loss of sarcomeres, not just muscle fibers) from disuse. This is referred to as disuse atrophy.[24,35,36,37]
- Decreased endurance from atrophy of fatigue-resistant muscles.[31]
- Decreased metabolic activity secondary to decreased oxygen uptake when no demand is placed on the muscle(s).[31,38]
- Some muscles (primarily antigravity muscles) atrophy more than their antagonists. This atrophy is related to the glycolytic response.[38,39]

Thus, skeletal muscle response to stroke and decreased use is due to the following:

- Muscle fiber atrophy.
- Decreased capacity to generate muscle force.
- Conversion of fast to slow muscle fiber type.

The changes in muscle physiology poststroke have been shown to correlate with the degree of severity of the stroke and are also correlated with the degree of functional impairment as measured by the Fugl–Meyer UE assessment poststroke; that is, the more severe the stroke, the greater the changes (losses) in muscle physiology and the greater the functional losses for the individual.[12,24,25] Similar losses occur in connective tissue and bone from immobility or lack of a load. These include adhesions, disorganization, and disuse osteoporosis. The disuse osteoporosis is greater in weight-bearing bones, such as the vertebral bodies and femurs.[40,41]

Muscle weakness and atrophy, tissue shortening, and bone demineralization can occur within hours of immobility. Individuals poststroke from a moderate to severe event are often immobile or at least less mobile for the first few days. Thus secondary impairments (e.g., range of motion restrictions, disuse weakness, and muscle atrophy) are often developing or present during the first clinical examination of the client. If the individual remains immobile or less mobile for any length of time, weight gain may occur, making mobilizing harder in general. With immobility, impairments in the cardiovascular and respiratory capacities (endurance) of the individual develop.[42,43] Thus poststroke, even in the short term, there is weakness, shortening of tissues, a risk of weight gain, and decreased cardiovascular and respiratory endurance/capacity, which may all increase in magnitude through a self-perpetuating cycle. When these primary and secondary impairments from the stroke and immobility are combined with the effects of aging, individuals poststroke (especially those over the age of 40 when aging-related changes begin to occur in muscles), face an uphill challenge to regain their function.[44] Therapists planning interventions with the client aimed at targeting the primary and secondary impairments of the stroke itself must also consider these secondary impairments from immobility and, in many cases, aging affecting the musculoskeletal system on both sides of the body, the cardiovascular system, and the respiratory system. It is challenging for an individual to work in therapy poststroke, and the effects of deconditioning render the task even more difficult.

Studies have demonstrated that exercise, aerobic and resistance, even when performed by individuals at an advanced age or many months or years poststroke, is effective at reversing many of these changes.[31,38,42,43,45,46,47,48] Studies have also confirmed that the sooner exercise is initiated poststroke, the better the outcomes.[49] In a meta-analysis of 21 studies, findings demonstrated that, for individuals in the acute phase (< 6 months poststroke) who engaged in resistance exercises, the strength and functional outcomes were greater than those who began their exercise after this period.[49] However, even in individuals who were considered more chronic (> 6 months poststroke), resistance exercise was beneficial in improving strength and functional performance.[50] The difference between the two groups was hypothesized to be because the individuals considered chronic stroke survivors (> 6 months poststroke) were suspected of having greater loss of muscle strength and motor unit activity from disuse weakness.[50]

Many strokes occur as a result of cardiovascular dysfunction. This leads to a hesitation on both the client's and the therapist's part to increase the demand on the cardiovascular system through aerobic exercise. Traditional physical therapy poststroke often does not provide enough cardiovascular challenge to the individual to address the deconditioning changes.[51,52] Studies have shown that individuals poststroke often have exercise capacities at ~ 40% below age- and gender-matched norms for sedentary individuals.[53] A balance must be found that does not overstress the individual's cardiovascular and respiratory systems but is challenging enough to ensure that the deconditioning does not become the limiting factor to recovery from the stroke.

When an individual is recovering from a heart attack (another result of cardiovascular dysfunction), standard care includes cardiac rehabilitation—exercise.[54]

If we recognize that regaining cardiovascular fitness is important to recovery from a heart attack, why would we not think the same for recovery from a stroke? A further convincing factor for increasing activity levels for individuals poststroke may be recent evidence demonstrating that aerobic and resistance exercise are believed to create an environment that promotes positive brain plasticity.[55,56,57] Exercise improves cerebral vascular perfusion, metabolism, and growth factor regulation.[57] In 2007, Cotman et al[57] reviewed the evidence for the beneficial effects of exercise on many aspects of brain functioning—learning, memory, depression, and neurogenesis. Aerobic and resistance exercise training poststroke is an important and emerging area of practice, and recent publications[58,59] provide health care professionals with current recommendations and guidelines.

Typical Primary and Secondary Impairments in the Neuromuscular and Musculoskeletal Systems for the Individual with Absent or Decreased Force Production

The following impairments can be present on both sides of the body but are greater on the more affected side of the trunk and limbs:

- Weakness (including and varying between the inability to initiate muscle contractions, the inability to generate sufficient force in muscles, and the inability to sustain muscle(s) contractions of the following:
  - Trunk extensors (lumbar, thoracic, cervical)—evident early.
  - Trunk flexors (external and internal obliques, transversus abdominis, rectus abdominis)—more evident once the trunk extensors improve and the individual is able to move out of an overall flexed alignment.
  - Lateral trunk flexors (quadratus lumborum).
  - Hip extensors or abductors (gluteus maximus and minimus, hamstrings).
  - Knee extensors—evident early.
  - Knee flexors—more evident once the individual is able to support his body weight against gravity in activities such as walking and stair climbing.
  - Ankle dorsiflexors and evertors.
  - Scapular stabilizers (serratus anterior), adductors, depressors, and upward rotators.
  - Glenohumeral flexors, external rotators, extensors, and abductors.
  - Elbow extensors.
  - Wrist and finger extensors.
- Overlengthened tissues.
  - Lumbar and thoracic extensors.
  - Scapular adductors and depressors.
- Shortened tissues.
  - Lateral trunk flexors.
  - Short cervical extensors.
  - Scapular elevators (upper trapezius and levator scapulae muscles) and abductors.
  - Glenohumeral adductors, flexors and internal rotators.
  - Elbow flexors.
  - Wrist and long finger flexors.
  - Thumb flexors and adductors.
  - Hip flexors and adductors.
  - Knee flexors.
  - Ankle plantar flexors, toe flexors.
- Joint limitations.
  - Decreased extension range of the thoracic spine joints.

Impairments in other body systems are also frequently present in individuals with this clinical presentation. Examples of these may include but are not limited to the following:

- Absent or impaired light touch sensation or proprioception.
- Impaired vision (e.g., hemianopsia).
- Visual–spatial perception impairments (e.g., inattention).
- Impaired cognition (e.g., impaired recent or short-term memory).

The reader is referred to Chapter 16 on occupational therapy for a more detailed discussion of impairments in these systems.

The foregoing list appears long, and at first glance, it seems to list all muscle groups. However, after a more detailed review, the reader may notice that the list contains primarily muscles and muscle groups on one side of a joint or limb (e.g., weakness of the glenohumeral external rotator muscles vs. weakness of the internal rotator muscles and weakness of the hip extensors and abductors vs. weakness of the hip flexors and adductors). There are always exceptions to every rule, but, for example, around the hip joint, clinicians will be wise to expect greater impairments in weakness of one side of a limb or joint versus in their antagonists. In the example of the hip joint, weakness of the hip extensor and abductor muscles is more common than weakness of the hip flexor and adductor muscles. This difference in strength is not to say that the hip flexor and adductor muscles will be normal from a motor recruitment perspective (this is rarely the case), but if the motor recruitment impairments in the hip extensor and abductor muscles (and the others in the list) are focused on early in evaluation and intervention, the impairments in these muscles' antagonists (the hip flexors and adductors in this example) are often less significant. In individuals after a moderate to severe stroke, almost all muscle groups in the trunk and on both sides of the body will demonstrate impairments in their ability to recruit force efficiently and effectively. However, the groups listed should be considered at the top of the clinicians' lists of hypothesized impairments for individuals in this category of absent or decreased force production. Also, whenever there is significant weakness in a muscle or muscle groups, clinicians are encouraged to examine for tissue shortening of their antagonists. Examples of these include the glenohumeral internal rotator muscles, the wrist and finger flexors, the hip flexors and adductors, and the ankle plantar flexors.

The NDT Clinical Practice Model recognizes that each individual is unique in his or her participation and activity domains of function. This uniqueness, combined with the severity of the stroke and the personal and contextual factors that each person possesses, leads to variations in the influence and, at times, severity of the list of impairments an individual will have after CNS injury. However, despite this uniqueness, common groupings of impairments leading to common clinical presentations are frequently seen in individuals poststroke. Within this clinical presentation of absent or decreased force production, the development of three frequently seen conditions, the hyperextended knee, the subluxed shoulder, and the edematous hand, will be presented. The evolution and combination of the primary impairments into secondary impairments that result in these clinical sequelae will be described. In each of the three descriptions, the importance of determining the underlying impairments to effectively manage these clinical symptoms in intervention will be discussed.

Knee Hyperextension

In standing and in gait, there is often a tendency for individuals following stroke and brain injury to be inactive in their postural trunk and hip muscles, specifically the thoracic spine extensors, the abdominal muscles, and the hip extensors and abductors, and to stand in slight hip flexion, possibly also in relative hip adduction. This alignment may cause a posterior and/or lateral deviation of the pelvis, resulting in a pelvis on the more affected side that is often rotated back and/or shifted laterally. These alignments change the ground reaction forces through the lower extremity. Ground reaction forces now fall in front of and/or medial to the knee joint, mechanically forcing the knee into hyperextension. With the proximal tibia forced back, the ankle is positioned in relative plantar flexion and inversion (if the lateral hip muscles are not stabilizing the pelvis). The alignment results of this biomechanical malalignment, stemming from an inability to coactivate the abdominals and hip extensors or hip abductors to maintain pelvic stability in this upright posture and throughout gait, is often a hyperextended knee. Without intervention to address these proximal muscle weaknesses and shortened tissues, little change will be made in the individual's gait deviations.

Often, a brace is prescribed for the ankle to attempt to address the knee hyperextension and ankle plantar flexion. However, the underlying impairments and the rerouting of the ground reaction forces remain unchecked. Lack of movement through range over time may result in secondary changes in mechanical and elastic properties of muscle (e.g. plantar flexors) further contributing to a hyperextended knee. In the case report for Carol in Unit V (A3), the client had significant weakness of her hip abductors and extensors as well as the thoracic extensors and lateral trunk flexors on her left side. In the early and subacute phase poststroke, she stood only long enough for a quick dependent transfer between surfaces and often with less than optimal trunk and lower extremity alignments. Her gastrocnemius–soleus muscle group became significantly shortened. The combination of these impairments resulted in knee hyperextension with a foot and ankle that tended to be in plantar flexion and inversion (**Fig. 11.2**).

Shoulder Subluxation

Shoulder subluxation is a common clinical picture poststroke. Many authors, including O'Sullivan,[6] Neumann,[60] Donatelli,[61] and Caillet,[62] cite the importance of capsular and ligamentous structures, the glenoid and glenoid labrum, as well as the activity of the deltoid and rotator cuff muscles that seat the head of the humerus in the glenoid fossa, as key to providing stability at the glenohumeral joint. Lo et al,[63] in 2003, identified the lack of muscle tone and muscle paralysis hindering the dynamic control and supportive function of the rotator cuff as substantial contributors to shoulder subluxation following stroke.

Neumann[60] and Caillet[62] identify the forward- and upward-oriented angulation of the glenoid fossa and the proper alignment and muscular support of the scapula on the rib cage as well as the support of the superior portion of the joint capsule as mechanical contributors to glenohumeral joint stability. Caillet[62] postulated that, in the absence of muscle activity, as in hemiplegia poststroke, the alignment of the scapula and orientation of the glenoid fossa may well become more significant factors in subluxation.

Neumann[60] and Donatelli,[61] in their discussion of functional anatomy and mechanics of the shoulder, both cite the scapulothoracic joint as key to the stability and mobility of the glenohumeral joint. Neumann[60] states that a chronically downwardly rotated scapula may be associated with poor posture secondary to paralysis or weakness of certain muscles. He states that regardless of the cause, the loss of the upwardly rotated position and gravity can pull the humerus down the face of the glenoid. Eventually, he states, the glenohumeral joint becomes mechanically unstable and will sublux.

Thus shoulder subluxations seen in individuals poststroke are a direct consequence of biomechanical malalignments and muscle inactivity. The role of the more proximal body structures to the development of shoulder subluxation, such as the thorax, lumbar spine, pelvis, and LEs, as critical components as bases of support for the shoulder girdle must also be considered. Adequate trunk muscle activity to support the alignment of the rib

Fig. 11.2 A client poststroke demonstrates alignments through the more affected lower extremity that frequently result in knee hyperextension.

cage and influence alignment of the scapula and orientation of the glenoid fossa is paramount.[60,64]

If an individual has asymmetry in the trunk from one or a combination of a sensory, motor, visual, or musculoskeletal system impairments, the result can be a malalignment in the shoulder girdle structures and optimal conditions for a subluxation. Commonly, the lumbar and thoracic spine remains in flexion with the pelvis in a posteriorly rotated position. The rib cage on the more affected side is also frequently rotated posteriorly. This position is perpetuated by long periods of sitting in wheelchairs or standing with more weight on the less affected LE. With a flexed thorax and asymmetrical rib cage alignment, the scapula typically sits on the thorax in more of an abducted, elevated, and often downwardly rotated orientation. Biomechanically, these alignments allow the humeral head to be unsupported from a structural perspective because the glenoid labrum is no longer underneath it. When the individual is also unable to independently move into and sustain thoracic extension and posteriorly extend and tuck the rib cage *and* is unable to use the dynamic muscle stabilizer system of the scapular stabilizers and the muscles of the rotator cuff to hold the humeral head into the glenoid fossa, the capsule of the glenohumeral joint becomes stretched and ineffective. Over time, this biomechanical alignment, muscle inactivity, and prolonged stretch on ligaments and muscles can lead to a shoulder subluxation (**Fig. 11.3**).

Similarly, when an individual has a bias toward an asymmetrical alignment in the ability to use his or her legs, the consequences from this BOS up to the shoulder girdle can result in the conditions for a subluxation to occur. For example, if there is weakness of the hip extensors or abductor muscle groups and/or tightness limiting ankle dorsiflexion from a joint or muscle length impairment, such as shortness of the gastrocnemius–soleus group, the individual's COM is no longer aligned evenly over both feet in standing (during transitions and in standing/gait activities). As previously described, the pelvis and hip are often shifted laterally or posteriorly on the more affected side. This shift tends to rotate the trunk posteriorly on the more affected side as well. The individual often sits and stands with the COM shifted over to the less affected side of the body, contributing to a counterrotation forward in the upper trunk for balance (i.e., a zig-zag). This weight shift may be further increased with the use of an assistive device, such as a cane. The result is a thorax that is flexed with an asymmetrical rib cage (posterior on the more affected side) leading to the scapular and humeral alignment that was described earlier. This alignment, if sustained over time and combined with impairments in the visual, neuromuscular, musculoskeletal, and/or sensory/perceptual systems, for example, once again sets up the conditions for a shoulder subluxation.

Hand and Finger Edema

Frequently, but not always, the individual who has profoundly impaired force production in muscles of the trunk and limbs may also experience increased edema of the hand and fingers.[65,66,67] The overall and extreme flexion of the thoracic spine as described earlier decreases the space between the clavicle and upper ribs and compromises neurovascular structures that lie in this subclavicular space. This decreased space, in conjunction with the absence of the natural venous pump action of muscle activity in the arm,

Fig. 11.3 Scapula malalignment and muscle inactivity poststroke contributing to shoulder subluxation on the left.

further compromises the situation. From the previous descriptions of the postural malalignments in the subluxed shoulder that may occur from asymmetrical postures sustained over time from impairments in multiple systems, the conditions for increased edema of the hand and fingers can be better understood.

Intervention Principles for the Individual with Absent or Decreased Force Production

The following list shows intervention principles for individuals with absent or decreased force production. As has been discussed, each individual is unique premorbidly and poststroke. However, these underlying principles may provide clinicians with guidance in choosing intervention strategies to achieve optimal outcomes for individuals within this clinical presentation. These principles are based on an understanding of the underlying collection of impairments contributing to this clinical presentation. They are not intended to be used in a particular order, as listed here, but are to be integrated within and throughout any given intervention session.

- Emphasize dynamic control in the trunk, primarily the lower trunk initially, with an emphasis on movements of anterior pelvic tilt with lumbar extension, posterior tilt with lumbar flexion, and lumbar lateral flexion to both sides. Even in individuals with poor head and oral motor control, as the control in the trunk improves, these functions begin to improve as well, as demonstrated in the case report about Ernie in Unit V (A4).
- Work in functional activities in a variety of postures and transitions.
    - *Postures:* Choose postures that emphasize movement from the individual's overall flexed position (into gravity) to a more upright extended posture (out of gravity) in multiple planes. Examples of postures to work in and sequence through while engaging in functional tasks are as follows:
        - High sitting (hips above knees).
        - Higher sitting.
        - Standing.
        - Squatting (various ranges).

      Once the client is in a dynamically sustained, coactivated trunk alignment (with the trunk muscles working primarily isometrically), engage the individual in activities while maintaining this stable BOS. Even in sitting (with the hips higher than the knees), limb muscle activation is required to assist with maintaining this posture or to engage in the task. Examples of activities in these postures could include visually scanning the environment for family members, having a conversation with the therapist, using the less involved arm to reach for contextual objects for the task (golf ball, paintbrush, hammer, toothbrush, etc.), sliding or stepping the less involved foot toward an object or in the direction of reach, and so on.
    - *Transitions:* Choose transitions that bias the more involved trunk muscles and limb extensor and abductor muscles to actively recruit to support and move in and through the transition. Transitions often require a more sustained activation of the trunk muscles while superimposing muscle contractions in the limbs in eccentric and concentric contractions. Examples of transitions to sequence through while engaging in functional tasks are as follows:
        - Lateral weight shifts in high and higher sitting in both directions but initially toward the less involved side to bias the more involved lateral trunk muscles and limb extensor muscles to actively recruit to "drive" the lateral shift.
        - High sit ↔ liftoff.
        - Scooting in all directions but initially toward the less involved side so the more involved limbs are more likely to actively recruit to move the body weight toward the intended direction.

    - High sit ↔ stand.
    - Transfers on and off various surfaces in both directions but initially toward the less involved side as explained above for scooting.
    - Standing and stepping with the less involved leg in all directions, but choose the planes of movement based on the most significant impairments (the next paragraph discusses further).
    - Early gait activities.

  In both postures and transitions, individuals need to gain control in all directions, but, initially, choose the plane(s) of movement based on the individual's most significant impairments. For example, if hip extensor weakness is the most significant weakness at the hip joint, initially choose movements in the sagittal plane. If hip abductor weakness is the most significant weakness at the hip joint, choose movements in the frontal and transverse planes initially.

- Work in functional activities and contexts that are familiar and meaningful to that individual. Functional tasks and subtasks are chosen based on two factors.
  - They are tasks that are meaningful for the individual, and he or she wants to resume these activities.
  - They are tasks or subtasks that allow the individual's impairments to be addressed.

Other considerations for the functional activities include the following:

  - The tasks or subtasks engaged in need to be specifically and intentionally chosen to facilitate the desired movement/activation.
  - The environmental setup of the individual (e.g., whether the client is sitting or standing, which foot is forward or back in the BOS, whether the less involved limbs are part of the BOS or not), and the location of the objects and tools of the tasks also need to be specifically and intentionally chosen to facilitate the desired movement/activation.

Examples to illustrate the foregoing choices include the following:

  - If sustained trunk extension in an upright extended posture is the movement or alignment that is desired, the objects to reach for need to be high enough to *require* trunk extension, and the duration of the activity needs to ensure sustained activation is achieved.
  - With an individual who is a seamstress and wants to resume this activity, and whose most significant trunk impairment is an inability to sustain thoracic extensor activity, it would not be a wise choice to have her in sitting on a typical height surface hunched over the sewing machine to thread the needle. More success would likely be achieved to target this impairment by choosing the subtask of reaching up into a higher cupboard for sewing patterns or pieces of material from a higher sitting position. Often, therapists will work on basic activities of daily living (BADLs) tasks with such an individual. This individual may have activity limitations in BADLs but she may not be interested in or as motivated to practice these activities in therapy compared with working on the subtasks and task of sewing. The underlying impairments limiting both of these activities (BADLs and sewing) are the same because it is the same individual.
  - Through working in tasks and subtasks that are meaningful and motivating to individuals, clinicians are able to help clients improve the impairments that limit them in a variety of activities, including the activities on a typical checklist of desired therapy outcomes in acute and outpatient care (BADLs, bed mobility, basic transfers between wheelchair and bed, wheelchair and toilet, etc.).

- Within each posture and transition, the more involved limbs are kept in closed kinetic chain functions as part of the active BOS. (As motor function improves in the more involved limbs, they can be challenged from closed kinetic chain activity to modified chain, and eventually open kinetic chain activity.)
  - The less involved limbs are typically chosen to be the action limbs for the activity(s) and are progressively challenged to gradually move out of the BOS, first with modified chain → open kinetic chain movements, with small → large ranges and for short → longer periods of time.

For example, in standing, initially both UEs (hands) may be on a stable surface while the individual is reading her favorite cookie recipe. A progression from this posture may be asking her to slide the less involved hand over the counter (a stable surface) to reach for a cup of sugar to make the cookies. Both legs are still part of a narrow BOS. The individual is then asked to lift the cup of sugar and pour it into the mixing bowl. Next, the individual is asked to slide the less involved foot to the side to reach for the bag of flour on the counter on the less involved side. This can be progressed to taking a small lateral step with the less involved leg for the next ingredient on the counter.

Hypertonicity or Motor Overactivity

Another clinical presentation commonly seen is that of the individual presenting with hypertonicity of muscles following a CNS lesion. Kandel and colleagues,[68] in 2000, defined *normal tone* as a slight constant tension of healthy muscle so that when limbs are handled, they offer only modest resistance to displacement. This normal muscle tone is influenced by the physical inertia of the limb, mechanical and elastic properties of muscle and connective tissue, and reflex muscle contraction (tonic stretch reflexes). Following a CNS lesion, the physical inertia of the limb is unchanged. The hypertonia or excessive resistance to passive movement that we see clinically must then have a mechanical and/or a neurological origin. The resistance from neurological origin can manifest as spasticity, rigidity, and/or abnormal cocontraction of muscle.

Much controversy still exists surrounding the definition and measurement of spasticity.[69,70,71,72] Lance,[73] in 1980, defined spasticity as a motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes (muscle tone) with exaggerated tendon jerks, resulting from hyperexcitability of the stretch reflex. Young[74] defines spasticity as a motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes that result from abnormal intraspinal processing of primary afferent input. A more recent 2005 definition describes spasticity as a disordered sensorimotor control, resulting from an upper motor neuron lesion, presenting as intermittent or sustained involuntary activation of muscles.[75] Thus there is a lack of clarity among medical and rehabilitation professionals as to the use of the terms *hypertonicity* and *spasticity*.

The mechanisms believed to contribute to hypertonia, of which one type is spasticity, are varied.[69,70,76] Research has determined that stroke results in an imbalance of excitatory and inhibitory input at the motor neuron level leading to upper motor neuron symptoms.[71] Sheean and McGuire,[76] in 2009, and Ward,[71] in 2012, wrote comprehensive review papers on hypertonia and spasticity. Sheean and McGuire[76] state that certain clinical deficits are present immediately after a lesion. These are referred to as the negative features and include weakness and loss of dexterity. In an earlier paper, Sheean[77] describes a period of shock he calls a "transitional interlude of non-hyperactive reflex responses." This period of flaccidity or hypotonia is variable in length, ranging from 5 days to more than 1 year poststroke.[77,78,79,80] This period of the negative signs, including weakness and lack of sensory input, is typically accompanied by inactivity (bed rest or minimal activity at best). This reduced activity or inactivity further contributes to weakness from disuse. As was discussed previously in this chapter, the secondary impairments from disuse weakness of shortened muscles, atrophy of muscle fibers, and conversion of muscle fiber types, can develop in a very short time frame.

There is still no consensus among researchers on all aspects of hypertonicity, including spasticity and its causes, triggers, severity, location, timing of its appearance, or how to measure it.[70,71,76,78] There is consistency in the literature, however, that the immediate of CNS damage are losses; for example, weakness, loss of sensory input, and loss of sarcomere length. Thus it seems that these losses, rather than hypertonicity and spasticity, should be considered the primary impairments of the stroke. Sheean and McGuire,[76] in 2009, wrote that a "delayed consequence of . . . damage to upper motor neuron (UMN) pathways is the appearance of some form of motor overactivity, including spasticity." The word *delayed* may suggest a more secondary rather than a primary role in the development of the impairments of hypertonicity (including spasticity). These impairments should perhaps be considered secondary impairments of the stroke.

Hyperstiffness is a term used to describe the increased resistance in hemiparetic muscle from a mechanical origin.[81] It results from changes in the mechanical-elastic properties of muscle and connective tissue. The tissue changes that occur are related to immobility (lack of movement of the muscle and joint) and can result in the following:

- Remodeling of muscle structural components, such as collagen, with an increase in the proportion of collagen to muscle fiber noted.[82]
- Shorter actual muscle length attributed in some cases to a loss of serial sarcomeres (i.e., reduced number and/or in others a decreased resting sarcomere length).[36,82]
- Associated decreased extensibility of other tissues, such as joint capsule and ligaments.

Carey and Burghardt[83] also suggest a higher proportion of skeletal muscle cross-bridge binding that results in this abnormal stiffness.

An underlying impairment that contributes to these mechanical changes in the properties of muscle is muscle weakness. This weakness results in clients having a decreased ability to generate sufficient force to move their body and limbs, especially their trunk and more involved limbs, through joint ranges. When the antagonist of the weak muscle is also overactive (i.e., hypertonic), the weak/paretic muscle has an even greater challenge to overcome this resistance.

As clinicians, we observe hypertonicity repeatedly in certain muscle groups and we oversimplify its origins. We classify someone as having a *high tone flexed upper extremity* or a *stiff high tone extended lower extremity*. Hypertonicity and spasticity are often assumed to be primary impairments after an individual has CNS damage. However, hypertonicity is a multisystem entity with an underlying cluster of single-system impairments that require further investigation. The literature hypothesizes changes in descending commands, changes in excitatory or inhibitory inputs to the spinal interneurons and α motor neurons as mechanisms resulting in the following:

- Delay in initiation of muscle contraction.[23,84]
- Reduced muscle firing.[84,85]
- Delay in termination of muscle activity, often expressed in the literature as an abnormal cocontraction of muscles.[23,85]

Again, reading the foregoing points, the descriptors for the hypothesized neurological changes that occur after CNS damage are negative signs versus positive signs—delay in initiation, reduced muscle firing, and delay in termination. Is it possible that the negative signs are the true primary impairments that then lead to the secondary positive signs of hypertonicity and spasticity? Is the hypertonicity seen in individuals with CNS damage a consequence of what is missing, decreased, or slowed in the messaging to the muscles throughout the body? Weakness of central or peripheral origin can occur within hours of disuse. Shortening of tissues can similarly occur almost immediately. We know from research that diminished or absent input to muscles itself can be the cause of the spasticity and subsequent hypertonicity.[76] Do clinicians and researchers often fail to fully acknowledge and appreciate the role of these negative signs as the key to understanding hypertonicity and spasticity?

A detailed clinical examination will often reveal that these issues are expressed clinically as body segments or muscles that are weaker, often in the postural and proximal limb muscles, with overrecruitment developing in distal limb muscles. It is important to identify the neurological and mechanical components of hypertonicity before intervention strategies can be chosen. The weak or inactive muscles may be the antagonists to the hypertonic muscles or muscle group distant to the hypertonic muscle that typically provides stability.

Typical Primary and Secondary Impairments in the Neuromuscular and Musculoskeletal Systems for the Individual with Hypertonicity or Motor Overactivity

The following impairments can be present on both sides of the body but are greater on the more affected side of the trunk and limbs.

- Weakness (including and varying between the inability to initiate muscle contractions, the inability to generate sufficient force in muscle(s), and the inability to sustain muscle contractions of the following:
  - Trunk extensors (lumbar, thoracic, cervical)—evident early.
  - Trunk flexors (external and internal obliques, transversus abdominis, rectus abdominis)—more evident once the trunk extensors improve and the individual is able to move out of an overall flexed alignment.
  - Lateral trunk flexors (quadratus lumborum).
  - Hip extensors and/or abductors (gluteus maximus and minimus, hamstrings).
  - Knee extensors.
  - Knee flexors—more evident in the ambulatory individual.
  - Ankle dorsiflexors and evertors.
  - Scapular stabilizers (serratus anterior), adductors, depressors, and upward rotators.
  - Glenohumeral flexors, external rotators, extensors, and abductors.
  - Elbow extensors.
  - Wrist and finger extensors.
- Shortened tissues (including those secondary to neurological and mechanical factors, such as hyperstiffness, hypertonicity, spasticity).
  - Lateral trunk flexors.
  - Short cervical extensors.
  - Scapular elevators (upper trapezius and levator scapulae muscles) and abductors.
  - Glenohumeral adductors, flexors, and internal rotators.
  - Elbow flexors.
  - Wrist and long finger flexors.
  - Thumb flexors and adductors.
  - Hip flexors and adductors.
  - Knee flexors.
  - Ankle plantar flexors and toe flexors.
- Joint limitations.
  - Decreased extension range of the lumbar and thoracic spine joints.
  - Decreased range at various joints of the upper and lower extremity due to joint capsule and ligamentous changes (which joints demonstrate limitations will vary from individual to individual).
- Overlengthened tissues.
  - Lumbar and thoracic extensors.
  - Scapular adductors and depressors.

As with the individuals who present within the clinical presentation of absent or decreased force production, these impairments of neuromuscular and musculoskeletal systems usually coexist with impairments in other body systems, such as the following:

- Absent or impaired light touch sensation and/or proprioception.
- Impaired vision (i.e., hemianopsia).
- Visual–spatial perception impairments (i.e., inattention).
- Impaired cognition (i.e., impaired recent and/or short-term memory).

As before, the reader is referred to Chapter 16 on occupational therapy from an NDT perspective for a more detailed discussion of impairments in these systems.

This list of impairments does not appear significantly different from that listed earlier for the absent or decreased force production. However, this difference should not be surprising, considering that the research findings presented previously support the hypothesis that hypertonicity develops secondary to the negative signs following a CNS lesion.

As with the individuals who present within the clinical presentation/category of absent or decreased force production, the exact clinical picture of individuals who present with hypertonicity will differ based on their personal and contextual factors, their participation/restrictions, activity/limitations, and their body structure and function integrities/impairments. However, despite these individual variances, common clinical conditions often develop over time from the interaction of the common grouping of impairments. Five of these frequently seen clinical conditions are presented with a discussion of the hypothesized impairments leading to the posture and movement dysfunction seen in each—increased extensor tone in the more affected LE in sitting, increased flexor tone in the more affected UE with standing and walking activities, the subluxed shoulder, the hyperextended knee in stance, and the stiff leg in the swing phase of gait. These commonly seen conditions are often attributed to hypertonicity.

Increased Extensor Tone in the More Affected Lower Extremity in Sitting

When sitting unsupported, individuals with CNS lesions frequently sit with a posterior pelvic tilt in trunk flexion and with the hips in relative extension. This posture places the shoulders and COM behind the hip joints. Often, impairments of musculoskeletal restrictions and muscle weaknesses in the trunk and hip muscles interfere with the individual's ability to obtain a more optimal sitting alignment (**Fig. 11.4**). Landel and Fisher[86] clearly outline this postural alignment and hypothesize that the stress of maintaining this posture biases the lower limbs to assume what is classically described as an abnormal lower extremity extensor pattern with equinovarus posturing of the ankles and feet (see Case Report A4 in Unit V).

Fig. 11.4 A client post–brain injury demonstrates a sitting posture and alignment that places the center of mass behind the hip joints and results in lower extremity extension (a strategy adopted to maintain balance in sitting).

An individual with an intact nervous system may adopt a similar lower extremity alignment in an attempt to maintain balance if sustaining this body position over a prolonged period of time. The difference is that the individual with an intact nervous system has other movement options and can move from this alignment and strategy. The individual with the CNS lesion may be limited to this LE position not because of the hypertonicity but, as stated earlier, due to musculoskeletal restrictions and muscle weaknesses of neural or musculoskeletal origins, primarily in the trunk, interfering with the person's ability to obtain a more optimal alignment.

For example, lack of range of motion into anterior pelvic tilt and lumbar extension or weakness of the lumbar and thoracic extensors would interfere with achieving this more optimal alignment. If the individual had access to the range of motion required to achieve an anterior pelvic tilt with lumbar extension and relative hip flexion to allow the COM to fall within the pelvis, the legs (and often the arms as well) would no longer need to overrecruit or stiffen to maintain balance. With the legs no longer needing to be stiffly extended and postured in front of the trunk as a counterbalance, the feet can be positioned on the floor, adding to the person's overall stability. Key trunk and proximal limb muscles allow the individual to control and sustain this alignment.

In review, in this example, the impairment is not hypertonicity of the extensors of the LE; rather, this overrecruitment is a logical balance response to a postural malalignment. If the initial postural alignment of trunk flexion and a posterior pelvic tilt with hip extension and a posteriorly shifted COM are sustained over time, further secondary changes are likely to occur in the mechanical-elastic properties of the muscles of the LE due to the constant alignment experienced by the individual.

Motor Overactivity in the Upper Extremity with Standing and Walking Activities

There is also the individual who may be reasonably stable in sitting, but on rising to stand and in walking, the upper extremity often postures into a position of increased humeral adduction and internal rotation with elbow, wrist, and finger flexion.[76,87] When the individual is unstable in space, available muscles are recruited either voluntarily or involuntarily to create hyperstiffness and thus stability in the postures. The mechanism behind this predominance for involuntary flexion in the UE has often been attributed to the presumed primary impairment of hypertonicity or spasticity of the upper limb flexors. However, the mechanism is not well understood. Kamper and Rymer[85] propose that, in addition to the reduced voluntary extensor excitation, the mechanical attributes favoring flexion, such as the greater cross-sectional area and the greater moment arms of the flexors of the upper limb, could provide an explanation for the net flexion typically seen. Kline et al,[87] having recorded through EMG significant biceps, wrist, and finger flexor muscle activity during walking as compared with less EMG activity noted during more static postures (e.g., lying, sitting, or quiet standing), suggest an interlimb coupling: an interaction between UE and LE muscles related to active motor tasks and contributing to a UE flexion bias.

Clinicians may jump to the conclusion that this is an arm that should be treated with Botox (Allergan) to decrease this pattern seen in standing and walking. Further clinical observation of the individual's overall alignment and movement tendencies often reveals an individual who consistently sits and stands with an inactive trunk and who may also leave the foot of the more involved leg further forward than the foot of the less affected leg in sitting and in transitions. As the individual then bends forward to rise to stand, the shoulders may deviate from midline toward the less affected side, and the individual comes to stand relying primarily on the strength of the less affected leg and arm to carry most of the body's weight. The effort of standing up primarily through use of only one side of the body and the instability in standing, typically due to the paretic hip muscles, results in the individual balancing primarily on one leg. This effort and imbalance may result in the overrecruitment of UE flexor muscles. To effectively address the overrecruitment issues, the practitioner must examine and address the primary impairments of weakness in trunk and hip muscles.

The Subluxed Shoulder

In the previous section on absent or decreased force production, the clinical condition of shoulder subluxation was introduced as an issue of malalignment and inactivity of muscle. Once again, inactivity or weakness in certain muscle groups, such as glenohumeral external rotators, extensors, abductors, and elbow extensors, as well as the individual adopting postures and malalignments in the trunk and lower limbs similar to those described in the example immediately previous (motor overactivity of the UE during standing and walking), leads to the UE adopting a predominant posture of shoulder flexion, adduction, and internal rotation with elbow flexion. The biomechanical conditions for a shoulder subluxation are thus again created. In addition, over time, overactivity in humeral flexors, adductors, and biceps, combined with shortened pectoral and other internal rotator muscles, may pull the humerus out of alignment, further contributing to a superior, anterior, or inferior subluxation.[88] Clients should be examined for secondary impairments of tightness and hyperstiffness of the upper trapezius, levator scapulae, pectoralis major, latissimus dorsi and teres major muscles as these muscles commonly develop mechanical shortening over time.[88] These secondary impairments must be treated in addition to the underlying primary impairments, such as proximal (around the shoulder girdle and upper quadrant) and distal (in the lower trunk and/or legs) weaknesses. The soft tissue tightness must be addressed to effectively treat the malalignments contributing to inferior and anterior glenohumeral subluxations.[64]

Knee Hyperextension in Stance Phase of Standing and Gait

In the clinical presentation of the individual presenting with absent or decreased force production, the development of knee hyperextension was also discussed. The development of the alignments and resulting forces acting on the trunk, hip, knee, and ankle joints were presented to demonstrate how these may contribute to this common clinical condition. In the individual with hypertonicity or motor overactivity, the same malalignments and resultant joint reaction forces may also develop. As listed in the impairments for this clinical presentation, these individuals demonstrate predicted weaknesses of certain muscle groups with overactivity of their antagonists. Secondary impairments of tissue shortening and hyperstiffness often develop over time and, as discussed previously, may occur relatively quickly leading to inefficient joint and body segment alignments.

For example, an asymmetrical trunk alignment from overactive and subsequently shortened lateral trunk muscles combined with weakness of the hip extensors or abductors, with perhaps overrecruitment of the hip adductors, and overactive and shortened plantar flexor muscles in the more involved LE, may result in an alignment of hip flexion and adduction in standing. These impairments and malalignments may cause a posterior and/or lateral deviation of the pelvis and often a pelvis on the more affected side that is rotated back. This alignment is now identical to that described for the individual with absent or decreased force production who is at risk of developing a hyperextended knee, an alignment that changes the ground reaction forces through the LE. The proximal tibia is forced backward, positioning the ankle in plantar flexion and inversion. The results of this biomechanical malalignment in standing and gait, stemming from impairments of muscle weaknesses, tissue shortening, and antagonist muscle overactivity, is often a hyperextended knee. This clinical condition in individuals with hypertonicity or motor overactivity results from a collection of impairments that are noticeably similar to those in the individual with absent or decreased force production (negative primary impairments of insufficient muscle recruitment) with the addition of the symptoms (hypertonicity or spasticity) and subsequent development of the secondary impairments of hyperstiffness, shortening of muscle, and joint limitations.

Stiff Leg in Swing Phase of Gait

Frequently, the same individual who exhibits knee hyperextension in stance due to the primary and secondary impairments already outlined will exhibit a stiff-legged gait during swing. Closer examination often reveals impairments of proximal trunk and hip muscles (inactivity and/or weakness of thoracic extensors, hip extensors and/or abductors) such that a midstance alignment is not achieved on the more affected LE during gait. This results in a quick and short step with the less affected foot. Consequently, a trailing limb position is not achieved from which to initiate swing of the more affected limb.

Efficient normal gait requires a trunk that is stable and coactivated, including a pelvis that is relatively stable in all planes of movement.[89] In the clinical scenario described here, in the presence of the trunk and hip weakness outlined, we see the rotation of the trunk and pelvis posterior as outlined in the clinical presentation of absent and decreased force production. As the weight is transferred from the more affected leg to assume stance on the less affected leg, the affected hip frequently moves into an externally rotated position. These two factors, absence of a trailing limb and rotation back through the trunk and pelvis, create a biomechanical disadvantage to initiation of swing. Weakness of the hip and knee flexors may further compound the problem of swing. However, even if the individual can activate these muscles, he or she is disadvantaged in accessing this muscle activity due to the compromised biomechanical alignment. The resultant compensatory pattern of hiking the pelvis, which in itself creates an extension versus a flexion alignment at the knee, contributes to a stiff-legged gait pattern for swing. Once again, we see primary impairments of inactivity or weakness contributing to this overall presentation. Secondary impairments of soft tissue tightness or hyperstiffness may also develop in the lateral trunk flexors, particularly the quadratus lumborum, latissimus dorsi muscles, as well as distally in plantar flexors due to the bias of limb to be positioned in these ranges more than in any other.

Our clients with neurological impairments do have increased tone issues, but understanding how the negative primary impairments of insufficient muscle recruitment contribute to a lack of movement options and lead to secondary impairments causing alignment issues allows clinicians to focus interventions on the causal factors of the dysfunction (the zig versus the zag). If the underlying primary impairments are not identified and adequately addressed, they often lead to additional secondary impairments, including the development of the mechanical components of hypertonicity.

Intervention Principles for the Individual with Hypertonicity or Muscle Overactivity

Although each individual is unique, both premorbidly and poststroke, these underlying principles may provide clinicians with guidance in choosing intervention strategies to achieve optimal outcomes for individuals within this clinical presentation. These principles are based on an understanding of the underlying collection of impairments contributing to this clinical presentation. These ideas are not intended to be used in consecutive order as listed but are to be integrated within and throughout any given intervention session.

- The intervention principles for this clinical presentation are similar to those for individuals with absent or decreased force production as the impairments of weakness (including and varying between the inability to initiate muscle contractions, the inability to generate sufficient force in muscles, and the inability to sustain muscle contractions) exist for individuals with this clinical presentation as well. Additional principles may be necessary, as outlined next.
- Stretch soft tissues that have become shortened.
  - The best results are obtained by the individual actively stretching himself versus an open chain passive stretch done by the therapist or caregiver.

    If the body segment can be positioned and maintained in a closed chain alignment, the individual actively stretches by moving the body over the tight segment.

    For example, for a tight gastrocnemius–soleus complex, the client sits on a Hi-Lo table surface raised to the height that the foot/heel can be positioned in contact with the floor. The therapist handles the client to assist in maintaining this position with the hip, knee, and foot in alignment (no or limited hip abduction/adduction, external/internal rotation) as the client is encouraged to reach and shift forward over the BOS, come to liftoff, or scoot forward, all of which increase movement toward ankle dorsiflexion. Over time, the foot is placed further back with the knee in increased flexion and the ankle in increased dorsiflexion and/or the Hi-Lo surface is lowered. Many joints can be ranged using this principle.
  - Choose the optimal position or alignment of the body and limb segment for the stretches. The surface chosen for the closed chain alignment may need to accommodate the tightness.
    - The first choice should be to place the body segment in a more optimal closed chain alignment. For example, the fingers and wrist should be brought into extension if possible (with care to preserve the arches of the hand), and placed on a firm surface for the active stretch, even if there is slight end-range resistance to this alignment.
    - When the range restrictions limit the client or therapist's ability to close the chain in a more optimal alignment, an alternate surface or alignment should be found. For example, when the wrist and finger flexor tightness limits the ability of the client or therapist to fully open the hand and place it on a surface in wrist extension, a firm, smooth-contoured surface should be considered to accommodate this tightness rather than traumatizing the joints and muscles by placing the hand on a flat surface.
    - Work toward more typical biomechanical alignments and more advantageous length–tension relationships for muscle contraction as range improves.
- Mobilize joints where capsular and ligamentous tightness exists.

- Consider adjuncts and consultations such as Botox or surgical interventions in cases of severe range of motion restrictions, such as contractures.

Ataxia

Ataxia is derived from the Greek word for *without order* and is generally used to describe incoordination of movement.[90] As with previous clinical presentations discussed, ataxia is a description of a clinical presentation. To effectively treat it, one must first identify the underlying impairments or system dysfunction.

Ataxia is most common in brainstem or cerebellar pathology. Several classification systems for ataxia are presented in the literature according to cause—hereditary (Friedreich's ataxia being one of these), nonhereditary (or acquired with stroke, multiple sclerosis, tumors, metabolic disorders, drug or alcohol intake), as well as idiopathic ataxia.[91]

Perhaps the classification that is most helpful to the clinician is one related to pathology, lesion location, or system involvement. This classification of sensory, vestibular, cerebellar, or mixed ataxia was first presented by Morgan,[92] expanded upon by Edwards,[93] and continues to be elaborated upon by those delving into the mechanisms of ataxia.[90] A summary of this information is presented in Table 11.2.

The mechanisms underlying ataxia are not well understood, but research is providing more understanding of the underlying impairments contributing to the incoordinated movements—overshooting, undershooting, intention tremor, and proximal postural instability—which tend to be the common clinical presentation for those individuals with ataxia poststroke or brain injury.

In studies of single-joint movements in individuals diagnosed as ataxic, the agonistic muscle activity was found to be reduced in magnitude and prolonged in time, creating impairments with acceleration of movement.[94] The antagonistic muscle activity was also delayed, contributing to impairments with deceleration. These impairments would explain the problems seen in clients poststroke with controlling the amplitude of movements, overshooting, and impairments with speed and rhythm of alternating movements.

More recently, research has substantially explored the problem of ataxia and control of multijoint movements.[95,96,97,98,99] This information is of significant interest to clinicians with our emphasis on remediation of functional tasks, which of course requires the control of multiple joints and multiple degrees of freedom.[95,96]

Table 11.2 Ataxia—lesion location and clinical presentation

Type	Lesion location	Potential effects/clinical presentation
Sensory ataxia	Results from disruption of afferent proprioceptive input to the central nervous system (any pathology in afferent portions of peripheral nerves, dorsal roots entering spinal cord, dorsal column of spinal cord, medial lemnisci of brainstem, sensory receiving areas of thalamus, parietal cortex)	• Wide-based, stamping gait • Rely heavily on visual feedback • Have increased postural sway with eyes closed • Are particularly disadvantaged in the dark
Vestibular ataxia	Occurs with peripheral vestibular disorders (labyrinthine pathology) or central disorders (e.g., medullary stroke)	• Disturbances of equilibrium in sitting and standing • Staggering gait • Broad base of support • Decreased head and trunk motion • May be accompanied by vertigo and nystagmus
Cerebellar ataxia	Results from lesions affecting the cerebellum or its afferent or efferent connections • Dorsal and ventral spinocerebellar pathways • Pontine nuclei • Any of the three cerebellar peduncles	Lesions of midline structures produce bilateral symptoms • Truncal ataxia • Titubation (tremor affecting the head) • Abnormalities of gait and equilibrium • Dysarthria and nystagmus may also be present Lateral lesions give rise to • Ipsilateral limb symptoms (e.g., dysmetria, dyssynergia, dysdiadochokinesia, tremor) • Balance abnormalities (e.g., increased postural sway, excessive or diminished responses to perturbations, poor control of equilibrium during motion of other body parts, trunk oscillations) • Abnormalities of gait (variable foot placement, irregular foot trajectories, wide base of support, veering path of movement, abnormal interjoint coordinated patterns)

Bastian and colleagues,[96,97] in two studies, demonstrated that movement at one joint creates interaction torques or moments that influence the motion of adjacent joints. These torques are velocity and acceleration dependent and therefore increase as movements become faster. Muscles are always acting to create torques, which assists with the intended movement and counters those that oppose the intended movement. Individuals with ataxia, particularly cerebellar ataxia, demonstrate difficulty with multijoint movement. Bastian and colleagues[97] hypothesized that ataxia may result from an inability to exploit or counter these intersegmental interaction torques.

Shumway-Cook and Woollacott[100] state that "coordinated functional movement requires the scaling or grading of force appropriate to the metrics of the task." This information provides background as to why clients with ataxia have such difficulty with grading or scaling the degree of muscle recruitment and consequently such problems with incoordination of movement.

In addition to impairments in grading muscle activity between agonists and antagonists, particularly in the limbs, individuals with ataxia demonstrate problems with postural control.[90,101,102,103] In response to unexpected perturbations, hypermetric postural responses or an inability to set the correct size or gain of the response has been noted.[102,103] Diener et al[103] also demonstrated that subjects with cerebellar disease produce abnormally timed preparatory postural muscle activity, and because the postural muscle activity is not appropriately coordinated with the limb movement, postural stability is compromised.

Treating the individual with ataxia can often be a very challenging experience for the clinician. Perhaps this challenge arises from the fact that we have often focused on addressing the clinical symptoms rather than the underlying impairments. As clinicians, we are well aware that the individual with ataxia is quite capable of activating muscles, especially in the limbs, but, as the literature has demonstrated, these individuals have difficulty grading muscle activity. They also have impairments with postural control, including anticipatory postural control, as well as grading the postural muscle activity appropriate to that required for stability upon which to superimpose body and limb movement.

Primary Impairments in Ataxia

- Inability to sustain trunk coactivation (lumbar and thoracic extensors with abdominals).
- Inability to grade and time coactivation of trunk muscles with limb movement (i.e., anticipatory postural adjustment).
- Inability to grade and time the agonist/antagonist muscle activity of the limbs.

Impairments of the sensory and regulatory systems further compound the individual's ability to grade and modulate movement of the limbs and body in space. These impairments may include, but are not limited to, a loss of or impaired tactile and proprioceptive sensation, visual impairments (e.g., nystagmus, diplopia), and vestibular impairments resulting in vertigo and nausea. The incoordination of movement is also evident in oral and facial muscles, resulting in dysarthria of speech. The reader is directed to Chapters 16 and 18 on occupational therapy and speech-language pathology for further discussion of these impairments.

Intervention Principles for the Individual with Ataxia

Recent systematic reviews of the rehabilitation of individuals with cerebellar ataxia reveal a lack of research studies.[104,105,106] The majority of intervention studies are case studies or case series. Many clinicians will use the application of weights to the limbs, axial skeleton, or assistive devices to control the individual's ataxic movements. Studies into the effectiveness of this intervention are inconclusive, with results ranging from improvements in some subjects to deterioration in function reported in others.[107,108,109,110] The interventions that show positive changes have been those that do the following:

- Address trunk control/stabilization through active remediation of trunk muscle strength.[101,111,112,113]
- Include a component of task-specific training or functional task practice.[112,113,114]
- Progressively challenge the individual with movement over a smaller base of support or decrease the amount of propping/reliance on the upper extremities.[111,112,115]

This literature provides support for examination and intervention within the NDT Practice Model. The underlying impairments of decreased trunk and limb control (decreased anticipatory postural control and grading this postural control in the trunk and decreased ability to grade muscle activity in the limbs) are addressed in functional tasks in a progressively challenging way. A summary of these intervention ideas follows. These ideas are not intended to be used in consecutive order as listed below but are to be integrated within and throughout any given intervention session.

- Use verbal cues cautiously. Individuals with ataxia can activate muscles. When verbally directed, they initiate movement, but it is uncoordinated and lacks grading, and they easily perturb themselves due to the lack of anticipatory activation of postural muscles.
- Facilitate trunk coactivation in a variety of postures during various functional activities to enhance postural control/core stability while the limbs are being challenged in closed kinetic chain functions initially, but with the joints in midranges so that the limbs cannot be used as passive props. Examples include but are not limited to the following:
  - The upper extremities may initially be part of the BOS, but the surface height is such that the elbows are in slight flexion, not locked in hyperextension.
  - The lower extremities can be worked in a squat position. However, the individual does not

just sustain the squat but is asked to move in small ranges in this position and is challenged to weight shift and unweight one foot (initially the less affected), perhaps to slide it forward or sideways, progressing to stepping in these directions. In this manner postural control is challenged through movement over a progressively smaller base, and LE extensor muscles are strengthened and learn graded recruitment as they support the body weight.

  - Further challenge is added by limiting the individual's ability to oversupport through the UEs. The individual might hold an object in one or both hands, progressing to sliding the object on a surface, progressing to no UE support, progressing to stepping and reaching for an object in this squat position. Activity examples might be loading and unloading a dishwasher or clothes dryer or reaching for items in a lower cupboard or workbench.
  - Further progression may be to demand controlled movement not only in these mid- and small ranges but by gradually increasing the range through which the individual moves the limbs and body. In this way the challenge to postural control is continually progressed by superimposing limb and body movements while also challenging the individual with graded recruitment of muscle activity required to move with control through greater ranges.
- The more affected limbs are progressively challenged from closed kinetic chain activities and through greater ranges, to modified chain movements prior to open chain movements. The individual with ataxia derives great benefit from the sensory feedback of modified chain setups to scale and grade muscle recruitment. For example, the person could slide the hand along a slanted surface to guide the trajectory of reach to a cupboard or overhead shelf. Do not rush the more involved limbs out of contact with objects and surfaces that help grade and organize the movement. This principle applies to both the UE and the LE.
- When the chain is first opened in the UE, consider keeping an object in the hand (such as a cup) to provide feedback to assist in organization of movement. Choosing an object or a task with consequences may assist with this feedback. For example, the cup may be a Styrofoam cup or be full of water.
- Monitor alignments constantly and try to avoid allowing the client to rely on bony and ligamentous structures for stability.
- Incorporate functionally oriented, dynamic tasks into treatment—tasks that are meaningful to the individual and will be used in everyday life.

Keeping these key principles in mind, many intervention strategies used within an NDT framework with other individuals with CNS lesions can be applied to the individual with ataxia. The individual from Guha and Rock's case report in Unit V (A2) did not have a diagnosis of ataxia, but the sequence of activities used in her care plan demonstrates this progressive challenge.

Pushing Behavior—Contraversive Pushing

Pusher syndrome was first mentioned in 1909.[116] Davies[117] gave the first clinical description in her book *Steps to Follow* in 1985. Most authors cite the incidence of this behavior in individuals poststroke at ~ 10% of the acute stroke population (5.3% of the entire stroke population and 10% of the stroke population who receive rehabilitation).[118,119] However, other studies, including Danells et al,[120] in 2004 (63% of the stroke population), and Lafosse et al,[121] in 2005 (40–50% of the stroke population), state the incidence to be higher. The phenomenon of individuals poststroke who push as described by Davies[117] has been referred to as contraversive pushing, pusher syndrome, ipsilateral pushing, or pushing behavior.[120,122,123] It is defined as "an individual who has had a stroke *actively* pushes away from the non-paretic side leading to a loss of postural balance and falling towards the paralyzed side."[124] These individuals strongly resist passive correction to the earth vertical midline in both the frontal and sagittal planes. This resistance to correction is especially strong if the correction is done abruptly or without any functional or task context. This behavior can also be present in individuals after other kinds of CNS damage, such as trauma or tumors.[125]

Individuals poststroke who demonstrate pushing behavior as described are not to be confused with individuals with lateropulsion and thalamic astasia.[123] Individuals with lateropulsion and thalamic astasia do not actively push. Rather, the lateral tilting or leaning in these individuals is from a loss of balance to the more involved side from their underlying impairments of absent or decreased motor control.[123]

Karnath[123] and others[120,121,122] state that the pushing is often not detected if the individual is assessed only in supine. It is typically only when the individual is brought to sitting or standing that the pushing becomes evident, as seen in **Fig. 11.5**. The supine posture inherently means a large, stable base of support. However, it is possible that individuals could perceive themselves as unstable even in supine and in rare but severe cases pushing tendencies can be observed in this posture.

Karnath and various colleagues[123,124,126,127,128,129] have been conducting extensive research with this population to determine the origin of pushing, and more recently, to suggest management and treatment strategies. In a 2000[128] study, researchers determined that pushing is associated with unilateral lesions of the left or right posterior thalamus. A second group determined that, less frequently, lesions in the insula and postcentral gyrus can also cause pushing behavior.[130] Lesions in these areas of the brain are believed to cause this "distinctive disorder of postural control causing an altered perception of the body's orientation in relation to gravity."[126]

Karnath et al,[129] in 2005, also determined that the type of stroke resulting in pushing behavior is more likely to

Fig. 11.5 A client demonstrates pushing behavior.

be a hemorrhagic versus an ischemic stroke. Ischemic infarctions are also less frequent in the posterior thalamus. Some researchers argue that this pushing phenomenon is more prevalent in individuals with right brain damage (65% compared with 35% with left brain damage).[124] Others have found no difference between sides.[118,120] It is now widely accepted that pushing behavior may be present in individuals with lesions in either hemisphere.[118,123,127,128]

Karnath et al,[124] in their 2000 paper, referred to this behavior as contraversive pushing. Subsequently, other groups now commonly refer to this behavior as contraversive pushing.[130,131,132,133] Previously, individuals who demonstrated this behavior were diagnosed as having pusher syndrome. However, use of the term *syndrome* denotes the presence of other signs and symptoms.

Spatial neglect and other neuropsychological impairments were traditionally suspected to be causes of this pushing behavior.[117] However, further research has determined that these other phenomena are not causal to this pushing behavior.[118,120,123,130] There are, however, strong correlations between pushing behavior and spatial neglect after right hemisphere lesions. In Pérennou et al's[122] 2002 study and Karnath et al's[124] 2000 study 100% of individuals with right hemisphere lesions demonstrated spatial neglect. Eighty percent of individuals with right hemisphere lesions demonstrated spatial neglect in Saj et al's[134] study in 2005, 67% in Karnath et al's[129] 2005 work, 62% in Danells et al's[120] 2004 paper, and 40% in Pedersen et al's[118] review paper. There are also strong correlations between pushing behavior and aphasia after left hemisphere lesions (100%,[126] 80%,[121,126,130] 60%,[129] and 47.1%[118]). These strong correlations (spatial neglect with right hemisphere lesions and aphasia with left hemisphere lesions) occur because the relevant brain structures associated with these functions lie in close proximity to each other, not because of a causal relationship.[127]

Researchers have demonstrated that both the visual and the vestibular systems seem to be intact in these individuals.[124] However, their subjective perceived vertical (SPV) is at ~ 18% to the ipsilesional, nonparetic side. That is, these individuals perceive themselves upright at this alignment in the earth vertical orientation (upright in relation to gravity). Thus the researchers in this field believe that the pushing behavior is due to an altered perception of the body's orientation in relation to gravity.[123,124,129,130] Evidence thus argues for a second graviceptive pathway for organizing ourselves in gravity (separate from the visual/vestibular graviceptive system for perception of the visual world). There is some evidence to suggest that the peripheral receptors for this second graviceptive system are located in the trunk versus the head and neck or lower extremities and are in or near the kidneys with the information relayed via the renal nerve and also via the phrenic or vagus nerves, respectively, from the large blood vessels or viscera in the abdominal cavity.[135]

Clinically, clients who demonstrate pushing behavior push to the contralesional, paretic side. However, as just stated, research has definitively confirmed that these individuals' SPV is actually at ~ 18° to the ipsilesional side.[124] To date, researchers have been unable to fully explain this apparent contradiction of the SPV being on the ipsilesional, less involved side, but yet the individual actively pushes toward the contralesional, more involved side.[122,123,124] Ongoing research is warranted to explain the discrepancy between the clinical presentation and the research.

There is some debate among researchers about which group of individuals should be classified as pushers based on the amount of motor recovery present on the more involved side of the body (limbs and trunk).[118,120,124,129,132] Some believe that individuals are only considered as pushers if there is severe involvement, including essentially no motor recovery on the more involved side of the body. If there is relatively good motor recovery on the more involved side, these individuals are *not* categorized as pushers, despite their very active pushing away from the less involved side with active resistance to correction to vertical midline.[118,120,124,129]

Karnath et al[124] developed a scale, the Clinical Scale for Contraversive Pushing (SCP), to determine if an individual is a pusher or not poststroke and to rate the degree of pushing behavior. The scale has three domains: symmetry of spontaneous posture, use of the nonparetic limbs to increase pushing force through abduction and extension, and resistance to passive correction of posture. Clients are assessed in both sitting and standing postures. The greater the score out of a maximum score of 6, the worse the pushing behavior. Clients are identified as pushers if they score > 0 on any of the three domains.

The SCP is the scale most widely used to detect pushing behavior. However, two other scales have been found to be both reliable and valid to detect pushing behavior; the Burke Lateropulsion Scale and the Modified Scale for Contraversive Pushing.[136] The Burke Lateropulsion Scale measures the degree of action or reaction to keep or change a position and is the only scale that assesses pushing behavior in supine rolling and walking. A recent study demonstrated that the Burke Lateropulsion Scale may be more sensitive to detect mild pushing behavior in standing and walking.[137]

Until recently, all the studies related to this pushing behavior have included only subjects who have moderate to severe paresis on the contralesional, more involved side.[118,120,124,126,129] Danells et al[120] and others[118,124] suggest that the recovery of pushing behavior is not strongly associated with the recovery of motor control. Pushing behavior was often completely resolved by 3 months (71%[120]) or by 6 months (100%[118,126,129]), yet there were still profound motor deficits/paresis in all these groups. Santos-Pontelli et al,[132] in 2007, published a study that examined the pushing behavior in an individual poststroke with only minimal paresis. Their results showed that, as the pushing behavior decreased, the functional outcome measures increased (using the Barthel Index), whereas the paresis level did not statistically change. This study supports the hypothesis that pushing behavior is not strongly associated with the recovery of motor control.

The researchers can debate and determine these variations and which criterion puts an individual into the pusher or nonpusher category. For the purposes of this chapter and, in fact, for the relevance of clinicians, all individuals poststroke who actively push away from their less involved side, primarily in the frontal and sagittal planes, and resist correction to the vertical midline, should be included in this pusher category regardless of the amount of motor recovery on the more involved side of the body.

Anecdotally, clinical experience suggests that individuals who demonstrate pushing behavior poststroke have a range of mild to severe paresis. Those who have mild paresis on the more involved side of the body seem to overcome their pushing tendencies more quickly. The more severe the pushing behavior, the less likely the client demonstrates motor activity on the more involved side, even if there is only minimal to moderate paresis. These individuals are perhaps so disorganized in their orientation in space that they feel off balance in almost all postures (including supine in the most severe cases). This disorganization may mask the preserved motor movement on this more involved side. These individuals so strongly actively push with lateral trunk muscle activity and extensor and abductor activity in the limbs on the less involved side as they search for their earth vertical midline that the less involved limb and trunk muscle activity is inhibited or is seen in flexor withdrawal patterns/synergies of movement. Clinically, when any individual, whether she has had a stroke or not, perceives herself to be falling to one side, she will actively recruit antigravity muscle activity on that side, the side she feels she is falling toward. This increased effort or muscle overactivity often results in recruited flexor activity in the limbs on the opposite side. This flexor activity on the non- or less loaded side happens as part of a balance reaction and also as a result of the increased effort to actively recruit muscle activity on the less involved side. Thus, for individuals who demonstrate pushing behavior, if they are pushing to overcome their mismatch between subjective perceived vertical (SPV) and subjective visual vertical (SVV), it makes sense that they would activate their antigravity extensor and abductor muscle activity on the less involved side and flexor activity on the more involved side. Clinicians often misinterpret this flexor synergy as spasticity or hypertonicity attributed to the stroke when it could logically be a balance reaction or muscle recruitment to the individual's perceived, albeit impaired, midline.

Pedersen et al,[118] in the Copenhagen Stroke Study of 1996, concluded that "ipsilateral pushing did not affect functional outcomes but slowed the process of recovery considerably." In this same paper, these individuals required an ~ 3.6 weeks longer period of active rehabilitation to reach the same functional outcomes as individuals without ipsilateral pushing. Danells et al,[120] in 2004, found this increase in length of stay (LOS) to be 4.57 weeks longer for individuals who demonstrate pushing behavior compared with nonpushers to reach the same functional levels. The functional outcome measures used were the Barthel Index and Fugl–Meyer.[118,120] Despite persisting severe paresis at 3 and 6 months poststroke, as the pushing behavior decreased with these individuals, the functional outcomes increased.

Typical Primary and Secondary Impairments in the Neuromuscular and Musculoskeletal Systems for the Individual with Pushing Behavior

As discussed previously in this book, it is critical to determine the client's most significant impairments in order for the clinician to make appropriate intervention choices to maximize the client's functional outcomes. Individuals who demonstrate contraversive pushing behavior can have clusters of impairments on their more involved side similar to those of individuals who do not push. For example, impairments in the neuromuscular, musculoskeletal, and sensory/perceptual systems will be similar regardless of whether the individual pushes or not. However, we can add two unique impairments to the list of the individual who pushes:

- An altered perception of the body's orientation in relation to gravity (i.e., of the graviceptive system).
- Inappropriate overrecruitment of the muscles of the less involved side (lateral trunk and limbs), specifically, concentric activity of the extensors and abductors in the arm and leg and the lateral trunk flexors.

From a motor stabilizing perspective, individuals who demonstrate pushing behavior do the opposite of clients with stroke who aren't pushers. They do not accept weight on the less involved side of the body. The upper and lower limb extensors and abductors and the lateral trunk flexors on the less involved side contract strongly in concentric contractions. This does not allow these individuals to support their body weight on this side of the body (with eccentric and isometric contractions).

Individuals who don't push overrecruit the muscles on their less involved side (trunk and limbs), but they do this in a way that seems logical. They know their more involved side does not work as well as it did prior to the stroke so they accept weight onto the less involved side and use their less involved limbs and ipsilesional trunk muscles for stability on the ipsilesional, less involved side. The overuse with these individuals is logical and appropriate given their impairments on the paretic side. Individuals who demonstrate contraversive pushing tendencies overuse their less involved side limb and trunk muscles in an inappropriate way; the pushing behavior does not help them preserve their balance and alignment in upright postures but rather contributes to a loss of balance.

Principles of Intervention for Individuals with Contraversive Pushing Behavior

Applying strategies to help individuals who demonstrate pushing behavior integrate and resolve the pushing tendency as early as possible in the recovery phase may ensure that clinicians shorten the period of pushing and thus facilitate earlier return to the same levels of functional independence that our clients who don't push poststroke can achieve.

Karnath and Broetz[127] suggest that a new intervention strategy to treat the pushing behavior is to train these individuals to correct their earth vertical alignment using their visual systems. They acknowledge that this would require training because individuals who push do not seem to be able to spontaneously use this visual information to stay upright. Clinicians, for decades, have been incorporating visual feedback (e.g., objects in the environment) to help individuals who push overcome their perceptual postural impairments of the SPV. This has been met with only moderate success, perhaps because normal, everyday movement requires the individual to attend to the task, not the visual information in the environment unless it is relevant to the completion of the task. Teaching an individual to use visual information as a compensatory strategy at the expense of retraining the underlying impaired mechanisms (e.g., the graviceptors in the trunk) may also interfere with the neurological recovery (via neuroplastic mechanisms) that is possible for these individuals. Clinicians need intervention strategies to help these individuals resolve this pushing behavior as quickly as possible but, preferably, strategies that promote positive neuroplasticity rather than compensatory substitution.

The following guidelines and intervention strategies are based on the NDT Practice Model for working with this subpopulation of individuals with stroke who demonstrate contraversive pushing. These ideas are not intended to be used in consecutive order as listed but are to be integrated within and throughout any given intervention session.

- Treat both sides of the body (and of course, the trunk).
  - The inappropriately overactive less involved side demonstrates different, but equally significant, impairments compared with those on the more involved side. It is referred to as the less involved side to be consistent with the use of terms in this book for all individuals who have strokes. With this subgroup, however, the terms *less involved* and *more involved sides* may be regarded as misnomers. The pushing, less involved side is equally as troublesome.
  - The less involved side needs to accept weight eccentrically and isometrically.
  - The more involved side requires the lateral trunk muscles and the leg extensors to activate and sustain activity (this is true in the arm as well, but, initially, the therapist may only be able to manage and handle the trunk and leg and thus needs to prioritize).
- Work from the midline to the less involved side, back to the midline, to the less involved side, back to the midline. The midline that is impaired is in both the vertical frontal and the sagittal planes, with greater impairment in the frontal plane.
- Disadvantage the less involved limbs.
  - Keep these limbs more in flexion than in extension (especially the middle joints; knee and elbow). Examples for the foot/leg are on a step, tucked back in a narrow base, restricting where and what the foot can contact or push against.
  - If the upper extremity pushes too much if allowed to remain on a stable surface and it is difficult to keep it disadvantaged, take it out of the BOS and/or give it another job that has either a consequence or is distracting for the individual. Ideas for this include holding a cup of water or sliding/reaching for a specific desired object across a table or chair placed forward and/or to the less involved side.
  - Keep the less involved limbs engaged in activities/movement so the muscles don't have time to build concentric extensor and abductor force to push.
- Keep the more involved limbs in closed chain setups (see Chapter 9 on intervention) that demand extensor and abductor activation. As the more involved side becomes more active, the less involved side's overactivity will decrease.
- Work in real-life functional tasks that are familiar and meaningful to that specific individual, help organize the movement, and distract the person from the incorrect perception of midline.
  - Choose activities that are familiar and motivating to engage the individual motorically and cognitively.

  - Have the individual reach, slide, step, push real objects to the less involved side, upward, and forward.
  - Clients do better when the less involved limbs are doing these reaching, sliding, stepping, and pushing activities in modified chain setups (i.e., while in contact with an object/surface, and, sometimes, this surface may need to be a little unstable to prevent being used as a fulcrum for pushing).
- Individuals may need time-outs. This allows them to break the cycle of pushing and gives the clinician time to think of the next several activities. Examples of time-outs include the following:
  - Leaning down on the *less* involved elbow if in sitting.
  - Resting the entire body over a pillow on a table/plinth in front if in standing (often referred to as prone standing).

Note: The clinician may need to physically place the individual in these positions to *win* against the pushing of the trunk and less involved limbs.

- Be careful what is asked for. It is best to distract the individual or trick the person into transitions, such as liftoff and sit ↔ stand, versus asking the person to stand up. For example, get him to reach forward, push a chair forward and to the less involved side when in high sitting. If he goes far enough, liftoff occurs without him realizing it. Asking him to stand up or lift off the surface typically begins the inappropriate overrecruitment activity in the extensors and abductors of the less involved limbs pushing in the opposite direction than required. As such, these transitions become very difficult and inefficient for both the clinician and the client.
- Work in functional activities in a variety of postures without staying in any one posture for too long. Working in transitions is an even better choice; see the next bullet point for the rationale and some ideas. The following are examples of postures to work in while engaging in functional tasks:
  - High sitting.
  - Higher sitting.
  - Squatting (a great posture to work in with this population).
  - Standing and stepping (don't rush to standing and when in standing, keep the less involved arm and leg moving).
- Work in transitions more than in sustained postures. Movement may provide the proprioceptive information the individual is seeking as she searches for the midline. The following are examples of transitions to work in while engaging in functional tasks:
  - Scooting—work mostly forward and back and to the less involved side long before encouraging scooting to the more involved side. Scooting to the more involved side feeds into the pushing tendencies.
  - Sit ↔ liftoff.
  - Sit ↔ stand.
  - Transfers on and off various surfaces.
    - Again, work more toward the less involved side long before encouraging transfers to the more involved side as previously explained for scooting.
    - If at all possible and safe, choose surfaces that are stable but not too stable. Examples may include a regular kitchen chair, a desk chair with wheels on it, a bar stool.
  - Walking and carrying or pushing movable objects.
  - Stair climbing. Work only on the bottom few steps when going all the way up and down is too difficult to manage or unsafe.
  - Running, if possible.
- Tap into the automaticity of functional movements, such as walking (at moderate to normal speeds if possible), dancing, reaching into cupboards, cross-country skiing, swinging a golf club, and stair climbing.
  - The walking and stair climbing may not look anything like typical walking or stair climbing at first and will require much physical assistance from the helper(s).
  - When the therapist taps into the automaticity of very familiar tasks and normal movements for these individuals, they are more likely to organize their movement.
  - Functional activity demands the individual's attention, which helps to decrease the pushing behavior. The more contrived and exercise-like the activities are, the worse the pushing typically is.
- Working at higher levels of challenge helps to integrate the pushing behavior at lower levels of postures/transitions.
  - For example, don't keep the client in sitting if the goal is to have the client function better in sitting. Work in liftoff or scooting to decrease the pushing in sitting activities.
  - Continue to practice higher levels of challenge, especially when there is sufficient help to keep it safe.
  - Working in higher level activities (like walking and stair climbing, even when a client is still quite low level), will help the client to progress faster and further. Krewer et al,[138] in 2013, noted in a single-session case study that forced control of the upright position during locomotion (using a Lokomat, Hocoma) showed potential to decrease the pushing behavior more than conventional therapy (i.e., time spent in sitting activities).

- Even if it feels out of control in the lower-level postures and transitions, if sufficient resources are available to keep it safe, try walking or stair climbing. Sometimes, the challenge of the higher-level activity and the automaticity of the functional activity itself will decrease the pushing tendencies. For example, it may seem like the clinician is barely managing to maintain safety during standing and stepping activities with the client; however, if the individual can be progressed to walking with enough help for safety, the pushing will sometimes decrease with each step.

Summary of Key Points of Intervention with Individuals with Pushing Behavior

- Keep them moving.
- Work in functional tasks with real objects.
- Work more in transitions versus postures.
- Work in familiar tasks for that specific individual.
- Work on higher levels of challenge, including getting them onto their feet as soon as possible.
- Disadvantage the less involved limbs/trunk (in flexion or out of the BOS).
- Activate the more involved side/trunk (and in closed chain setups).
- Don't push back; this strategy only increases the pushing behavior.

11.3 Summary

Each individual is unique in his or her participation and activity domains of the ICF. This uniqueness, combined with the severity of the stroke and the personal and contextual factors that each person possesses, leads to variations in the influence and, at times, the severity of the list of impairments an individual will have after CNS injury. One individual might have been active in fitness and sports programs, whereas another led a sedentary lifestyle prior to the stroke. Some people have access to many resources for support and rehabilitation (family support, financial resources, proximity to therapy centers, internal motivation, etc.), whereas others do not. The premorbid inventory of body structure and function integrities/impairments, activity/activity limitations, participation/participation restrictions, and the availability of resources after the stroke to assist with recovery can result in significantly different outcomes for clients.

A thorough examination of each individual with consideration of the unique activities he or she engages in for home, work, family, and community roles will guide the clinician to identify the system impairments that specifically interfere with this person's ability to function as before. Each aspect of a holistic evaluation is critical. However, the clinician *must* determine the detailed and specific underlying impairments that are limiting the individual's ability to participate in activities in an efficient and effective manner.

Statistics from the American and Canadian Heart and Stroke Foundation[1,2] state that 50% of individuals post-stroke are left with some residual hemiparesis, 30% are unable to walk without some assistance, 19% have aphasia, 26% will require institutional care, and 26% require assistance for basic and instrumental ADLs. These numbers are large and a significant cost (emotionally, psychologically, and financially) to the individuals who suffer strokes, their families and caregivers, and society. Every effort we can make to reduce these disabilities and improve activity outcomes should be pursued. As clinicians, our evaluations need to take us beyond the symptoms to the identification of the underlying impairments interfering with each individual's participation and activity abilities, and we need to do this as quickly as possible to develop more targeted and effective interventions to help these individuals get back to their lives.

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Theoretical Framework for Neuro-Developmental Treatment Practice

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III

Introduction

Janet M. Howle

This unit describes the following:

- Changes in theories of motor control.
- How integrated systems for posture and movement systems are organized and contribute to motor control.
- How motor skills are learned, retained, and transferred to meaningful contexts.
- How movement develops and changes across the life span.
- How plasticity in neural reorganization affects development and recovery from neural insult.
- How all of the foregoing points support Neuro-Developmental Treatment practice.

Theories in Motor Control, Motor Learning, and Motor Development: What Do They Offer the Clinician?

Scientific theories are tools for understanding, explaining, and formulating hypotheses, and they allow clinicians to make predictions about observed phenomena and changes. Any theory is meaningful only when given a context for its application. The Neuro-Developmental Treatment (NDT) Practice Model describes what clinicians do and how they do it. Understanding theories of motor control, motor learning and motor development can help explain why what clinicians do works.

Theoretical explanations are reasonable, logical models based on the best available scientific and clinical research that help explain any set of phenomena. This means that, although clinical observations may not change, the understanding and explanation for them may change. For example, clients with neuropathology have impairments in posture, transitions, and selective motor control. The theoretical explanations change as more knowledge and experience are gained as to why this occurs. In seeking to understand what works and what doesn't, the theoretical support for NDT has changed as theories have evolved that better explain, interpret, and predict observed phenomena. Theories will continue to advance based on research from various fields of study. This unit describes the state of the currently accepted science that is relevant to the NDT approach. The four chapters in the unit review theories in motor control, motor learning, and motor development, and the effects of neuroplasticity, as well as the implications these have for NDT practice.

12 Motor Control

Janet M. Howle

Neuro-Developmental Treatment practice currently draws heavily on elements of dynamic systems (DS) and neuronal group selection (NGS) theories to explain the nature of typical movement, how posture and movement are organized, and how posture and movement change due to impairments in various body systems. This chapter defines motor control and focuses on theories which emphasize the dynamic interplay between brain, body, and environmental context which are fundamental principles of NDT.

Learning Objectives

Upon completing this chapter the reader will be able to do the following:

- Link the importance of NDT assumptions to motor control.
- Describe the changes in motor control theories, including reflex/hierarchical theory, motor programs, central pattern generators, dynamic systems theory, and neuronal group selection theory, and relate the tenets of these theories to NDT practice.
- Define the tenets of the theory of neural group selection, including developmental selection, primary repertoires, secondary repertoires, and global maps.
- Apply tenets of neuronal group selection to the NDT practice model focusing on concurrent changes in the brain and body systems, experience, and context.
- Explain the principles of dynamic systems theory, including coordinative structures, self-organization, rate-limiting factors, and state transitions.
- Apply dynamic systems theory to NDT practice, particularly focusing on the importance of body systems and environmental contexts when developing intervention strategies.

12.1 What Is Motor Control?

This chapter defines motor control (MC) as an explanation of how the central nervous system (CNS), environment, and body systems interact and organize individual joints and muscles to produce coordinated functional movement. The theories of MC are drawn from various fields of study, each one trying to understand the nature of movement. Theories have changed based on observations of typical and atypical motor behavior and the scientific study of neuronal mechanisms, muscle physiology, cognition and perception, motivation, and purpose—all variables that contribute to initiation and execution of movement. For our purposes a definition of MC must also include how an understanding guides clinical practice.

12.1.1 Changing Theories of Motor Control

Reflex/Hierarchical Theories

In the late 1930s and '40s, as the Bobaths sought to explain their clinical observations, like everyone else, they relied on models of MC accepted at that time. They cited reflex/hierarchical theories (R/HTs) based on work from Jackson, Magnus, and Sherrington that linked the control of movement to specific structural levels in the brain.[1] These theories assumed that the structures of the brain were organized and developed in a hierarchy and that there was a fixed relationship between function and structure. Each successively higher level of brain structures provided more precise movement integration. Therefore, as these structures developed, function changed accordingly.

The lowest level of fundamental movement patterns were sensory-elicited reflexes, which were then integrated into the automatic postural reflex mechanism as the higher brain levels developed. These automatic movements, including righting and equilibrium reactions, were considered to be the basis for skilled voluntary movements. These predictable, reflexive movements were continually modified and refined at each neural level until the final outcome was a rich array of adaptable combinations of automatic postural reactions that supported discrete voluntary movements. It stood to reason, then, that a lesion in the higher neural centers permitted expression of normally suppressed patterns of movement, which would dominate the person's posture and movement.

The R/HTs helped to explain the stereotypic movements and postures seen in persons with neuropathology. These were acceptable neural control models until the late 1960s and, although they did offer explanations for predictable movement seen in cerebral palsy (CP) and stroke, their limitation was that they did not account for context-based movement variability, individuality, novelty, and context-based behaviors.

Generalized Motor Program Theory

A critical shift in thinking came about in the 1960s and '70s, as investigators theorized that motor programs stored in the brain, rather than reflexes, were the substrate for motor behavior.[2,3] Keele proposed the existence of a set of commands in the CNS that he called *motor programs*, which were assembled and initiated without sensory input and performed in the absence of peripheral feedback. These motor programs, later called generalized motor programs (GMPs) contain the abstract representation of movement, including the commands for movement, codes of action, and general features of movement sequences as well as the recruitment of appropriate agonists and synergists with adjustment of antagonists.[4] For example, there could be basic motor plans for reaching and grasping and rhythmic movements for walking or speaking that are assembled prior to the need to move. Simple sequences could then be linked together to produce complex actions, such as walking down a slope or up a flight of stairs, writing a thesis, reciting poetry, or singing. The richness of the GMPs developed from both experience and learning.

As this theory evolved, GMP theory (GMPT) recognized that movement has both variant and invariant features in which variant features could be modified, whereas the invariant features were difficult to change. This was the explanation for changes that were seen following neural insult, as well as the explanation for lack of change. GMPs acknowledged that skilled movement required interactions of both central and peripheral mechanisms.[5] GMPT supported the idea that, once learned, an individual's movements and postures are more or less "automatic" and do not require attention for the individual to perform them effectively and efficiently. These programmed movements acted as the supporting system for the intentional elements of a particular self-initiated movement, much like the postural reflex mechanism was seen as the support system in R/HTs.

Central Pattern Generator

The emergence of the idea that motor programs were the basic unit of MC renewed the interest in the concept of central pattern generators (CPGs). Investigators became interested in neural networks in the spinal cord capable of producing rhythmic movement even when isolated from the brain and sensory systems. CPGs have been established as the basis for specific rhythmic movements in invertebrates, fish, and cats.[6,7] There was increasing evidence that specialized neural circuits do exist in the brain stem of vertebrates for breathing, chewing, and swallowing, and in the spinal cord for locomotive functions.[8,9] However, evidence of the existence of CPGs in humans remains indirect.[10] The fact that rhythmic movements can be obtained in the absence of supraspinal and sensory inputs should not be interpreted as meaning that these inputs are not important in pattern generation in persons with intact neural systems, but suggests that if rhythmic movements for walking can be elicited in persons with neural impairment, then perhaps this can be a strategy for the development of more adaptive motor behaviors.

12.1.2 How Do These Theories Relate to Clinical Practice?

Partial body-weight-bearing (PBWB) gait training is one intervention that gains support from CPGs. It is a method currently used in conjunction with Neuro-Developmental Treatment (NDT) intervention to train or retrain walking in persons with neuropathology. This intervention uses a support harness to provide alignment, reduce the need for independent balance, and remove the fear of falling. Unweighting the body, particularly when combined with treadmill walking, changes the environmental constraints and makes stepping easier and more rhythmic (**Fig. 12.1**).

Fig. 12.1 Partial body-weight-bearing on a treadmill reduces constraints of balance, and alignment makes stepping easier and more rhythmical.

Many researchers and clinicians use GMP and, in particular, CPG theory, to explain improved rhythm between stance and swing in walking patterns in adults with spinal cord injuries and stroke and in children with CP when body weight is partially supported and stepping is encouraged on a treadmill.[11,12,13,14] The rhythmical components of reciprocal stepping on a treadmill may be organized by networks of neurons in the spinal cord; however, afferent somatosensory inputs have been shown to be powerful cues that bring about stance-to-swing-phase transitions and promote neuroplasticity in persons with impairments of the nervous system.[14] CPGs support our understanding of the rhythmic nature of walking, but this is just one change that is reported by clinicians studying changes in PBWB intervention. Although results vary, changes in step and stride length, base of support, weight shift, hip and ankle kinematics, speed, cardiovascular fitness, and energy expenditure, and, in children, improvements in gross motor skills, have all been reported.[13,14,15] These findings are not related to rhythmic movement. Models of MC that stress the interplay of information between the CNS and the body systems shaped by the need to function in specific environmental contexts may be more useful in understanding the overall benefits of this intervention strategy.

12.1.3 Models of Motor Control That Emphasize Dynamical Interplay between the Brain, Body, and Environment

There is growing evidence that the development of and changes in function, typical or atypical, are linked to neural networks distributed throughout the nervous system, the competencies of all the other body systems, the context, and the task goal, functional context, and dynamical interplay of all these elements.[16,17]

These newer system-based models, including the theory of dynamic systems (DS) and neuronal group selection (NGS), recognize that, to understand the control of movement, it is equally important to understand the influence and relationships of all the neural and body systems, the specific task that organizes the motor components, and the environmental and sociocultural context within which the action occurs. A more expanded definition looks at the interactions of variables within a single body system; the dynamical, complementary relationships between neural and body systems; the codevelopment of these systems to create constraints and opportunities for adaptive behaviors; and feedback among these systems and their environmental contexts.[18]

NDT practice currently draws heavily on elements of DS and NGS models conceptualized by Bernstein[19] and Edelman,[20] respectively. The tenets of these theoretical models have been applied in therapeutic intervention programs for infants, young children, and adults.[21,22,23,24,25,26] DS and NGS both emphasize process—how motor behavior occurs and how multiple systems are constrained to create new motor strategies, or to recover from pathology.

Both models hypothesize that there is not any one internal system or external context that determines outcome; rather, function is the driving force—functions that have value to the individual and enhance the person's capacity to carry out meaningful life roles. The primary difference in these two theories is the importance placed on the role of genetically determined neurodevelopmental processes. In NGS, genetic characteristics and experience play equally powerful roles.[24] Both models stress the importance of experience and relevance of the context. The relative importance of one system over another will depend on the outcome needed at any given moment to permit continued participation in a changing environment. For the individual to successfully create appropriate and flexible behaviors, there must be intact physical and neural systems and a supportive environment coupled to each other to provide feedback between the body systems and the environment. These theories support NDT assumptions in MC.

12.1.4 NDT Assumptions of Motor Control

- Motor behavior emerges from ongoing interactions among multiple internal systems of the individual, the characteristics of the task, and the specific environmental context, each contributing different aspects of MC.
- The neural control for movement is distributed throughout various levels of the CNS, all contributing to the final motor outcome. No single site or any one level is responsible for any particular behavior.
- Movement is organized around behavioral goals, and function drives the selection of body and neural elements that best meet the needs of the individual.
- A hallmark of efficient human motor function is the individual's ability to select and match a potentially infinite number of movement combinations that are attuned to the forces of gravity, forces generated by the musculoskeletal system, and constraints posed by environmental conditions.
- All persons, with or without neuropathology, begin life with a repertoire of movements that, when repeatedly selected and modified by experience and exploration, form the basis for movement combinations designed to meet the needs of the individual throughout the life span.
- It is possible to influence a person's motor behavior by accessing those body systems at times when they are most susceptible to change.

Because our clients have an impaired CNS, the next section examines the role of the brain and nervous system, how the brain and nervous system develop and contribute to adaptive behavior, and how neuropathology disrupts this process. Theory of DS contributes most to explaining the importance of experience and the relevance of context, whereas theory of NGS very specifically outlines the role and development of the nervous system as the basis for adaptive behavior. For this reason, this next section uses the theory of NGS to explain organization and role of the nervous system in the process of developing movement.

12.1.5 Developing Movement Competency

In practice, NDT stresses selecting functional activities outcomes and intervention strategies that match each client's interests, competencies, and strengths while addressing the client's impairments that contribute to functional limitations. The theory of NGS, developed by Gerald Edelman,[20,27] is one theory that supports this NDT premise. NGS states that (1) as brain structures develop and are organized, they insure that the person has variation in the way he or she can respond to any input, and (2) neural elements can be selected from multitudes of potential possibilities, which are determined by genetic coding and experience, to create individual diversity. These ideas make this theoretical basis consistent with a primary construct of NDT; focus on the individual and his or her needs, abilities, and limitations.

12.1.6 Theory of Neuronal Group Selection

A key premise in NGS is the concept of selection. According to Edelman,[20] selection is, first, the process by which groups of neurons compete to provide structural diversity in the formation of the anatomy of the brain, and it is also the process which guarantees that the brain and body maintain the conditions for continued life in changing environments. To do this, the brain instantaneously "selects" the response that adapts to external conditions and that is the most fit for each individual person.

Inherent in the word *selection* is the concept that some responses are more fitting than others for the survival and advancement of an individual. NGS places importance on the brain's ability to select behaviors that are useful and have value to the individual. In this way, NGS differs from DS in that NGS does not assume that a specific organization comes about from random, self-organizing events. Rather, NGS assumes that selection of a particular response pattern is the result of repeatedly selecting and using those neural circuits that the individual needs to build meaningful behaviors. (During embryonic and fetal development this occurs at the cellular and neuroconnectivity level. However, we will assume this same selective process occurs at the behavioral level.) Edelman agrees with other theorists that the brain operates as a dynamic selection system, which implies that selection (of neural pathways or behavioral responses) occurs without a controller. However, in the theory of NGS, the belief is that the neural system is organized by behavior because the behavior has value to the individual. The process is dynamic in that it occurs instantaneously as the individual needs to adapt or change throughout the life cycle and within various environments.

The absolute end product of NGS is individual diversity, which states that, within a population, all individuals have common patterns of behavior, such as the way we hold a pencil; greet a friend; respond to stress, joy, or grief; or walk down a slippery slope. Yet all of us have individual differences in how we execute those behaviors based on genetic predispositions, physical differences, contextual experiences, and enormous variation at the levels of neuronal chemistry, network structure, and synaptic strengths.[28,29] Individual diversity is what makes each of us interesting and recognizable as individuals. In addition, individual diversity results because each person has different attributes, such as height, age, intellect, coordination, balance, strength, emotional stability, and so on.

These individual attributes mean that individuals differ in the ways they respond and adapt to environmental contexts or task conditions. Individual diversity explains why we respond to the same inputs in different ways, the variation in how we benefit from experiences, and why we have different interests and skills and seek different activities. Understanding that there is variability at the neuronal level helps to explain why the expression of CP or stroke varies so much from one client to another. It is not just the location, size of the lesion, or age at which the insult occurs. This concept of individual diversity and all it means is a fundamental idea that NDT therapists consider when they meet new clients, develop a plan of care, and evaluate the success or failure of any specific intervention strategy.

12.1.7 How Does the Idea of Individual Diversity Support NDT?

Two assumptions of NDT practice are supported by these ideas.

1. NDT therapists respect the differences in every client and plan intervention strategies to target specific system impairments within activities and contexts that are meaningful in the life of the person.
2. Each individual's behavior is shaped by experience. NDT intervention becomes part of life's experience, and the NDT therapist has the opportunity to increase the probability that the person will select actions that will allow him or her to effectively solve motor problems. Therapists do this by doing the following:
    - Using a problem-solving approach and introducing a wide variety of strategies flexible enough to address the specific system impairments of the individual.
    - Practicing and repeating postures and movements to strengthen the possibility that a particular behavior will occur when the client needs it. For example, in Case Report B6 in Unit V on Jagraj, the therapist described intervention aimed at developing postural stability and tolerance for oral feeding. As he makes progress in both areas, he is able to eat at the table with his family.

- Focusing on the appropriateness and usefulness of the task (or posture and movement) for the individual. Function drives selection of appropriate responses. For example, in Case Report A1 in Unit V describing Mark, a 51-year-old man poststroke, the therapist used his desire to play golf as a way to achieve functional grasp and release, strength, and balance to walk on uneven terrain.
- Using handling in a carefully applied manner to establish or reestablish the postural control and movement components that will enhance temporal, spatial, and force requirements needed for skills.
- Creating a conducive environment, including use of family or other key persons, selecting tools or toys that are reinforcing, and using the therapist–client relationship in a positive way.

Understanding individual diversity means that we can expect clients to have various ways to move and solve motor problems. The clinician's role is to identify how we can adapt our intervention to take advantage of the characteristics of the person and fit the intervention to the various system impairments that are standing in the way of solving their functional limitations.

We expect previous experiences to impact on the person, and we acknowledge the importance of this as we build intervention strategies. A preterm infant who spent 6 weeks in a neonatal intensive care unit (NICU) with beeping monitors, heel sticks, and medical procedural interruptions might be easily provoked with bright lights, sudden touch, or loud unexpected noise. Intervention strategies may include damping down sensory input so that the infant is not distracted by extraneous information and can focus on important cues to build meaningful movement repertoires.

On the other hand, the importance of previous experience can work to the advantage of the therapist. For example, an adult who had many interests and skills prior to stroke, as seen in Case Report A2 describing JW, allows her therapists to draw on a vast array of activities she had been previously engaged in, including gardening, aerobics, canoeing, running, walking her dog, and dragon boat racing, as they planned the intervention. This taps into well-learned and efficient motor memories, uses significant persons in the client's life, and takes advantage of supportive environments.

Diversity helps explain why individuals respond differently to intervention strategies. NDT therapists recognize that what works well for one individual may not work at all for another. Therapists are required to explore various ways to solve any given set of problems, keeping in mind all the systems involved and various avenues for input. Therapists who use the NDT Practice Model do this by observing and analyzing each person's functional skills and limitations to determine the best choice of intervention strategies for that individual. Intervention is an ongoing, problem-solving approach that leads to the best functional outcomes by minimizing impairments and preventing secondary disability. The therapist expects each client to participate actively in intervention, and, when possible, to take part in goal setting and providing feedback about the effectiveness of various intervention strategies. Although an adult can often provide verbal feedback, therapists need to be sensitive to both verbal and nonverbal feedback from infants, children, and adults.

12.1.8 Three Tenets of the Theory of Neuronal Group Selection

Edelman[20,30] states that there are three basic tenets in NGS that describe the following:

1. How the anatomy of the brain arises and takes shape during development, yielding structural variability and primary neuronal repertoires.
2. How experience strengthens and activates certain patterns of response by their adaptive value, yielding secondary repertoires that best fit any given situation.
3. How the resultant maps of the brain are interconnected and give rise to uniquely individual behavioral characteristics in response to environmental demands.

Viewed together, these tenets provide solid support for many of the assumptions of NDT intervention; for this reason, each tenet is reviewed in this chapter. These tenets are depicted in **Fig. 12.2**.

Tenet 1: Developmental Selection and Primary Neuronal Repertoires

Edelman[20] proposes that the formation of the basic neuroanatomy of the brain is determined by neural elements—cells, dendrites, and axons and their neurotransmitters. As they compete and connect to other neurons, they have the ability to change the timing, amplitude, and sequences of firing of the neurons they contact. These neural elements are genetically determined and have evolved to both serve the species and impose a set of constraints on the formation of brain structures. In the NGS model, the brain has no wiring diagram; rather, neural structures are determined by the competition among neural elements to assure variation in neuroanatomical structures. Neurons branch in different directions, competing to create immense, variable, and diverse neural circuits. This competition includes cell division, migration, adhesion, death of neurons, and the formation and retraction of synapses that selectively strengthen network connections during fetal development. This competition sets up variation in the basic brain anatomy and sets the stage for uniqueness in responses.

In addition, when hundreds of thousands of strongly interconnected neuronal circuits act as structural/functional units, called neuronal groups, they increase their effectiveness. Any single neuron can *only* be either facilitatory or inhibitory, but when a neuron is part of a neuronal group, the group, because it can change its members, can be facilitatory or inhibitory as needed. In this way, a single neuron can have either

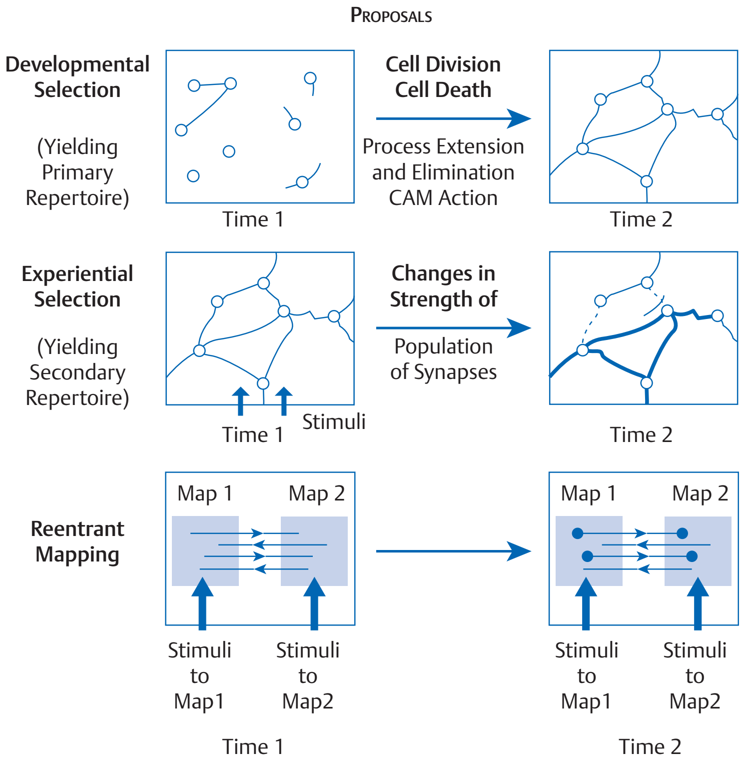

Fig. 12.2 Tenets of the theory of neuronal group selection.

facilitatory or inhibitory effects. These structural units or groups, when they function together, form primary motor repertoires.

Primary motor repertoires are movements characterized by variability and are not connected to either sensory inputs or function (Edelman uses the term *primary neuronal repertoires*). For our purposes we will refer to these repertoires as primary (and secondary) motor repertoires, because the interest of NDT clinicians is related to motor functions. (For further discussion in these areas, the reader is referred to Edelman's work.[20,27,30])

Neural development alone does not explain diversity in primary motor repertoires. At the same time that the nervous system is developing, the sensory system, capable of detecting and recognizing movements that have value to the infant, the musculoskeletal system, and other body systems, develops, resulting in a primary repertoire of species-specific yet unique behaviors.

These connected neuronal groups initially develop by genetic instructions and are not tied to the specifics of a situation or feedback from it. But as the fetus develops, they will be affected by signals from the body (exploration in the womb) and eventually by development in an extrauterine environment.[26] The resultant primary motor repertoires contain a broad range of movement patterns, which, while they do not yet adapt to the specifics of a situation, have value for survival and the *capacity* to accommodate and adapt to the environment. This is the basis for providing the infant with a wide range of choices. This very early neural plasticity supports the hypotheses that the brain is a highly dynamic organ capable of structural and functional organization and development in response to internal and external pressures.[26,29] Even at birth no two brains are alike, and each infant's brain is continually changing. The concept of plasticity is an important assumption in the NDT approach as it affects infants, children, and adults.

These primary motor repertoires are present at term birth:

- Orienting the head and eyes to light and sound.
- Orienting the head to clear the airway when prone.
- Coordinating suck and swallow.
- Bringing the mouth to the hand.
- Following moving objects with the eyes.
- Projecting the arm toward objects.
- Reciprocal kicking.
- Sensory elicited reactions and responses (sometimes referred to as primitive reflexes, such as head and body righting, palmar grasp, rooting reaction, Moro reflex).
- General motility.
- Attachment to the human face.

Initially these primary motor repertoires are characterized by profound variability with considerable degrees of variation in speed, amplitude, participating body parts, and movement direction.[26] These early movements appear unrelated to any specific set of conditions. Although all babies have elements of these primary motor repertoires, the expression is highly variable. Some babies appear to be well organized; others do not. The eventual organization and connection between stimulus and action that has value to the infant changes these primary repertoires to secondary through a process called developmental selection, which is discussed under Tenet 2.

Primary motor repertoires are basic to the infant's development, and if they are reinforced by a supportive environment, people in it, and the infant's success in fulfilling his or her needs, they lead to an even richer, purposeful secondary repertoire of responses. These early interactions between infants and their environment must be coupled with success to reinforce the selection of a particular set of behaviors. This success causes certain neural pathways to be selected and strengthened and results ultimately in infants with diverse ways of expressing needs and wants.

If, on the other hand, the infant's primary motor repertoires are not reinforced, perhaps not intentionally, by caregivers or the environment, and the value of the primary repertoire is lessened, the neural pathway diminishes in strength and brings about a paucity of movement or less variability in the infant's motor repertoire.[31] Edelman[30] hypothesizes that, when the brain is in unusual sensory circumstances, events of brain development are modified.

For example, think again of the infant in the NICU who might shut down when bombarded with a loud or bright stimulus that has no connection to the infant's possible motor repertoire. The result may be an infant who cannot link her motor responses to sensory input or continually tries random movement in an attempt to make sense of her sensory world. A premature or sick infant whose attempts to reach out, bring the mouth to the hand, or turn to visual or auditory stimuli, may be so feeble that caregivers do not recognize the relationship between the movement and the intent. Either of these scenarios changes the most primary motor responses and prevents the infant from learning from experience. Als[25] reported that infants born prematurely showed more mature fiber structure in the cortex when they received an individualized care program than those who did not.

How Does This First Tenet Support NDT Intervention?

First, NDT clinicians systematically observe and analyze each client's competencies and limitations to determine the best choice of intervention strategies for that client. Although NDT intervention is directed at both single- and multisystem impairments, which the clinician hypothesizes interfere with the client's function, the therapist recognizes and respects the differences in each person and the impact that previous experiences have on a client's posture and movement and responsiveness to various sensory inputs. NDT therapists use a problem-solving approach to plan intervention strategies that are flexible enough to accommodate the differences of each individual client. Case studies in Unit V describe this process.

Second, the development of the neuroanatomy by selective competition supports the hypothesis that variability of movement, a hallmark of typical motor development, is established while the brain is developing, and we should expect to see diversity in newborns and young infants. On the other hand, if an insult occurs during fetal development, we can expect to see a reduction of neuronal circuits and therefore a reduction in variation or even loss of primary motor repertoires. One of the major signs of infants with neuropathology is movement that is devoid of variation, complexity, and adaptability.[32,33]

Therapists can also anticipate that adults who have a sudden onset of neuropathology will in all likelihood exhibit characteristics of primary motor repertoires since these are the first, and most primitive, movement patterns that emerged. This does not mean they demonstrate infantile behaviors, but as the person again attempts complex motor functions, the movements are highly variable and disorganized in spatial, temporal, quantitative, or qualitative aspects. In Case Report A4 of Ernie in Unit V, this 20-year-old with traumatic brain injury (TBI) showed disorganized head, eye, and mouth postures and movements, which improved with intervention.

The idea of destabilization is also described as a key concept in DS theory and is viewed as part of the normal developmental process.[19,34] Bernstein[19] refers to this as a *transition state*—a time when new movements are most likely to occur. Transitional phases, during which behavior is less stable, are the optimal times to effect changes, providing experiences directed toward functional tasks, structuring the environment, and manipulating control parameters that constrain movement.[23,35] For example, as a child with hemiplegia experiences a normal growth spurt at age 2, he may appear clumsy, fall more frequently, stand with more of his weight on the less involved side, or even walk without placing the heel (on the more involved side) on the ground during the stance phase. This is a time to increase the intensity of intervention to take advantage of the variability in gait and balance.

Finally, NDT therapists recognize that variability, while inherent in primary motor repertoires, can interfere with organizing more meaningful behaviors. If the individual with CNS impairment practices poorly organized repertoires, this will interfere with the selection and organization of more adaptive responses. NDT therapists use strategies that can help individuals organize their movements in ways that achieve immediate needs and prepare people for more complex functions.

How Do We Apply These Ideas within Intervention?

We recognize that variability is part of a primary repertoire, and it is important to allow clients, within reason, to select their own way to organize motor responses. Intervention includes assisting the client to organize movement repertoires in relevant contexts. Based on an in-depth knowledge of typical development of the posture and movement systems and changes over time, we set parameters and guide movement to increase the possibility that individuals practice the components of the motor repertoires in ways to assure that eventually they will become part of the individual's efficient, self-selected, adaptive responses as shown in Case Report B4 in Unit V describing Makayla.

In summary, we now have infants with similar yet highly individualized brain structures. This structural variability, developed through competing neural elements, formed primary motor repertoires. The primary repertoires are characterized by profound variability, allowing the infant to explore all motor possibilities within the neurobiological and anthropometric constraints of human development.

According to Edelman,[30] once primary repertoires have been formed, development proceeds by experiential selection, which combines the primary repertoires with experience in and feedback from external conditions. The transition from primary to secondary repertoires occurs at function-specific ages.[36] The product of this second phase is called secondary neuronal repertoires and contains those motor strategies that are the best solutions for a given situation.

Tenet 2: Development of Secondary Repertoires of Movement

The second tenet of NGS theory states that the experience of moving, which activates the sensory receptors' abilities to perceive the effects of various movements in the environment, eventually strengthens or weakens the primary neuronal repertoires. Secondary repertoires of functional circuits develop from the neuronal groups that are part of the primary repertoire of behaviors that have proven to have value for the infant. On a neuronal level, increased synaptic strength or efficacy within a pathway leads to a greater likelihood of conduction across that pathway, whereas decreases in synaptic strength diminish that likelihood.[37,38] On a motor level, the more an infant practices a movement repertoire, and gets positive feedback from the movement (value), the more likely the movement is to recur. If there is no value to a movement, the movement drops out of the infant's repertoire.

For example, by 2 months, babies show a specific movement pattern when placed in supine of the head turned to the side (**Fig. 12.3**). This rather predictable movement is often called the asymmetric tonic neck reflex (ATNR).

The movement allows the infant new musculoskeletal experiences—elongation of the pectorals and elbow flexors of the arm on the face side, movement away from physiological flexion seen in newborns, and the option to experience differentiated movement of one upper extremity from the other. In addition, this repertoire connects the hand with the eyes and provides the beginning of a body perceptual experience for the developing infant. At some point, the nervous system starts to use the afferent information provided by the experience for selection of the motor behavior that fits the conditions for exploration. This pattern of movement continues as long as it is useful to the infant. Normally, by 4 months of age, developing infants explore their hands with their eyes in various positions (due to development of antigravity muscles, increased strength, experience, and increased movement repertoires). Although it is still possible to observe the ATNR posture, more variable movements of the extremities are demonstrated that are not tied to movement of the head. This begins the phase of secondary or adaptive variability. This primitive asymmetrical posture can be functional at any age and can be seen when a child or adult must reach outside the base of support (BOS). While making cookies, a 6-year-old girl stands on a small step to reach the counter (**Fig. 12.4**). She must maintain standing balance on that step as she reaches outside her BOS to decorate her cookies. The predictable asymmetrical posture is accompanied by her head turn and visual attention, aiding her stability.

This shift to secondary repertoires is based on active trial-and-error experiences that are unique to the individual. (We will also see that Bernstein[19] calls this change a transition or phase shift, an important concept in DS theory.)

Three important changes are part of Edelman's second tenet.[20] First, experience changes the strength of neural pathways and their synapses, so that continually experimenting with a particular behavior becomes easier to

Fig. 12.3 A 10-day-old infant with an asymmetric tonic neck posture in supine.

Fig. 12.4 An example of a functional asymmetrical posture as this child reaches outside her base of support.

reproduce when the situation calls for the behavior. Second, the infant organizes postural control as an essential element of all movement repertoires. Third, secondary repertoires link sensory features to specific motor behaviors.

Hadders-Algra[26] points out that the process of learning to select the most appropriate motor solution is based on implicit motor learning and not conscious decision making. This process of selecting appropriate motor solutions occurs at various levels of neural organization. Linking postural control to specific movement solutions depends on strengthening the synaptic connections between neuronal groups that can anticipate the forces created by activation of muscles. In terms of MC, selection occurs as the infant tries out various motor strategies. Trying and failing, trying and succeeding, changing strategies and trying again.

During the process of learning, both the amount and the quality of variability change. For example, as infants begin to develop sitting or standing balance, they express great variability in postural adjustments. As the infant matures, this variability is fine-tuned to the situation until direction-specific postural muscles that are appropriately linked to task requirements are recruited.[36,39] Initially, the numbers of muscles recruited are more than necessary for effective postural control, but as the infant ages and experiences sitting, postural synergies include fewer direction-specific muscles. As adults learn skills, task-specific, flexible muscle synergies adapt to the demands of the situation in much the same way.[40,41]

When do the changes from primary to secondary repertoires take place? Investigators have shown that this transition occurs at function-specific ages. The change from nonspecific sucking to nutritive sucking differs in organization among small-for-date infants, preterm infants, and infants born at term. But in all cases normal nutritive sucking patterns are present soon after birth.[42,43] The development of successful reaching and grasping emerges during the first 4 months of life, changing from movements that are variable in path, speed, and accuracy, and only grossly directed toward the object, to reaching movements with mature kinematics involving fewer movement units.[44] The nondirected infant stepping, characterized by a lack of segment-specific movement, excessive cocontraction, and variable muscle activation is seen at birth. Changes to goal-directed independent walking happen over the first 18 months. All of these changes are not just changes in synaptic formation and neural circuitry. The development of secondary repertoires also depends on changes in the musculoskeletal system, perception, experience, and a gradual change in agility, adaptability, and the ability to make complex movement sequences.[26]

The precise editing of secondary repertoires continues throughout an individual's life, fine tuning various aspects of the motor synergy to respond to changes in the body—growth, aging, changes in strength, contexts, and the like. The results are favored functional synergies; motor synergies that match the motor components with the precise needs of the individual.

The process of developing efficient functional synergies requires selecting the best solution from an unlimited number of possible solutions. Although the individual will ultimately settle on those repertoires that efficiently meet the requirements for the skill they need, these neuronal groups and the resulting motor repertoires are never hardwired. The nervous system is capable of instantaneous change with normally occurring events or in the presence of neuropathology.

Think of it this way—the most frequently traveled (neural) pathway is the most direct route. If it is kept in good repair, it is possible for nerve impulses to travel quickly and without detours. However, less often selected (neural) routes are available, so that if a neural insult renders this "superhighway" nonfunctional, "back roads," with poor surfaces, through multiple towns and stoplights, are options. Travel will be slower, at least until one becomes familiar with the new route, but it still provides options to achieve the destination—functional movement.

How Does the Development of Secondary Repertoires Support NDT Intervention?

The development of secondary repertoires involves three important aspects of NDT practice. First, secondary repertoires develop when sensory afferent information is connected with motor outcomes in a meaningful way. NDT intervention constructs a purposeful relationship between sensory input and motor output and recognizes that action depends on matching sensory and motor processes with perceived requirements of the task. NDT intervention strategies provide very specific input that grades the intensity, rhythm, and duration of somatosensory, visual, and auditory inputs while allowing the client to attend to specific aspects of the task.

Second, a critical aspect of secondary repertories is connecting postural control with movement sequences. Knowledge of the differences in the posture and movement systems is used when designing intervention strategies, as described in Chapter 9. Intervention always includes both posture and movement, but the therapist recognizes that it may be necessary to stress one or the other when setting up an intervention sequence to facilitate the client's need for function.

Finally, experimentation and practice make access to effective motor solutions easier. NDT intervention recognizes that repetition is an important component in motor learning. Motor activities that are task specific and repeated throughout a session with variability and are included in a home program have a better chance of becoming part of the client's favored functional repertoire. Repeated experience, including both practice with guidance and experimentation alone, is necessary for each client to find the best solution for motor problems. Whether we are structuring a task or guiding a movement, we must leave room for clients to experience errors and place their own variations on the general requirements.

Tenet 3: Linking Neuronal Maps: Forming and Connecting Global Maps

According to Edelman,[20,30] the continual selection of neuronal groups during development and through repeated selection binds neuronal groups together to form neuronal maps. These maps are connected by reciprocal and parallel fibers which strengthen the possibility that different areas of the brain work together in space and time (**Fig. 12.2**). The strong, yet flexible, linkage is the basis for signaling between maps that are distinct and often from distant areas of the nervous system. This means that multiple maps can be spontaneously selected and activated in response to internal or external cues. When maps are repeatedly selected to produce meaningful behavior, they form global maps. These global maps ensure integration among multiple body systems to form complex functions and behaviors. Edelman[20,30] describes this phenomenon on a neural level, involving neural circuits, synapses, and their neural transmitters.

For our discussion, let us assume that the same phenomena exists on the behavioral level. Imagine a reach and grasp action. There are different neuronal maps that contain visual perception, cognition, emotion, memory, and posture and movement characteristics, all linked through parallel and reciprocal connections to form efficient global maps. At a minimum, a reach–grasp action would combine selections for the hand motor areas of the primary cerebral motor-sensory cortex with maps that receive visual and tactile information (Map 1) and with other maps that are concerned with the postural function of the head, neck, and shoulder (Map 2) to produce visually directed reach–grasp from a stable posture.[44,45] Linking these maps together (along with many other maps) assures that the individual makes instantaneous postural adjustments as reaching occurs.

Edelman[20,30] states that these parallel and reciprocal connections between maps are the most important concept in NGS because they explain how functionally segregated activities "talk together," producing a coherent output. In NGS theory, these linked connections explain how the unlimited degrees of freedom of the neuromuscular system are constrained to produce meaningful, efficient functional skills. Because the members (neuronal maps) of a global map can be selected and changed instantaneously, this concept also offers an explanation on how new functions are learned and how old functions can be relearned as changes occur in other body systems, task parameters, and contexts. This is an important foundation for the NDT approach because it offers an explanation of how recovery can be facilitated and why we can expect functional change throughout the life span.

Because these maps can be selected instantaneously and are linked through reciprocal connections, the individual can produce the reach–grasp action whether the primary signal is visual, tactile, emotional, or cognitively initiated, such as reaching to push up glasses automatically, whether the person perceives the difference in vision or touch on a slightly different place along the bridge of the nose. Because individuals have variations in their neuronal maps based on (1) the early competition of neural circuitry that forms primary repertoires, (2) individual experiences producing secondary repertoires, and (3) unique body structures, individuals show similar yet unique strategies for accomplishing a reach–grasp action. The broader the experience with slightly different task parameters or slightly different focus permits various neural maps to be linked together.[46]

Along with this idea that different signals, either internal or external, can be the stimulus for a group of maps to work together, it is important to realize that neuronal maps can belong to many different global maps. Global maps are not static, but form and change depending on the need to be assembled and precisely adapted to accomplish a particular behavior.

Why Are These Ideas Important in NDT?

The concept that maps are connected to other maps is the basis for using various inputs to gain a particular motor output when neuropathology renders the default neural pathways (and their synaptic connections and circuits) unavailable. For example, Map 1 includes trunk rotation, Map 2 includes visual attention, and Map 3 includes lower-extremity interlimb coordination. Normally these three maps work together to organize movements that allow moving from side sit to kneeling. However, Map 1, trunk rotation, and Map 2, visual attention, also interact with Map 4, weight-bearing through the upper extremities, so a therapist has the possibility of facilitating trunk rotation through activities that involve moving while weight-bearing through the arms, shown in **Fig. 12.5a, b**, rather than in standing.

Both in therapy and on their own, as children and adults solve motor problems, they blend the discovery of the most stable trajectory, joint coordination, patterns of muscle activation, preferred posture, and energy level with memory and prior experience to create or strengthen their own global maps. Essential to the development of global maps is sufficient experience with slightly different tasks to permit the neuronal maps to respond differently to various objects and events in the environment and still produce a movement synergy that solves the problem.

To complete the understanding of MC, therapists following the NDT practice model look closely at the role of the body systems, the importance of structuring the task, and the context to enhance the outcome.

12.1.9 Dynamic Systems Theory

Although the theory of NGS offers a great deal of theoretical support for the practice of NDT, systems theories, and particularly DS theory, provide support for the NDT assumption that a hallmark of efficient human motor function is the ability to select and match a potentially infinite number of movement combinations that are attuned to the forces of gravity, forces generated by contracting muscles, and constraints posed by a variety of environmental conditions.[47] DS examines the biomechanics of the body systems and the importance of structuring the task and context in which the task takes place. Bernstein[19] applied the principles of dynamic systems to the understanding of human motor behavior. He contended that biological systems, like other physical systems, are complex, multidimensional, cooperative systems in which no one subsystem has priority

Fig. 12.5 **(a, b)** This child bears weight through his left arm on the mirror while rotating to a kneeling position (as he cleans the mirror).

for organizing the behavior of the system. His ideas have since been applied to infant motor development by Thelen[48,49] and Heriza[50] and to the management of persons with neuropathology.[51,52] Like the theory of NGS, the theory of DS maintains that interactions among the elements of a system give rise to patterns that are organized in space and time without instructions or without a controller.[48] Both theories propose that individuals who explore a variety of possible solutions to motor problems will increase their movement repertoires, have greater success, and have an easier time meeting the demands of tasks in their daily lives. However, a central issue for DS is that, although movement possibilities (or degrees of freedom in a system) may be constrained by any of the body systems, they are primarily constrained by the biomechanical and anthropometric properties of the musculoskeletal system. This way of thinking provides a great deal of insight into the workings of the body systems for the NDT therapist and adds to the knowledge used by clinicians practicing within the framework of the NDT Practice Model.

Bernstein[19] argues that, at the beginning of a learning process, selection, spatial and temporal qualities, force, and amplitude of muscle combinations are random. These random elements allow the person to experiment with all possible repertoires of movement until ones that work best are linked together. These linkages are functional and can be reorganized as a person learns, grows, develops, ages, and solves various motor problems. By repeatedly linking musculoskeletal elements, the components self-organize, producing units of movements called coordinative structures, which therapists often describe as movement synergies.[49,53]

The following example of breathing demonstrates the functional linkage among biomechanical properties and musculoskeletal structures and functions. When a person inhales and exhales, the mechanical properties of the muscles and joints in the thorax and spine push and pull the spine backward and forward, linking the timing of the muscle action to the respiratory functions.[54] The biokinematic linkage of head and spine dictates that the head should move with the spine, but instead, the head is stable throughout the cycle of spinal movements. This stability occurs because, with inhalation, rather than responding to the biokinematic link, the pelvic girdle and cervical region move forward to the same degree that the thoracic region is pushed backward, thereby maintaining head stability. There appears also to be a functional linkage among the muscles of the cervical–thoracic–pelvic groups. The muscles relevant to inhalation are anatomically separate from those muscle groups involved in the movement of the pelvic girdle and also separate from those muscles involved in the movement of the upper part of the spine. Yet they are linked at both the musculoskeletal level and the neuronal level to produce efficient movement of the chest with stability of the head. This is an example of functional linkage, indicating that muscles are not controlled individually but are linked with other muscles to form movement synergies as dictated by the task. According to the theory of DS, establishing functional links between groups of muscles simplifies MC by reducing the elements that the human system must continuously cope with as the person develops and ages.

Following this example, therapists can understand the impact that contractures at the hips and pelvis or immobility of the scapula and thoracic spine might have on head control or respiration. It is also possible to hypothesize that intervention strategies designed to take advantage of the global maps that contain spinal posture, head control, and respiration can enhance any one of these functions.

DS also hypothesizes that there is a change in the flexibility of coordinative structures as learning takes place.[49] When first learning a movement sequence, the learner attempts to control the degrees of freedom by limiting the number of muscles and joints (chosen for the movement) to an excessive degree, a familiar concept in NDT that contributes to increased stiffness in many clients. This initial coupling takes advantage of normal biomechanical constraints but controls more movement combinations than necessary, resulting in movements that are rigid and energy and attention consuming. As learning takes place, more movement options become available to adapt to subtle changes in task requirements as neural and musculoskeletal constraints give way to flexible functional combinations, allowing for more variability and a higher level of success. It should be noted that, even in normal circumstances, both adults and children recruit synergistic muscles in patterns of coactivation to provide stability when they are unstable, such as walking on ice, on a narrow beam, or on a swaying bridge. Stiffness, in and of itself, is not atypical, but the excessive use of coactivation and the inability to use more flexible, functional strategies is problematic for clients with neuropathology.[47]

Let's take this one step further. *If* an individual with neuropathology begins with reduced movement repertoires (primary and secondary) and is driven to control the degrees of freedom in an attempt to acquire posture or motor skills, and *if* the strategies to do so involve excessive coupling and are functionally preferred early in learning, and *if* neuropathology limits the possibilities for developing flexible global maps and coordinative structures, *then* constrained movement combinations can become increasingly stable and prevent the selection of more flexible groupings. The client will appear stiff and limited in range of motion, further restricting the ability to form new movement solutions in novel situations. This is one of the explanations that NDT clinicians use to account for the appearance of excessive stiffness and limited movement synergies in clients with neuropathology.

Tenets of Dynamic Systems Theory

Much like NGS, the theory of DS pays a great deal of attention to individual variability and the role variability plays in skill development. In this way, DS supplements the tenets of NGS by focusing on the role of the body systems and the environment in which the movement occurs. In the theory of DS, variability is part and parcel of human movement, but not because of the brain's ability to select variable repertoires for experimentation; rather, by the person's need to respond to changes in the details of the context in which the movement takes place.[50,51,53] DS theorizes that movement and changes in movement patterns are organized as much by the task; the environment; and the individual's history, experience, and biomechanical factors as by neural and genetic factors. These might include body weight, muscle strength, joint configuration, postural support, neural firing, mood, attention, and specific environmental conditions, such as inertia and gravity, or the task goals, such as eating, dressing, or bathing. The interactions among the elements of these systems give rise to movements that are self-organized—one of three key principles that define DS.

Self-Organization

Self-organization implies that interacting systems, through repetition and practice, can organize themselves and create movement repertoires out of continual activity.[34,51,55] Due to the properties of dynamic pattern formation, these components spontaneously adopt a specific organization by trial and error and practice with slightly different configurations. This theory deemphasizes instructions or neural selectivity to achieve coordinated actions and instead looks for explanations based on physical parameters. Change occurs because one control parameter, or variable, reaches a critical value, which causes a change in the entire system. For example, change in velocity regulates a change from walking to running.[49] Change in the slope alters step frequency and step length in young children.[56] These variations in performance reflect adaptations to changes in the biomechanical properties of the developing musculoskeletal system or changes in the environmental conditions. This is a different point of view but similar to Eldelman's[20] proposal that secondary repertoires are developed and strengthened by exploration and experience within a specific context.

Self-organization is also seen in adults. Wu and colleagues[57] reported that persons with stroke showed nearly normal reaching kinematics (velocity patterns and decreased movement time) when the goal of reaching and grasping was placed in a task context that offered real objects, such as reaching for and drinking from a cup. Self-organization is contingent on prior events as well as current experimentation, and supports the assumption that self-exploration of motor solutions is necessary for accomplishing efficient, goal-directed actions, an important component in NDT practice.

How Does This Principle Support NDT Intervention?

The idea that NDT therapists recognize individual diversity has already been discussed earlier in this chapter. The concept of self-organization follows this same line of thinking, supporting a client's attempt to explore and experiment with movement solutions. The NDT therapist must realize this and permit the client to use previously learned patterns, even if less effective, when the individual needs to retreat to a "comfort zone." The clinician accepts that relearning movement patterns will not be easy initially and will not be smooth or efficient. However, the therapist also identifies which patterns can develop into smoother, more flexible ones, and also identifies which patterns might further limit the development of functional skills. Self-organization implies that the spontaneous motor strategies will emerge from the contribution of many subsystems in a more efficient way, given the present constraints on the motor abilities of the individual. Both Edelman[20] and Bernstein[19] point out that frequent repetition of particular movements causes them to become more stable. Although this is not a problem for persons with intact sensory and motor systems who can develop their individualized diversity, this increased stability of tightly linked patterns might cause individuals with fewer options for variability to become "stuck" by constrained and repetitive posture and movements that could lead to further disability. For this reason, NDT does not *always* allow the client's own solution to a motor task but guides the client to flexible solutions. For example, in Case Report B4 of Makayla in Unit V, the physical therapist describes intervention to develop sitting on a bench independently of hand support so that the child can develop options for play and mobility in sitting.

Rate-Limiting Factors

A second important aspect of DS theory is the assumption that each subsystem develops at its own rate but is constrained or supported by physical and environmental factors. Any component that prevents success at a functional task can be rate limiting. This suggests that clinicians can identify constraints that limit functional change and develop intervention strategies which directly target these rate limiters. For example, in early infancy, the mass of the child's head relative to the size of the rest of the body places constraints on, or limits, the rate at which head lifting and visual following can occur.[21] Delays in independent sitting constrain the foundations for manual development, mother–infant face to face interactions, and reaching behavior by 6-month-old infants.[58,59,60] In adults with CP, moderate weakness, increased muscle tone, bone and joint deformities, and progressive asymmetry in posture are independently responsible for limitations in independent activities of daily living (ADL) such as transfers and balance for standing and walking.[61,62] In people following stroke, recovery of sit-to-stand and curb-climbing functions can be limited by impairments affecting balance, knee extension strength, and kinetic energy.[63]

How Does the Understanding of Rate Limits Support NDT Intervention?

These examples support the NDT assumption that impairments to function can be identified and intervention can be designed to address these rate-limiting factors. For example, Arndt et al[64] and Harbourne et al[58] both described changes in postural control when specific therapist-guided trunk protocols were used to reduce the factors limiting function. Accepting rate-limiting relationships explains why change in the *rate* of development is not a stated outcome in NDT intervention with children. Attaining a specific developmental milestone, such as sitting, may be a part of a function or activity goal within the ICF model, but an NDT therapist also addresses rate-limiting factors when designing programs to meet these goals.

Transitions

A third tenet of DS theory is the concept of state transitions. Specific motor skills emerge from a series of states of stability, instability, and phase shifts in which new states become stable aspects of behavior. These changes of state come about through exploration of movement opportunities and practice, given the current state of subsystem characteristics and context. Even stable aspects of behavior are "softly" assembled so that variability is possible, depending on the specific requirements needed to meet the task goal. During development, as the subsystems of developing systems change, motor behaviors can either become more stable or destabilize. These periods of destabilization are referred to as *transition states*. During these times, new forms of movement are most likely to occur. These transitions are characterized either by an increased latency in time to return to a stable state after perturbation, or by increased variability in behavior. Various studies of reaching have shown that between 4 and 6 months of age infants demonstrate increased variability in reaching patterns.[65,66] Variability in muscle activation patterns is seen in both infants developing typically and infants with Down syndrome as they begin upright locomotion before they settle into a strategy that reflects their unique biomechanical and neurophysiological constraints.[67] Although stable patterns do emerge, based on incorporating previous experiences, the healthy individual continually maintains a range of possible solutions that can be produced under changing task demands.[68]

On the other hand, people with neuropathology with limited repertoires of movements may lack variability, and destabilizing these limited patterns is difficult. The person continually tries to use the limited repertoires in all situations, and transitions from one state to another are increasingly difficult. The result is movement that is stereotyped and rigid. Both Fetters[35,69] and Heriza[50] propose that identifying transition phases provides optimal times to effect changes in movement by providing experiences directed toward functional goals or tasks, structuring the environment, and providing personal and environmental constraints that elicit and support functional actions.

NDT therapists use their skills of observation and analysis to identify when and why a client appears "stuck" with limited movements, and then may choose to change any of the parameters of the intervention—frequency, intensity, time, and type of intervention. A recent research summit describes the importance of these dose–response relationships in establishing intervention efficacy and determining intervention protocols.[70] Focused intervention may have a greater effect on changing outcome. Specificity of training—working in real functional tasks with the right tools and in meaningful contexts—is critical for maximizing neuromotor control and functional outcomes.[69,71] These concepts are discussed in depth in Chapter 13 on motor learning.

How Do These Principles of DS Theory Support NDT Intervention?

DS supports the NDT assumption that characteristics of body structures and functions, the task, and the context are critically important to emergent movement strategies and that attention to these contextual elements is a critical part of NDT intervention planning.

The theory of DS directly supports the NDT intervention assumption that intervention is most effective during periods characterized by high degrees of variability. These are often the periods before the person has used limited repertories of movement to the extent that they limit the variability of movement options or during times of growth, new experiences (and environments), or recovery from a neural insult (see Case Report B2 in Unit V describing Russell following a TBI). NDT recognizes that these periods of transition are the times that intervention can promote and direct efficient motor patterns as the client is working out new functional movements in increasingly complex contexts.

12.2 Summary

Theories of MC will continue to change as research validates some ideas and negates others. Any theory is only useful when it provides a better understanding for what we do and when tested provides the evidence that what we do is effective. Currently, NDT practice is best understood in a theoretical framework that emphasizes interactions between neural and physical systems, emphasizes task goals and contexts, and provides the flexibility to apply these ideas to people with or without impairments at any point along their life span. We will continue to seek the best information that supports our practice, applying the available knowledge and research on MC, motor development, and motor learning to shape the framework for planning intervention and assessing the outcome of patient care.

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13 Motor Learning

Janet M. Howle

Motor learning (ML) results from experience and practice of motor skills in specific contexts that relate to function and participation. This chapter defines ML and differentiates between motor learning and motor performance. Neuro-Developmental Treatment (NDT) intervention provides active learning opportunities taking into account the characteristics of the typical and atypical learner, the importance of setting goals in contexts that are meaningful, and the use of hands-on guidance and verbal and nonverbal instructions to engage and support the learner.

Learning Objectives

Upon completing this chapter the reader will be able to do the following:

- Apply motor learning assumptions to NDT practice.
- Identify and differentiate between the characteristics of motor learning and motor performance.
- Analyze the importance of various principles of motor learning as they relate to NDT practice and International Classification of Functioning, Disability and Health (ICF) domains, including
  - preparation of effective motor learning experience;
  - task characteristics;
  - instructions for motor learning;
  - importance of practice—scheduling practice, intensity and frequency;
  - feedback; and
  - effective learning environments.

13.1 What Is Motor Learning?

Motor learning (ML) is defined as a set of processes directly related to practice or experience leading to relatively permanent changes in motor skills.[1] Most therapists implicitly apply ML principles during intervention for both adults and children who have impairments in posture and movement, including identifying the value of the task, designing active transfer-oriented practice, providing feedback, relating learning to the stage of development or recovery, and focusing on the importance of the environmental context.[2,3,4,5,6] Neuro-Developmental Treatment (NDT) practice accepts that ML results from the dynamic interaction of all the body systems needed to carry out a specific task in a meaningful context. Each system (neuromotor, musculoskeletal, sensory, regulatory, etc.) is necessary, but not sufficient, to drive change in motor function. ML strategies are fundamental in planning NDT intervention programs and include informational and motivational characteristics to enhance generalization and transfer learning of motor skills beyond intervention.

Over the past decades, ML theories that hypothesize how motor skills are acquired through practice or experience have evolved, and parallel changes have taken place in the incorporation of ML principles in NDT, moving from the therapist determining the patient's functional limitations and directing intervention to recognizing the importance of self-determination in goal setting to ensure carryover of functional changes into participation in everyday life. Early on in NDT practice, the client was a more passive recipient of structured, well-controlled intervention that stressed changes in motor performance (MP) rather than ML. Although the Bobaths[7] included age-appropriate tasks and environmental considerations in their early writings, the focus on their methods that changed the quality of movement overshadowed these aspects of their intervention approach. As dynamic theories on learning emerged, NDT therapists increased their attention to the importance of verbal and nonverbal feedback, task-specific training, practice variability, and meaningful context.

Practice of motor skills, when conducted in a meaningful context, has been shown to reduce the gap between intervention and function and provides a clear link between therapy and daily living.[8,9] Our understanding of the importance of practice and its context has significantly changed and enhances our ability to help our clients achieve carryover from therapy to life.

ML principles are currently integrated into both examination and intervention and are accepted as part of the NDT Practice Model that is described earlier in this text. Assumptions in ML listed below, along with those of motor control and motor development, help therapists organize and plan NDT intervention.

13.1.1 Neuro-Developmental Treatment Assumptions in Motor Learning

- ML results from experience and practice of motor skills in specific contexts that directly relate to function and participation.
- NDT intervention is structured to provide active learning opportunities in an appropriately stimulating and supportive environment.
- Based on an understanding of plasticity and recovery, the effectiveness of intervention varies with stages of development and recovery.
- Variations are seen in every client's learning level, style, and capability, and therapists expect changes in these characteristics over the life span.
- Tasks must be appropriately motivating, stimulating, achievable, and meaningful to ensure motor learning.
- Intervention is structured to evoke active participation on the part of the learner.
- NDT therapists use physical, cognitive, verbal, and nonverbal instructions and provide both verbal and nonverbal feedback at appropriate times.
- Goals and outcomes that are set in active partnership with the learner and are specific, meaningful, attainable, and of moderate difficulty have the greatest effect on ML.
- Clients develop strategies for solving motor problems, and NDT clinicians recognize that individuals are influenced by past experiences, their system competencies and limitations, motivation, priority, value, and necessity.
- Practice, with increasing degrees of challenge, is prerequisite for ML and varies with the stage of the learner.
- Errors during practice can facilitate learning. Therapists let clients make mistakes within a range or margin of error needed for learning while ensuring safety.
- Changes in motor skills occur under conditions that most closely resemble the task specificity the learner will encounter during the performance of that skill.
- Hands-on guidance is an important NDT teaching–learning strategy that if used judiciously influences ML. Therapeutic handling can be used as a practice strategy or a form of nonverbal feedback.
- An optimal state of readiness, including readiness in the attentional, physical, emotional, cognitive, and sensorimotor systems, prepares the individual for the motor action.
- Preparing a client for movement includes a supportive therapist–client relationship; a safe, comfortable environment; motivational activities; consideration of alignment and posture; and a level of challenge that matches the capabilities of the client.
- Previous experience, experimentation, memory, and recall are additional elements that enhance ML.
- Improved performance (the ability to perform better immediately following practice) does not automatically equal ML (the degree of long-term retention of performance capability). NDT recognizes that ML requires a transfer of skills to the daily life setting.

13.1.2 Differentiating Motor Learning from Motor Performance

ML and MP are two distinct concepts with different goals of intervention. It is important for the clinician to understand the difference between ML and MP when planning intervention to enhance ML. This chapter focuses on ML, defined as the direct result of practice or experience that influences the individual's ability to process information and leads to relatively permanent changes in skilled actions that can be retained, transferred, or generalized.[1,10] Skill is the consistent performance and attainment of an action-goal with economy of effort and is the result of organizing movement for an individual solution to a motor problem. ML is the set of underlying events, occurrences, or changes that happen when practice enables a person to become consistently skilled at some task. Research has shown that the more closely the demands in the practice environment resemble those in the actual environment the better will be the transfer of skill.[11,12,13] ML can be measured either by the degree of long-term retention of performance capability or by the amount of transfer to other tasks or different settings.[12,14,15]

MP, on the other hand, is the change in motor behavior that comes from a variety of temporary factors during and immediately following practice.[16] Improved performance does not necessarily imply that learning has occurred, and it is important to make the distinction between improved MP and increased ML. In fact, practice conditions that promote long-term retention might be different from the practice conditions that produce immediate improvement in MP. Setting up conditions for long-term retention for ML may actually decrease the quality of immediate MP. Errors during practice can facilitate learning. This implies that therapists need to be comfortable letting clients make mistakes within a range or margin of error needed for learning while ensuring safety. Therapists need to provide the client with opportunities to correct their own errors without immediately providing corrective feedback.[14,15]

13.1.3 Planning an Effective Motor Learning Experience

Task Requirements

Effective ML requires tasks that are goal directed, meaningful, attainable, and of moderate difficulty for the learner.[17,18] Selection and sequencing tasks in an ML framework take into account the characteristics of the learner, including age, body system integrities and impairments, functional abilities and limitations, social participation and participation restrictions, as well as environmental contexts. Tasks that are self-initiated, self-controlled, and require active participation of the learner are the most satisfying and therefore of great importance for ML. Client-centered goal setting is often discussed as a key to successful ML. Missiuna and Pollock[19] reported that children as young as 5 are able to set goals and priorities for occupational therapy and could identify which tasks were most difficult for them; however, therapists do not always include client-centered goal setting. Even with adults poststroke, studies show that therapists often do not include client-centered goal setting as a consistent part of their practice in rehabilitation settings.[20,21]

Preparation

Preparation for an ML experience involves addressing the overall context that is conducive to the individual's learning ability and style. Children and adults respond positively to a multicontext approach that requires the individual to apply the newly learned skill to multiple situations.[22] Providing real contexts for practice leads to ML under a variety of conditions. For example, children with cerebral palsy (CP) demonstrated better quality of movement when reaching for a doll while playing a game when compared with reaching without an age-appropriate purpose.[23] In contrast, Higgins and Spaeth[24] showed that the narrower the context, the narrower the solution and the more consistent, or stereotyped, the movement.

Movement is the means by which individuals solve motor problems and includes cortical and subcortical awareness of the kinematics of the movement as well as the external and internal forces needed to exactly match the features of the movement with the task. In addition, the structure of the movement can be consistent (stereotypic) or variable (nonstereotypical), depending on the problem and the context.

Understanding movement characteristics can increase effectiveness in planning sessions for learning tasks. Changing movement characteristics, such as fluency, variability, originality, flexibility, and elaboration on movement patterns, leads to an increase in problem-solving capacity and ML. Individuals who solve similar movement problems using several different organizational strategies are more likely to develop permanent changes in motor skills and a wider range of strategies that they can use for future movements under a variety of conditions.[8]

Goal setting and instructions before practice are part of ML preparation. The pretask period is important for information processing, decision making, and response programming.[25] Various investigators found positive effects on MP and ML when the learner selected specific movement goals of moderate difficulty, contrasted with the results when the instructor selected easy or vaguely stated movement goals.[26,27,28] Although cognitive understanding of instruction makes ML faster, ML can still occur when a learner is limited in the ability to process instructions, such as clients with Alzheimer's disease, traumatic brain injury (TBI), or mental retardation.[27] In all cases, the learner must be motivated to learn a motor task for intentional learning to occur. Larin[6] described three factors in motivated learning.

1. The learner must perceive that the skill is meaningful, useful, desirable, and has personal value and implications. For example, Carol in Case Report A3 was an expert seamstress and loved to swim for exercise prior to her stroke, whereas Sam in Case Report B9 is a 6-year-old boy who loved music, singing, and books. In both cases, the therapists used the clients' interests to reach the objectives of the therapeutic intervention.
2. The learner must experience satisfaction from executing a movement. Movements that are self-initiated and self-controlled are most satisfying and therefore of great importance for ML. Children often engage in movements that seem purposeless to adults. This is particularly true of newly learned movement in which the child engages in the activity over and over. Adults usually refer to this as play or practice, but these variations are functional behaviors representing important components of ML and serve to link motor and cognitive development.[29] Repetition serves a variety of useful functions, such as muscle strengthening, trials of various organizational strategies, tests of postural control and balance, and learning about the reactive forces in the body produced by the contraction of prime movers.
3. The learner must find encouragement toward higher, achievable goals after task execution by feedback from significant persons, from self-monitoring, or from the pleasure of the experience. Children often participate in the "watch me" game, setting up their own program of feedback, which invariably leads the "watcher" to suggest, "Can you climb higher, run faster, or jump or swim farther?" If the watcher's attention fades, the child will attempt to achieve more to reengage the watcher. Adults use more subtle means for encouragement from external sources and more often set up their own rewards, such as, "I will swim four laps this week, finish weeding the garden before I stop for tea, or walk my dog every night after dinner." Wulf and colleagues[30] found that MP and ML could be positively influenced if older women were given the feedback that their performance was above average when they were learning novel balance tasks. Their ability-related concerns and nervousness were reduced and resulted in more effective learning. McKay and associates[31] found a similar result regarding performance under pressure when the individuals were told they were well suited to perform well on the task.

Instructions for Motor Learning

Instructions prior to the motor task are important for motivational purposes and also as feed-forward input to convey information about the task requirements.[12]

Instructions include a description of the task requirements, including what will occur and when, and are based on the learner's competencies—the neuromuscular and musculoskeletal systems as well as perceptual, cognitive, and executive functions. Cognitive, behavioral, and memory impairments may interfere with the client's ability to process and readily act on instructions. These impairments require the therapist to give the client a chance to respond to instructions without further distracting the client or providing additional instructions. The clinician may consider alternative strategies to help the client understand the task requirements, such as use of mimicking, demonstration, and mental imaging. Use of these alternate strategies does not mean ML will not occur; it might mean ML will take longer. Well-designed anticipatory instruction can enhance the individual's selective attention, allow the learner to process the information for task completion, and foster the ability to separate task-regulatory information from nonregulatory information.[32,33]

Environmental features are always considered when one is developing instructions for ML. Regulatory conditions are those environmental features that the movement must accommodate to successfully reach the goal, in contrast to the background information that is irrelevant for movement organization. For example, when a key is placed in a lock, the size and weight of the key and the shape and placement of the lock (in the door or car) are regulatory conditions that directly affect the organization of the movement. The presence of other persons in the environment, sounds in the background, or color of the key are irrelevant to the movement features and therefore are nonregulatory, although they may be factors that influence the performance of a task.

Instructions can (1) be verbal or nonverbal (demonstration, modeling, or mimicking), (2) include implicit information about the general action ("See if you can do this," then demonstrating and modeling the task, e.g., reaching for a cup) and/or explicit information about the movement goal ("Keep your shoulder down, straighten your elbow, reach your hand toward the cup, and pick it up"), and (3) include a way to recognize goal attainment ("Once you have reached the cup, see if your elbow is straight"). Most therapists agree that the practice of functional, relevant goals elicits faster and smoother movements than nonfunctional goals. However, Boyd and Winstein[34] found that when explicit factual knowledge about the task and sequence was provided prior to practice, participants with middle cerebral artery stroke did not demonstrate better motor sequences, suggesting that explicit information may be more useful to focus the learner's attention than providing information about the task. The ability of children to benefit from explicit information may differ. Instructions to children may need to be more concrete, depending on the child's age and abilities.[35]

13.1.4 How Do These Concepts of Motor Learning Impact NDT Practice?

Prior to either examination or planning intervention, the NDT therapist considers various ML assumptions. First, the therapist recognizes variation in every client's learning level, style, capability, and motivation, and therefore plans flexibility into the approach for a given client. Second, the therapist structures a supportive environment, and as much as possible, provides real context, tools, or toys to enhance learning. Third, the therapist includes the client in setting goals that are of value to the client. This is often a difficult step because it means therapists may have to put aside their own values and priorities and focus on what the client feels are important priorities. This does not mean that the client is expected to set goals independently—in many cases the therapist may need to guide the client to set subgoals or alter expectations so that the goals are realistic and achievable, yet satisfying. Finally therapists will try out various instructional strategies to see which ones match the client's abilities, attention, and motivation.

13.1.5 Practice in Motor Learning

Practice is often considered the most important condition for ML.[1] The number of possible solutions for any one task far exceeds the number of solutions that are used. Learners reduce the scope of possibilities through experimentation and repetitions in practice. Practice should promote relevant, functional, purposeful tasks and use strategies that match the readiness of the learner to respond to the difficulty of the task.[36] Practice has different effects depending on the stage of learning. During the early learning phase of a task, practice allows the learner to select among many possibilities, a reasonable, effective approach to goal attainment.[1] During the early learning phase of a novel task, the learner's variability is necessary and allows the learner to respond to changes in the environment and to respond differently depending on the situation. Once the learner has determined an effective way to perform a task, practice allows the learner to concentrate on skilled performance that includes expedient solutions characterized by economy of effort and successful action. A healthy individual maintains variable solutions that can be produced under changing task demands. Ultimately, variability establishes an organizational framework for the behavior. During this period, the individual learns which environmental conditions are regulatory, plans the initial movement patterns, and attends to feedback for organizing subsequent attempts.

Verbal guidance, observation, and attention all appear to be important for adults in the early learning phase.[12] This phase of ML is cognitive with increased variability in performance and errors as the learner uses active problem solving with a high level of attention to the task goal and informational feedback. In later learning, practice changes the processing of information and organization of movement. The learner becomes more proficient in coping with task constraints. Movements become more efficient with refinement of control processes, so that movement is consistent and smooth. This phase is considered automatic because there appears to be minimal attention cost, freeing the learner from thinking about movement production so that the learner can multitask, simultaneously attending to other inputs, people, or events going on in the environment, integrating information, and planning strategies for future movement sequences.[1]

These differences in early and late learning might not be applicable in young children. Adolph et al[37] showed that the first movement strategies selected for a risky task, such as descending a steep slope, are goal directed but can be highly inefficient and do not take into account environmental cues. Children who had practiced descending slopes as crawlers tried to descend upright when they had learned to stand, even when it was not safe. They were no more proficient at the task than those children who had no previous experience with the slope. They did not recognize which conditions of the environment were regulatory or did not understand their own motor abilities. Children must relearn control in each position, and prior experience with the environmental conditions does not help. During development, children appear to try out a variety of movement strategies that happen to occur to them, perhaps accidentally, before attending to the details of the environment, the forces, the timing required, and the consequences of their actions in selecting the safest and most economical one for the task at hand.[38,39]

Practice can take place in *blocked, serial,* or *random* sequences. *Blocked sequencing* refers to practice in a drill-type repetition, during which the individual completes all trials of a given task before undertaking another task. The more complex the skill is, the longer blocked practice may be beneficial. In the early-learning stage, blocked practice is slightly more effective than random practice in acquisition of performance, that is, until some semblance of at least part of the motor behavior is established.

Random practice refers to a mixed repetition of various tasks and has proven more beneficial than a blocked sequence when measured on retention tests because it involves repeated problem solving. Random sequencing requires a greater number of trials, and performance can actually deteriorate during the practice sessions.[1] Wulf and Shea[40] reviewed studies with children and found that random practice was less effective for learning complex skills because of the demand for attention, memory, and motor sequences. They found blocked practice to be more effective in this population.

Physical practice is essential to ML; however, mental practice or motor imagery is also a useful strategy for ML.[41] Mental imagery is imagining the correct performance of a motor task without any associated overt movement. Individuals can use this strategy pretask, posttask, or between physical trials to enhance performance and learning. There is abundant evidence for the positive effects of motor imagery practice on MP and learning in adults with stroke. In separate reviews, both Malouin and colleagues[41] and García Carrasco and Aboitiz Cantalapiedra[42] found that the greatest improvements occurred with interventions that combined physical and mental practice. Specifically, investigators showed changes in gait parameters and upper extremity functions.[43,44] Studies of typically developing school-aged children described the benefits of visual imagery combined with physical practice.[45] Based on the results of studies with adults with stroke, motor imagery as a method to enhance ML for children with CP is being investigated.[46] Mental imagery for children sparks interest and motivation and can potentially lead to spontaneous repetition of movement sequences.

Recently, NDT therapists have included the use of popular Nintendo Wii and Wii Fit video games, an intriguing method that combines elements of physical and imagery practice. Video games that provide a consistent repetition of a realistic task are being used with both children and adults with neuromuscular impairments. Various studies have looked at changes in attention, motivation, energy expenditure, balance, bimanual dexterity, postural stability, and use of the upper extremity.[47,48] Berg and colleagues[49] reported on a case study involving a 12-year-old child with Down syndrome who self-selected video games over an 8-week intervention period. They reported positive changes in postural stability, manual dexterity, upper-limb coordination, balance, and agility. The literature suggests that video games that require physical activity along with virtual imagery are an enjoyable and valuable means of facilitating changes; however, the level of effectiveness is still inconclusive at this time.[50]

Physical or verbal guidance while practicing can be an effective method for limiting excessive movement errors during the performance of a task and assists the learner through the postural adjustments and movements needed for task completion. Continuous guidance has been shown to have a positive effect on performance during trials of the practiced task but not on learning. In particular, continuous physical guidance can modify the feel of the task, reducing its specificity and transfer potential.[51,52] Trial-and-error or "discovery" procedures result in effective retention and transfer performance. If the therapist includes guidance as a method of instruction, more effective learning will occur if there is an alternation between trial and error, independent movements, and guided movements, all while allowing the person to be as independent as possible and to make mistakes within the margin of error and safety, minimizing fear.[1]

NDT intervention includes physical guidance.[53] The current view is that physical guidance or handling, used judiciously, is an appropriate strategy for enhancing both MP and ML. Some writers have expressed concern that physical guidance or handling in NDT intervention might direct attention away from the appropriate sensory cues, encourage dependence on the therapist's cues, and possibly interfere with the client's ability to learn actions independently.[52] However, Harbourne et al[54] found that infants in a perceptual-motor intervention group who received movement guided by a skilled therapist showed greater variability and exploratory behavior in sitting, whereas those in the home program group actually decreased variability. In various studies with typically developing infants and their mothers, the mothers' handling enhanced balance, locomotion, grasping skills, and differences in gaze and affect.[53,54,55,56,57,58] NDT views physical guidance as a way to permit clients to allocate their attention to the component of performance that will lead to ML when they are engaged in multiple activities.

How Are the Principles of Practice Used in NDT?

NDT intervention is an opportunity for practice of newly emerging motor skills under the guidance of a trained therapist. Therapists have the opportunity to help clients find the best solutions for their level of learning, development, or recovery. Therapists need to keep in mind the differences in practice during the early stage of learning (or relearning) a function versus those principles of practice that accompany later learning. For example, a therapist may use the strategy of partial body-weight-bearing (PBWB) treadmill training with a young child who is just beginning to step or who is recovering stepping following selective dorsal rhizotomy (SDR) surgery, as seen in (**Fig. 13.1**).

According to the ML research on early learning, the therapist first lets the child experiment with stepping while supported in a harness. Later, once a reasonable stepping pattern is established, the therapist guides the child to achieve a longer stride, an even step-stance rhythm, and a heel–toe sequence, along with walking overground, to move the child from stepping toward fully weighted functional walking, as seen in (**Fig. 13.2**).

PBWB gait training is an example of blocked practice, using drill-type repetition during which the child completes all trials before undertaking another task (see the beginning of the Practice in Motor Learning section). In this setting, a trial lasts until the child's "best pattern" deteriorates. The rest period requires only stopping the treadmill and allowing the child to stand in the harness before the next trial begins.

13.1.6 Scheduling Practice

Scheduling practice trials is an element of ML that influences both performance and learning. *Distributed practice* describes a model in which the amount of rest or breaks between practice trials equals or exceeds the amount of time of the trial. This model, the most commonly used by pediatric physical therapists, has the greatest effect on learning continuous tasks and leads to better retention and transfer.[59,60] Studies using distributed practice with adults with hemiplegia have shown gains in upper extremity and hand functions.[61,62]

Distributed practice has a positive learning effect on continuous or complex tasks because tasks of this nature require greater energy expenditures, and rest periods become increasingly important. Scheduling practice and breaks is important in ML because continuous practice can cause muscle fatigue. In children with CP or adults with neuromuscular impairments, significant fatigue

Fig. 13.1 During early-learning phase after selective dorsal rhizotomy, this child experiments with taking steps on a treadmill.

Fig. 13.2 The therapist guides the child to achieve specific components of the gait pattern.

resulting from repetition of activities is correlated with a lower rate of progress toward certain motor activities and can put the individual at risk for injury.[63,64] The NDT therapist attempts to achieve the right amount of challenge—one that is motivating and difficult, yet achievable. Practice needs to be somewhat effortful for learning to occur, but also needs to involve effort without causing fatigue.

Massed practice is a model in which the amount of practice time is greater than the amount of rest between trials. It works best for discrete tasks in which the goal of practice is to increase performance on well-learned tasks. Hubbard and colleagues[65] suggest that this practice model be used to manage poststroke upper limb recovery in a program of task-specific training. Massed practice, usually combined with an intense intervention schedule, is also used in mobility training involving body-weight-supported treadmill training for both adults and children, as already described.[66]

Another factor that affects ML is the amount of *variability* within a practice sequence. There are two main purposes for including variability in ML. First is to enhance generalization and transfer or adaptability when the practice of one task contributes to the performance of another task in the same category. Variability, a hallmark of typical motor development, is discussed in Chapter 14. Infants learn by exploration of a vast array of movement experiences and from the solutions and consequences they discover. If we assume that individuals with neural impairments do not inherently have the options for variability, then it is important to build variability into our intervention programs to engage both children and adults in this process.

Second is to establish competence throughout a movement sequence while maintaining the same fundamental pattern. Although this may seem contradictory, ultimately, once an individual experiments with a multitude of ways to seek motor solutions, each person must find stable solutions that work for his or her body systems and in the current context, yet are flexible enough to change with development, aging, or change in purpose. Overall, low-variability practice translates into greater performance on the practiced task but decreases the ML benefit. High-variability practice yields high performance on transfer to a task with a similar movement and better retention. For example, if a child practices stepping up onto benches of various heights (**Fig. 13.3**) over a bolster, and onto a step while holding various toys in his hands in a therapeutic environment, this practice may generalize to stepping up onto a curb or onto the school bus step with a backpack while in a crowd of children.

In a study to evaluate long-term effects of intervention, Horn et al[67] found that children with CP were able to generalize movement components to unrelated activities from skills they had gained during NDT intervention sessions.

13.1.7 Frequency and Intensity

There is mounting evidence over the last decade that increasing the frequency and intensity of practice can affect outcomes in the various domains described in the ICF model.[68] Improvements in single-system and multisystem impairments, as well as in gait parameters and balance, were seen after periods of intense programs for children with CP and adults following stroke.[60,66,69] Clinical studies suggest that various aspects of posture and movement improve in both MP and ML and in transfer to unstructured environments.[70,71] In children with CP and adults poststroke, changes in walking, including strength, speed, symmetry, joint motion, and cadence, have been reported when the intensity of intervention is increased.[72,73,74] Other studies have reported improvement in stepping and gait efficiency in individuals poststroke with task-specific intensive intervention.[66,74,75] Balance also improved in persons poststroke with intense intervention.[66,76] Other studies that examined upper extremity function showed that clients gained upper extremity function and muscle strength after participating in an intensive therapeutic program.[77,78]

Fig. 13.3 Variability in practice translates to flexible solutions for function.

In most studies on the effect of treadmill walking with children or adults with motor impairments, investigators showed that intense training has a positive effect on developing or changing gait characteristics.[66,79,80] Other studies have measured functional changes in children with CP and found a positive relationship between the intensity and frequency of physical therapy and functional outcomes when measured by the Gross Motor Function Measure (GMFM).[60,70,81]

Finally, studies that examined the effects of the level of intensity in the domain of participation in both children with CP or persons following stroke showed improvements in self care. Combs and colleagues[78] showed that persons with chronic stroke improved in the personal goal-related activities as measured by the Canadian

Occupational Performance Measure (COPM), and Stroke Impact Scale, and the effect was maintained for 5 months after the intervention. Sorsdahl and associates[82] reported improvements in self-care and a decrease in the need for caregiver assistance in children with CP as measured on the Pediatric Evaluation of Disability Inventory (PEDI) after participating in an intensive, goal-directed, activity-focused program. The intervention took place in a group setting with parent participation. The setting had a positive impact on the daily life of children and their families.

Intense NDT Intervention: How Can We Apply These Principles?

NDT therapists are using models that examine dosing parameters for children with cerebral palsy, in particular the frequency and intensity of intervention. Bierman[83] describes the use of an intensive NDT intervention for a child with dystonia and spastic quadriplegia over a 5-month period. Gains were reported in the domains of body systems, functional skills, and participation. Partners for Progress, Inc., a nonprofit organization founded by NDT instructors Kliebhan and Alexander, apply NDT interventions for short-term intensives. These programs include physical therapy, occupational therapy, and speech-language therapy. In written communication, Kliebhan reports that data collected by Evans-Rogers on the Goal Attainment Scale (GAS) showed improvements in the children who participated in these intensive programs in 2009 and 2010. Unfortunately, the decision to increase the frequency and intensity of therapeutic intervention is determined by the third-party payers in the United States.

13.1.8 Feedback

Feedback is another important variable for ML. It has an informational function as well as motivational properties that have a positive influence on learning.[12] Feedback can occur before the task, in the form of comments on previous practice sessions; during the task, as verbal or nonverbal information; immediately after the task; or delayed in relation to task execution. The form of this information, the amount of it, and the time at which it is presented can affect performance and learning.[14,84]

Feedback consists of two types: intrinsic and extrinsic. *Intrinsic feedback* occurs as a natural consequence of motor behavior and relates to the learner's various sensory channels involved when practicing a task. There are two categories of intrinsic feedback. The first provides information about the components of the movement, sensing speed, direction, accuracy, joint angles, muscle strength, and other factors. This feedback often involves the vestibular or somatosensory receptors and is an open-loop or feed-forward system.

The second type of intrinsic feedback provides information about outcome and gives indications concerning the degree of goal attainment through vision, hearing, or the feeling of success. Depending on the duration of the movement, intrinsic feedback often allows the learner to evaluate the success of a movement prior to completion. Because the body does not retain specific sensory consequences, feedback about outcomes is organized with reference to the goal. Theorists propose that intrinsic feedback is compared with a learned reference of correctness in a closed-loop or feedback motor control framework. This reference acts in conjunction with the feedback in an error-detection process.[1] (**Fig. 13.4**) provides a schematic of open-loop and closed- loop systems.

Extrinsic feedback is external information about the task that is supplemental to intrinsic feedback. Extrinsic feedback can occur as a movement takes place, such as a buzzer in the client's shoe that sounds with each heel-strike, or after the movement, such as the therapist's comments. Extrinsic feedback about the nature of the movement pattern is called *knowledge of performance* (KP). Extrinsic feedback that provides information about the outcome of the movement in the environment is called *knowledge of results* (KR).[1]

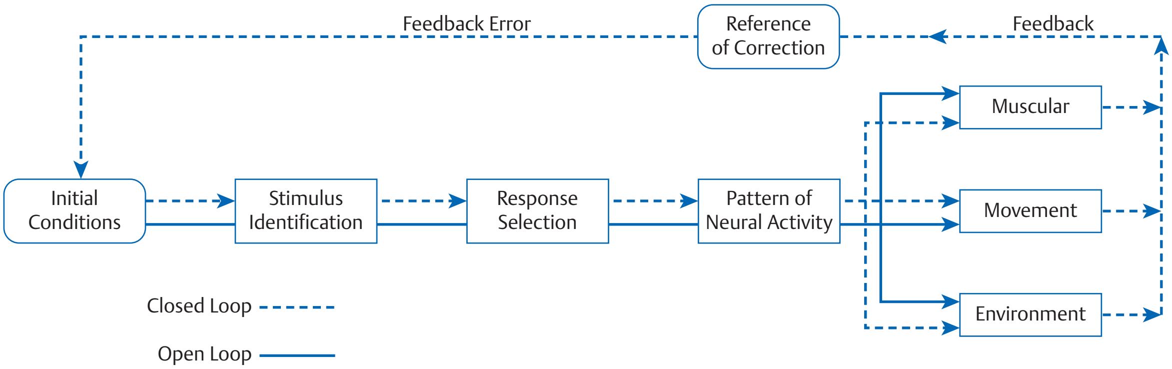

Fig. 13.4 The feed-forward (open-loop) and feedback (closed loop) systems complement each other as necessary to anticipate, regulate, and adapt to the dynamics of the physical world. Reprinted with permission of the Neuro-Developmental Treatment Association. Howle, J. *Neuro-Developmental Intervention Approach: Theoretical Foundations and Principles of Clinical Practice*. Laguna Beach, CA: NDTA; 2002.

Knowledge of Performance

Two types of KP feedback relevant to clients with motor control problems are kinematic feedback and kinetic feedback. *Kinematic* feedback consists of verbal observations that refer to aspects of movement, such as position, time, velocity, acceleration, and patterns of coordination. “You were able to hold your weight on your right leg without hyperextending your knee,” or “You will need to slow down in order to step down safely from the curb.” A component of kinematic feedback is to inform the learner about some aspect of the movement pattern that the learner might not otherwise perceive, such as information about the relative timing differences in two joints or subtle changes in velocity. Most investigators suggest that the effectiveness of kinematic feedback depends on the nature of the task goal. For example, if the goal of the task is to improve weight shift forward over the feet, a pattern necessary to rise from a chair, then verbal kinematic feedback describes what went wrong: “You need to bend your body more forward to help bring your weight over your feet before rising.” This information will be an effective way to improve this movement pattern since the feedback matches the task goal. Not all clients can benefit from verbal kinematic feedback because it requires the person to be able to understand and assimilate information about the body systems. These details of the musculoskeletal systems are often beyond the understanding of children and many adults; however, nonverbal kinematic feedback is possible through therapeutic handling.

As described earlier in this chapter, physical guidance or therapeutic handling is a primary intervention strategy used during practice for motor learning; however, it is also an effective nonverbal way to provide feedback about the effect of the movement as it occurs. Although continuous guidance may have a positive effect on performance by correcting and modifying a movement strategy as it unfolds, clients need to feel their own body response to achieving a functional goal if ML and transfer of learning are to occur. Therapeutic handling as kinematic feedback informs the learner through the contact of the therapists’ hands about the timing, position, velocity, and pattern of coordination needed for efficient function and provides a reference of correction, supplementing verbal kinematic feedback. However, control through therapeutic handling must decrease and be phased out so that clients can eventually move independently and initiate and evaluate their own movement successes in different contexts.

Kinetic feedback gives information about the forces that produce the variables, including the muscular forces that organize movement, and their durations, such as, “Keep your hand lightly on the paper cup while you drink,” or “Keep a tight grip on the jump-rope handle.” Although there is less research in this area, it appears that feedback about the force needed for successful task completion affects both performance and learning.[14]

KP appears to have the greatest effect on learning when it precisely specifies information that is critical for movement efficiency. This information is most useful when it promotes active, problem-solving activities in the learner. For example, Thorpe and Valvano[85] examined the effects of KP during practice of a novel motor skill in 13 children with CP. The researchers found that, with or without KP, all children benefited from practice, but when KP was used and enhanced with cognitive strategies, children were able to make greater gains in learning a novel motor skill.

Van Vliet and Wulf[86] found that persons with stroke benefited from KP when the focus was on the effect of the movement rather than on the specific muscles needed for the movement. Freedman and colleagues[87] reported similar results when individuals engaged in oral-motor tasks. Focus on the effect of the movement produced greater accuracy and less variability than did focus on the body part or muscle for movement.

Knowledge of Results

KR is extrinsic feedback that provides information about the outcome of the movement in the environment.[1,16] Very little learning occurs in the absence of KR.[1,16] This type of extrinsic feedback provides information about how the outcome of a task compares with the level of success in attaining the goal. In many real-life learning situations, the goal of the task is not connected to a specific movement pattern; rather, the individual can achieve that same outcome through various movement patterns. In the example of rising from a chair, the client might use the hands to push down on the chair arms or seat, or might not use the hands at all and still successfully rise from the chair. The goal in this example is not to shift the weight or use a particular muscle synergy but to stand up from the chair in the most energy-conserving or quickest manner. KR is particularly useful when the goal is for the individual to achieve the best possible result by taking into account the person’s unique physical attributes.

Feedback on accuracy or error in completion of the task provides information about the ways in which the person could modify the movement the next time and prescribes a means to improve performance. Persons who received KR as a reference were able to discover and reproduce the most efficient movement. The frequency of KR and the time between task completion and KR were variables in enhancing learning. More immediate feedback during practice facilitated performance but was detrimental to learning by producing dependence. However, a slight delay in feedback after completion of a task leads to learning by allowing clients to assess their own success in completion of the motor task.[88] Finally, both KP and KR make the task appear more interesting, keep the learner alert, and cause the learner to set higher performance goals. Many of the case reports in Unit V, both pediatric and adult onset, demonstrate this principle.

13.1.9 Importance of the Environment

NDT recognizes that the characteristics of the task and the specific environmental context are as important as the contributions from the nervous system and the body systems in assuring motor learning. The physical environment, including the people in it, is a powerful incentive or disincentive for movement in individuals with and without neuropathology. For example, infants who sleep in the supine position, as recommended by the American Academy of Pediatrics task force on sudden infant death syndrome (SIDS), were less likely to have rolled over at 4 months of age and had lower developmental scores at 6 months of age than infants who slept in prone.[89] Changing the infants' relationship to the environment and therefore the ability to practice the movements of rolling to prone from supine appears to have affected the timing of motor development. This finding does not mean, however, that therapists and parents should oppose the "Safe to Sleep" movement, because all investigators found that the differences in developmental scores disappeared in typically developing infants, and they walked independently within a normal time frame.[89,90] Daytime supervised periods of time are suggested to promote overall development in infants. Studies of the relationship of the home environment and infant motor development found that more supportive and stimulating home environments correlate with higher infant motor development scores.[91,92,93] In another study, siblings who were educated about CP and included in home programs had a positive effect on the functional independence of the sibling with CP.[94]

The physical environment and the support of people in it are important factors for the life satisfaction of adults with stroke.[95,96] Hartman-Maeier and associates[97] found that activity limitation and restricted participation were strongly correlated with stroke survivors' life dissatisfaction. Bélanger and associates[98] evaluated the importance of the environment on the social integration of adults with stroke and found that environmental characteristics, including a regular supportive presence of children or other relatives at home, had a positive correlation with retention of motor skills gained after stroke

The importance of an active learning environment includes creating a setting that encompasses the common challenges of everyday life and is organized to match the level of the client's performance—neither over- nor understimulating or distracting. Researchers have documented changes in posture or function in children or adults with modifications in the environments, such as using adaptive equipment.

Several studies have credited proper seating as an important factor contributing to motor function and voluntary control of the upper extremities in children with CP.[99,100] Other studies on the influence of walker design on the mobility of children with CP found that the use of posterior walker designs produced a more upright posture during walking, more "normal" alignment when standing, and improved gait characteristics, including stride length, step length, and speed, than did anterior walker designs.[101,102]

The effects of providing a positive, supportive learning environment are not new to NDT therapists. Larin[6] described characteristics of the environmental context in which tasks take place as variables in developing strategies to improve ML.

- *Abstract aspects of the environment*: A context that is appropriately motivating, stimulating, and challenging for the age, cognitive level, and emotional stability, as well as the attentional, sensoriperceptual processing, and motor abilities of the client. The environment is organized to match the client's level of performance, considering the client's cultural and social aspects.
- *Physical aspects of the environment*: Size and physical layout of the room; placement of furniture and persons; level of noise, light, color, temperature, and safety; and comfort factors that encompass the common challenges of everyday life.
- *Interactive context*: Supportive, confident instructor–learner interaction; promotion of initiations by the learner; creation of problem-solving situations; effective guidance with shared control of decision making and incorporation of risk-taking tasks; mental and motor challenges; timely, responsive feedback that focuses on modifying, recommending, or expanding motor behavior rather than on corrective feedback.
- *Multicontext situations*: Application of newly learned skills to multiple situations and in real contexts, such as the home, school, and community, for varied practice leading to ML under a variety of conditions, aimed at decreasing dependence on the instructor or any one particular context.
- *Task characteristics specific to the environmental context*: Characteristics that drive motor behavior; purposeful, meaningful tasks that are initiated by the learner; specific tasks with which the learner has some prior knowledge and experience; tasks containing components that can be generalized in other settings and to other tasks; tasks that provide both an action goal—"Can you put on your jacket?" and a movement goal—"Can you make a fist, straighten your elbow, and push your arm through that sleeve?"; tasks that are specific, consistent, and attainable; tasks that are basic for solving a variety of motor problems in the client's own environments; tasks that capitalize on the individual learner's strategies.

Gentile[32] proposed a taxonomy that described "closed" and "open" environmental conditions. *Closed environmental conditions* are those in which the critical features of the environment (objects, other people, and the support surface) are stationary. Movements are controlled by the spatial features of the environment (e.g., the length and width of the room and placement of doors, lighting, furniture, and persons). Learners are free to perform at their own pace, to decide when to start, and how long the movement will take. These conditions, while predictable and safe, with few environmental and task variables, lack stimulation, challenge, and problem-solving possibilities. This may be an appropriate environmental context for learning new tasks in some cases because it reduces the need to adapt to a variety of variables and allows the individual to attend to the task. However, such predictability reduces the opportunity for transfer of the skill to functional settings. At the lowest end of the taxonomy, the individual is stable, sitting or standing, and is not engaged in manipulation: for example, sitting on a bench, listening to a story, watching television.

In *open environmental conditions*, the spatial and temporal conditions are variable. The motions of people and objects in the environment influence the learner's movements, and conditions change with successive attempts. This environment helps the client to develop flexibility in MP and actively search for critical environmental cues to determine successful task completion. This is a much more demanding context for movement because the learner must become adept at developing and controlling movement patterns that fit environmental variations. An example of an open environment is shopping in the mall, where an individual needs to cope with a constant but perhaps irregular change in his or her own position and interpret changing visual and auditory stimuli while adapting to changing velocities of other shoppers.

Physical laws governing the environment enhance or constrain movement. The support surface characteristics and the forces of gravity, friction, and inertia are variables that affect the individual's center of mass (COM) relative to the base of support (BOS). All movement involves changing the body's relationship to the support surface.[103,104] Efficient contact with the support surface is necessary as a foundation for movement from that surface. Increasing the friction of the surface decreases the ease in moving away from that surface but increases the stability of maintaining posture in contact with the surface. For example, sometimes something as simple as placing a nonskid material, such as Dycem (Dycem Ltd.), on the seat, or changing the seat depth and back height, increases the amount of body in contact with the surface, which increases stability and body alignment. If the goal, however, is to move in a sitting position to dress, then a low-friction seat without a back and with a surface such as varnished wood enhances weight shift and movement within a seated position.

The effects of gravity are so fundamental to posture and movement, it is difficult even to think of this in a separate context. Gravity is the one consistency among highly interactive, interdependent brain, body, and environmental systems. Throughout life, individuals (with or without neuropathology) must adjust and adapt to the invariant effects of gravity. Gravitational forces, along with the various mechanical and genetic coding, affect bone structure, growth, and resultant shape of the skeleton in developing children.[105] The newborn must organize movement against the forces of gravity, a particularly difficult task for infants who are small or premature. Neonatal nurseries have increasingly made many efforts to structure the environment to support behavioral organization and stimulate the flexed midline position, based on positioning against the force of gravity.[106,107] The body segments change rapidly in mass and size in the first year, and the infant must constantly cope with the interactive effects of gravity and these dynamic physical changes.

The effects of gravity are important in adults as well. Gravity affects posture, skeletal alignment, balance, and strength in adults aging typically. Bones develop and change in response to external forces, such as gravity and the dynamic biomechanical changes that occur throughout life. NDT is particularly concerned with compromises in alignment and posture of the spine and extremities, based on body system impairments and typical age-related changes in joint mobility, muscle extensibility, and joint mechanics that secondarily affect balance, movement patterns, and quality of life.[108,109,110,111]

13.2 Summary

The various principles of motor learning are constantly evolving as new information becomes available. Understanding how practice and feedback can effect a permanent change in motor skills, and the critical role of the environment and the task in designing intervention programs, are all part of the NDT practice model. The importance of planning intervention *with* the client, making sure that the goals and strategies used are important and motivating to the person, has been reinforced from the evidence.

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14 Motor Development

Janet M. Howle

As movement develops, it changes the way in which typical and atypical individuals manipulate and interact in their environment. This chapter examines motor development (MD) and postural control across the life span. It presents MD as a dynamic process emerging from changes in the neural and body systems that are influenced by exploration, stimulation, and learning in various contexts. Neuro-Developmental Treatment (NDT) practice relies on understanding the variation and predictability of MD and the connection to the various sensory systems to create intervention strategies that are age appropriate and meaningful.

Learning Objectives

Upon completing this chapter the reader will be able to do the following:

- Link the NDT assumptions to the current principles of MD.
- Apply the principles of MD to changes in movement throughout the life span for both typical individuals and those with neuromotor dysfunction.
- Describe the stages and sequences of MD.
- Describe the development of postural control and its influence on functional motor skills.
- Explain the importance of variability and competition of motor patterns in building meaningful movement.
- Explain the sensory systems' contributions to functional movement in the developing child.
- Describe the features of the musculoskeletal system that support MD.
- Analyze how MD influences the way individuals interact, experience, and learn from the environment.
- List ways in which various aspects of MD impact NDT intervention.

14.1 Motor Development as a Lifelong Process

As Campbell states, "Working knowledge of motor development is the very basis of the practice of pediatric physical therapy."[1] Knowledge of motor development (MD) is equally critical for occupational and speech-language pathologists working with children because MD changes the way children manipulate and interact in their environments.[2] MD provides norms for (1) identifying competencies and impairments in developing body systems, (2) developing effective plans of care, (3) establishing age-appropriate skills as functional outcomes, (4) structuring intervention strategies to facilitate learning and motor control, and (5) selecting play and activities of daily living and contextual factors to promote participation in real-life settings.

Therapists who work with adults know that changes in the expression of motor milestones continue across the life span. These changes influence social development and quality of life, including education, employment, and independent living.[3] For older adults, the aging process may require new motor strategies and adaptation of motor skills to accommodate stiffer joints, weaker muscles, and changes in vision, hearing, and balance.[4,5,6]

Neuro-Developmental Treatment (NDT) has always had a strong foundation in MD. Almost since the inception of their approach, the Bobaths[7] wrote and taught that understanding the development of posture and movement, and the changes that occur over time, provided the means for recognizing differences in typical movement and movement pathology. In an NDT framework, MD is considered a process that occurs throughout the life span. In children, movement repertoires develop, are refined, and adapt as a child grows, and responds to and learns from the demands of new contexts.

Different movements are needed to cope with typical aging processes. Older adults may shorten their step and stride length, use hand support to ascend and descend stairs, hyperextend their neck to accommodate bifocals, and tilt or turn their head to listen with a better ear. Throughout life, experience and learning within specific environmental contexts strengthen certain motor behaviors, and at the same time provide opportunities for change. Therefore, in the NDT framework, MD is viewed as a lifelong process that explains uniquely individual motor characteristics while retaining the same general form of motor behavior at any point in time.

14.1.1 Changes in Thinking about Motor Development

Over time, researchers have offered different perspectives in MD. From the 1920s through the 1940s, MD was viewed as a neural-maturational process; genetic instructions were viewed as the driving force.[8,9,10,11] Reflexes were considered the foundation of movement, and MD was thought to proceed from reflexive movement to highly skilled movement as the levels of the central nervous system (CNS) matured.[7] The inhibition of reflexive movement brought about an orderly and predetermined progression of postural reactions and motor milestones that each child passed through on the way to adulthood. After maturity, the adult CNS was hardwired and fixed, and any substantial recovery of function was impossible no matter what intervention was used.[10] Health care practitioners adopted a "wait and see" attitude. Although this practice persisted for many years, the Bobaths insisted that it was possible to produce changes in MD with specific intervention strategies.[7]

An initial shift of paradigm came from behavioral theories that stressed interactions between the infant and the environment. Skinner and Piaget emphasized the significance of environmental opportunities and the importance of learning and reinforcement on motor behavior.[12,13] This shift paralleled changes in thinking about motor control as described in Chapter 12 of this unit. The impact that this had on the NDT approach was to shift the center of attention from facilitating motor progression to include exploratory movements and problem-solving activities for motivation and a focus on the importance of a supportive environment to foster and shape MD.

The next shift in thinking has been the introduction of dynamic theories in motor control put forth by Bernstein and Edelman (see Chapter 12) and applied to MD development by Thelen[14,15] and Hadders-Algra, among others.[16,17,18,19] This new paradigm placed motor milestones as the end product of a complex and variable schema. Today, MD is thought to emerge from the cooperation and dynamic interactions of many subsystems—intrinsic and extrinsic—in task-specific contexts. Development of specific motor behaviors depends on a balanced combination of neural and body systems, including the biomechanical, kinematic, and anthropometric changes; cognitive and perceptual factors; and the individual genetic code (nature) and an environment that provides a context for experience and learning (nurture). The current NDT practice emphasizes *variability*—the way in which children carry out a particular motor function, and *predictability*—the progression of MD.[20,21,22] These concepts underlie NDT assumptions in MD.

14.2 NDT Assumptions in Motor Development

1. MD is a dynamic process rather than a linear progression that occurs throughout the life span and changes the way individuals interact with their environment.
2. MD emerges from the cooperation and changes in the neural and body systems that are influenced by exploration, stimulation, and learning in various contexts.
3. Body systems develop at different rates, enhancing or constraining the development of various motor behaviors.
4. Directionality of development, such as cephalocaudal and proximodistal, is only a general schema, whereas functional, skilled movement is a composite of postural stability and mobility patterns that support the observable function.
5. Newborns have primary motor repertoires that are complex and variable, but such repertoires must be connected to sensory input and feedback within context to result in meaningful actions.
6. The development of posture and movement is dependent on different muscle physiology and neural pathways; efficient motor function depends on the integration of these two aspects of motor behavior.
7. The various sensory systems—visual, olfactory, auditory, somatosensory (tactile and proprioceptive) and vestibular—are key elements in MD.
8. Motor milestones appear as discontinuous, discrete behaviors with a definable onset but actually result from continuous processes involving all the developing body systems.
9. Variability and competition among motor patterns are essential components of MD.
10. Understanding typical and atypical motor patterns that underlie motor function can enable one to identify differences in movement in both children and adults with CNS pathology.
11. MD provides guidelines for creating intervention strategies that are age appropriate and facilitate variation in movement and enhance motor learning.

14.3 Contemporary Principles in Motor Development That Support NDT Practice

14.3.1 Stages of Motor Development

Stages of development reflect observable motor skills that are often described as motor milestones. The goals of MD are to develop upright posture, mobility, speech, and manipulation for mastery and control in changing contexts. Perfecting these skills leads to functional activities, including self-care, play, and social interactions. Knowledge about the stages of motor development addresses the question, What can I expect of infants at various ages? The answers provide a starting point for observing and identifying differences in typical and atypical development. What drives or constrains MD in a specific child requires an in-depth analysis of the processes underlying motor skills. Therapists start by examining observable motor activities to decide if a child's MD is progressing as expected, taking into account individuality, culture, and experience. Various authors describe and illustrate the observable stages of motor milestones in children, including the progression of a stable head posture, rolling, transitions from prone to sitting and four-point position, creeping, pulling to stand, standing and walking, babbling and speaking, reaching, grasping, and hand control.[23,24,25,26] As these postures or movements are attained, further development entails perfecting postural control in the new position and effortless transitions from one posture to another. As stated in the first assumption, MD is not viewed as a linear progression but as a dynamic one in which body structures and functions jointly mature, albeit at different rates, ultimately leading to observable milestones.

From birth onward, infants begin with movement repertoires that are unique, complex, and species specific. These primary repertoires, listed in Chapter 12, sustain life and serve the newborn's basic needs. Infants have a challenging job; they must cope with variability, link sensory input to multiple motor possibilities, determine which movements have (or will have) value in their lives, and solve increasingly complex problems that occur as they confront the force of gravity; all this while their own body is changing and growing.

Neonates are gravity dependent, and their motor development begins as they discover, from among endless combinations, preferred motor patterns that are stable yet adaptable. At every age, emerging motor behavior must be adaptable enough to change *along with* changes in the musculoskeletal system (and other body systems) and with the intent of the movement, yet be stable enough to permit specific motor function to occur *in spite of* changes in the body systems or intent.

14.3.2 Directionality

NDT therapists know that observing the progression of the stages of MD is just a starting point in understanding motor behavior. Directionality, such as cephalocaudal and proximodistal, is only a general schema.[23] The development of skilled movement is a composite of influences, and assigning developmental direction depends on (1) coordination of various parts of the body performing different functions (such as stability or mobility), (2) the interaction and feedback from the environment in which the motor function takes place, and (3) the purpose or goal.[27] For example, head lifting from prone is an early benchmark of typical development. Head lifting begins in the first month and involves the muscles of the cervical spine and neck as the infant lifts and rights the head. This movement to clear the airway is seen before the infant activates postural muscles deep in the neck to sustain the posture against the force of gravity. Stability of the head in prone also requires concurrent biomechanical changes in the lower trunk, pelvis, and legs (**Fig. 14.1a, b**) In the newborn, head lifting is constrained by the flexed position of the legs and the lack of spinal extension. Newborns can turn their head to clear the airway while prone, an important life-sustaining primary repertoire (see Chapter 12 for information on primary repertoires). Initially, the overall flexed posture of the lower extremities raises the pelvis higher than the shoulders so that the center of mass (COM) is forward and much of the infant's weight is on the shoulders, arms, and face. This posture, combined with the large mass of the infant's head, makes head lifting against gravity nearly impossible. Although the weight on the face may constrain head lifting, it provides an important sensory experience to the lips and cheeks as they make contact with the surface as the infant attempts to turn or lift the head. This experience guides the organization for later active oral-motor activity.[26] By 3 to 4 months of age, as infants activate their body against the force of gravity, the hips extend and the pelvis contacts the support surface and weight is taken on the lower rib cage, elbows, and forearms. Head lifting includes head and upper trunk extension combined with glenohumeral flexion. This pattern of movement shifts the COM distally and provides a stable base, which allows the infant to lift and turn the head freely and easily. Along with this biomechanical change comes a shift in the weight-bearing surface from the shoulders to the lower trunk and legs, and a concurrent increase in muscle strength in the shoulder girdle.

Fig. 14.1 **(a)** A 10-day-old infant in prone. Head lifting is constrained by flexed posture, weight forward on shoulder and face and the large mass of the head. **(b)** Changes in head lifting by 3 months of age correspond to increased extension in trunk, weight shift caudally, strength in neck and shoulders, interest and fixation with the eyes, and practice in a stimulating environment.

Exceptions to the cephalocaudal–proximodistal progression have been described in the literature and suggest that many aspects of motor development undergo simultaneous development. Neural and body systems develop at different rates to share in the control of motor behavior, enhancing or constraining particular motor patterns at different times over the lifespan. Rate-limiting variables include muscle strength and length, postural control, perceptual capabilities, body morphology, experience, memory, and opportunity for object exploration and positional experience.[28,29] For example, various investigators have shown that precision grasp and release are not used for functional skills until the infant develops stability of the head, trunk, and shoulder girdle between 4 and 5 months of age, even though complex precise finger movements and hand shaping for grasp are seen in infants as early as 1 month of age.[30,31] This relationship suggests that proximal stability must develop to support distal control needed for function.

In the example of head lifting described earlier, head control develops in prone as the load-bearing surface gradually shifts caudally, taking weight off the face and shoulders. This caudal shift allows the shoulder girdle muscles to strengthen and frees the arms for reaching and exploring. The rate limitation factors include the size of the child's head (relative to the body), the amount of time spent in prone, and the level of interesting sounds and sights to motivate the infant to lift the head.

In the first 3 months of life, motor skill development focuses on both movement and postural stability of the head. From 4 to 6 months of age, infants develop postural control and balance for sitting, which frees the hands for grasp and play. From 7 to 9 months of age infants gain control over the lower extremities and pelvis in the upright position, and the hands and arms are no longer needed for support. Finally between 10 and 12 months of age infants gain control in upright stance and overall postural control for further independent exploration. Refinement of all these skills continues through the early school years, with new skills developing as environments and opportunities for dance, skiing, and other athletics become available.

The following outline uses the principle of directionality to list observable motor behaviors as they relate to body movement in and through space, as well as speech and fine motor skills.

Birth to 3 Months—Development of Functional Head Control

- Gains stable vertical head position.
- Lifts and turns head in prone.
- Engages in meaningful visual gaze.
- Develops social smile.
- Vocalizes with movement; begins cooing.
- Swipes with arm and hand when supine; begins goal-directed reaching.

Four to 6 Months—Development of Upper Trunk Control

- Pivots in prone.
- Rolls supine to prone and prone to supine.
- Plays with legs in air in supine.
- Develops ability to sit alone (but cannot move into and out of sitting).
- Frees hands in supine, prone, and sitting for manipulation of objects; poking with fingers.
- Utters long repetitive sound sequences, varying pitch, intonation, and loudness.
- Vocalizes pleasure or displeasure.
- Coordinates arm and hand control with vision.

Six to 9 Months—Lower Trunk Control

- Mobility in prone; crawling, creeping.
- Moves into and out of sitting.
- Bounces in standing, pulls to stand; cruises.
- Refines arms and hands for pointing, precise release, transfer hand to hand; finger feeding.
- Produces long chains of combinations of vowel and consonant sounds—babbling.

Nine to 12 Months—Lower Extremity Control in Upright Position

- Creeps with increased velocity.
- Activates feet in transitions to sitting, creeping, and walking.
- Takes first independent steps.
- Walks with or without using arms for balance.
- Refines manipulation based on size and shape of object and task or goal.
- Holds and manipulates two different objects.
- Produces first real words.
- Uses jargon; engages others in conversation.

MD is a complex progression based on (1) neural system organization, (2) perceiving and accommodating to environmental demands, (3) body changes that accompany growth, and (4) the interplay and continuity of development of various body systems. Directionality of development results from interactive functioning of internal systems that infants bring to the exploration of a task and the capacity to benefit from the environmental context. The question remains, What enhances or constrains this seemingly effortless and orderly progression?

14.3.3 What Supports the Progression of Motor Development?

The progression from non–goal directed mobility to accurate and skilled movement is supported by principles of (1) variability, (2) competition of motor patterns, (3) development of postural control, and (4) links between the sensory and motor systems. The following sections examine each of these concepts and relate them to NDT practice.

Variability in Motor Development

Variability is the capacity to link movement to intention and the ability to select from a wide repertoire of possible motor solutions the one most appropriate for a specific situation.[32] Variability is the broad spectrum of motor behaviors that characterize every typically developing infant's movement. Variability is seen in the spontaneous arm, leg, and head movement of newborns[32,33] **Fig. 14.2a, b** and has been shown to be characteristic of early sitting,[34] reaching,[35,36] and independent walking.[37] The role of variability in MD supports those NDT assumptions that focus on the dynamic nature and system interactions of MD. In 2010, several investigators described the variability in posture and movement as an essential element of both development and motor learning.[20,21,38] Once thought to be a constraint on development, variability is described as a driving force, giving the infant and child nearly unlimited possibilities with which to explore the environment, relate to persons, and develop a repertoire of movement strategies to solve motor problems. Variability reflects adaptations to changes in the biomechanical properties of the growing musculoskeletal system, maturation of the nervous system, changes in the environmental conditions, and increasingly more effective solutions to task demands. In the infant developing typically, both the amount and the quality of variability change over time.

Heineman et al[21] stress that in the process of learning, the infant (and later child and adult) selects the most appropriate movement variation to allow increasingly complex skill. This capacity to select and match movement with the task goal is indicative of humans' capacity for adaptive variability.

In infants developing typically, both the amount and the quality of variability change. Some variability must decrease to lead to increased consistency in outcome, whereas variability in other parameters increases to boost flexibility in performance. For example, a decreased variability in postural control is needed for a child to gain stability in the upright posture and to be able to attend to tasks, accurately perform functional activities (e.g., speech and manipulation of objects), and use these functions in activities of daily living. On the other hand, an increase in variability in hand movements leads to the development of in-hand manipulation of a wide variety of objects. Grasping depends on the correct hand orientation and the ability to switch between power and precision grips. Think of the ability to pick up coins with the radial digits while holding additional coins in your hand with the ulnar digits.

Von Hofsten and Rönnqvist[39] presented evidence that neonates' spontaneous arm movements show distinct patterns of spatiotemporal organization that have one acceleration and one deceleration phase similar to those that occur in the reaching patterns of 5-month-old infants. However, in the neonate, the movements of the two arms are strongly coupled in all three planes, moving together along the body's longitudinal axis, abducting and adducting together, and extending together in the forward direction. By 4 months of age, the trajectory is irregular and fragmented as the infant experiments with single-limb reaching. In order for the movement to become straight and fluid, purposeful reaching and manipulation involve, at the very least, postural control; development of control of arm movements (kinematics) against the force of gravity; development of a flexible coupling in eye–head and hand coordination and coordination between the two hands; shaping and molding of the hand as a terminal device; interpreting exteroceptive,

Fig. 14.2 **(a)** This newborn shows variability in arm and hand posture. The arms are symmetrical with hands fisted asymmetrically. **(b)** The newborn also shows variability with the arms asymmetrically postured and the hands fisted symmetrically.

proprioceptive, and visual information; developing control of strength, velocity, timing for initiation, and braking; as well as experience, learning, and desire.[35,39,40]

Infants have complex variability in grasp patterns produced by multijoint actions, but this must change for the infant to develop precision involving subtle single-joint motions with infinite combinations. Generally, the hand shape depends on specific objects in the environmental context. The hand shapes itself around an object and accommodates its own shape to the shape of the object. To do this, the hand must be expandable and malleable, and patterns of grip must be sufficiently variable to shape around both large and small objects. At times, the hand needs to be powerful and at other times delicate in its approach to grasp and manipulation. The ability of the hand to be functional in all these situations depends on the balance between the long finger flexors and extensors, the capability for alignment between the wrist and hand, the mobility of the carpal and metacarpal bones, and the activity of the intrinsic muscles of the hand. These biomechanical contributions, including the kinetics and kinematics of the upper extremity (UE), play an important role in the development of reach and grasp. Compromise of any of these anatomical structures or intrinsic movement dynamics will constrain hand trajectory, joint coordination, and muscle activation patterns. Increased variability is a source of information for exploration, tool use, and other task-specific actions[38] (**Fig. 14.3a–c**).

How Does Variability Impact NDT Intervention?

NDT therapists appreciate individual variability in task solutions and recognize that when a person is gaining (or regaining) a skill, active problem solving involves trying out various solutions, some of which may seem awkward, inappropriate, and even counterproductive to the developmental process. Clinicians allow individuals to experiment and discover what works best for them within the parameters of their musculoskeletal and neuromuscular abilities and constraints. Therapists also recognize that there is a developmental process to variability with periods of organization, variability, and reorganization as new skill develops. With greater variability, less postural muscle activation is used to stabilize the person against gravity, and there is more activation of muscle groups that create precision movements. Therapists are, therefore, responsible for recognizing which components of posture and movement are needed for skill development and for guiding or limiting the individual's experimentation in order for this process to occur in a timely manner to ensure optimal development or recovery.

Lack of variability may be indicative of neuropathology in both full-term and preterm infants.[41,42,43] Variability is inherent to human behavior and is needed for exploration and interactions; however, therapists need to recognize when variability serves the development of the child and when it constrains function so they can adjust intervention strategies to the need of the child at the moment. For example, a child with athetoid cerebral palsy has too much variability when attempting intentional movement. The excessive movement often includes muscles normally used for postural control so that posture is not sustained. NDT therapists develop intervention strategies that focus on slow movements in short ranges to allow postural muscles to be used to their physiological advantage in patterns of coactivation and support for function (see assumptions 6, 9, and 11 in Section 14.2 earlier in the chapter.)

Competition in Motor Patterns

Closely linked to the principle of variability is the concept of competition in motor patterns. Kong and Quinton developed methods of early detection and described



Fig. 14.3 **(a–c)** Variability in hand grasp patterns in an 11-month-old child is adapted to different orientations to manipulate both large and small objects.

competition of motor patterns in infants developing typically as well as in infants with neuropathology.[44,45] Like the principle of variability, this concept is supported by theories of motor control and the current literature on human development.[21,38,46,47] Quinton describes three characteristics in normally competing movement patterns. First, one pattern of movement never dominates any other. For example, one instant a newborn may show asymmetry in the arms, and in another moment, show symmetry as shown in **Fig. 14.4a, b**.

Second, competing patterns develop simultaneously. For example, at 4 to 5 months of age an infant in supine demonstrates flexion of the pelvis, hips, and knees, whereas in prone the infant shows pelvic extension with hip and knee extension as shown in **Fig. 14.5a, b**.

Third, each new pattern competes with previous patterns. New movements are based on the infant's experience with previous patterns and the effort to combine an old pattern with some new attributes, such as postural control. The old pattern may temporarily overpower the structure of the newer, less practiced pattern, destabilizing the organization of movements, and then reorganize movements into broader functions, such as creeping on different surfaces as shown in **Fig. 14.6a, b**. For example, as a child works to constrain alternating hip flexion with extension to creep on the hands and knees, the earlier pattern of crawling with the belly in

Fig. 14.4 **(a, b)** Competing arm postures in 10-day-old infant.

Fig. 14.5 **(a, b)** At the same time that an infant demonstrates flexion in supine she also shows development of extension in prone.

contact with the support surface, which does not require such precise coordination of hip flexion and extension, is still often seen.

We have already seen that infants developing typically have repertoires of movements that can be arranged in endless combinations. Through continual experimentation, these repertoires become linked to sensory inputs to form meaningful functions. Both competition and variability exist in the emergence of a function and are critical elements in typical development. At no time does one pattern of movement dominate to the exclusion of any other patterns.[21,45] With repeated experience, the infant developing typically prefers and repeats those posture and movement patterns that best fit the infant's particular morphology, developing body systems, and desire to produce movements that have increased adaptability.

What happens if the infant has atypical movement patterns? Most investigators agree that an early expression of a brain lesion is a reduction in variation and complexity in motor behavior.[21,22,32,48,49] Infants with neuropathology begin life with a reduced variability in their primary repertoires and with a nervous system that is less capable of managing competing motor patterns. The infant, while practicing with limited movements, limits the opportunity of experience with additional movement repertoires. For example, the more time that the infant spends with the head turned to one side in

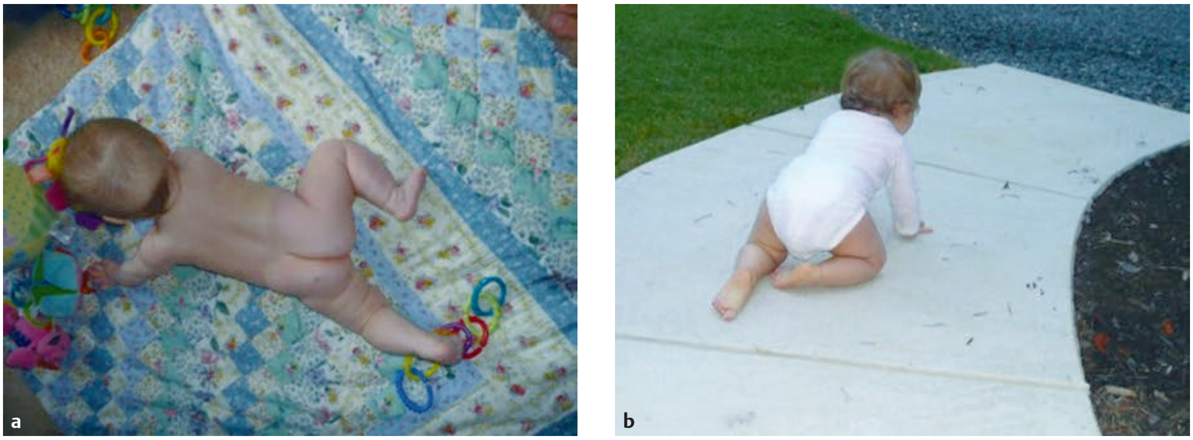

Fig. 14.6 **(a)** Crawling with excessive hip and knee flexion. **(b)** Creeping with controlled excursions of hips and knees.

supine, the more the musculoskeletal system molds to the effect of gravity and the neuromuscular system accepts this as "the new normal." Keeping the head turned to one side becomes easier and maintaining the head in the midline harder, reducing the opportunity for developing the hand-to-mouth function. Subsequently, rather than alternating between symmetry and asymmetry, asymmetry dominates, and variability and experimentation in supine decrease.

Once an infant developing atypically continues to practice and experience movement with a limited repertoire, the motor patterns become more stereotypic, further limiting movement exploration. The reduced variability in movement is accompanied by a limited repertoire of postural adjustments and the capacity to adapt posture to the specifics of a situation, which forces the infant to use the same strategy for all tasks and limits exploration.[50]

In summary, infants developing typically present with a highly complex repertoire of movement possibilities. When the internal body systems are intact, the competition of motor patterns leads to selection of appropriate stable, yet flexible, movements that combine posture with movement in optimal ways to solve increasingly complex motor problems. Infants who have impairment of the neural or body systems, however, present with limited repertoires and practice ineffective motor strategies that limit their movement experiences. Infants born prematurely with a poorly regulated nervous system or persons with an impaired neural system are unable to benefit from implicit experiences. As stated in assumption 11 in Section 14.2, NDT therapists, guided by the knowledge of MD, construct intervention strategies to aid these infants in perceiving and experiencing movement possibilities and lead them to develop strategies to improve motor control.[51,52] Case Report B6 on Jagraj provides examples of applying these principles in a program for oral-motor control and oral feeding.

The Importance of Competition of Movement in NDT Practice

As NDT therapists observe postures and movements in children, they recognize infants and children prefer one posture over another, or one movement pattern over another, but that this is not necessarily a sign of atypical development. Families may strongly adhere to the principles of Safe to Sleep programs, and the infant may have had little opportunity to spend time in prone. Or the infant's room may be set up so that stimulus comes from one side, or the infant may be adapting to the parents' strong preference for holding and carrying. Therapists consider external constraints as well as internal system impairments when analyzing preferences and variations in posture and movement. As long as the typical competition among motor patterns does not inhibit the infant's success in reaching the goal (e.g., turning over, bringing hand to mouth, feeding, or vocal play), variation is valuable in the search for multiple ways to engage with the world.[32] For this reason, the NDT therapist observes movement in every position available to determine whether a preference for a posture or movement is (1) an expression of typical competition among well established movement and newly developing ones, (2) an attempt to maximize opportunities for exploration, (3) a function of the child developing body systems, or (4) an indicator of atypical development.

The Role of Postural Control in Motor Development

Postural control is a critical part of the development of the body's movement in and through space, skilled manipulation, locomotion, speech, orientation, and attention.[21,25,34,53] Postural control depends on inputs from visu-

al, vestibular, and somatosensory receptors, as well as the ability of the CNS to interpret each input. The neural system must activate, time, and execute synergistic muscles at mechanically related joints to ensure stability while permitting mobility at other joints, all the while comparing the executed movement with the intended action.[54]
Postural control includes the following:

1. Alignment and weight bearing.
2. Proactive or postural orientation that anticipates the appropriate relationship among body segments in a task-specific context.
3. Postural stability or steady-state balance, which is the ability to maintain the COM within the limits of the base of support (BOS).
4. Postural adjustments or equilibrium reactions, which are flexible, variable responses to perturbations from the environment, self-induced movements, or a moving support surface.

The gradual development of postural control constrains developmental milestones requiring body control against the force of gravity and enhances motor skills that entail orienting body segments to each other and to the effects of gravity. For example, as postural control develops in prone, the 4-month-old infant changes from rolling as a unit to rolling with dissociation between the pelvis and shoulder girdles, as seen in **Fig. 14.7a, b**.

In a different example, seen in **Fig. 14.8a, b**, an infant can take full body weight on the legs at 4 months of age but cannot stand unsupported until 11 months, when postural control develops in standing.

The development of postural control requires the integration of sensory information to assess the position and motion of the body in space and the motor ability to generate forces for controlling body position and to prepare for the reactive forces of movement. In a general way, the development of postural control in infants and children follows a cephalocaudal progression—control of the head and neck preceding that of the trunk, which precedes the hips and lower extremities (LEs). This progression results from the interaction of multiple neural subsystems and the biomechanical aspects of the musculoskeletal system to meet the goals of orientation and equilibrium as infants develop optimal ways to adjust their body over their BOS.[34]

Various components contribute to the emergence of postural control for independent stance and locomotion, including (1) sensory subsystems that include visual, vestibular, and somatosensory systems for detecting imminent (or threatened) loss of balance; (2) motor mechanisms, including postural tone and muscle synergies, for controlling balance; (3) adaptive systems for modifying sensory and motor systems to changes in task or environment; and (4) biomechanical and kinesiological forces and body morphology for alignment and weight bearing.[34,54,55,56]

Several researchers[57,58] have investigated the effects of vision on postural control in sitting and standing. Although results have varied somewhat, most researchers agree that newly sitting infants rely heavily on visual inputs to control body sway. This dependency on the visual system decreases with experience and with the formation and control of postural muscle synergies, as seen in **Fig. 14.9a, b**. As infants mature, they become less dependent on vision and rely more on the faster transmission of vestibular and body proprioceptors to control postural action.[59] By the time an infant can sit independently, postural responses are direction-specific and controlled primarily by somatosensory inputs and correlated with spontaneous goal-oriented motor behavior.[60]

Shortly after they begin to walk, if infants are confronted with conflicting sensory information, they are able to ignore misleading visual information and use somatosensory information to control equilibrium[61,62] (**Fig. 14.10**).

Adult-like responses with minimal sway, however, are not apparent until early school years. These adaptive capabilities indicate that the child is able to modify sensory information and form new motor strategies in accordance with changing task and environmental conditions, even though this capacity is not refined until the child is ~ 7 years old.[62,63]

Periods of instability in postural control can also result from changes in skeletal growth and the child's attempt to adapt body alignment to new skeletal length and morphological relationships among body segments. Musculoskeletal changes progress rapidly in the first few years of life and are influenced by internal muscle and skeletal development and external mechanical and gravitational forces.[64]

Fig. 14.7 **(a, b)** When rolling at 5 months of age, postural control is needed to orient body segments to each other and to the effects of gravity.

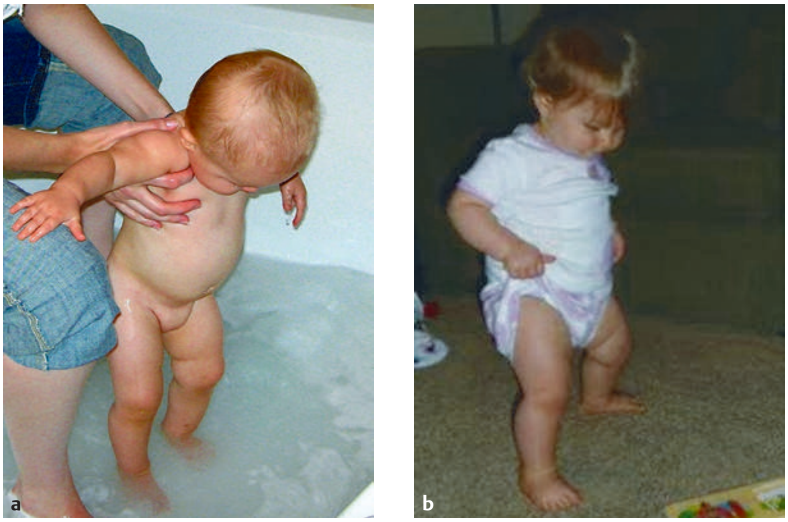

Fig. 14.8 **(a)** Weight bearing is possible at 4 months of age, but independent standing is constrained by lack of postural control. **(b)** At 11 months of age, postural control allows for independent standing.

Fig. 14.9 **(a, b)** By 8 months of age, postural control in sitting depends on somatosensory input at hip joints. The infant is free to focus on a near toy or a distant person and is not dependent on vision for postural responses.

Postural control requires generation and coordination of forces that effectively control the position of the body in space. Hedberg et al[65] reported that infants as young as 1 month old demonstrate a basic level of organization of postural adjustments to external perturbations. However, precise muscle synergies that control spontaneous sway to remain upright continue to develop over time. Infants without prior experience initially show irregularity and multiple strategies at the beginning of sitting, and over time they develop consistent, directionally appropriate responses to perturbations.[66] As neuromuscular responses become better organized, infants demonstrate a decrease in sway velocity, a decrease in onset latency, improvement in timing and amplitude of muscle responses, and a decrease in variability of muscle responses. For example, the emergence of independent sitting is characterized by the infant's ability to control spontaneous sway of the head and trunk with anterior/posterior and side-to-side perturbations. By the time the infant can sit independently, postural muscle synergies relating the head and trunk segments for postural control activate spontaneously, and the infant is stable.[60]

Stable posture is affected by the development of sensory and neuromuscular elements and by the alignment of body segments that contribute to stability in the upright position. *Alignment* refers to the arrangement of body segments with respect to one another as well as the position of the body with reference to the force of gravity and the BOS. In ideal alignment, the various parts of the body are maintained in a state of equilibrium with the least expenditure of energy.

Anticipatory components of posture establish a stabilizing framework that supports intentional movement. This feed-forward system occurs when a person anticipates and initiates the postural and movement requirements of a task proactively, in advance of the motor act. From the initial onset of sitting, infants show changes in

Fig. 14.10 Walking on a sandy beach in bare feet does not interfere with equilibrium in this 13-month-old walker.

Fig. 14.11 A 2-year-old boy experiments with a unique set of parameters that contains novel features.

posture in advance of most reaching movements.[66] Van Balen et al[67] found that reaching movements are accompanied by direction-specific postural adjustments 100% of the time between 10 and 18 months of age. The same activation relationship occurs in children in standing at a later age. These anticipatory components of posture take place before the infant is able to sit or stand unsupported, suggesting that the ability to activate postural muscles in patterns of feedback and feed-forward develop simultaneously.[68] The feed-forward components of posture are necessary for the child to initiate skills in postures against the force of gravity.

How Does the Development of Postural Control Influence NDT Practice?

The relative importance of each system (and subsystems) appears to vary with age and contextual demands. As infants gain a new posture, they must learn the critical parameters for the particular set of problems in that position, as well as develop new strategies to cope with changing conditions and the novel features. For this reason, learning postural control in prone does not directly translate to control in standing.[35,69] Because each position in development contains its own set of parameters, postural control must be learned as the child experiences and experiments in each position. Control in sitting (or standing) and transitions in and out of sitting (or standing) must be practiced in those positions so that the child can learn strategies to cope with the complexity of the position and the demands placed on various body systems. New strategies involve activating different muscle groups for balance and sway, using and correlating visual, vestibular, proprioceptive, and other sensory inputs to build perception–action linkages to predict postural needs for a variety of actions. Across time, both children and adults use a variety of strategies and find diverse solutions to the same challenge (**Fig. 14.11**).

Although broad, successful earlier experiences in other developmental positions are important, therapists cannot expect a child or adult who lacks postural control in standing to improve in this skill by practicing weight shift and balance while prone on the elbows. This concept is particularly important for older children and adults who have incurred a sudden brain insult from stroke or head injury and discourages an approach based on the traditional sequence of developmental positions. For example, in an NDT approach an adult who needs to develop functional shoulder and arm movements or stability after stroke can work on weight bearing with a modified grasp on a railing (**Fig. 14.12**) or while standing at a counter while washing his face, grooming his hair, or retrieving silverware. In **Fig. 14.13**, the woman doing her laundry has been assisted to include her right arm in her base of support. These postures are more effective ways to develop shoulder stability because they tap into meaningful functions such as self care, recreation, and occupation.

Fig. 14.12 Ron uses a small towel, which provides less friction as he supports and progresses his arm and hand forward on a railing.

Fig. 14.13 Engaging in a typical activity for this patient post-stroke assists her to begin to regain shoulder function.

Perhaps not as obvious are the changes in postural control with advancing age. Older adults face challenges in postural control with changes in physical functioning. Many factors contribute to changes in posture and declining balance in older adults. Various studies have documented impairments in the sensory systems, including changes in visual, somatosensory, and vestibular senses, and changes in the neuromuscular and musculoskeletal systems—body systems that are fundamental to everything we do. Every task requires a stability component (to maintain the COM over the BOS) and an orientation and anticipatory component (to maintain appropriate relationships between body segments in specific contexts) to support action.[3,4,5,70]

Requirements for postural control change over the life span, with new environmental requirements and increasingly demanding functions, which include time constraints, energy demands, and complex activities. NDT therapists are cognizant of each client's need for postural control and develop intervention strategies to include both elements of posture and movement. Since muscles used primarily for postural control and those used for movement differ in their physiology, spinal inputs, and neural mechanisms, therapists must be conscious of the requirements placed on various muscle groups. This concept of control of postural muscles and movement muscles is discussed in Chapter 4.

Changes in postural control that occur in persons with CNS dysfunction might be typical variations that develop with various experiences in movement during the developmental and aging process or might result from the type, location, and extent of neural lesions and the primary or secondary impairments resulting from this pathology. In short, postural control is a multidimensional issue, and the specific relationship of postural control and functional limitations is often difficult for clinicians to determine.

Sensory Systems Contribution to Motor Development

All the body systems contribute to motor development, but it is beyond the scope of this chapter to enumerate all the contributions made by the various body systems. This section focuses only on the sensory (sub)systems, which serve to link perception to action. Sensory feedback and feed-forward are important aspects of motor development beginning with the newborn. The extrauterine environment contains gravity, light, and sound—forceful first effects on development. The infant begins to select responses (and eliminate others) due to the feedback from specific tasks, such as sucking or soothing, that are practiced in context.[71,72] All sensory systems are active at birth, but various sensory systems influence the infant's motor development in different ways and at different times. For example, the visual and auditory systems are the infant's first link with people and the environment.

In infants and young children, vision is the most powerful sensory system in regulating posture, both in feedback correction and in feed-forward anticipatory postural strategies. Bertenthal and von Hofsten[58] reported that infants as young as 60 hours of age orient by righting their head toward a source of visual stimulation when their head and trunk were supported. However, as previously discussed, the lack of strength due to an immature musculoskeletal system and the mass and weight of the head constrained the postural response so that infants were unable to maintain head stability and alignment, as seen in **Fig. 14.14**.

Vision has also been linked to acquisition of language and speech production abilities in infancy. Lewkowicz and Hansen-Tift[73] tracked four English-learning infants listening to a voice reciting words in English and in Spanish. Between 4 and 8 months of age, the infants shifted their attention from the eyes to the mouth and back to the speakers' eyes regardless of the spoken language, but by 12 months they maintained eye contact when English only was spoken. The researchers propose that young children shift their gaze to use redundant audiovisual cues when recognizing and learning language, but older infants, who are familiar with their native language, focus on the speaker's eyes to gain social cues. Nyström[74] reported that 6-month-old infants showed the capacity to understand language (and social) cues when they observed goal-directed actions.

Vision has also been associated with the link between perception and imitation. Infants are capable of imitating facial expressions that they see. This ability links the visual system with a mirror neuron system in the brain and supports behaviors used in social interactions and the infant's motivation to connect to meaningful persons.[75]

Beginning with body exploration, the tactile system is important for self-perception. As described earlier in this chapter, the contact of the newborn's face with the support surface is an important part of tactile input to the cheeks and lips. The combination of the visual and tactile systems plays a role in the development of infant reaching.[76] The somatosensory system is linked to sleep states, stress responses, and self-regulation in newborns.[77] The proprioceptive and vestibular systems are used in anticipation of postural disturbances. Perceptual, visual, and tactile systems are significant for the development of fine motor and manipulative skills. This sensory–perceptual–motor–sensory linkage is shaped by a supportive environment and appropriate management by persons in the environment.[78,79] Movement uses sensory information in two systems of control—feedback and feed-forward—which are described and illustrated in Chapter 13.

Fig. 14.14 Orientation of the head with visual input at 2 months.

Changes in the Musculoskeletal System: Critical to Motor Development

Changes in the musculoskeletal system are strongly linked to the neuromuscular system in children developing typically. Impairments in the musculoskeletal system impact both posture and movement in children and adults with neuropathology. For these reasons, this system will be discussed separately for adults.

Newborn infants have immature musculoskeletal systems—bones are not completely ossified, and weight-bearing joints are not fully formed. The musculoskeletal system can be easily influenced by positioning, especially in infants born prematurely or those with neuropathology who do not move or who have limited variability. Generally, infants show a dominant flexed posture in both supine and prone as seen in **Fig. 14.15a, b**, a physiological characteristic from intrauterine positioning and shortened flexor muscles.

Even early vigorous kicking and active wide swipes of the upper extremities do not display full extension of the joints. These movements are random and unorganized but do contain the elements of more complex movements that will be used for crawling, walking, or reaching out. These early movements become part of repertoires used to interact with objects or people, for self-comforting, and to change positions. From the musculoskeletal and biomechanical perspective, they serve to activate the extensor muscles and lengthen the flexor muscles.

Newborns do not have full range of motion (ROM) or sufficient muscle strength to oppose gravity. Organization of the system is driven by spontaneous movement exploration and the sensory feedback from those actions within the physical laws of the environment.[33,80] Infants develop muscle length before they use muscles in synergies against the force of gravity. NDT therapists follow this same sequence of development of the musculoskeletal system in planning effective programs for persons with neuropathology.

Muscle strength is an important factor in the development of postures needed to oppose gravity, maintain the upright posture, and anticipate and respond to perturbations. But for strength to develop, the child must gain muscle length. Until 4 months of age, limitations in active spinal extension, hip extension, hip internal rotation, and shoulder flexion constrain the coordination of movement patterns of reciprocal kicking, stepping, and reaching.[40,81] Infants gradually increase the ROM at each of their joints

Fig. 14.15 **(a, b)** A 10-day-old infant with flexed posture in supine and prone.

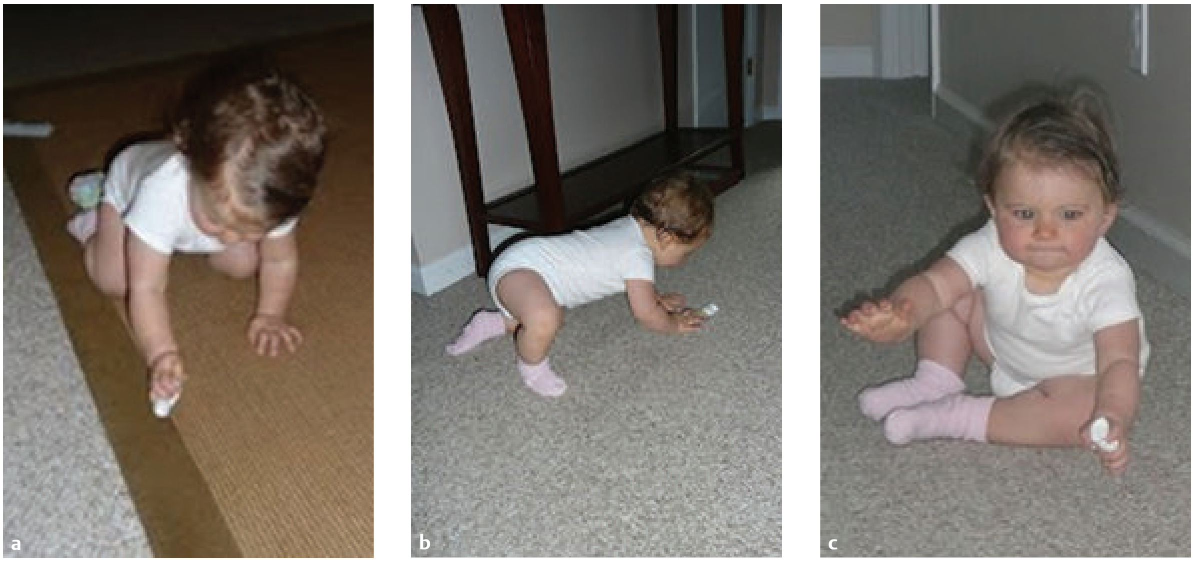

Fig. 14.16 **(a–c)** Transitions from creeping to sitting at 8 months of age with rotation around body axis.

by practicing a variety of movements in the sagittal, frontal, and transverse planes as seen in Fig. 14.16a–c. They experiment with active flexion and extension in supine; extension then flexion in prone; lateral weight shifts to each side in supine, prone, sitting, and standing; and rotation around the body axis as they transition in and out of these positions.[25,45]

Flexion and extension occur in the sagittal plane, lateral movements of abduction and adduction occur in the frontal plane, and rotation occurs in the transverse plane. As the constraints on joint range and muscle strength become more flexible, so do the muscle activation patterns involved in motor control. Normal movement is characterized by orderly phasing in and out of muscle activation, coordinating coactivation of muscles with similar biomechanical functions for posture and phasic activation of muscles designed for speed and range.[82,83,84] Changes in the characteristics of movement are linked to the stresses placed on the musculoskeletal system and to activity opportunity and practice in various positions.[47] Infants who are healthy and eager to move challenge their bodies to even more interesting opportunities.

How Do Impairments in the Musculoskeletal System Affect NDT Practice?

Many individuals with neuropathology develop a wide range of musculoskeletal impairments, including hip dislocation, scoliosis, contracture, overuse syndrome, weakness, and arthritis. Particularly in adults, these secondary musculoskeletal impairments have a great impact on the individual's ability to carry out daily living tasks and impact severely on societal participation.[85,86] NDT therapists are cognizant of the effect of secondary impairments on the infants and adults they treat and plan intervention strategies both to take into account existing musculoskeletal impairments and to reduce the potential for secondary effects.

Infants with CNS pathology maintain only a few positions and do not make transitions between positions. Even within a position, movement shows limited variability leading to a limited repertoire of general movements.[21,43] These infants have difficulty activating and elongating their muscles; consequently, they may never experience full ROM of their joints and become vulnerable to muscular contractures and skeletal deformities.[64,86] Children with CP have impaired abilities to activate appropriate muscle synergies in response to the demands of the task. They often exhibit reduced speed of movement, abnormal reciprocal muscle activation patterns, or excessive coactivation.[87,88] NDT therapists plan intervention strategies that target appropriate muscle synergies in tune with the task and environmental demands. NDT therapists recognize that all movement requires both posture and movement. However, various times within a single intervention session, the clinician moves from strategies that selectively address either coactivation for postural control, or movement components that are needed for speed and accuracy to produce a meaningful functional skill as described in Chapter 9 in Unit II.

Adults who have had a stroke also show constraints on posture and movement based on musculoskeletal impairments.[54] Movement in either supine or prone is performed with difficulty given that the entire body is the BOS and the extremities are long and heavy; consequently, any activity in these positions must resist both friction and gravity. Intervention often begins with the client upright in a chair to provide an easier (and familiar) position.[89] Musculoskeletal impairments, such as decreased spinal mobility or diminished ROM of the hips, knees, and ankles, may restrict a client's ability to move from sit to stand so the therapist selects strategies that take these coexisting musculoskeletal impairments into account.

14.4 Summary

NDT recognizes that development of motor behavior is not a linear progression but is based on a dynamic process that includes (1) ongoing development, organization, and interplay of internal body systems; (2) adapting to and learning from environmental demands; (3) internal changes accompanying growth and aging; and (4) changing task goals throughout the life span. Even the infant's earliest motor synergies are inherently complex and variable, designed to obtain information and stimulation from their world.[90] They continually reorganize and form new combinations of posture and movement suited to accomplish tasks commensurate with emerging physical capabilities and needs of the individual. Different phases of the human life span are characterized by changing motor behaviors designed for efficient functions at those times. Infants and children develop many motor behaviors simultaneously in different positions against the force of gravity, eventually preferring some over others to solve motor tasks. This same phenomenon is present in aging adults who must adapt to changes in the body systems and environmental contexts.

NDT therapists understand not only the progression of motor stages and the systems involved but also the underlying complexities that make the emergence of motor milestones appear so effortless. This knowledge of typical child development and application to motor changes throughout adulthood allows therapists to recognize the impact atypical development has on a person with neuropathology and design appropriate intervention strategies.

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15 Neuroplasticity and Recovery

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This chapter surveys the research in neuroplasticity that seeks to explain how structures and functions of the brain change in persons developing typically and persons with neuropathology. This body of research shows that the brain can reorganize in response to experience, training, and environmental demands. Neuroplastic changes in the brain may be optimized when practice and specific goal-directed activities are combined in a meaningful environment. The findings in neuroplasticity differ between adults with mature brains and infants and children with developing brains. However, this research points out that in a model of neurorecovery, such as Neuro-Developmental Treatment (NDT), the timing and intensity of intervention during critical periods of recovery can influence the brain of any age, albeit in different ways.

Various studies have demonstrated that therapeutic intervention influences neural reorganization. Constraint-induced movement therapy (CIMT) is one protocol that has been used to show a link between specific intervention strategies and intensity of intervention to neuroplasticity. Examples from that body of literature are presented in this chapter. However, the information from these studies supports many of the assumptions that are the foundations of NDT and are currently part of the NDT Practice Model. Specifically, that well-directed, intense, and well-timed precise intervention strategies can produce permanent changes in the brain, which are reflected in changes in function. The authors state that therapists need to become acquainted with the neuroplasticity research to consider how plasticity may be enhanced or restricted as they plan interventions for their clients. With this in mind, the reader is referred to the case reports in Unit V to link this body of research to the current NDT Practice Model when considering new directions in NDT intervention.

Learning Objectives

Upon completing this chapter the reader will be able to do the following:

- Describe how neuroplasticity is linked to brain development and changes across the life span.
- Differentiate between concepts of neuroplasticity in adults with mature brains and infants and children with developing brains.
- Describe factors that can enhance neuroplasticity (e.g., repetition, intensity, and environment) and how they can be incorporated in NDT interventions for adults and children.
- Describe how the concepts of neuroplasticity can influence the design of NDT intervention.

15.1 Introduction

One of the most exciting research topics of the past few decades is the study of brain plasticity and recovery. Plasticity is the ability of the central nervous system to reorganize its structure, connections, and function and its response to intrinsic or extrinsic stimuli throughout life.[1] Therefore, the brain and its function change dynamically in response to experience, practice, and the environment.

Emerging knowledge regarding neuroplasticity has enormous implications for the rehabilitation of infants, children, and adults who have sustained injuries to the brain. Impaired movement is a major consequence of neuropathology in adults and children.[2,3] As described in the International Classification of Functioning, Disability and Health (ICF) model, impaired movement affects a person's ability to perform functional activities and to participate fully in the home, school, community, and workplace.[4] In addition, there are direct and indirect costs associated with conditions such as stroke and cerebral palsy.[5,6,7,8] And, as medical care improves, the numbers of infants, children, and adults surviving with long-term neurological sequelae are increasing. Therefore, it is logical that individuals with neurological injury look to habilitation and rehabilitation options, in the form of physical, occupational, and speech therapies to address the effects of their injury and to aid them in achieving a full and productive life.

During therapeutic intervention delivery, the variables that practitioners manipulate may impact neuroplasticity positively as well as negatively, and influence functional gains for people with neurological conditions.[1,9] Therapeutic interventions, however, are diverse and vary among countries and regions. In the past, the philosophy of therapy has been one of either compensation or functional neurorecovery.[10,11]

In the compensatory approach to intervention, the therapist minimally incorporates the involved side in the functional activity, teaching the client to rely on the less affected extremity for function. As a result, compensatory movement patterns are developed to take the place of those lost as a result of the injury. One example might be teaching an adult or child with hemiplegia how to eat using only the less involved extremity.

In a functional neurorecovery model, such as NDT, the client is guided to use the affected extremities as part of the movement and to recover or relearn movements that were interrupted or lost as a result of the injury.

Our understanding of molecular, cellular, synaptic, and network neuroplasticity is currently more advanced with respect to animal models. However, research is in the decisive stages of identifying the mechanisms that lead to neuroplastic changes in the human brain and the application of this knowledge to the intervention for adults and children who have sustained brain lesions or injuries.[12,13] For example, the neurorecovery model has been incorporated into activity-based interventions, such as constraint-induced movement therapy (CIMT) and treadmill training, that are specifically designed to enhance function in a specific part of the body. These intensive interventions demonstrate preliminary positive outcomes supported by pre– and post–brain imaging data. As our understanding of brain plasticity grows, we will acquire additional knowledge to modify and create rationales for intervention. In the not too distant future it may be possible to augment neural repair and maximize functional outcomes after brain injuries using pharmacological, rehabilitative, experiential, and environmental paradigms.[9]

Our understanding of the developing brain and the possible mechanisms of brain recovery, adaptation, and/or compensation secondary to the effects of disease or injury supports and provides insights for the development of NDT interventions for individuals with neurological conditions.

15.2 How Is Plasticity Studied?

There are numerous technologies available to facilitate the study of brain plasticity and recovery in adults and children. The gold standard for visualization of brain structures or the extent of a brain lesion is structural magnetic resonance imaging (MRI). In the infant. it is most often used very early before myelination is fully developed, with follow-up at 18 to 24 months when myelination is complete and the brain structures can be fully visualized. When used in conjunction with diffusion tensor imaging (DTI), the white matter integrity or damage can be better visualized.[14]

Additional technologies that are employed to study the brain include functional MRI (fMRI), which measures changes in blood flow to detect and monitor brain activation during functional tasks (e.g., motor, language, and somatosensory stimulation) and transcranial magnetic stimulation (TMS) and evoked potentials (EPs) to quantify cortical responses to somatosensory or visual stimuli. However, because active cooperation is required, these technologies cannot be used in newborns, infants, and young children.[15]

15.3 Plasticity: Adaptive and Developmental

Prior to discussing current research associated with plasticity as it relates to the neurological conditions commonly treated using NDT, it is important to describe models of plasticity associated with recovery in adults and children. This information will aid in understanding key mechanisms that underlie the brain's ability to respond to injury. To address the broad nature of this topic, we divided this chapter into two neuroplasticity categories—adaptive and developmental plasticity.

15.3.1 Adaptive Plasticity

Adaptive plasticity is an area of neuroplasticity research that addresses how the central nervous system (CNS) maximizes remaining functions and compensates for lost function following brain injury. Research on adaptive plasticity is most advanced with regard to adults with stroke and is reviewed here. More recently, research on adaptive plasticity has expanded our understanding of this process in adults with spinal cord injury,[16,17] amputations,[18,19] and those with chronic pain.[20]

Neural Recovery and Neuroplasticity Process: Poststroke

Stroke is caused by an occlusion to the blood vessel or a hemorrhage in the brain, resulting in ischemia of the brain tissues (see Chapter 11 on stroke in unit II for additional information). Ischemia sets off a cascade of biochemical reactions leading to inflammatory processes and/or cell death and disintegration of supporting structures within 2 minutes of brain injury.[21] Following a stroke, treatments are targeted toward neuroprotection to decrease lesion size, neural survival, motor deficits, and, in turn, disability.[22]

When neurological structures of the brain are injured, the brain may demonstrate spontaneous recovery, defined as the ability to recover function without intervention. This type of recovery occurs predominantly during the first 3 months following the onset of stroke.[23] Spontaneous recovery from stroke is often attributed to resolution of edema and return of circulation in the area surrounding the stroke, called the *ischemic penumbra*—brain tissue that surrounds the main brain injury site area and is salvageable if intervention is provided within a certain time window to reestablish blood flow to the area.[24] In addition, resolution of diaschisis, a depression of blood flow and metabolism of remote sites that are connected to the site of injury, is also believed to play a role in spontaneous recovery.[25] See "Time-Sensitive Critical Period" later in this section for a discussion on using the spontaneous recovery period for NDT intervention.

Another critical contributor to recovery is neurological reorganization, which occurs at multiple levels of the brain—physiological, anatomical, and functional. Examples of neurological reorganization include changes in excitatory response and efficacy of spared cells, axonal sprouting, dendritic branching, and synaptogenesis. Any of these mechanisms may have the possibility of forming new connections in the cortical areas adjacent to or far from the site of the injury and rerouting and/or unmasking alternative neurological pathways.

The process of neural organization known as vicariation may access other structures of the brain to substitute for the function of injured areas.[26] There are several patterns of vicariation: (1) functional map extension accesses an area adjacent to the injury by reorganizing it to take over parts of the function of the injured site; (2) homologous region adaptation recruits the contralesional hemisphere to take part of the function of the injured site; and (3) cross-modal reassignment uses structures previously devoted to processing a particular mode of sensory input to accept input from a new sensory modality.

This process is reflected in the individual with a visual impairment who learns to read using tactile information. It is widely held that the neural structures which are functionally related to the injured areas can be a key to brain reorganization and support the recovery of function.[27] In addition, optimally administered rehabilitation intervention is believed to augment neurological reorganization and enhance the functional outcomes.[27,28]

15.3.2 Developmental Plasticity

Neuroscience research in animal models has contributed to our understanding of the consequences of brain injuries and the possible mechanisms of recovery in humans. However, we are also left with many questions and with the awareness that not all rehabilitation processes result in improved functional outcomes, particularly in the developing brain.[9] NDT therapists accept that functional outcome can be altered, for good or bad, through internal and external (i.e., environment, experience) dynamics. These variable dynamics are why NDT strategies are tailored to the individual client and reexamination is part of the NDT Practice Model.

In the developing brain, injuries can result from hypoxic, vascular, traumatic, or other etiologies, and the result of the injury is also influenced by location, age, and severity. In almost every case, the injury results in damage or disturbance to the neural networks causing glial and neuronal death, damage to axonal pathways, and disruption of the neurotransmitter and vascular systems.[29]

Reponses to neural insult, in the form of recovery, include restitution and substitution.[30] Restitution proposes that the damaged brain heals and function is restored. Substitution describes the reorganization of the brain through the transfer or reorganization of control to healthy areas of the brain.

Diaschisis, one form of restitution, was discussed earlier with respect to recovery in adults. Diaschisis is that period of rapid recovery that immediately follows a brain insult and allows for stabilization of undamaged areas and recovery of functions that have not been destroyed. However, there are also traumatic processes that accompany a brain insult, which may not be well tolerated by the developing brain. Studies of hypoxic ischemic insults in animal models during the perinatal period have shown that cell death can affect the neurotransmitter systems and disturb the balance of the developing brain. Therefore, injuries to the developing brain can result in poorer recovery than described in adults and have caused neuroscientists to consider the fetal and infant brain as structures that are more vulnerable to early injury.[14,29] That is, early injury may not result in the same recovery processes described in adults, and the brain's attempt to recover from injury may cause further damage. With respect to other recovery processes, regeneration, sprouting, and other mechanisms, there is little evidence to support the effect of these processes on the developing brain.

With respect to interventions to minimize further brain damage (i.e., brain cooling and pharmacological adjuncts), additional research is needed to determine if these interventions can successfully minimize the effect of early brain injuries and support improved brain plasticity.[31] In a review of eight randomized, controlled trials, the findings support the use and effectiveness of therapeutic cooling following hypoxic-ischemic events in newborns.[32] However, additional studies are needed to develop specific guidelines for the use of this intervention protocol.

Pharmacological interventions show several promising options designed to minimize the effects of injury to the developing brain. For example, antenatal magnesium sulfate administered during preterm deliveries has been shown to reduce mortality and long-term neurological sequelae, but the results are not consistent. Divergent results may be related to the gestational age of the infant, when the drug is administered, and/or the dosage.[33] Further studies are needed before this intervention can be considered beneficial in preventing the long-term effects of early brain injury. Finally, plasticity and recovery may also depend on factors such as age at the time of the insult and environmental factors.

15.4 Neurophysiology of Brain Injuries in Infants

Animal and human studies show that neural plasticity is present in the adult and infant brain.[15,34] Studies of brain insults in infants reveal that structural pathology depends more on the age of the fetus or infant and the developmental stage of the CNS at the time of the injury rather than on the precise nature of the injury itself.[35,36] Injuries to the brain that occur in the first and second trimester of the pregnancy influence neuronal proliferation, migration, and cortical organization of the developing brain and result in malformations of the brain structure.[14] In the third trimester of pregnancy (i.e., after 24–28 weeks of gestation), brain insults result in gliotic or cystic lesions of the brain, which predominantly manifest as damage to the periventricular white matter and cortical, subcortical, and deep gray matter of the brain.[14]

Infants are particularly vulnerable to white matter injury between 24 and 36 weeks of gestation, whereas gray matter injuries more commonly occur in the late trimester, after 36 weeks of gestation. In each type of injury, the resultant effect on function is related to which brain structures are disrupted and to the extent of the injury.

15.4.1 Injuries to the Developing Motor System—Corticospinal Projections

Corticospinal projections sprout in the motor cortex and migrate away from the brain, creating pathways that will eventually connect the cortex with the brainstem and spinal cord. By 20 weeks of gestation, the corticospinal axons arrive at the level of the cervical spinal cord segments and through synaptogenesis make connections with target cells, predominantly α motor neurons, at each level of the spinal cord.[37]

During the developmental period of the corticospinal tract (CST), each hemisphere sends ipsilateral and contralateral corticospinal projections to innervate α motor neurons in both the ipsilateral and contralateral segments of the spinal cord. As development continues, this competition resolves, and the contralateral projections are strengthened while ipsilateral projections are withdrawn.[38] This process continues in the last trimester and throughout the first year of life.

In the case of a brain insult in gray matter, ipsilateral projections from the noninjured hemisphere can play a role in innervating spinal motor neurons on the contralateral side of the injured hemisphere, thus ensuring that corticospinal connections can be achieved even in the absence of projections from the contralateral hemisphere. The presence of these ipsilateral projections may be significant in the reorganization process following a brain injury, particularly in the pre- and perinatal periods, which coincide with the development of ipsilateral and contralateral projections.[39]

Magnetic resonance imaging (MRI) can be used in children with brain insults to assess the presence of ipsilateral projections arising from the noninvolved cortical hemisphere. Functional hand movements during imaging can reveal whether the movement is associated with activity in the injured or the noninjured hemisphere. This finding would indicate that both of the child's hands share input from the same hemisphere.[15]

Another mechanism that can significantly disrupt the CST occurs when the brain injury causes significant white matter damage to the internal capsule (e.g., a periventricular injury). This can damage the crossed corticospinal projections from the motor cortex, as they pass through the internal capsule on their way to the brain stem and spinal cord. In this scenario, the CST projections from the noninjured hemisphere, often detected with MRI, can innervate the spinal cord on the involved side.

With regard to hand function and ipsilateral CST projections from the noninjured hemisphere, many children who demonstrate minimal to moderate control of the involved hand and fingers have MRI findings that have traced movement ability back to the ipsilateral CST projections. However, there have been no reports of near-normal hand function supported by ipsilateral CST projections alone.[40]

However, there are children with ipsilateral projections who have no functional use of the involved hand. This may be in part related to the age at which the injury is sustained. It seems that earlier injuries to the brain result in a prognosis of greater functional use of the hand.[41] As a result, despite the presence of ipsilateral projections, there will be some children who will not develop functional use of the hand if the injury to the brain occurs at or around term age. If this information is available to the NDT therapist, it can be useful for program planning and setting realistic outcome goals.

15.4.2 Injuries to the Somatosensory System

The age of the infant at the time of the brain insult influences an infant's ability to receive afferent sensory information, including tactile and proprioceptive information. Information travels via the posterior column–medial lemniscus pathway to the thalamus and connects via thalamocortical projections through the internal capsule to the sensorimotor cortex. These thalamocortical fibers reach their destination during the third trimester of pregnancy (28–40 weeks of gestation). If a periventricular injury causing damage to the internal capsule is sustained before the onset of or in the early weeks of the third trimester, the thalamocortical projections can bypass the injured area and reach the primary sensorimotor cortex.[42] When damage to the internal capsule occurs later in the third trimester or during the perinatal period, the path of the thalamocortical projections through the internal capsule has been completed and those neuronal projections will likely be damaged together with the internal capsule, thus interfering with their ability to reach the sensorimotor cortex.[43] Confirmation of such reorganization of the sensorimotor system gives rise to an additional hypothesis regarding restructuring of the brain following early-gestation-stage injury.[42,43]

This information is important to therapists because it implies that the delivery of sensory information may be perceived and processed differently depending on both the type and the age of the injury. The evidence also implies that some infants who sustain brain insults at the end of the third trimester or during the perinatal and postnatal periods may have significant impairments to the sensory system, which should be considered when planning intervention. Therapists might consider using additional sensory information (e.g., visual and/or verbal cues) to augment or replace the feedback normally acquired through the tactile sensory input.

Another form of the reorganization of the sensorimotor cortex has been studied with respect to middle cerebral artery (MCA) injuries, which affect adjacent corticosubcortical areas of the brain, particularly those injuries that cause damage to the postcentral gyrus where the sensorimotor cortex resides. To date, there has been no evidence to support cortical reorganization in these areas following brain lesions resulting from damage to the MCA.[42,44]

15.5 Applying Concepts of Neuroplasticity to Adults and Children

15.5.1 Concepts Applied to Adults

One of the principles of the NDT Practice Model is to provide therapeutic services that guide clients to the most optimal functional outcomes. The NDT model looks at the therapeutic environment as a way to guide the client to (re)learn activities to maximize participation and quality of life.

Therapists take into account the knowledge necessary to design therapeutic interventions that promote neuroplastic changes that will support the anatomical/physiological/behavioral remodeling necessary for optimal client function. Unfortunately, the available evidence is difficult to apply, and we are far from understanding the relationship between the evidence and the intervention.

This section discusses three parameters: (1) predisposing nontherapy-related factors that affect plasticity, (2) therapy that has been shown to support neuroplastic change and functional improvement, and (3) therapeutic technologies or intervention strategies shown to optimize functional results that can be correlated with neuroplastic changes.

Predisposing Factors That Affect Neuroplasticity

Age

Normal aging is associated with neurological atrophy and degradation.[45] It is reasonable to hypothesize that neuroplastic change and functional gain slow with age. Studies in animal models support this assumption by demonstrating that neurological repair in response to stroke is delayed or diminished with age.[46] However, direct correlations between the integrity of the brain structures and clinical manifestations in older adults do not always exist. Adaptive neuroplastic changes with aging may be responsible for older adults who can perform neurocognitive tasks as well as younger adults despite the natural degradation of the brain that occurs with aging.[47] Thus we can expect qualitative and quantitative differences in how learning is reflected in younger and older adult brains.

Variables Related to Brain Injury

Although there are many discrepancies in the research results, scientists are beginning to uncover which brain injury parameters are good predictors of functional therapeutic outcomes. Some studies[48,49] suggest that the integrity of specific descending tracts are more important predictors of therapeutic outcomes than infarct size and baseline clinical assessments. These investigations can potentially lead to tailoring therapy to characteristics of brain insult, types of rehabilitation needed for types of injury, and required neural reorganization in the future.

Therapy Parameters Based on Neuroplasticity

Kleim and Jones[50] suggest that neuroplasticity research evidence in animal models cannot be directly applied to human rehabilitation protocols, but can offer guidelines for therapists to consider when planning intervention protocols. In this section, we offer a summary of these research-based neuroplasticity parameters for therapists to consider when making clinical decisions and planning intervention.

Time-Sensitive Critical Period

Researchers report that there may be a critical period after the injury when neuronal structures are more sensitive to the effects of training and exercise (for an animal study see Biernaskie et al[51]; for clinical findings see Horn et al[52]). Therapeutic training provided too early or at a high intensity has been shown to produce negative outcomes in rats with induced strokes. Forced use of the impaired forelimb within the first 7 days after a stroke induced in the sensorimotor cortex resulted in poorer functional outcomes than in control rats that were free to use both limbs.[53,54] This phenomenon has been attributed to excessive excitotoxicity in tissues surrounding the site of the brain injury.[55]

Similarly, researchers reported functional outcomes in two groups of human subjects who had sustained strokes. In one group, very early delivery of high-intensity intervention (average start of therapy between 8 and 10 days poststroke) resulted in lower functional outcomes than in a group who received lower-intensity intervention.[56] Conversely, delay in therapy can facilitate self-taught compensatory behaviors and also interfere with rehabilitation training targeted to restore function.[50]

When comparing early versus delayed start of CIMT for patients with stroke (3–9 months and 15–21 months poststroke, respectively), researchers found that both groups improved their motor outcomes post CIMT, but the improvements were significantly better for the early group.[57] Based on these results, we should consider careful timing of NDT strategies with appropriate intensity and continually reexamine whether or not the client is reaching the outcome goals.

In summary, neuroplasticity and functional gains have been observed in the affected upper and lower extremities in chronic stroke patients; however, precise delineation of the critical period for intervention[58] and a final consensus of which type of stroke is most amenable require further investigation.[21]

Generalized Aerobic Exercise

Animal studies demonstrated that generalized aerobic exercise in poststroke rehabilitation can increase metabolic demand in the brain and lead to angiogenesis and neurogenesis important for learning and memory.[59] Research in healthy older adults has shown that regular participation in aerobic exercises induces neuroplastic changes, including synaptogenesis, angiogenesis, neurogenesis, release of endogenous neurotrophins, and enhanced brain network function. These changes are associated with enhanced cognitive ability, learning, and memory[60] and would presumably exert a positive effect on motor learning and rehabilitation outcomes.

Task-Specific Training

Task-specific training in rehabilitation refers to goal-directed practice and repetition of context-specific functional tasks. Task- or skill-specific training in animal models induces changes in neural architecture, including sprouting, synaptogenesis, synaptic potentiation, and dendritic branching,[61] all of which are associated with motor enhanced (re)learning.

In humans, task-specific training of the upper limb has demonstrated changes in brain activation patterns measured by fMRI and TMS.[62] In another study, acquisition of skilled ankle movement in a healthy group of subjects resulted in changes in corticospinal excitability, whereas groups who were asked to perform either non-novel active ankle movements or passive ankle movements did not.[63] Thus neural coding is likely specific to experiences gained as a result of training.

Repetition, Intensity, and Time (Massed Practice)

It is important to note that acquisition of skill itself is not enough to induce neuroplasticity.[64] Based on animal models, it is hypothesized that repetition of a newly learned task over time is necessary to induce lasting neuronal changes that are resistant to decay in the absence of training.[65] In humans, positive correlations between levels of therapy intensity and functional outcomes have been reported in some rehabilitation protocols. For example, a meta-analysis by Cherney et al[66] found a moderate level of evidence for better outcomes with higher-intensity constraint-induced language therapy in subjects with chronic stroke-induced aphasia. NDT intervention considers intensity as a critical element in program planning (see Case Report B9 about Sam in Unit V). The data relating intensity of intervention to functional outcomes in adults are inconsistent,[56,57] and correlations between intensity of therapy, functional outcomes, and the impact on neuroplasticity have not been definitively established in humans.

Engagement/Attention/Motivation

When designing an NDT-based program, therapists must set goals together with the client and design them to enhance function and participation. The therapist structures each session to increase active involvement, engagement, attention, and motivation of the client. These are key behaviors that support the attainment of the individualized goals.

In animal models, these concepts are often manipulated with environmental/social enrichments.[67] Studies have been designed to investigate a variety of enrichments, from housing size, available equipment, complexity and novelty of equipment, colors/textures/smell of equipment, to the number of animals in the housing, to provide opportunities for stimulation of some sensory, motor, cognitive, and/or social experiences. In animal models, there is mounting evidence that these environmental/social enrichments enhance motor, sensory, cognitive, and social recovery poststroke.[68] Environment enrichments have also been shown to decrease infarct volume[69] along with other neurochemical and structural changes that indicate repair and recovery from brain insult.[67]

In humans, a study is under way to test the effect of environment enrichment on outcomes of stroke rehabilitation.[70] Increased attention is also thought to accompany motor learning of tasks with appropriate levels of complexity, challenge, and novelty.[71] This concept has been applied when designing virtual reality (VR) rehabilitation programs where task parameters can be carefully tailored to each individual's impairments, presentation, and needs. VR rehabilitation technology has been used in programs for clients poststroke and has been shown to be potentially useful for improving locomotion, balance, and upper extremity function in a recent meta-analysis.[72] Another type of training seldom included in the attention category is the act of mental practice. This subject is reviewed in the following section.

Therapy Technologies and Training Protocols Based on Neuroplasticity Principles

There are many emerging therapy interventions based on the theoretical foundations and evidence pertaining to neuroplasticity. Here the most established therapy methods from the stroke literature, noninvasive and invasive brain stimulation, and mental training and practice, are reviewed.

Brain Stimulation

Human fMRI and positron emission tomography (PET) studies show there is an increase in contralesional hemispheric activity and a decrease in ipsilesional hemispheric activity following stroke, which creates interhemispheric imbalance.[22] There is also growing evidence that individuals who show optimal recovery from stroke exhibit activation of ipsilesional brain hemispheres, whereas those with less optimal recovery exhibit bilateral cortical activation with movement of the more affected limb.[21]

In attempts to normalize activity in healthy and injured hemispheres and to promote recovery, transient direct current stimulation (tDCS) or TMS has been applied to either (1) inhibit contralesional hemisphere excitability or (2) increase excitability of the ipsilesional hemisphere. Using tDCS, a weak direct current is delivered to polarize neural tissues beneath two surface electrodes placed over the area of brain injury. Commonly, the anode (active electrode) is used to increase excitability of the ipsilesional hemisphere or the cathode is used to decrease the excitability of neural tissue in the contralesional hemisphere. Both anodal and cathodal paradigms have been shown to improve motor functions in clients poststroke.

In TMS, a magnetic coil is placed over the scalp to hyperpolarize or depolarize the neural tissues below. Repetitive high-frequency stimulation increases the excitability, whereas repetitive low-frequency stimulation decreases excitability of neural tissues.[73] Similar to tDCS, excitatory stimuli applied to ipsilesional hemispheres[74] or inhibitory stimuli applied to contralesional hemispheres[75] have led to increased motor function in patients with stroke. In addition, tDCS can be paired with peripheral nerve stimulation during functional arm movements and has been shown to enhance rehabilitative outcomes beyond the effects of using each modality independently.[76] However, the long-term effects of these interventions have not been studied.[77]

Moreover, the concept of contralesional cortex activity as negative for functional recovery is still under debate.[22] For example, it is argued that contralesional hemispheric contribution is an important compensatory recovery mechanism for the function of the affected limb and not necessarily a reflection of maladaptive plasticity, especially in the chronic phase of stroke.[78]

Deep brain stimulation is used to provide electrical stimulation to the neural tissues by placing the electrodes inside the brain. This procedure has now become widely available for treating patients with Parkinson's disease, tremor, and chronic pain.[79] In Parkinson's disease, the effect of deep brain stimulation is showing normalization of neural circuitry, which likely contributes to alleviating symptoms.[80]

The effect of deep brain stimulation for patients poststroke, however, remains questionable. Strong evidence has been established to demonstrate improved functional upper limb movements when this intervention was applied to animal models with induced strokes. However, a group of patients who received a deep brain stimulation paradigm concurrently delivered with a therapy regimen to regain upper extremity function showed similar outcomes when compared with a group of patients who received the therapy regimen delivered without deep brain stimulation.[81]

Mental Practice/Training

Mental training is defined as the active and repetitive process of cognitively rehearsing specific actions to improve motor performance.[82] Mental practice of a particular task has been shown to activate similar brain regions for the foot, hand, and arm, or locomotive movements as those engaged during physical performance of the same task.[83,84,85] Page and colleagues[86] implemented two studies of twice-weekly physical therapy provided over a period of 6 weeks. In one study a group of subjects participated in mental practice combined with a specific physical therapy protocol[86]; in the second study, 30 minutes of therapy was followed by a mental training paradigm.[87] The outcomes of both studies demonstrated better hand function in the mental practice groups than in the control groups who received only the physical therapy protocols.

Other therapy methods based on neuroplasticity principles are emerging; for example, mirror training, action-observation training,[88] music therapy/training, and VR training.[89] Also, pharmacological intervention to increase arousal and attention in combination with rehabilitation training, and its effect on neuroplasticity, is being investigated.

Therapeutic Intervention Studies That Support Neuroplastic Changes—Adults

CIMT and associated neuroplastic changes in brains of adult patients poststroke is one of the most researched treatment protocols.[90] The goal of this treatment is to improve functional use of the more affected hand by splinting or bracing the less affected upper extremity. CIMT is often delivered intensively, with massed practice, and shaping; it is a method of systematic delivery of therapy that progresses the level of movement difficulty as tasks improve and provides consistent encouraging feedback about task performance.[91]

In general, the results of these studies indicate that functional outcomes are better for patients who participated in a CIMT program as compared with patients who participated in regular therapy sessions or no therapy.[92] However, the long-term effect of CIMT on hand function continues to be researched.[93]

The neuroplastic changes associated with CIMT include increased cortical excitability in the lesioned brain hemisphere,[94] increased motor representation of the affected hand,[95] and increased volume in the sensory and motor cortical areas in ipsi- and contralesional brain hemispheres.[96] Increased ipsilesional brain activation with affected arm use has also been suggested but remains controversial (refer to the earlier section, "Brain Stimulation"). These results support that changes in brain plasticity following CIMT are promising and would suggest the need for continued CIMT research.

Finally, the research appears to support the positive functional and neuroplastic effects of an intensive, constraint-induced intervention. However, the duration of the program, the number of hours per day, and the interventions vary from study to study.[90,96,97] These authors suggest that this leaves the door open for a study to assess the effects of an intensive NDT intervention protocol based on the current practice model described in Unit II, Chapter 5.

15.5.2 Concepts Applied to Infants and Children

Therapeutic Intervention Studies That Support Neuroplastic Changes—Infants and Children

The evidence supporting positive correlations between therapy and cortical remapping in children is growing.[98,99,100] As in adults, this support comes from research into intensive CIMT programs for children with hemiplegia. The findings from these studies are relevant to NDT therapists because the etiology of the brain injuries is similar to those of the children typically treated using NDT.

In a case study of a single subject with hemiplegia who participated in an intensive 3-week CIMT program, Sutcliff et al[99] reported improved hand function based on the Pediatric Motor Activity Log. In addition fMRI prior to intervention and postimaging immediately following the program and 6 months postprogram revealed a shift in the laterality index from the ipsilateral to contralateral (injured) side.

Cope et al[98] studied a cohort of 10 children with hemiplegia. The subjects participated in a 2-week intensive CIMT protocol, and the findings were mixed. Children with less significant functional impairments showed improvements on the Melbourne Assessment of Unilateral Upper Limb Function. In addition, there was a moderate correlation between changes in pre- and posttest function, and two of the children showed increased contralateral cortical activity following CIMT. Given that the time frame varied and the intensity for this intervention has not been fully established, the results of this study add some support to a correlation between intervention and brain plasticity. These findings may be more supportive of the intensity of intervention than the particular therapeutic protocol used.

A third study of 10 subjects with congenital hemiplegia caused by cortical or subcortical infarctions of the middle cerebral artery also demonstrated improved hand function following 14 days of intensive therapy. fMRI revealed increased primary sensorimotor cortex activation of the affected hemisphere secondary to passive and active movement of the affected hand. These clinical studies demonstrate that therapeutic paradigms based on a neurorecovery model contribute to improved functional outcomes, as well as cortical reorganization in the injured brain. We are a long way from knowing the precise dosing and specific intervention paradigms that will most effectively alter function and neural changes, but we can begin to understand that our therapies may be beneficial on multiple levels for infants and children with congenital and traumatic brain injuries.

It has recently been suggested that CIMT programs should consider both unilateral and bimanual tasks as part of the training protocol.[101,102] In addition, the evidence supports the positive impact of CIMT training on improved quality of life for children with cerebral palsy.[103] For this reason we again suggest that a study using NDT-based unilateral and bimanual CIMT intervention should be developed. These authors suggest that an NDT-based clinical study applied in an equally intensive setting would expand this body of research and help to clarify whether brain changes are more dependent on the intensity of therapeutic intervention or on the specific intervention strategies.

Expanded cortical remapping has been reported in fMRI studies of partial body-weight-supported treadmill training[104] and use of video game paradigms to improve upper extremity function in children with hemiplegia.[105,106] These are strategies that are often included in an NDT intervention session. In each of these studies, improved functional outcomes were accompanied by increased cortical activation. Although all of the researchers report the difficulty of using fMRI in children, all felt the technology was useful because it expanded understanding of brain plasticity.

Armed with this information, it is up to all therapists to become acquainted with the therapeutic and neuroscience evidence when planning interventions for their clients. Knowledge about neuroplasticity paired with insights gained from interventional research can guide us to employ the most efficacious interventions for our clients. Further, therapists can begin to develop new interventions based on our clinical experience/expertise, research evidence, and the most up-to-date information on brain plasticity. As new interventions are developed, clinical case studies may provide neuroscience researchers with innovative paradigms to investigate the effects of intervention on brain plasticity.

15.6 Final Thoughts: Recovery versus Compensation

Recovery and compensation have been the focus of discussion in neurological rehabilitation. *Recovery* is used synonymously with *normalizing* movement with that of nondisabled peers and with *restoration*. *Compensation* is synonymously used with *adaptation* and *maladaptation*, *substitution*, and *alternative* strategies. This dialogue centers around what therapists should be aiming at in different stages of rehabilitation:

1. To work on impairment level goals, meaning working on elements of movement that make up a functional task in order to promote neurological repair that leads to minimal compensation patterns in a wider range of tasks.
2. Or to work on functional and individualized goals (i.e., patients can walk a certain distance safely and independently to move around the house safely at discharge from inpatient rehabilitation) with little focus on quality of movement to achieve such goals.

Currently in the clinical setting, both strategies are used in varying degrees depending on multiple factors and priorities that are often unique to each patient as well as to each therapist who provides the service. With future advances in neuroplasticity research, recovery and compensation rehabilitation strategies can be delivered corresponding to the patient's stages of neuroplasticity. For example, depending on the brain injury, the brain may have the ability to completely heal structurally and functionally, commonly called restitution. If this is not possible, the brain will resort to substitution or reorganization of the brain through the transfer of control to healthy areas of the brain. In both cases, the therapist will likely guide the patient to facilitate the neuroplasticity process and obtain the most optimal and functional outcomes. Although these relationships have not been established in research, draw on your own professional experience and framework and each patient's individual needs, and look for the following in the literature to implement neuroplasticity concepts into your clinical practice:

1. Therapists will need a marker(s) of some type to identify the critical time period to engage in intensive therapy to target impairment-level recovery. Although a critical time period for a well-controlled lesion in the nonprimate has been somewhat established, it is unclear in humans post stroke at this time. As reviewed previously, too early can be detrimental or not useful for outcomes in rat and human models (see section on "Time-Sensitive Critical Period").
2. Therapists also need to establish indicators for plateaus of the effects of therapy. Performance-level plateaus are likely not direct reflections of plateaus of neurological changes associated with learning. (see "Repetition, Intensity, and Time (Massed Practice)" section). This will allow therapists to decide

when to initiate different therapy that may be more conducive to further learning.

3. Therapists should look for and evaluate predictors of outcome for specific therapy interventions and for specific neurological injury and presentations. This specificity will allow for better education and cooperation with patients and their caregivers and health care providers.

15.7 Conclusion

This review of neuroscience research has shown that neuroplasticity can be influenced by diverse conditions and is experience dependent, time sensitive, and strongly reliant on our ability to motivate and direct the attention of our clients. For this reason, these authors encourage therapists to continue to learn about the ever-increasing knowledge of neural plasticity; to carefully consider how plasticity may be enhanced or restricted based on the location of the injury and the age at onset of injury. NDT therapists must also consider how the brain can change when environment, practice, and specific goal-directed interventions are combined to meet the rehabilitation needs of the clients we serve. All of these concepts are part of our NDT education, and now we must apply them with greater precision and understanding to develop the best evidenced-based interventions for our clients.

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IV

Introduction

Cathy M. Hazzard

This unit describes the role that the core Neuro-Developmental Treatment (NDT) team members, the occupational therapist, the physical therapist, and the speech-language pathologist play in the evaluation of and intervention for individuals with central nervous system dysfunction. The chapters discuss the knowledge that each of these three disciplines brings to the NDT team as well as what the NDT Practice Model adds to each discipline's skill set.

Since its inception, the NDT Practice Model has always involved an integrated team: the client in the middle, surrounded by a team invested in working toward optimizing the client's functional outcomes (at the Activity and Participation levels of the International Classification of Functioning, Disability and Health [ICF]). The extended client team involves many players: informal caregivers, including family members, and professionals, such as therapists, physicians, teachers, and orthotists.

Three disciplines within this group form the core NDT team: the occupational therapist (OT), the physical therapist (PT), and the speech-language pathologist (SLP). Each of these three therapists brings unique, specialized skills to the NDT team. For example, the OT brings expertise in the sensory and perceptual systems and in task analysis, the PT brings expertise in movement analysis and the biomechanics and kinesiology of the body systems, and the SLP brings expertise in the intricacies of feeding and oral-motor and respiratory systems and the individual's communication mechanisms.

In turn, the NDT Practice Model has given each of these disciplines a broadened perspective and knowledge base in how posture and movement interface between the Activity and Participation domains and the Body Function and Structure domain of the ICF. Therapists' skills are enhanced when the therapists are able to understand how an individual organizes postures and movements to efficiently function within tasks. This knowledge enhances clinicians' abilities to problem-solve optimal intervention strategies to address the single- and multisystem impairments limiting clients' activities and participations.

The three chapters in this unit highlight each of these disciplines' contributions to the practice of NDT and, conversely, what NDT adds to the knowledge base of the OT, PT, and SLP.

16 The Practice of Occupational Therapy from a Neuro-Developmental Treatment Perspective

Kim Barthel, Chris Cayo, Kris Gellert, and Beth Tarduno

This chapter examines the role of occupational therapy, providing the reader with an understanding of sensory processing, arousal and attention, play, and activities of daily living within the Neuro-Developmental Treatment (NDT) Practice Model. Alternately, NDT as a frame of reference within occupational therapy emphasizes the analysis and understanding of impaired posture, movement, body structures, and functions in the neurologically challenged individual. Clinical examples throughout the chapter demonstrate how merging the knowledge bases of occupational therapy and NDT can enhance outcomes for the activities and participation domains of neurologically challenged individuals.

Learning Objectives

Upon completing this chapter the reader will be able to do the following:

- Define who an occupational therapist (OT) is in terms of professional responsibilities and functional outcomes addressed in client management.
- List at least three skills NDT education enhances in the professional skills of OTs.
- Analyze an occupational therapy outcome with a specific participation or activity of a client in his or her own practice using the NDT Practice Model.

The partnership of Neuro-Developmental Treatment (NDT) and occupational therapy is a marriage of perfection. At the heart of this merger between NDT and occupational therapy are a set of complementary principles and a shared philosophy, both intending to optimize human occupation and function. Specialized knowledge fundamental to NDT expands the OT's professional skills, thereby enhancing intervention for this target population.

16.1 The Occupational Therapy Profession

The World Health Organization (WHO)[1] definition of *occupational therapy* identifies the OT as using careful analysis of physical, environmental, psychosocial, mental, spiritual, political, and cultural factors to identify barriers to occupation. Whether the individual is an adult or a child, the therapist enhances occupational performance by addressing individual needs through direct intervention, modifying the environment, or changing the requirements of the task.

As a profession, occupational therapy began in the early 1900s. OTs initially worked to help wounded soldiers of World War I. Over time, the occupational therapy profession evolved, and in the years between the 1940s and 1960s, OTs thrived during the period referred to as the rehabilitation movement. OTs were called on not only to organize and run programs for the wounded military personnel but also to provide care for those who previously would not have lived without advanced medical sciences to help treat spinal cord injury, traumatic brain injury (TBI), and cerebral palsy.

16.2 Occupational Therapy and Neuro-Developmental Treatment

OTs were first introduced to the work of Dr. and Mrs. Bobath in the 1960s. Even in the early stages of their theory, the Bobaths recognized the importance of the interdisciplinary approach. The concepts taught by the Bobaths have long been embraced by OTs worldwide. Schleichkorn indicated, "It is felt that, apart from their treatment, one of the major contributions of Dr. and Mrs. Bobath has been in helping to break down the artificial barriers which have existed for too long between the disciplines of physical therapy, occupational therapy, and speech therapy."[2] The foreword of Eggers's book, *Occupational Therapy in the Treatment of Adult Hemiplegia*, written by Karel and Berta Bobath states, "It requires team-work and the close collaboration of physiotherapists, speech therapists and occupational therapists. . . . We have long awaited this book, which meets a need in the area of total management by relating physiotherapy and occupational therapy. It will be of special value to occupational therapists who are working in hospitals where each member of the team follows the same concept and principles."[3] Eggers goes on to say, "This concept, which was developed for physiotherapists, can, and in my opinion, be well incorporated into occupational therapy because it has the facilitation of normal movement sequences, which are necessary for all activities of daily living, as the goal."[3]

An American OT, Judy Murray, who resided in London and had conversations with the Bobaths, merged the concepts of activities of daily living (ADLs), play, vision, sensory, perceptual, and adaptive equipment into the NDT treatment approach. Mechthild Rast, an NDTA-certified OT instructor, also helped shape the original theory by incorporating the importance of upper extremity performance and play as the work of the child. These early roots of occupational therapy have influenced, and continue to influence, the NDT curriculum, accentuating the holistic team approach within NDT intervention.

Therapists treating children will most likely examine the occupations of play, education, rest and sleep, ADLs, instrumental ADLs (IADLs), and social participation. Occupations for adults include employment, child and family care, leisure, ADLs, IADLs, social participation, and an array of other activities performed throughout the day. Each of these human occupations can be evaluated and treated through an NDT lens, emphasizing the posture and movement components of each function.

NDT, being a dynamic hands-on intervention practice model, guides the OT globally in the evaluation of and intervention for children and adults with neurological impairment. Being a client-centered approach, NDT promotes an individualized problem-solving framework of clinical reasoning and analysis for managing identified impairments. Guided by the WHO's International Classification of Functioning, Disability and Health (ICF), an OT using the NDT Practice Model will examine body functions and structure and the domains of activity and participation, identifying what tasks the individual has not yet learned to do or is no longer able to accomplish. Layers of depth are then added to the examination by identifying specific impairments within the motor and body structure domains that may include neuromotor, cognitive, perceptual, and sensory systems influencing social and individual functions.

Observation, analysis, and intervention for function are fundamental principles of occupational therapy, requiring the therapist to develop hypotheses about behaviors, which guides clinical reasoning and intervention planning. Distinctly, NDT highlights the analysis of typical movement and its progression across the life span, helping the OT develop theories about why individuals with neuropathology move the way they do within an occupation or an activity.

The emphasis on analysis of typical movement is embedded in the NDT Practice Model because typical movements are the most efficient movements leading to the possibility of more complex movement patterns. As discussed in Chapters 2 and 14, NDT does not expect clients to gain or regain all typical movements; rather, therapists seek to develop more efficient motor skills within the individual's capabilities that also minimize impairments in body systems. For example, in typical adult reach, the action is initiated with a visual gaze to the target with the eyes focused, the hand opening, and the arm following the direction of the hand motion. Reach may also involve the trunk and legs, even in sitting, when reach demands movement of the center of mass over the base of support. Following a stroke, the individual may initiate this action with scapular elevation, humeral abduction, and internal rotation, and lack control of the hand position, with the pelvis dropped into a posterior pelvic tilt position as seen in **Fig. 16.1**.

Children with neurological pathology may also exhibit atypical patterns of reach. The child may attempt to bring his arm forward by laterally flexing his trunk, elevating his shoulder girdle, internally rotating the shoulder, hyperextending the elbow, pronating the forearm while extending the wrist, and fisting his hand when reaching toward the object of desire as seen in **Fig. 16.2**. In both examples atypical body structure and function patterns such as these significantly alter the effectiveness of reach in forward space to interact with an object or the environment.

The NDT frame of reference also deepens the OT's knowledge of compensatory and atypical movement patterns that arise from primary and secondary impairments. Whether providing intervention to children or adults with neurological impairments, OTs need to understand how and why atypical movement patterns develop following neuropathology.

Fig. 16.1 To raise her left arm poststroke this individual weight shifts to the left, lengthens and posteriorly rotates her trunk on the left, and rotates and extends her neck. The humerus moves into horizontal abduction and internal rotation.

Fig. 16.2 This child brings his arm forward by laterally flexing his trunk, elevating his shoulder girdle, internally rotating the shoulder, hyperextending the elbow, pronating the forearm while extending the wrist, and fisting his hand when reaching.

Evident threads of repeating movement impairments will be illuminated as the therapist analyzes and observes the effects of varying gravitational and biomechanical forces involved in movement sequences, motor planning demands, environmental requirements, and quality of movement sequences themselves. For example, when a child or adult with hemiplegia moves from sit to stand to answer a telephone, she may shift her weight to her less involved body side and push up to stand with the less involved arm, paying little, if any, attention to the more neurologically involved side of her body.

The OT using the NDT framework of practice would have an appreciation of both the most efficient and possibly atypical movement sequences involved in the sit to stand movement, providing the therapist with knowledge to develop therapeutic intervention strategies. The therapist may use select handling strategies to alter the alignment of the individual's body over her base of support in relationship to the forces of gravity prior to and during the sit to stand movement sequence to facilitate a more efficient and functional movement pattern. Handling strategies are used to decrease the use of excessive muscle force employed to stabilize body segments, compensations used to hold the person up against the forces of gravity. Gradual withdrawal of facilitation occurs as the individual assumes increased internal control of her movements, activating and modulating her own muscle forces.

The NDT-educated OT may also alter the environmental or task demands to influence the posture and movement choices. For example, having the individual stand from a higher surface initially may place less demands on motor control, thus increasing the likelihood of successful movement patterns. In addition, having individuals reach forward and up with the less involved hand for a desired object may offer insights to the impairments interfering with the earlier attempts.

When evaluating occupations, the OT using the NDT Practice Model emphasizes the analysis of the client's posture and movement strategies by combining observation of motion and palpation of muscle and postural tone while the individual is both at rest and in action. While observing task performance, the OT using the NDT Practice Model evaluates both the individual's movement competencies and the single and multisystem impairments. Special attention is directed to the postural alignment and the interaction of the body systems. Joint range of motion, postural control over a base of support, and synergies of motor action are examples of posture and movement components evaluated within the context of an occupational task.[4] Intervention within the NDT frame of reference provides individuals experiencing neurological impairment with the opportunity to experience or reexperience efficient movement within the context of function.

The artful skill of handling is a powerful and unique tool central to the NDT process. Through graded external manual guidance provided by the NDT-educated therapist's contacts and body movements, the individual with neuropathology receives input that emulates the feeling and embodiment of more efficient posture and movement components.

With their hands on the individual, NDT therapists feel and perceive the individual's anticipatory movements and bodily responses to changes in posture and movement, facilitate and expand an individual's postural control and movement strategies, inhibit movements that interfere with task performance, and constrain movements that may lead to secondary impairments over time. Moment by moment sensory feedback between the individual and the therapist informs the clinical reasoning process and guides the therapist in grading the handling, changing the hand placement, giving the directional cues, and gauging the intensity of sensory input provided. The examination and intervention are woven seamlessly together as part of the holistic perspective of NDT intervention. When, why, and how handling is employed within an NDT session is a fluid progression based on this interchange between the therapist and the individual with neuropathology. As the individual acquires increasing movement competence, handling is faded and eventually removed from the intervention process, decreasing reliance on the therapist as seen in **Fig. 16.3a–c**. This unique handling and clinical reasoning skill set rooted in NDT is a powerful adjunct to the practice of occupational therapy for individuals experiencing neurological impairment.

16.2.1 Task Analysis

Within the context of NDT, individuals with neuropathology are not expected to improve function by simply practicing a skilled activity over and over again using their existing impaired posture and movement strategies. Individuals experiencing neurological impairment do not

Fig. 16.3 **(a)** This child eats Cheetos by bringing his mouth to his hand when attempting to feed himself. **(b)** Hand to hand compression through the rib cage and down to the base of support to activate hip extensors. **(c)** Compression directed through the rib cage down toward the base of support to activate the postural system musculature to support the child in bringing his hand to his mouth while feeding himself a Cheeto.

consistently have the capacity to autonomously select or activate appropriate motor patterns necessary for independent task performance.

Historically, occupational therapy has been identified within the health care community as the discipline dedicated to promoting independence in functional tasks or occupations. The OT is educated in the ability to break down a skill set into subskills and to analyze the components of the task (occupation) and the environment. Subsequently, the NDT-educated OT carefully selects therapeutic activities and specific subtasks of the activities to address the individual's impairments through task analysis, avoiding the possibility of excessive effort, which may result in overrecruitment of atypical and less efficient posture and movement strategies.

For example, when working with a child with neurological impairments, the therapist may identify core musculature weakness as a primary impairment. Selection of a therapeutic activity, such as drawing in shaving cream on a mirror while sitting on a moving surface, may activate and strengthen the deep postural muscles while the child works to control the movements of her upper extremities in space.

OTs are professional experts in task analysis. The movement analysis skills embedded in the NDT frame of reference enhance the OT's existing ability to scrutinize motor components of the task. With this additional knowledge afforded by the NDT Practice Model, the OT is better able to select the appropriate subtask, work surface, base of support, and tool use to capitalize on the movement-learning opportunity for the individual and to address the individual's specific impairments. For example, by having a child draw on a vertical mirror as opposed to a horizontal work surface, such as a table, the orientation of the activity in space discourages the child from collapsing into a less efficient postural strategy of trunk flexion. The nature of reaching for and drawing in the transverse plane of movement demands a postural control strategy that asks for activation of postural muscles to work against the forces of gravity.

OTs using the NDT Practice Model also employ their task analysis skills when treating the adult with neurological challenge. For example, in the task of baking, the subtask of kneading dough may be the intervention activity chosen, with the intention to promote typical posture and movement strategies and to address the individual's underlying impairment of weakness of the abdominal oblique muscles. With thorough analysis of the adult client's required posture and movement patterns, the OT could alter the environment and task components, such as the use of stiff dough placed on a slightly inclined or high counter with the client in a standing position. While an individual participates in a task, the therapist provides handling to the postural system while continuously modifying the environment and the task, facilitating or inhibiting muscle synergy patterns to develop autonomous control of the movements necessary for function.

Although handling is a significant component of NDT, continual evaluation and alteration of the environment and task ensure that the individual is appropriately challenged within the activity selected. Repetition with variety, along with practice at home, school, work, or play, supports carryover of newly acquired movements.

16.2.2 Examining, Evaluating, and Intervention of Sensory Processing for Function

The OT brings to the NDT Practice Model a specialization in understanding the sensory processing contributions to posture and movement. Neurologically challenged individuals are often unable to appropriately detect and identify sensory information, which can result in significant deficits in motor control. Sensory data are coded and stored within the nervous system, providing a reference point or map of the body, space, and how the body moves within the spatial array.[5]

Previously learned movements and whole functional skills are stored in motor memory, relying on precise sensory processing for future analysis, comparison, and movement production. Any interruption in the detection, coding, or interpretation of single-sensory or multisensory information can give rise to maladaptive postural orientation or movement. When the body map is impoverished or unpredictable, individuals with neurological impairment will have difficulty knowing where their body is in space, which muscles to recruit, how much force to enlist, how to coordinate synergies of muscles together, and how to move the body within the environment.[6]

Previously experienced sensation from body movements provides individuals with feed-forward capacity, a backdrop pulse of neuromuscular activity preparing postural set, getting an individual ready to move.[7] Interference within the sensory processing systems may result in challenges with anticipatory posture and movements as well as sensory feedback from movements necessary for functional performance.

Tactile, Vestibular, and Proprioceptive Processing

The tactile, proprioceptive, and vestibular sensations are processed at multiple levels throughout the nervous system, contributing to motion, perception, emotion, and cognition. Individuals may experience oversensitivity or underresponsiveness to these body senses, resulting in either an overmagnification of sensory perception or a minimization of sensory experiencing.[5] For example, a child with tactile sensitivity may find textures, clothing, light touch, or unexpected touch to be painful or uncomfortable, often evoking an emotional response. Adults with TBI, neuropathology, or central nervous system impairments may also experience tactile sensitivity interfering with their function and the learning of new movements.

During an experience of tactile sensitivity, the fight–flight–fright pathway in the autonomic nervous system may be triggered into a heightened state of threat, preventing the individual from feeling safe to explore or experience touch in a relaxed and comfortable way.[6] When discomfort to touch is evident, an individual may limit exploration of movement and the environment.

Handling components of NDT intervention may be rejected or resisted by the tactilely sensitive individual, altering full participation in the intervention process. Therapists must pay close attention to the depth of touch during handling, minimizing the speed and frequency with which they change key points of control while monitoring the individual's stress response to handling. Handling with deep-pressure touch can help to mitigate sensitivity to touch, organizing an individual's overall state of arousal and making touch experiences less frightening.[6,8]

OTs working within an NDT framework integrate intervention strategies based on their sensory processing knowledge to help modulate tactile processing issues. Deliberate and mindful provision of deep-pressure touch to an individual's body is typically perceived as a calming and organizing stimulus. The appreciation of deep-pressure touch as a sensory tool merges elegantly with NDT principles of handling. Inhibition of tactile sensitivity and facilitation of tactile responsiveness are underpinnings of and parallel processes to the NDT practice model.[6]

Alternately, individuals with neurological impairment may also experience an underresponsiveness to touch. Individuals who do not perceive or feel tactile stimuli may crave touch, with excessive exploration of the tactile environment. Many individuals who are underresponsive to touch mouth objects, seek out messy play, and typically enjoy intense sensations like vibration. Underresponsivity can be observed in both children and adults with neurological challenge. Following a stroke, for instance, many individuals experience absent or decreased sensory awareness of their hemiplegic body side. Limited awareness of the body parts affects muscle recruitment, initiation, activation, and movement of that body part as it moves in space.

Tactilely enriched and sensory demanding activities, such as playing with shaving cream (**Fig. 16.4**), finger painting, sand play, and walking in bare feet, accentuate the tactile sense, alerting the brain to this component of the sensory array. Intervention for adults experiencing neurological challenge may similarly load the tactile system with emphasis to increase body awareness and feedback to the movement system. Many tasks introduced during intervention with adults should demand bimanual or bilateral (**Fig. 16.5**) use to highlight attention to the affected arm and the task or have a consequence, such as water spilling from the cup if the hand/arm does not hold it upright.

Proprioceptive processing and vestibular processing are also frequently altered by neuropathology, affecting the substrates of motor control.[9] The vestibular system provides information about gravity, direction, and speed of movement in space and sends information to the muscles of postural control, responding to perturbations in balance and equilibrium.

Overresponsiveness to vestibular information can leave individuals feeling dizzy, ungrounded, and lost in space, challenging their relationship to the forces of gravity. This type of overresponsiveness, if not addressed in intervention, can be tremendously disruptive to learning and experiencing movement within the NDT intervention

Fig. 16.4 Playing with shaving cream provides sensory input to enhance body awareness and fun.

Fig. 16.5 Bilateral tasks, such as carrying heavy items, are used to increase attention and place demands on the more involved side. This helps with increasing perceptual, tactile, and proprioceptive awareness.

process. OTs typically label this type of sensory processing challenge gravitational insecurity.[5] When experiencing gravitational insecurity, the individual will experience movement off the support surface as terrifying, especially movements in backward space. Individuals may become tense and hold their body stiffly in a guarding fashion to counteract the sense of falling or feeling out of control. By facilitating movements that are grounded on the support surface, which can be slow moving, in a linear direction, and combined with deep-pressure touch, the therapist provides the individual with gravitational insecurity so that he can learn over time to feel safe with movement in space (**Fig. 16.6**).

For adults with neuropathology who may also experience vestibular impairments, movement can be challenging. Atypical movement patterns can develop from the individual's fear of falling or altered sense of midline. Some strokes insult the vestibular system directly, creating central nervous system vestibular disturbances. The vestibular system can also be damaged peripherally by head trauma, infection, or damage to the labyrinth itself. Symptoms of vestibular dysfunction can include benign paroxysmal positional vertigo (BPPV), dizziness, motion sickness, and nystagmus, which result in significant functional impairment. Many individuals are so profoundly disturbed by vestibular challenges that they are unable to roll over in bed without experiencing incapacitating symptomatology. Fatigue and stress responses with anxiety frequently accompany vestibular limitations, requiring immediate intervention with emphasis on the correction of vestibular processing prior to the initiation of handling and movement.

When evaluating motion sensitivity, the therapist must identify the specific movements in space that induce dizziness. Specific maneuvers of the vestibular rehabilitation protocol may be introduced to potentially alleviate the limiting symptomatology, helping the individual habituate to the vestibular disturbance. It is important not to wait until vestibular symptoms resolve before initiating NDT intervention.

For the adult client, a fear of falling forward, especially during the acute stages of recovery, often results in an atypical pattern of movement of leaning to one side or pushing backward to find a sense of centeredness. This compensatory attempt at centeredness may produce a postural bias away from or toward the weaker side of the body, dependent upon the location of the stroke lesion.

Fig. 16.6 Slow vestibular input is often required to influence arousal and posture.

The NDT-educated OT may opt to use weight shifting of his or her own body on the individual's body to model the sensation of weight shift into forward space. A large body contact surface area will enhance proprioceptive/tactile body sensations, giving groundedness to the sensitive vestibular system. This direct contact with multiple body parts helps the client to reexperience a more typical movement pattern via the feeling of the therapist's simultaneous weight shifts. The therapist may also modify the environment to increase security. For example, placing a table or an object in front of the individual may occupy space and direct purposeful reach or engagement in the task. Engaging the individual in a meaningful task is critical to assist with the integration of the vestibular information.

Alternately, many children and adults with neurological impairment are underresponsive to vestibular and proprioceptive sensation. Individuals who present with a high threshold to vestibular and/or proprioceptive sensations present as either hypotonic, low arousal, underresponsive individuals, or individuals who actively seek movement, or who enliven in arousal, alertness, and postural activation when they are engaged in a movement activity. The vestibular nuclei may not receive sufficient input, resulting in an impoverished message down the spinal cord to the muscles that extend the neck, arms, back, and legs. Individuals may have trouble holding their head up while sitting, or they may become easily fatigued when working against gravity.[5]

The postural systems of underresponsive individuals need enhanced vestibular/proprioceptive data to perceive and respond to alterations in space. Careful examination of this system allows the NDT-educated OT to accentuate movement opportunities with differing speeds, direction, and demands, combined with proprioceptive input to open the nervous system's capacity to sense and produce posture and movement. Movement on the therapy ball, swings, rolls, and other moving surfaces can offer a multitude of sensory opportunities that emphasize vestibular/proprioceptive input for the child (**Fig. 16.7**).

Fig. 16.7 Providing vestibular input to influence postural control.

For the adult, vertical postures of high sitting and supportive standing can stimulate the reticular activating system through the vestibular sense, increasing overall arousal and alertness. The incorporation of moving surfaces that are functionally relevant to the adult client, such as a rolling office chair, an escalator, a treadmill, a moving walkway, can also be used to enhance the nervous system's ability to sense and produce posture and movement.

Visual and Auditory Processing

Sensory input from the somatosensory systems converges with visual and auditory information at varying levels throughout the brain, increasing integration and perception in preparation for action. Together, visual and auditory sensations help to drive the movement system, help to map environmental space, and orient the body within the spatial array. Visual and vestibular system information merges in the brainstem, collaborating to stabilize visual gaze, maintain a stable visual horizon, and orient the eyes in relationship to a target. Accurate reception of vestibular input is necessary for optimum eye muscle recruitment, observed when visually tracking and employing saccadic eye movements. Limitations in either the vestibular or the visual system alter the function of their partnership due to the integrated nature of their interaction.

The vestibular system has the job of interpreting the orientation of the head and body so that the individual can orient properly to what is observed through the visual system. When an object or the environment moves in front of the eyes, the brain must know whether it is the object, the head, or the whole body that is moving in space.[5]

Visual processing is commonly impaired in individuals experiencing neuropathology. The complexity of the visual system renders it vulnerable to interruption when neurological insults are experienced. For example, children with neurological impairment may experience difficulty isolating eye movements from head movements. Oculomotor functions unfold in concert with the development of postural control, and in the absence of these typically developing patterns of postural control, smooth visual pursuits and saccadic eye movements will likely be compromised.[10]

Head control and sensory registration of the proprioceptors in the neck help to integrate vision with vestibular information, allowing the vestibulo-ocular reflex and the optokinetic reflex to work together in harmony. The ramifications of these visual motor challenges influence many areas of functional performance across the life span. The NDT-educated OT is aware of how posture and movement limitations affect visual system function, how visual control affects movement, and how movement affects vision.

There are many categories of visual impairments that OTs need to understand and assess. Ocular visual impairments (anterior visual system), oculomotor impairments, visual field deficits, and cortical visual impairments

(CVIs) (posterior visual system) are different categories of visual system dysfunction often identified in individuals with central nervous system dysfunction.[11]

OTs treating individuals with identified visual impairments frequently work as part of a team that often includes neuro-ophthalmologists, ophthalmologists, optometrists, and vision therapists. If visual issues are suspected but have not been diagnosed, it is critical to refer these individuals to ophthalmologists for an appropriate medical evaluation.

Functional vision varies in individuals diagnosed with visual impairments; thus intervention is variable. The NDT therapist's knowledge of posture and movement is beneficial when addressing cortical visual impairments because the postural system is a base of support for vision. Poor coactivation in the proximal musculature can further impair visual performance. Intervention, which strengthens the core and the shoulder girdle musculature, improves the base of support for vision. However, a balance needs to be found between challenging the postural support mechanisms and providing enough postural support to the individual for gravitational stability for vision during intervention. To optimize outcomes it may be necessary to selectively challenge the impairments in each system. Identifying an individual's visual strengths and employing those assets within the intervention process are essential aspects of the OT's contribution to the NDT Practice Model. Strategies such as simplifying the visual environment, using study carousels to cancel out the background and light boxes or reflective toys to draw the eyes to colors or lights of interest, and providing contrasts are all straightforward adjunctive interventions.

Children and adults with poor postural control often have difficulty moving their eyes separately from their head. The knowledge that the NDT-educated therapist uses to develop postural control and movement positively influences this skill (**Fig. 16.8**), The OT's ability to treat the whole body when working with individuals with neuromotor impairments as well as cortical visual impairments by evaluating and treating the posture and movement systems positively affects the outcomes in visual skill development and recovery.

The visual system is also a critical aspect of adult NDT intervention. Insults such as stroke or brain injury can disturb the entire visual system, having vast implications for an individual's functional skills and overall participation. Most strokes affect one side of the brain, often resulting in partial visual impairment (**Fig. 16.9**). For example, if the right occipital lobe is injured, then the left visual field in each eye may be affected, whereas a stroke of the left occipital lobe may disturb the right visual field in each eye.

Functional peripheral (ambient) vision helps individuals to detect approaching objects and people in an almost unconscious, automatic fashion. When a moving car passes, we detect and sense the object in its approach. When peripheral, ambient vision is altered by a hemianopsia, objects seem to appear suddenly, often startling the individual. The person may feel unsafe and even overwhelmed by visual information, often experiencing anxiety and panic in crowded and visually stimulating environments.

Visual impairments often resolve following a stroke. However, as with other impairments, this can take time, and the visual impairments may not fully resolve. Therefore, an OT's role for visual training intervention strategies may include teaching individuals to use their remaining vision to its fullest potential within the context of functional tasks.

Integrating the intervention of visual impairments within functional tasks while also addressing the individual's other impairments allows the NDT-educated OT to maximize outcomes. For example, with individuals who have a left visual field impairment, placing items on their left side for activities such as grooming, dressing, and eating, so that they need to scan the environment to locate needed items, allows practice at visual scanning within the context of these functional tasks. Another example for reading is to place markers, particularly red, as a guide on the side of the page where the eye needs to go to see full text. When individuals and their families understand

Fig. 16.8 Stabilizing the head to align and dissociate the eyes.

Fig. 16.9 Visual impairments may include visual processing difficulties, visual neglect, or visual field cuts, all of which can impact an individual's ability to complete functional tasks.

the complexity of the visual system, and that visual retraining and environmental adaptations can assist with success of functional tasks and effectiveness of these strategies, they have a stronger tendency to incorporate recommendations into home programs.

Practice of functional tasks can be designed to address impairments of the perception of space, along with visual scanning impairments. For example, during the task of making cookies, the person is required to move in all directions within the environment, operating appliances such as a mixer or oven, reading a recipe, and automatically turning the head for visual tracking, scanning to locate items in cabinets, drawers, and the refrigerator to complete the task.

There is a complex interplay in the individual with neurological damage between visual spatial neglect and body neglect. The NDT-educated OT plans interventions carefully to provide the right challenge for the individual to achieve a level of success with daily life skills. Modifying the task and modifying the environment are strategies used to optimize recovery. For example, in a self-feeding task, the OT may place the individual's more involved left arm on the table beside the lunch plate to provide a visual boundary that reminds the person to visually scan to the left with each bite to see all items on his plate. The therapist may initially need to begin with items to the right of midline, then gradually and systematically draw the individual's attention toward the left side. The client's family members may also be intentionally positioned on the more involved side so that their voices become a stimulus for visual and postural orientation.

Within the NDT Practice Model, handling in functional activities to activate the base of support through the hips and trunk, as well as the shoulder girdle as a specific base of support for the head for eyes, can be used as an intervention strategy. Movements of the head, neck, and spine help to "unlock" the eyes if they are overstabilizing, whereas allowing mobility throughout the body to achieve mobility of the eyes supports dissociation of the eyes from the head.

Aging individuals may also experience degenerative changes of their vision, adding additional challenges to the overall sensory processing picture. Macular degeneration, glaucoma, cataracts, and overall visual degeneration may need to be considered as additional layers of the visual evaluation within the OT frame of reference.

Visual impairment can occur as a stand-alone impairment or in conjunction with multisystem impairments. The NDT-educated OT brings to the rehabilitation team the knowledge of potential functional outcomes of visual impairments and the relevance of visual intervention as an aspect of posture and movement system interventions.

In summary, the OT using the NDT Practice Model integrates her knowledge of sensory processing by facilitating active engagement in movement experiences embedded within tasks with mindfulness of the sensations provided. Through handling and movement, the neurologically impaired individual feels sensations that provide the potential for new motor learning.

16.2.3 The Sensory Systems and Oral Skills

OTs and speech-language pathologists (SLPs) typically collaborate in the intervention for oral motor and feeding issues. The NDT-educated OT and SLP understand sensory and oral functions as they relate to typical motor development, postural alignment and control, biomechanics, and body systems' interactions and impairments.

Sensory-related feeding disorders are common for both pediatric and adult clients with neuropathology. The NDT-educated OT provides unique input to the holistic evaluation of feeding issues, contributing an integrative knowledge of sensory processing to the oral motor aspect of the NDT Practice Model. The over- and underresponsivity of sensory processing observed in the body can be observed distinctly within the mouth. For example, children and adults may experience difficulties with texture and taste of foods, resulting in gagging and swallowing impairments, which may arise from either over- or undersensitivity and require careful analysis for intervention planning.

Individuals who experience underresponsivity to texture and touch within the mouth may not know where the food is located within the oral cavity, making it difficult to initiate the chewing and swallowing process. For example, many children often experience difficulties when changing from pureed to junior foods and specifically encounter problems with temperature and texture.

Interventions may range from using overall calming or arousing strategies prior to feeding to help maintain an optimum state of arousal, to providing specific oral sensory interventions aimed at sensory processing within the mouth and preparation for oral motor control. Deep-pressure input to the whole body organizes the arousal level and is an example of preparation prior to treating the mouth. Foods, utensils, and the environment are all elements of the evaluation and intervention process that can be altered to help increase competency in feeding. This knowledge of sensation will be integrated with intimate analysis of the motor components of feeding to create a comprehensive intervention.

Adults with neuropathology often lack the motor activity and sensory awareness to self-correct oral sensory and motor challenges. A primary goal of intervention is often efficient head and trunk alignment combined with alertness and attention necessary for safe and efficient self-feeding.

The NDT-educated SLP and OT also collaborate in evaluating oral and pharyngeal function as they relate to feeding and swallowing. The OT's holistic approach includes the social aspect of eating with family and friends, which may encourage the individual to manage sensory issues with heightened motivation and awareness. The collaboration among members of the NDT team, particularly the OT and SLP, provides a comprehensive view of oral motor function as it relates to participation.

16.2.4 Examining, Evaluating, and Intervention with Multisystem Praxis

Ayres was one of the first researchers to describe a relationship between praxis and sensory processing, specifically a relationship between somatosensory processing and motor planning.[12] Motor planning or praxis is the ability to conceptualize, organize, and direct an unfamiliar purposeful action.[13,14] For intervention planning it is important to differentiate between poor skill development due to motor execution deficits resulting from neuromotor impairments and poor skill development due to difficulties in motor planning.

In Smith-Roley et al,[12] it is noted that, in the 1970s, Ayres described praxis as the equivalent to motor planning and used both terms interchangeably. In 1985, Ayres[14] described two other components associated with motor planning/praxis: ideation or conceptualization and execution. In this monograph, she defined praxis as “that neurological process by which cognition directs motor action, ideation as the concept of possible object–person interaction and some idea of what might take place during that interaction and action planning as the intermediary process which bridges ideation and motor execution as the motor expression of ideation and motor planning.”[5]

Ideation involves the ability to generate an idea regarding the limitless possibilities of interaction within the environment.[13] Ideation is closely related to cognitive abilities and is evaluated, for example, by observing how the child interacts with novel toys or therapeutic equipment. In the child with cerebral palsy, ideational skills can be evaluated by requiring the child to conceptualize an activity. In the child with limited language and impaired movement, ideational skills are difficult to evaluate.[15]

Postural reactions, centrally programmed movements, and learned motor skills do not require much attention or volition; they are relatively automatic and require very little cortical activation. Motor planning, on the other hand, requires attention and cognition, enabling the brain to plan the kind of messages to send to the muscles and the sequence in which to send them.[6] Individuals with distinct motor planning challenges will have the concept of the goal but be unable to translate their ideas into an action plan.

Adequate integration of sensation is needed for all steps of motor planning. In order to form a goal, an individual must notice and orient to novelty in the environment and be motivated to explore. If the environment is overstimulating or threatening, the individual will tend to avoid the environment rather than explore it. Similarly, if an individual cannot optimally process the tactile and proprioceptive information obtained from motor action, the body scheme will not be adequate to support motor planning and the development of motor skills.[16]

Execution is the final expression of praxis.[13,15] Children with cerebral palsy exhibit deficits in motor execution; therefore, it is necessary to identify if poor execution is due to the neuromotor basis of cerebral palsy alone or to an additional practice deficit.[15]

Challenges with praxis are evident in both children and adults experiencing neuropathology. Apraxia in the adult client can have profound effects on the ability to perform even basic living skills. Both ideational apraxia and motor apraxia impede an individual’s ability to learn and carry over new motor tasks. Therefore, intervention is designed to help the individual use tools and motor patterns in the intended functional context.

Ideational apraxia is not an impairment of object recognition but a loss of knowledge of tool use. An individual with this impairment may demonstrate a lack of initiation and/or disordered sequences of movements to complete a task. This individual may show perseverative movement patterns without error correction. With motor apraxia, any body part may be involved. Therefore, limb, oral, and respiratory apraxia can exist. In adults, as in children, ideational apraxia is a conceptual disorder, whereas motor apraxia is a disorder of movement production.[17]

Intervention for apraxia requires the OT to be vigilant throughout the intervention process. Repetition of more effective motor patterns is imperative for the individual to acquire new or recover earlier motor patterns. The NDT-educated OT knows exactly which aspect of a movement sequence will be challenging for an individual and anticipates the correct amount of assistance required. Over time, as facilitation fades, the individual is allowed to reestablish preinsult routines or create new routines and habits of motor performance. Verbal, visual, and tactile cues and even modeling movement behaviors are ways to help facilitate changes to patterns of movement. As always, the NDT-educated OT is seeking ways to gradually withdraw sensorimotor input and thereby increase the individual’s autonomy. It is essential to grade activity by controlling the degrees of freedom, speed, resistance, number of steps, and tool or task complexity. In the case of apraxia, allowing the client to make errors safely is an important aspect of intervention because it allows the opportunity for error identification and correction.

16.2.5 Examining, Evaluating, and Intervention with Physiological Arousal

Arousal is the foundation of attention, behavior, and learning. The neurobiology is typically organized in such a way as to provide a pulse of background energy, providing sufficient excitability for arousal state adaptation to the demands of the environment. This underlying mechanism is frequently altered in both adults and children with neuropathology. An optimum level of arousal is necessary for flexible and integrated self-regulation for all forms of functional engagement.[6]

The NDT-educated OT is highly skilled at observing, monitoring, and treating the arousal level of the individual relative to the task, the movement demands, and the environment.

Arousal levels in individuals operate on a continuum from sleep through alert, attentive wakefulness to states of emotional dysregulation and fear. To ensure survival, the brain is designed to monitor the environment for danger. When the sensory systems operate ineffectively, typical danger cues may be misinterpreted, heightened, or dampened. To learn, the survival brain must be in a relaxed state, free from fight–flight–fright. Clients with neuropathology who experience difficulty with modulation of arousal and orientation will experience limitations in their ability to learn, focus on, and control posture and movement.

A baby experiencing posture and movement challenges may spend an entire therapy session crying inconsolably while the therapist attempts to influence the motor system. This child is likely overly aroused beyond the window of tolerance, which limits the child's overall potential for learning new movement patterns. Alternately, an individual who is lethargic and low energy in appearance may exhibit limited motivation despite high-intensity attempts to generate engagement and is also unavailable for learning.

Dysregulation of arousal has a tremendous influence on many aspects of critical function. Sleep regulation is a common issue for both children and adults with neuropathology. The OT brings to the examination process the ability to gather information as to how each sensory system supports or interferes with the person's ability to fall asleep and to return to sleep after waking. This evaluation aids in the design of interventions that foster self-regulation and modulation of arousal. For example, some individuals may require rocking or movement in silence, whereas others may benefit from sensations, such as music or white noise, to downregulate to a sleep state.[16]

Intervention for arousal-related impairments will depend on whether the individual presents as low arousal or high arousal. Sensory soothing or calming experiences can help any individual who is anxious and are also helpful when individuals experience sensory defensiveness. Calming activities help to relax the nervous system and can reduce heightened states of arousal. Deep-pressure touch, snuggling in a sleeping bag (or swaddling a younger child), slow rocking or swaying, slow swinging, spandex clothing, sucking, and reduced noise and light are examples of intervention activities that the NDT-educated OT can incorporate within the NDT intervention plan to calm and organize the individual's overall state of arousal.

Alternately, upregulating activities are helpful when the individual requires alerting and organizing. Bright lights, fresh or cool air, fast swinging, unpredictable movements, and visually stimulating objects and rooms can help to alert an individual who is underaroused, passive, lethargic, and disconnected from the environment. Positioning individuals in an upright posture stimulates the reticular activating system, shifting the state of arousal into alertness and orientation. Sensory interventions, such as loud or alerting sounds, bright colors, meaningful objects and pictures, and familiar smells, such as favorite foods, flowers, or perfumes, are often introduced to "wake up" the nervous system—therapeutically arousing and organizing the individual in preparation to learn and move. Arousal can be influenced with meaningful, motivating activities that are typically provided in the vertical position.

The NDT-educated OT, who intimately understands self-regulation and sensory contributions to arousal, will influence the nervous system arousal state by providing sensory experiences embedded in play, activity, or movement to either alert or calm the state of arousal in preparation for attention and focus to learn. The therapist may enlist a multisensory opportunity to align state with action.

Arousal dysregulation is often an acute issue for individuals recovering from a stroke or brain injury. The size and location of the infarct or brain injury, the amount of time since the injury, and the probable sedating effects of medications are all factors that contribute to an impaired arousal state in the adult with neuropathology. Adults may present with either low or high arousal, especially during the acute phase of recovery.

A decreased state of arousal during the acute stage is not unexpected. However, a prolonged inability to wake and attend to stimulation may present with a poorer prognosis for the individual. During the recovery process, a worsening arousal state is a sign requiring communication with medical professionals. Increased edema or infection in the brain or elsewhere in the body can alter arousal states and requires immediate attention.

It is important to inquire about an individual's sleep pattern prior to the insult or injury as it relates to the current arousal state. The third-shift worker, for example, may have difficulty adjusting to the 7 a.m. to 5 p.m. therapy schedule. It may be preferable to provide therapy later in the day to enhance the possibility of this person's participation. Collaborating closely with the team and knowing when medication changes occur, the side effects of medications, and possible drug interactions help the OT understand the many interrelated factors that contribute to low arousal.

The individual who presents as overly aroused may exhibit a poor ability to grade muscle activity and demonstrate ballistic muscle actions. Facilitating graded control during both gross and fine motor movements helps to enhance the individual's ability to grade components of movement during functional activities. Guiding a slow and gentle movement with a hairbrush, allowing the client to brush her own hair, may be calming. The therapist is challenged to select appropriate activities that facilitate success and reduce frustration or overexcitability.

16.2.6 Examining, Evaluating, and Intervention with Attention and Higher Cognitive Skills

Arousal and alertness are prerequisite skills for the individual to be able to cognitively attend. Once the individual is able to maintain an adequate state of arousal, attention is more available for learning. Attention is described as the organizing force for all behavior. Attention can be divided into specific components. Sohlberg and Mateer[18] noted that, although the attentional system appears quite vulnerable to disruption, it also appears to be amenable to intervention.

Sohlberg and Mateer[18] describe five levels of attention in a hierarchy:

1. Focused—seconds.
2. Sustained—minutes.

3. Selective—the ability to ignore extraneous stimulation/pay attention in a busy environment (e.g., ignoring the people at the next table while having a conversation in a busy restaurant).
4. Alternating—doing one activity, stopping to do another activity, returning to the first activity (e.g., stirring a pot of soup, then taking laundry out of the dryer, returning to stir the soup).
5. Divided—two activities at once (e.g., cutting vegetables for a salad while talking on the phone).

Attention is a precursor for memory, meaningful communication, and executive functioning according to Sohlberg and Mateer.[19] Attention is a necessary cognitive substrate for the formulation of memories.[19] Therapists will need to understand the different forms of memory and their neural substrates. Understanding the difference between procedural memory and declarative memory will guide the clinician in knowing what type of practice is most beneficial in helping clients learn and relearn skills as well as whether verbal cues about the movement and task details are helpful to the learning process. This knowledge is especially pertinent with individuals experiencing damage to the language center of the nervous system.

Executive functioning is defined as the CEO of cognition and includes skills such as initiation, problem solving, decision making, planning, organizing, self-regulation, time management, and error correction. Higher-order cognition also involves intellectual thinking, anticipatory thinking, self-awareness, and self-reflection. In collaboration with other team members, such as psychologists and special educators, the NDT-educated OT brings to the team an understanding of cognitive limitations' effect on learning of movement, memory of movements, and generalization of movements across tasks and environments. Cognitive impairments affect function due to difficulty recalling moving patterns and task sequences, difficulty with home programs, and carryover.

Individuals with TBI suffer severe cognitive impairments that can impede motor ability and limit all aspects of ADLs/IADLs. During the early stages of recovery, cognitive impairment may represent the greatest challenge to the clinician. Clinicians working with individuals with TBI must systematically approach cognitive impairments as eagerly as they would approach a motor deficit. Just as a therapist cannot wait for all aspects of lower extremity range of motion, strength, and coordination to return before placing the individual into standing, that same therapist cannot wait for attention to improve before adding a cognitive demand during a meaningful, familiar, functional task.

NDT-educated therapists are skilled in the ability to pinpoint a client's functional activities and activity limitations as related to the specific body systems that are intact or impaired. Therapeutic interventions and outcomes must be designed with cognitive functioning in mind. Frequently, cognitive impairments are looked upon as a stumbling block to future functioning, rather than a changeable condition that can be specifically addressed.

Individuals with cognitive impairments may present with decreased speed and efficiency when processing information and may need additional time to respond. They may demonstrate disrupted attention and concentration, which, in turn, affects memory and ability to learn new information. They may struggle with perceptual disturbances and communication deficits and have decreased executive functions. An integrated holistic intervention plan that considers the cognitive system can improve an individual's ability to reduce, manage, or cope with any of the above impairments.

A task can be made less demanding or more challenging by changing the environment. For example, locating the items necessary to make a sandwich in a quiet kitchen is a very different task than locating items on a grocery list at a busy store on a Saturday morning. A therapist can modify the task to ensure the activity provides a challenge and sets the stage for a successful outcome. For example, choosing a simple, familiar task, such as combing the hair, will be easier initially than the entire grooming or dressing process. Providing consistent verbal cues and handling strategies to an individual with cognitive deficits will be helpful in overcoming motor and perceptual impairments.

Contextual cues also provide guidance for the activity. For example, if the goal is for the client to attend to a grooming task, he is provided with actual grooming tools (toothbrush) at the specific time these would be necessary (in the morning after breakfast), and in the appropriate environment (standing in the bathroom in front of a mirror and sink). The therapist may need to help him initiate the correct motor plan to start the task, such as hand-over-hand cueing to begin to bring the toothbrush loaded with toothpaste to the mouth. The therapist's handling decreases as the client engages in or takes over the task.

For the individual with communication or language impairments, gestural cues may be a good option. At times, it is sufficient to simply set up the environment, such that the necessary items for task completion are within the visual the field (visual cue.) However, a single auditory cue, "Brush your teeth," may be necessary to allow the individual to begin, engage, and complete the task.

The Contribution of Neglect to Inattention

Neglect and inattention are two challenging deficits to address in the individual following a stroke. It is important to start with an understanding of the difference between unilateral body neglect and unilateral spatial neglect. The conceptual definition of unilateral body neglect is the failure to report, respond, or orient to a unilateral stimulus presented to the body side contralateral to a cerebral lesion.[19] It can result from defective sensory processing or attention deficit, which causes ignorance of or impaired use of extremities. Operationally, unilateral body neglect presents as an individual who does not dress, wash, shave, comb his hair, or attend to the more involved side of the body, as noted by Arndottir.[19]

Unilateral spatial neglect, on the other hand, is defined conceptually as "inattention to or neglect of visual stimuli presented in extra-personal space of the side contralateral to a cerebral lesion because of visual perceptual deficits or impaired attention."[19] This may occur independently of visual deficits or with hemianopsia (synonymous with unilateral visual neglect) and operationally presents as an individual who does not account for objects in the visual field on the affected side, usually on the left side. For example, the individual tends to, when moving, run into furniture, doorways, or walls located in the affected visual field.[19]

Unilateral neglect usually involves infarcts in the inferior parietal lobe, temporoparietal junction, and/or the superior temporal lobe. Most theories of the nature of neglect assume that neglect involves dysfunctional attentional mechanisms from right parietal lobe pathology, leading to body scheme disorders that may include unilateral spatial or body neglect.[20] The parietal lobes process somatosensory and complex sensory information from multimodal stimuli contributing to the internal schema of the body.[20]

The right hemisphere is responsible for the mediation of attention and is also dominant for intention, including preparation for action or readiness to respond. Attention is important for processing information from sensory modalities. Intention is an important component for movement. Thus it is evident that unilateral spatial or body inattention and neglect are multifaceted impairments involving sensory processing as well as cognitive abilities. These place NDT-educated OTs in a unique position of holistic examination and intervention given their appreciation of the interplay between these facets of function.

Within the context of the NDT Practice Model, the OT would introduce handling, active weight bearing, and weight shifting to draw attention to the neglected side of the body within all tasks in functional contexts. The individual would have an opportunity to activate the whole body while increasing somatosensory experiences to the neglected side through these closed-chain movements. As demonstrated in Case Report A3 about Carol in Unit V, the therapist used familiar and meaningful environments for the client, such as her sewing room and her garden to work on active support through her more involved left arm and leg while she attended to task objects within these environments, including those on her left, neglected side. Positioning the objects used for these tasks, such as thread, sewing patterns, and scissors for sewing, and pruning shears, potting soil, and the trowel for gardening, on her left side and directly in front of her, required Carol to scan and find the objects to complete the task(s).

When providing intervention for children with hemiplegia, therapists find that unilateral spatial or body neglect is very difficult to evaluate in young children because their parents dress them, bathe them, and feed them. The examination of unilateral spatial neglect in children becomes easier when one is observing mobility strategies. When neglect is suspected, the pediatric NDT-educated OT employs strategies similar to those already described, emphasizing sensorimotor experiences on the neglected side within the context of active movements in task. People, objects, toys, and activities are deliberately positioned on the neglected side. Often, children with neglect can actively grasp items in their hands; however, they may forget that an object remains in their hand. The object may drop or stay trapped within the hand without active use of the object. Active weight bearing and weight shifting within closed-chain activities is recommended within the NDT Practice Model for the pediatric client as well.

Garments such as the Stabilizing Pressure Input Orthosis (SPIO), Dynamic Movement Orthosis (DMO), as well as fabrifoam wraps, kinesiotaping, and e-stimulation, are examples of helpful adjuncts that can assist in the alteration of sensory input to bring greater sensory and attentional awareness to the neglected side. Additionally, modified constraint-induced movement therapy (CIMT) may potentially support increased visual awareness of the neglected side of the body and space.

16.2.7 Examining, Evaluating, and Intervention with Emotional and Social Skills

Those with physical or cognitive challenges often face real, and sometimes self-imposed, difficulty in building relationships. For children, delays in social, emotional, and even physical development can occur simply because a child is having difficulty communicating, fitting in, or feeling accepted. Emotional, attentional, and behavioral challenges can impede a child's ability to learn, grow, and develop. Together with other team members, the NDT-educated OT can contribute in the evaluation and intervention of social and emotional challenges as they relate to individuals' participation in their life roles.

Attachment is the relationship strategy that develops early on between child and caregivers to ensure protection from danger and to ensure survival. The attachment strategy can potentially become an insecure strategy when the child experiences a developmental disability. Quinn and Gordon[21] evaluated the effects of cerebral palsy on early attachment patterns in rural South African mothers. A child with cerebral palsy may not be able to signal the need for physical proximity or closeness in a conventional way due to motor, sensory, or cognitive deficits. This may affect the caregiver's attachment response to the child as a result of the challenges in attuning to and interpreting the child's signals of communication.[22]

Attachment behavior is observed when the infant initiates proximity-seeking behaviors such as crying, smiling, babbling, and gesturing. The adult in an attachment relationship responds to these cues with sensitivity and demonstrates behaviors such as holding, speaking to, feeding, or performing an action the child expected.[23]

According to Quinn and Gordon,[21] perceived security enables the infant to explore the world with confidence. In this study, mothers indicated that, although they love their children, a child with cerebral palsy was more demanding emotionally and physically. The following statement corroborates this point. "The biggest difficulty is that I don't know what is going on with him, sometimes it is like he is sick, even when he is crying without the tears, you know that there is something wrong and he is not able to tell. I find that very hard and I feel hurt because I can't tell and he can't tell me."[21] Insecure attachment has been correlated to anxiety, social deficits, and, at times, social phobia.[24]

In a study conducted by Vogtle,[25] an examination of the long-term outcomes of cerebral palsy's effects on social participation and quality of life in adulthood illuminated several conditions that contribute to social and emotional limitations across the life span. Two factors that significantly affect social integration and participation in adults with cerebral palsy are education and employment. Cerebral palsy can influence cognition, thereby varying educational achievement and employment. The Vogtle article also indicates that, generally, adults with cerebral palsy do not have the same level of intimate relationships or autonomy that adults without disabilities have. Social acceptance may play a role in the difficulties that adults with cerebral palsy encounter in trying to establish intimate relationships.[25]

Depression and anxiety are common phenomena in individuals following a stroke. Emotional responses to disability, such as from a stroke, often occur as individuals gain increased awareness of their situation, deficits, and changes in their life roles and participation. Collaboration with team members may be necessary as an aspect of integrated intervention with the use of medications, cognitive behavioral intervention, and the introduction of a purposeful occupation to increase motivation and a sense of well-being.

16.2.8 Identifying Activities of Daily Living and Their Limitations

The achievement of functional independence is the foundation of the profession of occupational therapy. The NDT-trained therapist brings to the NDT intervention process the ability to evaluate and intervene with impairments that lead to activity limitations identified by individuals or their family.

For example, if an OT's goal is to increase a child's ability to don a shirt by pulling it over his head, the child's ability to activate his core musculature so his arms can move away from his body to reach overhead needs careful evaluation. Repeated postural strategies, such as the inability to weight shift in sitting, may suggest a system impairment that interferes with the achievement of a stable base of support for postural control in sitting.

When evaluating an adult after a stroke or other brain injury, the therapist may find that challenges in donning a shirt may result from a complex interplay of factors, such as the inability to sustain trunk coactivation, shortened pectoral muscles limiting glenohumeral external rotation range, weakness of humeral flexors, weakness of the intrinsic muscles of the hand, visual perceptual challenges, and motor planning issues.

Dressing, grooming, bathing, and self-feeding skills are repeated daily and are integral to independence. If a daily life skill is repeated using atypical movement strategies, performing these tasks will reinforce the atypical patterns of movement, potentially creating secondary impairments. Secondary impairments may include muscle length–tension impairments, weakness and loss of passive range of motion, and tight or overstretched ligaments, all factors that may contribute to pain and swelling.

For example, if an adult with neuropathology puts on and takes off shirts and jackets by collapsing his trunk over his lower body in sitting, the pattern reinforces the progression of increasing spinal flexion. With repetition, this pattern will negatively influence the individual's ability to activate his base of support and core musculature for postural control in activities that require spinal extension and lateral trunk control. Subsequently, this inactivity and malalignment will affect head and neck alignment and control, potentially altering the ability to organize and isolate eye from head movements for visual exploration of the environment or effective eye contact for communication. Thus secondary impairments, such as progressive shortening of the cervical extensor muscles, may result as the individual attempts to use his vision with a forward head position, further limiting the ability to coactivate neck musculature for vision efficiency in all quadrants of the visual field.

When treating adults or children with an ADL or IADL outcome in mind, preparation to address system impairments may be required. For example, when working toward developing shirt-donning skills, preparation may include lengthening the muscles and soft tissue around the shoulder girdle combined with facilitating active support through the arm. Simulation may consist of the therapist creating activities that demand more typical muscle activation patterns, requiring the same components of movement and postural control necessary for the performance of the entire functional task. For example, simulating putting on a shirt over the head may be introduced by having a child put necklaces, hoops, or sleeves of fabric over her head. By using objects that are associated with play, the therapist can facilitate necessary components of movement in a way that is fun. Simulation may also include reach, grasp, and release of items, first with the less involved arm and then, when able, with the more involved arm, using objects in the environment requiring similar patterns of movement.

For example, moving objects from waist level to over the shoulder and behind the trunk replicates the actions of donning a shirt. Following simulation, practice involving the actual items of the ADL skills is performed within both therapeutic contexts and natural environments.

Throughout the intervention process, handling is often combined with adjuncts to achieve goals of alignment, improved patterns of movement, and, ultimately, independence in functional tasks. Adaptive equipment for ADLs and IADLs, splints, orthotics, garments, kinesio tape, and individualized seating systems, are only several of the tools that may be used to complement therapy.

When addressing functional skills that require hand function, such as eating with a fork, the NDT-educated OT needs to evaluate not only the various subtasks of the activity, such as how the hand shapes and moves, but also the mobility of the hips over the femurs to determine whether the individual can anteriorly shift his weight to reach for the fork or a piece of food, and the ability of the individual to activate the postural muscles of the trunk and muscles of the legs to allow for both movement and support. The arm requires shoulder girdle strength to connect the tines of the fork to the food and then pierce it. The ability to activate capital flexion and shift the gaze downward to locate the food on the plate is also a needed subcomponent requiring both evaluation and intervention. All individual tasks and subtasks can be evaluated and treated with observation, manipulation of the environment, and handling. The NDT frame of reference elegantly integrates the evaluation and intervention of all of these movement components, holistically emphasizing the posture and movement aspects of a task.

16.2.9 Focusing on Play, Work, and Leisure

Play is often referred to as the work of the child, whereas leisure conjures up images of relaxation and fun for the adult. Play, work, and leisure are areas of occupation that OTs evaluate and treat to facilitate exploration and participation for individuals.

Play influences every aspect of child development. Play nurtures children's creativity and problem-solving capacity. Play activities build strength and coordination and enhance emotional health. The involvement of the body in play helps develop connections between the cerebellum and the pre-motor cortex, and this connection accelerates a child's ability to learn. Brown and Vaughn[27] report that the period of maximum play is tied to the rate and size of growth in the cerebellum. The functions and connections of the cerebellum have recently been discovered to be responsible for key cognitive functions, such as attention, language processing, sensing musical rhythm, and more.[26]

Curiosity about and manipulation of objects is a pervasive, innately fun pattern of play and represents its own state (intrinsic pattern) of playfulness.[27] Children with neuropathology often experience difficulty with object manipulation due to primary and secondary impairments, limiting this intrinsic form of play. NDT-educated OTs who comprehend both the process of play and playfulness integrate these concepts into the NDT Practice Model. Incorporation of play into a therapeutic session becomes the backdrop for learning and rehearsal of new patterns of posture and movement. The choices of play activities are selected with deliberation to address identified impairments. Therapists choose activities based on (1) what is motivating for the individual and (2) what will address the individual's impairments. For example, impairments in sustaining activity in postural control muscles can be addressed by incorporating play activities that encourage reaching into space repeatedly, such as hitting a suspended target or spreading shaving cream on a mirror mounted vertically in space. With a focus on strengthening the postural system (**Fig. 16.10**), the control necessary to support fractionated movements of the upper extremities and visual system is enhanced, expanding the child's ability to participate in tasks.

The NDT-educated OT can assist with toy adaptation to increase accessibility. Altering demands of the task, changing the environment, and facilitating the appropriate components of movement during a play sequence are integral to the NDT practice model for all disciplines. The ultimate goal is to achieve participation in play that facilitates learning, self-esteem, and overall competency.

Fig. 16.10 Facilitating rotation for postural control within a motor accuracy task.

Similar to play for the child, the NDT-educated OT analyzes, adapts, and facilitates leisure activities for the adult client. Following neuropathology, individuals may lose their ability to participate in their prior leisure activities. Using the NDT Practice Model, OTs assess functioning in all domains, including the ability to resume roles in society and the family. Participating in leisure activities allows individuals to express themselves and to rediscover their full personality and potential. Leisure activities include reading, cooking, gardening, book clubs, sports, horseback riding, walks with family, and myriad other interests. Participating in leisure activities supports a return to social functioning, which is instrumental to feelings of self-worth and enjoyment, contributing to quality of life through personal satisfaction. Studies have indicated that, without question, the ability to engage in leisure was meaningful and improved the quality of life.[25]

Returning to work is the goal of many individuals following neuropathology. Work is a way for individuals to provide a means of self-efficacy, both psychologically and financially, prevent isolation, and restore their quality of life. Vestling et al[27] concluded that individuals who had returned to work after a stroke had a much higher subjective well-being than those who did not.

Determinants of whether individuals can return to work are often based on the severity of the stroke and the resultant single- and multisystem impairments.

According to one study by Black-Schaffer,[28] there was a positive correlation between the number of stroke survivors returning to work and a high Barthel Index on admission. There was also a correlation between those with aphasia and those not returning to work. In addition to functional impairments, depression following stroke can affect the desire to return to work.[28]

Returning to work involves a complex interrelationship between the person's personality, support systems, skills required for the job, and stroke-related impairments. A recent study by Hartke et al[29] reports that "intrapersonal or psychological, interpersonal, and organizational issues" are faced by stroke survivors in returning to work and that "it is apparent that the process of return to work is multi-factorial and involves more than stroke impairments."[29]

Factors that may prevent a return to work include physical, visual, perceptual, cognitive, and speech impairments that continue despite rehabilitation efforts. In addition, depression, living alone, and lack of transportation have been identified as factors in returning to work.[30] An NDT-educated OT, working with an individual for returning to work, needs to have a thorough understanding of the primary and secondary impairments limiting the person from doing so and must then be able to address the impairments to prepare the person functionally for job-related skills. Work simulation and work site evaluations are helpful in determining possible difficulties. Remediation of the posture and movement components within the context of the occupational task requirements is incorporated into the intervention regime.[31] Problem solving with the individual for possible adaptations, technology, and environmental changes is also critical. In Case Report A2 about JW in Unit V, the client was eager to return to work as an information technology educator at a large university. The therapists working with her needed to understand her work activities and environments so that they could determine the movement components necessary for her to return to work successfully. From this analysis and understanding of her occupational tasks and environments, they were able to make the right choices for intervention activities to challenge her impairments and help her return to work. They practiced simulation activities in the therapy department as well as organized practice time at her office and in the classrooms on the university campus for her to gain confidence and skill in her movements in the real environment. JW's NDT-educated therapists collaborated with an OT from the community who could see the client at the work site. Modifications (some temporary and others longer term) in the organization of her office, the phone and computer setup, and how she managed her briefcase and jacket as she moved from office to office or to classrooms through doorways, up and down stairs, and in crowds on campus, were considered and incorporated to help the client transition back to work.

The NDT-educated OT evaluates the individual holistically in return to work situations and thus collaborates with vocational rehabilitation services, vocational counselors, employers, family, and the entire health care team to achieve this outcome. Suggestions may include schedule flexibility, part-time employment, alternate work responsibilities, work station/environmental changes, and work-from-home possibilities.

OTs working within an NDT framework are in the position to assess all systems that may affect the person's potential to return to work and coordinate community resources to help clients achieve their highest potential to return to all prior functional activities, including employment.

16.3 Conclusion

The profession of occupational therapy is profoundly enhanced, advanced, and expanded through the learning, knowledge, and handling skills acquired during the NDT education process. The philosophies of OT and NDT merge naturally, making the OT an integral contributing member of the rehabilitation team serving individuals experiencing neuropathology.

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17 The Practice of Physical Therapy from a Neuro-Developmental Treatment Perspective

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This chapter first traces the history of the profession of physical therapy (physiotherapy), which provides the reader with a focus that continues to influence the profession today. The addition of the Neuro-Developmental Treatment (NDT) Practice Model and its influences on the profession follow, along with specific examples of problem solving and decision making using commonly addressed activities and participation that physical therapists (PTs) encounter.

Learning Objectives

Upon completing this chapter the reader will be able to do the following:

- Define who a physical therapist/physiotherapist (PT) is in terms of professional responsibilities and functional outcomes addressed in client management.
- List at least three skills NDT education enhances in the professional skills of PTs.
- Analyze a physical therapy outcome with a specific participation or activity of a client in the reader's own practice using the NDT Practice Model.

17.1 Definition of Physical Therapy (Physiotherapy)

Physical therapists or physiotherapists (PTs) "are health care professionals who diagnose and treat individuals of all ages, from newborns to the very oldest, who have medical problems or other health-related conditions that limit their abilities to move and perform functional activities in their daily lives."[1] Physical therapy as a profession provides clinical services aimed at the acquisition, refinement, restoration, maintenance, and rehabilitation of physical function.[2] These services include diagnosis and management of movement dysfunction and the promotion of physical wellness, fitness, and prevention of injury and disability.

PTs manage their patients or clients through a process of examination, evaluation, diagnosis, prognosis, and intervention using therapeutic measures to achieve functional physical outcomes. They manage their patients and clients to alleviate pain; prevent onset or progression of impairment, activity limitation, and participation restrictions due to injury or disease; and restore, maintain, and promote overall fitness, health, and optimal quality of life.[3] Although the profession has always been closely aligned to the medical profession, current entry-level education and licensure in many countries or parts of countries allow autonomous practice.

17.2 A Brief History of Physical Therapy and the Origins of Neuro-Developmental Treatment

The official origin of the practice of physiotherapy can be traced back to Per Henrik Ling in 1813 with the founding of the Royal Central Institute of Gymnastics. Ling is known as the father of Swedish Gymnastics. The Institute was founded for massage, manipulation, and exercise. Through Ling's experiences in England, Germany, and France, and with a Chinese man who taught him martial arts, he realized the importance of using exercises for the health of others.[4]

The roots of the physical therapy profession may have begun much earlier, however, with evidence for the practice of massage in China as early as 3000 BC. There are also references to friction massage from Hippocrates (460–377 BC).[5] History and oral stories in many cultures describe hands-on physical manipulation in medical treatment, exercise for health benefits, hydrotherapy, protocols for individuals postparalysis and paresis, and therapeutic massage dating before the Common Era.[5,6,7,8] Thus the use of physical therapy to heal and rehabilitate was developed over thousands of years.[9]

In the late 19th century/early 20th century, two major historical events occurred that caused a fundamental adjustment to the practice of physical therapy.[9,10] Healing and restoration of physical function after traumatic injury during combat during World War I created a cohesive structure for a group of women called reconstruction aides. In the United States, this group of women with physical education backgrounds completed courses in anatomy and physiology and in care of individuals postamputation, postfracture, and with nervous disorders prior to being sent internationally to hospitals.[10]

The second group of individuals requiring this group's services resulted from poliomyelitis epidemics.[11] The intense attention to rehabilitation of the respiratory and neuromusculoskeletal systems in individuals with polio eventually broadened to the care of individuals with other pulmonary problems and to those who had had a stroke or who had cerebral palsy (CP).[11]

As physical therapy broadened from serving wounded soldiers and those with polio to a variety of individuals seeking physical habilitation and rehabilitation, educators, clinicians, and researchers began to develop an interest in various patient populations. The unique posture and movement impairments of individuals poststroke and those with CP, as well as the functional outcome needs of these two groups of people, drove the profession to learn more about each condition. As a result, PTs began a more focused look at two areas of physical function: development of motor skills and recovery of motor skills after a brain injury.

In the 1940s and 1950s, a dissatisfaction with the sole use of the orthopedic approach to surgery and bracing as a model for rehabilitation for these two groups led therapists to study how the central nervous system (CNS) works to more effectively treat individuals poststroke and with CP.[12] According to historical summaries by Gordon[12] and Cohen and Reed,[13] neurophysiological (or neurotherapeutic) approaches resulted and evolved: among these approaches were those of Kabat and Knott (proprioceptive neuromuscular facilitation), Rood, Brunnstrom, and Bobath and Bobath.

All neurophysiological approaches, including the Bobath approach that the Bobaths later named Neuro-Developmental Treatment (NDT), continue to evolve according to clinical observations and intervention results as well as the continual knowledge gained in the basic sciences.

17.3 Expertise and Contributions of Physical Therapists to NDT Practice

As noted in the brief history of physical therapy, the profession began as a medically oriented one, with an emphasis on anatomy and physiology. Worldwide, physical therapy education is now recommended to include the study of the anatomy and physiology of all body systems, biomechanics and kinesiology, exercise physiology (including posture and movement), and exercise prescription.[14] Entry-level education for PTs in many countries has a long tradition of single- and multisystem posture and movement analysis, including effective, ineffective, and compensatory posture and movement analysis. Physical therapy and physical therapist assistant (PTA) education focuses on biomechanical principles of human motion throughout anatomy and kinesiology courses. The PT brings all of this specialization to the NDT Practice Model as the movement analysis expert on the health care team.

The PT has in-depth knowledge of neuromusculoskeletal anatomy and physiology and a strong background in analyzing body systems in terms of mechanical stability and instability, synergistic action of muscles, and neuromusculoskeletal health and disease/disability. *Posture* and *movement* are familiar terms in physical therapy. Entry-level education prepares the PT and PTAs (in countries that educate PTAs) with postsecondary education to assess integrities and impairments in many body systems, including neuromuscular, musculoskeletal, respiratory, and sensory systems' reception and processing.

From the roots of the profession in massage, manual techniques, and exercise, to the more recent evolution of the specialized practice of manual therapy, physical therapy has long been considered the discipline within the health care team to provide the expertise in manual handling skills. The PT brings this skill to the practice of NDT where handling is one of the hallmarks.

In today's professional practice, PTs combine the centuries-long knowledge and skill base in the use of manual therapy and exercise, with the evidence supporting the potential for recovery of damaged neural tissue, to work with individuals who have dysfunctions of the CNS. The NDT Practice Model further adds to this skill set by honing the PT's understanding and integration of the role of the body's posture and movement systems in producing efficient movement that enables the individual to function at the level of the Activity and Participation domains of the International Classification of Functioning, Disability and Health (ICF).

17.4 The Contributions of NDT to Physical Therapy

NDT broadens the application of entry-level education for PTs into a structured practice model where the PT applies knowledge to the following:

- A focus on individualized, specific functional outcomes.
- Detailed biomechanical and kinesiological analysis of past, present, and potential future postures and movements.
- Intervention that affects whole-body function, posture, and movement.
- A big picture view of the effects of current function, posture, and movement on future function and body systems.

PTs are educated to assess, analyze, and intervene with body system functions and impairments in a detailed and thorough way. This process is one of the profession's strengths. NDT teaches the PT to use this skill within the context of how these individual single-system impairments affect the individual's functioning at the level of the ICF Activity and Participation domains using a cohesive practice model.

Bobath[15] stated in 1977, "[The therapist] must have a thorough knowledge of normal co-ordination and of the most essential 'basic patterns' which underlie a skill and make it possible. Only then can a systematic preparation for functional skills be made." In this same article, Bobath[15] advises therapists who are working with clients poststroke to note changes in postural tone and coordination of posture and movement, loss of normal movement patterns, loss of sensation, and loss of strength. She analyzed body system structures and functions long before the profession of PT as a whole began to do so.

Bobath's handling of her adult and pediatric clients was always taught as a means of assessment as well as treatment. She taught that handling could be used as assistance for body segment support, guidance and assistance of posture and movement, and sensory input. She taught that handling should be systematically withdrawn as the client is able to control and coordinate posture and movement.[16] She gave to the physical therapy profession the ability to observe constantly throughout intervention and to respond to the client constantly. She insisted that PTs observe and treat the entire body. She taught PTs that they could change the outcomes for people poststroke and people with CP.[17] So much of this mindset seems a part of standard PT practice now, but we may not know how it originated.

The core curriculum in current NDT education includes careful observation and handling to assess the posture and movement strategies of each client to determine whether they are functionally effective or ineffective. This analysis includes predictions of future postures and movements based on the current repertoire of the client. Effective postures and movements expand the client's functional possibilities.

Ineffective and compensatory postures and movements are thoughtfully analyzed and weighed as to their potential both to allow current function and to assist or impede future functioning. They are not accepted as inevitable nor are they viewed as completely unacceptable in and of themselves. In NDT education, ineffective and compensatory postures and movements are explored as to their potential to assist with function and to limit function. The ICF model assists in an understanding of the influence of ineffective and compensatory postures and movements on current and future activity and participation. The PT uses this information to become a more expert practitioner, who applies the depth of constant observation, the constant response of the client, detailed analysis of posture and movement, and whole-body and life span viewpoints to continue education beyond entry-level education.

17.4.1 Problem-Solving of the Physical Therapist Using the NDT Practice Model: A Child with Cerebral Palsy

An example of using the NDT Practice Model as a PT illustrates how NDT education deepens the PT's problem-solving skills. A child with CP often uses W-sitting as a functional way to sit on the floor (**Fig. 17.1**). This sitting posture allows balance and control of sitting in the presence of restricted hip mobility (especially hip abduction and external rotation range) and limited muscle length (especially length of the hip flexors, medial hamstrings, and hip adductors). W-sitting provides the child with a large base of support within these ranges of motion and muscle length impairments, providing structural stability to the child's trunk, which also may be limited in antigravity control and mobility. The position of the hips in flexion, internal rotation, and varying ranges of abduction/adduction, along with the trunk positioned between the hips in a way that limits the necessity of full sagittal, frontal, and transverse plane control for an upright position, provides skeletal stability to free the child's arms for play. This play, of course, is the functional desire of the child, who is unconcerned with *how* posture and movement must be achieved.

A physical therapist and parent are concerned about how the child sits, however, for several reasons.

- The posture, if practiced for prolonged periods, does not promote joint mobility and muscle length changes, especially in the trunk and lower extremities. It is ineffective in expanding neuromuscular, musculoskeletal, and perceptual functions as well as preventing the development of more effective postural control necessary for a variety of activities and participation.

Fig. 17.1 This child with spastic cerebral palsy W-sits. This position allows her to use her arms for play in the presence of posture and movement impairments in her lower body.

- The prolonged posture may contribute to skeletal deformity over time (i.e., increased spinal flexion, femoral antetorsion and anteversion, hip dysplasia, external tibial torsion) and continued shortened muscle length. These secondary impairments may ultimately result in a loss of current activity and participation. The child may lose the ability to sit in a chair at the dinner table because the hamstrings become so shortened that even short sitting becomes compromised, or the increase in thoracic kyphosis over time could affect the safety of the child's ability to eat and drink.
- Spinal and lower extremity (LE) positions used in W-sitting may predominate in other positions, most notably standing and walking, which contributes to high energy cost and potential joint damage. Therefore, limited choices for body segment alignment and muscle activity interfere with all activities now, not just sitting choices.
- High energy cost, joint damage over time, and limited opportunities for more complex postures and movements to develop may result, thereby limiting functions such as community-level ambulation, running, and stair climbing, as well as participation using these activities.

The NDT-educated PT understands, however, that the solution is not simple and easy. Simply telling the child and family that the child is not allowed to sit that way because problems could result leaves the child with no alternatives for function. The PT knows that if she recommends that a child no longer use W-sitting in spontaneous, functional floor play, a solution to floor sitting that is just as easy to get in and out of and that allows use of the arms for play is necessary for the recommendation to be easily accepted. Unfortunately, such a solution is rarely readily available. The PT must weigh many considerations when offering potential alternatives to W-sitting for floor play. They include, but are not limited to, the following:

- How easy will it be for the child to get in and out of an alternate sitting position?
- Will the alternative allow the child to play as easily and safely as when she is W-sitting?
- Will an alternative solution potentially cause another set of posture and movement and therefore function problems?

The PT, family, and possibly the child herself must discuss and problem-solve about this situation in a way that embraces the unique functioning of the family. Can the child be seated at a table or in a booster chair for play *sometimes* (this requires adult assistance) in a way that will promote erect postural control in the trunk and weight shifting from one hip to the other? Can the PT incorporate posture and movement intervention strategies into the current plan of care to accomplish alternative sitting positions *that the child can effectively assume and sustain spontaneously or with some level of parental assistance?* What may be the long-term participation restrictions if the child cannot achieve another floor-sitting position? Are these restrictions significant enough that measures to eliminate floor sitting from the child's repertoire of play are deemed necessary even when the child may not readily accept this solution?

17.4.2 Problem-Solving of the Physical Therapist Using the NDT Practice Model: An Adult Poststroke

Adults poststroke often begin to live and function on the less involved side of their body. They learn to sit, transition between postures, stand and walk, all with a heavy dependence on the less involved arm and leg. Therapy approaches may direct the individual to strengthen these strategies with repeated practice of functional tasks that emphasize the reliance on the less involved limbs. These strategies may include transfer practice in and out of bed, on and off the toilet, into and out of a wheelchair, all to the stronger side, or walking practice inside the parallel bars, and stair practice with instructions to "lead up with the strong leg and down with the weak leg." Often, devices such as hemi-walkers, quad- and single-point canes, grab bars by the bed and in the bathroom for transfers, and adapted tools for activities of daily living (ADLs), such as rocker knives, reachers, and other one-handed bathroom and kitchen devices, are prescribed for this individual to promote independence. (The advent of Velcro, as useful as it is in many realms of life, also contributes to this path to compensation.)

However, in this effort to promote independence, PTs may be encouraging a bias of strengthening what is still working at the expense of what is not working or is working but with impairments on the more involved side, including the trunk. A similar list of concerns and the sequelae of secondary impairments as outlined in the example of the child who W-sits could be made for this individual.

Over time, the overuse and dependence on the muscles, joints, and ligaments in the trunk and of the more involved arm and leg may lead to pain, fatigue, and skeletal deformities (**Fig. 17.2**). For example, chronic shoulder subluxation can lead to an overstretched capsule, overlengthened cervical and scapular muscles, impinged tendons and bursas at the shoulder, and pain. Chronic knee hyperextension can lead to overlengthened posterior knee capsular ligaments, joint surface deterioration, and shortening of the gastrocnemius–soleus muscle group. The effect of these alignments may guide the shoulder into further internal rotation and adduction leading to impingement syndromes, the hip into flexion and adduction and the ankle into plantar flexion and inversion causing further stress at these joints, and the trunk into thoracic flexion with lateral shortening. All of these changes lead to the individual's center of mass (COM) being shifted over a smaller and less dynamic base of support (BOS). This posture may result in impaired balance and difficulty shifting weight over the BOS in postures such as sitting and standing and in movements such that the individual's functions in activities such as walking in and outdoors, getting in and out of a car, swinging a golf club, and getting dressed for work all become compromised.

Fig. 17.2 Carol, a woman poststroke whose case report appears in Unit V (A3) shows malalignment in standing that contributes to poor balance and ineffective movement through space.

The client, the PT, and the involved family members must explore the possibilities for other movement solutions that still promote independence, in both the short and the long term, while also assisting CNS recovery from the stroke damage and the subsequent body system impairments the stroke caused.

Clearly, for the individuals in the foregoing examples, the PT must focus on each ineffective or compensatory posture and movement the client makes or is likely to make. The PT may decide with the client and family to accept some compensations (fully or in part) and not accept others (within their control). Understanding past, present, and future postures and movements that each person with CP or poststroke uses or may use requires a deep working knowledge of effective, ineffective, and compensatory body system development and function, biomechanics, kinesiology, and the effects of posture and movement repetition on function.

17.4.3 Exercise and Practice

NDT-educated PTs view activity and participation as the desired outcomes for clients with stroke, traumatic brain injury (TBI), CP, and related neurodisabilities. This view shapes their entire practice, from initial information gathering and examination through intervention and home/school/work/leisure program suggestions. Because stroke, TBI, CP, and related neurodisabilities adversely affect the ability to produce all of the posture and movement requirements of function, repetitive, open-chained exercises using isolated muscle activity are usually insufficient in meeting activity and participation requirements. NDT-educated PTs focus instead on posture and movement requirements within specific functional tasks chosen by clients as outcomes. However, the principles of exercise learned in entry-level university education assist in intervention in the following ways:

- The PT modifies the effects of gravity as appropriate, controls the effects of body and segmental position, provides support of the body segmentally and as a whole, and monitors demands on all body systems (i.e., neuromuscular, musculoskeletal, sensory, perceptual, cardiovascular, respiratory) while the client engages in participation, activity, and/or repetitions of functional postures and movements.
- The PT progresses activity, building from simple postures and movements for the client to control and coordinate to postures and movements of greater complexity.
- The PT includes practice and repetition, both for motor learning of participation and activity with the most effective postures and movements and for building endurance in body systems by increasing the level of challenge or interspersing rests as appropriate for each individual.
- The PT monitors the client's physiological responses to the physical work required.

For example, a PT working with a 6-year-old child with CP (spastic diplegia) sets a session outcome for the child to step up a 3- to 5-inch-high curb or to step using forearm crutches. The PT knows that each time this particular child attempts a new skill requiring more complex strength and balance (and in this case, the fear of using crutches in a new way), his first choice of posture includes increasing upper thoracic flexion, increasing weight bearing through the crutches with his hands, increasing shoulder internal rotation, breath holding, and increasing LE stiffness with more hip adduction and internal rotation than he uses when he is confident in his performance.

Strengthening and crutch use are skills PTs and PTAs learn in entry-level education, with faculty instruction and testing to ensure that the student monitors each skill for safety, correct procedure, and correct alignment. The activity outcome for this child requires much more than strengthening hip, knee, and ankle extensors concentrically to lift his body weight up the curb. The activity requires more than placing the crutches safely and properly. The PT and PTA following the PT's plan of care add detailed declarative and procedural knowledge from the NDT Practice Model regarding the following:

- Ensuring the client's best body alignment in all body segments in the initial posture in front of the curb, with one foot placed up on the curb, and in the ending posture.
- Ensuring the correct direction and amount of weight shifting needed to first unweight one LE, lift and place that LE on the curb step, shift weight onto that LE, and advance the trailing LE and crutches.
- Coordinating the child's posture and movement with respirations, and facilitating postures and movements that ensure effective respirations and continuous breathing throughout the activity of stepping up a curb. For this child, this coordination would include facilitating an upright trunk posture with active or active-assisted thoracic rotation and facilitating shoulder posture out of excessive internal rotation.
- Including practice sessions that progressively increase difficulty of the task, taking into consideration all body systems (i.e., not simply stepping up a higher step, but setting up the environment to reduce fear, progressing from a large space to place crutches to a narrower space if needed, controlling the visual perceptual demands of the task, and altering verbal and physical cues as needed).
- Ensuring practice of the more efficient postures and movements to complete the task while engaging this 6-year-old in activity commensurate with his age, cognitive, and attention needs.
- Providing information to the child's family for practice of the task that is safe and easy for the family to accomplish within their everyday routine and the child's activities (asking them to provide verbal and physical cues within their roles as family members vs. "doing therapy").

One scenario could be that the PT sets up an environment where the child steps up a 2- to 3-inch-high step and then a 3- to 5-inch-high step with physical assistance as needed to shift weight correctly and safely. Then the PT provides physical assist as necessary to align the LEs in that child's most efficient posture to use the extensors concentrically as he steps onto a platform with a large area. Simultaneously, the PT ensures a visually uncluttered environment and targets visual attention with a marker, such as colorful tape placed on top of the platform where his feet should step (**Fig. 17.3**).

The PT creates a game based on knowledge that this child enjoys water play, handing him small plastic animals to place in his pockets, after which he ascends the step and places the animals in the "bathtub." He descends the step to gather more animals. This game allows repetition of step/curb ascent and descent in a way that is engaging for the child. For a home practice activity, his mother is asked to place her hands on her son's shoulders to provide contact guarding and guide the correct weight shift as he steps up with his crutches onto the threshold step between the garage and the kitchen each time the family comes home from a car trip.

Fig. 17.3 A physical therapist assists a child to step up. Her handling assists trunk postural control and alignment of the leading leg.

This example emphasizes that, although the intervention for the outcome of stepping up a step or threshold requires specific repetitions of postures and movements that may require strengthening exercises of specific muscles, all major muscle activity is performed in closed-chain postures and movements of the entire body. In addition, lack of muscle strength is unlikely to be the only impairment or inexperience the child has.

Requirements of sensory feedback and feedforward, respirations coordinated with posture change and movement, the child's perception of safety and fear, joint mobility, and muscle extensibility are all a part of this function. Therefore, although the word *exercise* as it has been used for centuries is universally used and understood, our current knowledge from the movement sciences helps us to understand the relevance and importance of concepts such as movement being organized around the task, task specificity, and the criticalness of working within functional contexts. *Practice* of whole or partial task requirements with constant monitoring of all body systems that contribute to postures and movements of the task incorporates exercise into a larger view. Thus, for this reason, it is more accurate and appropriate to use the word *practice* to refer to what clients need to perform in intervention (within the session and between sessions as part of their home activity programs [HAPs]) versus calling this work exercise.

An adult following a stroke may benefit from improved LE extensor and abductor strength, greater extensibility in the plantar flexors to increase ankle dorsiflexion, and improved sustained dynamic postural control in the trunk muscles, but the reason(s) she would benefit from these individual and multisystem strengths brings in the relevant "So what?" factor. Why and when does this individual need more LE extensor strength or improved dorsiflexion range? A PT working within an NDT framework understands that each of these individual system impairments can contribute to multiple activity limitations alone and in combination: sit to stand for dressing, balance and control in walking, stair climbing, and so forth. Setting up exercise/practice to remediate these impairments in a variety of functional activities of interest to and of necessity to a particular client will contribute to greater carryover into functional outcomes. Laying an individual down for hip abduction strengthening exercises to help him walk better may have limited benefit. The greatest demand for the hip abductors in function is when the foot is in contact with a surface and the individual's body weight needs to be supported on this leg, for example, during sit to stand, and most familiarly, in the midstance phase of walking. In these functions, the limb is closed chain, half or more of the body weight is loaded onto the limb, the other antigravity muscles of the leg are also contracting, the deep postural muscles of the trunk are active for postural control, and the individual is in a vertical posture.[18] The conditions just listed are all part of the tasks of walking, rising to standing from sitting, climbing stairs, and many more. None, or very few, of these conditions are present with the individual lying in supine or side lying and sliding or lifting the leg in space. Based on the concepts of task specificity alone, little carryover can be expected.

An NDT-educated PT may have the individual in a high perch on a surface, meaning the surface height is such that his hips are significantly higher than his knees and he is almost standing. His feet are no more than hip joint distance apart and tucked under his knees to set up a narrow BOS. In front of the individual is an easel with a canvas for painting and a pallet of paints and brushes. He selects the brush and then, for many repetitions, moves between the paint pallet and the canvas as he creates his scene. As a progression, the less involved foot could be placed on a higher step stool to disadvantage its ability to support the majority of the individual's body weight, or the height of the sitting surface could be raised to demand that more of the body weight be actively supported through the legs. Over time, this task could be practiced in standing with similar challenges. The PT uses her hands and body to limit use of the less involved leg as part of the BOS and to encourage use of the more involved leg as an active support and the more involved upper extremity (UE) as either the support arm or the action arm of the painting task, depending on its functional ability. For home practice, the client is encouraged to either sit on a high bar stool or stand at the bathroom sink while shaving in the morning. The case reports in Unit V provide the reader with many examples of the use of exercise in the form of subtask and task practice, to address the clients' specific system impairments.

As already outlined, one of physical therapy's strengths is education in exercise. This knowledge includes understanding structure and function of the cardiovascular and respiratory systems of the body and exercise physiology. With this knowledge, PTs have a thorough understanding of the effects a sedentary lifestyle has on an individual's ability to participate in even the simplest of tasks of life (breathing, eating, dressing, moving around a room, etc.). When one considers the level of activity, or more accurately inactivity, inherently imposed on an individual with CP or poststroke secondary to the impairments caused by the neurodisabilities of these conditions, combined with disuse weakness over time, PTs know that these individuals struggle to participate in therapy practice.

Recent evidence has highlighted the influence of inactivity on individuals poststroke and TBI from an overall cardiovascular, respiratory, and endurance/fitness perspective.[19,20,21] In short, these individuals become profoundly deconditioned in a short period of time of limited activity or a lack of physical activity after their stroke. They are often unable to perform enough practice repetitions and to sustain the activity in functional practice at the level necessary for learning and fitness changes to occur.

People with CP are known to have reduced physical fitness levels compared with their age-matched peers without disability.[22,23] Both aerobic and nonaerobic metabolism are likely to be affected and are hypothesized to be the result of multisystem impairments.[22,23,24] For example, researchers hypothesize that hypertonicity reduces venous return, contributes to early muscle fatigue, and inhibits lactate clearance during exercise, whereas the higher percentage of type I fibers in muscles compared with people without disability may decrease anaerobic capacity.[22,24] Chest wall distortion and respiratory muscle overactivity may lower peak maximal oxygen uptake.[22] Treadmill training across levels I through IV of the Gross Motor Functional Classification System shows promise in increasing both aerobic capacity and functional skills as do other aerobic forms of exercise.[23,24,25,26]

PTs and PTAs possess knowledge from their basic education of how to help clients improve cardiovascular and respiratory system function. The PT or PTA working in an NDT framework combines this knowledge with an integration of endurance practice in functional activities chosen by the clients and families. Cardiovascular and respiratory system functions are considered in the wide ranges of functional outcomes clients are working toward. These outcomes may be as simple as breathing through a posture or a position change, as when a child with CP uses whole-body extension in an effort to communicate, to running and yelling to a teammate in a soccer match.

For example, in Case Report A3 about Carol, the client was deconditioned from her stroke, requiring frequent rests during her therapy sessions. She had enjoyed swimming and working out at the gym prior to her stroke. Her NDT-trained PT included cycling on a recumbent bicycle three to four times a week (with her husband's assistance), as part of her HAP. The PT also included weekly sessions in the community pool with part of the session focused on endurance activities, such as swimming strokes and treading water (**Fig. 17.4**).

Fig. 17.4 Carol in the community pool.

In Case Report B8 about Brandon, a child with CP who functions at the Gross Motor Functional Classification Level V, his cardiovascular and respiratory systems significantly affect his activity and participation function. His cardiovascular and respiratory impairments reflect poor regulation of basic functions. Instability of Brandon's heart rate and O_2 saturation levels correlate with periods of poor health. As these system functions deteriorated over his 10-year life span, his participation was more restricted; he was unable to continue schooling and frequently could not participate in family life at home because he experienced periods of hospitalization.

Brandon's PT focused on outcomes that allowed him to participate with his family as much as possible. At all times, therapeutic handling, postures, equipment selection, home programming, and planning for the future took into consideration cardiovascular and respiratory function and the function of other body systems as they support basic physiological health. For example, Brandon's PT could evaluate respiratory and cardiovascular status constantly during sessions via the use of heart and respiratory rate and O_2 monitors. Positions could be altered based on this flow of information. Equipment selection always included positions and support that maximized respiratory function as well as postures for attention. His trunk and base of support were carefully and continually assessed to ensure that alignment allowed optimal ease of respirations and consistent, acceptable O_2 saturation levels. Brandon's PT was not satisfied to simply acquire a piece of equipment or to position him in supported sitting. Rather, she worked constantly to ensure that cardiovascular and respiratory function supported his physiological needs as he participated in upright positions with equipment or support.

17.4.4 Hands-On Intervention

PTs and PTAs are educated to assist their clients physically. They learn safe and efficient body mechanics to assist clients with their postures and movements and are frequently called upon to teach other caregivers safe ways to transfer clients from beds, chairs, cars, toilets, bathtubs, and the like. They are educated to take leadership on the rehabilitation team in promoting mobility of their clients in the presence of participation restrictions, activity limitations, and body system impairments and advocating for that mobility. They are taught how to physically handle clients with a variety of posture and movement impairments and how to keep them safe. Early in their education, they learn that being a PT or PTA requires hands-on assistance for many of their clients during at least part of an intervention session.

In addition to hands-on assistance for helping clients with transfers and general mobility in space, many PTs specialize in manual therapy interventions with particular client populations or intervention settings. Their continued education often includes learning highly skilled hands-on examination and intervention. Examples include manual strategies to increase joint mobility, alter muscle activity, and influence respirations and coughing.

NDT education includes learning highly skilled handling strategies for examination and also for intervention with clients with complex posture and movement impairments. Because PTs are familiar with hands-on engagement with clients, they bring both experience and knowledge to the team caring for clients.

In developing NDT initially, Bobath said, "While treating the child, the therapist must carefully watch his reactions to her handling. She must be able to appreciate changes of muscle tone and constantly adjust her handling to them. . . . In advancing treatment the therapist's guidance and control must be withdrawn gradually and systematically."[16]

For example, a PT working with a child with CP places her hands on her client's rib cage and the musculature on either side of the thoracic spine to palpate and note muscle bulk, tension, and active contraction as the client prepares for a standing transfer from his wheelchair to his classroom chair. She then shapes her hands around the midthoracic area to determine if and when muscle groups contract as the client's caregiver asks the client to reach forward and up while flexing at the hips. From this handling examination, the client's PT determines that his upper thoracic extensors initiate and sustain contraction while his arms elevate to ~ 90° of elevation, but that the midthoracic extensors and musculature around the rib cage remain inactive and feel soft under her hands. Only a few superficial, multijoint muscles are active in this body segment: the latissimus dorsi, the pectorals working as shoulder internal rotators, and the scapular elevators. This information helps the client's PT plan intervention strategies to facilitate isometric muscle activity and later concentric muscle activity in the midthoracic and rib cage musculature to increase the activity of the client in the standing pivot transfer.

During an intervention session, the PT uses handling to align the client's trunk in extension with rotation while engaging in reaching and visual gaze activities to begin isometric contractions of the superficial and deep trunk extensors, the abdominal obliques, the intercostals, the rhomboids, the middle and lower trapezius, and the serratus anterior muscles. The isometric activity is followed by handling to assist active rotation with trunk extension while guiding his trunk to move in extension with rotation rather than lateral flexion (**Fig. 17.5**).

Handling is used in this scenario to assess muscle activity with a client's purposeful activity, align and support body segments to facilitate isometric contraction of muscles working together, guide the direction and plane of movement when progressing to concentric muscle contractions, provide augmented sensory awareness of movement, and allow for practice and repetition of movements that are needed to facilitate specific muscle activity for function.

In Case Report A1 about Mark, the therapist placed one hand on the client's right scapula and humeral head and the other on his left lateral trunk and hip area before she asked him to reach toward the handle of an upper cupboard for a cup. She used her hands to feel the initial alignment and muscle activity around the client's shoulder girdle complex and his LE and trunk movements to support this movement. This provided her with information about which muscles were active and in what sequence and to what degree. She was able to ascertain that the client's scapula rested in abduction, elevation and was winged on his thorax, and his humeral head was in internal rotation and adduction in the glenoid fossa. When he initiated reach to the overhead cupboard, he shifted his body weight to his less involved leg and arm (supporting on a cane) and used upper trunk flexion and rotation back to the left, with hip flexion to assist with the right arm reach. His right UE movements began with active scapular elevation and humeral abduction, internal rotation, and flexion to ~ 30° of humeral flexion. The NDT-educated PT was then able to make choices in the intervention sessions about where to place her hands and body to accomplish two key postures and movements.

- Stop (inhibit) his tendency to initiate UE reach movements with a lateral weight shift over his base of support, upper trunk rotation and lateral flexion, and scapular elevation and humeral abduction and internal rotation.
- Facilitate a forward weight shift over his base (over both legs), and the scapular stabilizers (i.e., primarily the serratus anterior muscle and trapezius muscle), depressors, and adductors to isometrically contract to provide stability before the humeral flexors contract in a concentric way to begin the lift of the humerus toward his target.

Fig. 17.5 The physical therapist guides trunk position for isometric activity of the deep and superficial extensors of the trunk and the abdominals, rhomboids, trapezii, intercostals, and serratus anterior while engaging the child in active reach and visual pursuits in a basketball game.

The information gained from handling during the examination in this and other activities guided the PT to begin the intervention progression toward reach with the right UE in a closed chain set-up on a lower surface with the humerus in flexion ranges between 30° and 100°. Objects of interest to the client (golf ball, golf tee, moving boxes, etc.) were placed forward, initially on lower surfaces and eventually on the floor. He was in a staggered stride stance with his right foot forward. This postural alignment and environmental setup demanded that the postural control muscles in the trunk and the right hip, knee, and ankle extensors stay dynamically active as he shifted his body weight over his base. The effects of gravity for the right UE were eliminated while he reached with his left hand forward toward the objects. Having the right UE in a closed chain set-up also stabilized the upper trunk, minimizing his tendency to use this body segment to assist with right UE active movement (**Fig. 17.6**).

The use of the right UE as a pivotal point of his BOS demanded that the scapular stabilizers, depressors and adductors (serratus anterior, lower trapezius, and rhomboids), and the humeral flexors, stabilize primarily isometrically in the ranges where the movement became inefficient in the client's upward reach. The placement of his feet in stride alignment, with the objects lower and forward of this BOS, also biased his movements such that the right LE extensor muscles were required to work eccentrically as he reached forward and toward the floor and concentrically as he returned to the starting position.

The PT used handling to align and maintain the right scapula toward depression and adduction and guided it into upward rotation as the humeral flexion range required this movement. Thus, when she felt him initiate activity in his scapular elevators, humeral abductors, and internal rotators, as was his tendency, she assisted

Fig. 17.6 Mark's physical therapist uses handling to optimize his upper extremity and body alignment as he squats for a golf ball.

with a more efficient sequence of muscle activation. She also assisted the forward and backward weight shift over his bilateral, staggered BOS at the same time as she limited the client's tendency to weight shift laterally to his left leg.

Handling, used judiciously within therapy, can be an effective component to guide clients in practice of more efficient posture and movement. As discussed in previous chapters, within each intervention session and in sessions over time, the use of handling must be withdrawn for the client to gain independence. PTs working within an NDT Practice Model are skilled in the use of handling as a critical component of movement reeducation.

17.5 Functional Outcomes in Physical Therapy

17.5.1 Mobility and Access to Multiple Environments

One of the areas PTs traditionally focus physical habilitation and rehabilitation on is function that requires postural control for mobility skills. Examples of these skills include activities such as walking, running, stair climbing, getting up and down from various sitting surfaces, sitting on various surfaces, getting up from the floor, rolling, and moving in bed.

Evidence exists that it is possible to improve postural control in children with CP and adults poststroke by providing physical therapy services.[27,28,29,30,31] Using the NDT Practice Model, the PT works to improve postural control within activity or participation. Because postural control demands vary according to the function performed, the NDT-educated PT designs a treatment session around the function, and then analyzes the postural requirements for that function. Finally, the PT determines the ineffective postural control that contributes to the activity limitation or participation restriction to design a plan of care.

For example, a PT is working with a baby born prematurely who is less than 1 year of age both chronologically and by adjusted age for prematurity. In Case Report B1 about the twins, Mya is unable to sit independently, and her PT hypothesizes that her ineffective posture includes a lack of organization of effective muscle synergies for sitting posture and a lack of anticipatory balance. Further, she hypothesizes that this ineffective postural organization includes impairments or ineffective strategies in Mya's ability to incorporate information from the regulatory, neuromuscular, and sensory systems. Evaluation includes the knowledge of the postural control Mya needs to sit independently, including effective muscle synergies, effective timing of muscle contractions, development of joint mobility in some joints, and effective sensory feedback and eventual feedforward. Intervention planning is highly individualized for Mya based on this detailed postural control analysis. Mya's control of sitting becomes effective (**Fig. 17.7a, b**).

Mya's NDT-educated PT does not merely practice sitting. Rather, she analyzes the context of when Mya uses sitting for play and the postural requirements of sitting in detail. She evaluates the missing postural requirements for sitting for Mya and develops her intervention plan to address these requirements while engaging Mya in active postural work transitioning in and out of sitting and active movement within the sitting position.

The young man in Case Report A4, Ernie, has poor postural control as a result of a TBI. He was completely dependent and required full assistance for all mobility tasks, including all his transfers. He sat poorly in his wheelchair with a custom seating system (**Fig. 17.8**). His hypothesized impairments in the musculoskeletal and neuromotor systems related to postural control included overlengthened trunk and cervical extensor muscles, resulting in weakness of his trunk and proximal limb muscles, with the inability to sustain activity in these postural muscles. The PT working with him within an NDT framework integrated his interest in motorcycles and worked in functional subtasks related to this interest that required him to visually track, reach forward and up in sitting, lift off to reach, stand and reach, and in walking, to challenge these impairments affecting his postural control stability. She also worked in a variety of postures and transitions in and out of postures to address his postural control

Fig. 17.7 **(a, b)** Mya's progress in sitting control. Mya is on the right in **(a)**.

Fig. 17.8 Ernie's sitting alignment (post–brain injury) demonstrates poor postural control.

impairments. Postural control is the subcortical stability system, functioning without conscious awareness at a completely automatic level, allowing an individual to superimpose efficient and effective movements in the form of function in transitions and postures. Humans are able to multitask, with attention focused on the task details as necessary without thought for the postural control demands.

17.5.2 Selected Mobility and Access Activities

The following activities are common gross motor skills on which PTs work with clients. Examples with adults poststroke and with people with CP show the problem-solving skills NDT education adds to the knowledge of PTs.

Transitions and Transfers

PTs and PTAs spend time in their entry-level education analyzing selected movements between postures and positions, such as moving from sitting to standing, getting out of bed, standing up from sitting on the floor, bending over to pick up an object on the floor, reaching overhead, and changing directions while moving between positions. Entry-level education allows the student time to learn general postures and movements that many people employ in commonly used transitions and transfers.

Transitions and transfers may be considered as a means to an end. An individual needs to transfer to and from his wheelchair to bed for sleeping or needs to move from sit to stand to begin to walk. If an individual poststroke is sitting for the early part of the therapy session and then the PT wants to next work with her in standing, the PT may view the transition between the two postures as something that needs to happen but without seeing the therapeutic value of the transition itself. Thus this transition may occur either with more than necessary assistance by the clinician or caregiver using in a compensatory way. Similarly, if the child is sitting in his wheelchair and the PT wants him on the floor or mat for the start of the therapy session, the child may be lifted and carried to the next surface so the therapy can start.

Transitions and transfers require an increased level of activity and control in multiple body systems compared with the control required to simply maintain a posture, even when engaged in a task in that posture. For example, increased postural control activity in the trunk through sustaining a dynamic grading of trunk flexors and extensors in all three planes of movement; increased muscle strength in the LEs with synergies working in isometric, eccentric, and concentric contractions; and increased range of motion demands in the LE joints would all be required to move between sitting and standing when compared with the demands on the same body systems while sitting and eating a meal.

The NDT-educated PT studies any and all transitions and transfers in great detail, analyzing and evaluating the salient features of effective and ineffective postures and movements while hypothesizing the contributions of the body systems to posture and movement in these transitions and transfers. In addition, the NDT-educated PT hypothesizes how the body systems, environment, task demands, and personal attributes interact to produce the postures and movements an individual expresses within the transitions and transfers.

Transitions and transfers are not always just a means to an end; rather, they are a part of the movement substrates of tasks requiring efficient control and stability in and of themselves. These movement components must not be overlooked in the therapist's examination and movement analysis and must be included in the intervention plan if functional outcomes with clients are to be optimized.

In Case Report A4 about Ernie, the client was unable to transfer to and from any surface without the maximum assistance of two of his family members. The NDT-educated PT working with him had to first understand the relevance of moving in transitions and transfers to becoming independent in these activities and second, examine and hypothesize the impairments contributing to these activity limitations. She was able to problem-solve because she had a detailed understanding of the invariant posture and movement demands of transitions and transfers (e.g., one or both feet on the ground, a forward weight shift over this BOS, and activation of the antigravity leg extensors to move the weight of the body from one surface up into space). Appreciating the musculoskeletal, neuromotor, sensory/perceptual, and other system demands for these movements allowed her to make choices in intervention to increase the likelihood that he would improve. As is detailed in this case report, his NDT-educated PT worked on functional tasks in high sitting and standing postures, and transitions such as lift off, scooting forward and backward, and sit to stand. She did not specifically work on transfers to and from his wheelchair initially (the task itself) but chose practice activities in postures and transitions that specifically focused on his underlying impairments limiting his function in transfers. The activities chosen were similar in range of motion demands, synergistic muscle demands, the demand to activate his postural control system in vertical postures, and so on, but they added the dimension of his cognitively attending to the tasks performed during this work (tasks related to his hobby of motorcycles) instead of cognitively attending to the movement itself.

The ability to move independently and efficiently in transitions and transfers should require little to no attention to the movement itself; rather, the focus can and should be on the end goal of the transition/transfer, for example, standing up to put his motorcycle jacket on. This client's PT helped him learn how to transfer between surfaces and transition between postures with less help and in a more efficient way by focusing practice on the movement substrates of these activities in a variety of conditions, environments, and tasks, instead of on repetitive practice of the isolated transfers and transitions themselves.

The PT working with 10-year-old Jamie (**Fig. 17.9**) described in Case Report B5 analyzes why he cannot perform the transfer independently from his wheelchair to another seating surface (other chairs, couch, bed, and toilet). These transfer activities were chosen based on the family's desired participation independence for his adult life.

Although his PT knows basic weight shifting and movement direction necessary to transfer from a wheelchair to another sitting surface, she has to examine and evaluate this boy's specific effective and ineffective postures and movements that result in his inability to independently transfer. By first identifying the participation this child and family desired and designing examination and evaluation around the transfer, she was able to identify the specific ineffective postures and movements as he attempted the transfer. She hypothesized the interaction of the body systems, environment, and personal factors that contributed to his inability to

Fig. 17.9 As Jamie attempts a transfer, he gets stuck because he does not know how or is unable to use movements outside the sagittal plane.

transfer. This analysis required a detailed knowledge of the pathophysiology of his type of CP and its likely effects throughout his life span, detailed knowledge of his body system integrities and impairments, and the ability to hypothesize how each system affects all other systems now and across time.

By working on this independent transfer now while the child is not fully grown and incorporating the transfer into daily life, his ability to transfer as he gains height and weight is much more likely to remain a skill he continues to possess, rather than one he must try to learn as an adult when he is too heavy to be lifted. Waiting to teach active transfers until the skill becomes unmanageable for caregivers often results in a skill that is difficult to learn, at best. Without using the muscle activity, range of motion, and perception of weight shifting during growth and body structure changes over the years, secondary impairments, such as muscle atrophy, loss of joint mobility, poor perception of weight-shifting requirements, and fear, often add to the primary impairments that make transfers difficult to begin with.

Gait

Gait describes a manner of walking on foot. Walking is often an activity that clients cite for seeking the skills of a PT. PTs possess detailed gait analysis skills, including knowledge about kinetics, kinematics, and energy cost.

The NDT-educated PT considers the wide range of participation that walking allows. Participation includes walking in various community, home, leisure, school, and play activities. PTs also consider function in the upright posture to be part of these participation considerations. Therefore, standing at a concert to applaud, stooping down to pick up a pen from the floor, taking a few steps backward or sideways in an elevator to allow room for others entering, are all examples of gait functions. Gait is not simply taking steps forward in space on varied surfaces; it should be considered in a much wider view. Functional gait includes the ability to move on one's feet in all directions, including direction changes; walking and carrying objects; varying the speed as the task and environment require; walking on a multitude of surfaces, including sandy beaches and icy walkways; walking in crowds while carrying on a conversation; and visually scanning the environment to find a friend while walking. The NDT-educated PT studies all the variations of gait as functioning in an upright posture.

For example, Sam, a 6-year-old with a mixed type of CP described in Case Report B9, is able to take steps with a posterior walker with forearm supports and with assistance of an adult within his home and classroom. He must be supervised with his walker to control speed and guide direction. His mother would like Sam to learn to use a quad cane for walking because she feels it is less cumbersome.

Sam's gait is characterized by excessive hip, knee, and ankle flexion throughout the gait cycle (crouch gait), which is an energy-costly gait and potentially damaging to the joints of the LE. Sam's PT incorporates trunk extension and rotation into his intervention, hip and knee extension, and practice walking with longer step lengths while incorporating the extension and rotation of his trunk and hips into his gait (**Fig. 17.10a–c**).

As Sam practices standing with his quad cane (**Fig. 17.11**), his PT continues to keep his posture active with weight shifting, visual scanning, and verbal instructions. As Sam becomes independent and safe using a quad cane, he will be able to maneuver more easily in a larger range of community environments, thus increasing his participation. Ensuring that his gait is as energy efficient and well-aligned as possible assists his long-term use of walking as a daily activity and increases his participation choices.

In Case Report A2, JW is an information technology educator in a large university environment. She needs to be



Fig. 17.10 **(a)** Sam's physical therapist provides safety, assists with trunk extension and rotation, and assists with stability of the cane as Sam learns to use it. **(b)** Sam practices lengthening his stride as his physical therapist assists lower extremity alignment and movement with her hands and hip extension with her shoulder. Trunk and hip rotation are needed to lengthen his steps as well as overall postural extension. **(c)** Sam's therapist assists active thoracic extension with rotation.

Fig. 17.11 Sam's physical therapist removes her hands-on assistance as Sam practices activities in standing erect.

able to walk from her office to classrooms and meetings in all four seasons of the year, managing stairs, opening doors, walking in crowds, walking at fast speeds to keep to her schedule, and carrying her briefcase and teaching materials. Initially, JW relied on a wheelchair for community mobility and a walker for indoor mobility. Her therapists with NDT knowledge needed to include multiple challenges in the interventions targeting her gait function that addressed her multiple musculoskeletal and neuromotor impairments in her trunk and more involved limbs. When JW's LE and trunk impairments improved, she gained confidence in balance and stability on her feet and was able to transition first to a walker, then to a straight cane, and then to no assistive device for community ambulation, freeing up her arms for other purposes (**Fig. 17.12**).

As noted in the introduction to this section on gait, many clients seek physical therapy to "walk better." The descriptions of Sam and JW have described that "walking better" is not just moving forward in space but involves an examination and understanding of the participation roles and activities performed while moving about on our feet. A PT working within an NDT framework is taught to consider all the participation and activity aspects of walking for each individual, to determine the underlying impairments interfering with an individual's ability to ambulate more efficiently, and to incorporate strategies in intervention (handling, activities to be practiced, environmental and contextual challenges) to help clients "walk better."

Fig. 17.12 JW carrying her shoulder briefcase in preparation for return to work.

Higher-Level Mobility Skills

Higher-level mobility skills are possible and necessary for many of our clients to expand activity and participation choices. NDT education contributes to the detailed understanding of postures and movements needed for many mobility skills that require subtle and frequent changes in posture and more precise timing of muscle activity than basic mobility skills.

Higher-level mobility skills include ascending and descending stairs, bleachers, hills, and ramps; jogging and running; riding bicycles and horses; climbing on playground equipment and building scaffolds; playing a fast-moving team sport such as soccer/football; stepping on and off an escalator; and many more. These activities are all valid outcomes for our clients as discussed in Chapter 14 on motor development and provide the necessary challenge for our clients to help achieve the outcomes in activities at lower levels, such as walking at normal speeds, standing at the mirror to apply makeup, and eating a meal in sitting.

For example, a child with CP is able to walk independently, but her self-selected speed does not allow her to keep up with her peers when she walks to the lunch room or the gymnasium, or plays at recess. Her PT sets an outcome of running the bases in a game of kickball, which is a game that is played frequently in her physical education class. To work on the outcome, her PT focuses on increasing the power of her plantar flexors for push-off in late stance and trunk and hip rotation to run the bases. The child enjoys the challenge of beating her previous week's time in running the bases as they practice the skill at the end of each intervention session. The PT also collects data on the child's self-selected walking speed, noting that it has increased during this episode of care. The child's teacher reports that the child can now usually keep up with the pace of her classmates when they walk to the lunch room and the gymnasium.

A PT is working with a teenager to descend a staircase step over step, alternating feet. This activity will be further refined for two participation outcomes: stepping over a concrete curb barrier at her community college and descending the staircase in her home. The PT identifies the following posture and movement abilities she has that will assist her in stair descent:

- Motivation for and understanding of the task.
- Sufficient joint mobility to perform the skill with minimal compensatory movements (her ankles lack a few degrees of dorsiflexion range, and her feet collapse into pronation).
- Sufficient concentric and eccentric strength of extensors at the hips, knees, and ankles to safely complete the skill.
- Sufficient visual perceptual skills to negotiate steps in familiar environments.
- Sufficient timing of muscle contractions and use of effective muscle synergies to complete the skill.

The PT makes the following clinical observations related to posture and movement for this skill:

- At times, she is unable to stand completely upright and so begins her weight shifting for descent of stairs with a slightly crouched posture (**Fig. 17.13**).
- During stair descent, she has difficulty using transverse plane trunk movements when advancing each LE.
- She tends to compensate for difficulty moving from heel to toe across the weight-bearing foot by substituting transverse plane motion around her hip joints (and possibly stress to knee and ankle ligaments), so that her feet "twist" in the transverse plane rather than move in the sagittal plane in a close-chained movement (**Fig. 17.14**).

The PT then hypothesizes the impairments contributing to these clinical observations. In an intervention session, her PT facilitates trunk and LE extension throughout the treatment session as a prerequisite for all weight-shifting activities (**Fig. 17.15**). This work is followed with thoracic rotation. Rotation is isolated at first in a more stable position of sitting (**Fig. 17.16**) because the movement is difficult for her to initiate. Thoracic extension is combined later in the session with erect standing and stair descent. As stair descent is practiced, the PT facilitates movement across her feet in the sagittal plane from heel to toe, emphasizing metatarsophalangeal extension as she travels onto the front of her foot (**Fig. 17.17**). By the end of the session, this teen practices on her own with occasional verbal cueing (**Fig. 17.18**).

Fig. 17.13 This teen stands with a mild crouch position of excessive hip, knee, and ankle flexion.

An NDT-educated PT working with an adult client who was an avid runner prior to her stroke understands that walking forward at normal speeds, as desirable an outcome as this is, is not good enough for that individual. The PT must understand the postural and movement as well as body system demands for the function and then work with the client in intervention to remediate her impairments within this high-level mobility skill. For this client, not only is it reasonable to expect her to be

Fig. 17.14 As she steps down, she twists her ankle with movements in the transverse plane. This movement could be occurring in the trunk, hip, knee, and/or ankle/foot.

Fig. 17.16 The teen works on thoracic extension with rotation to assist components of stair climbing and descent and to separate lower extremity position.

Fig. 17.15 Working on active lower extremity extension.

Fig. 17.17 The physical therapist assists weight shifting from heel to toe as the teen descends the stairs.

Fig. 17.18 At the end of the session, the teen practices stair descent independently.

able to run again, the high-speed, challenging intervention strategies practiced during the therapy sessions and included in her home practice activities will contribute to improved outcomes in this individual's other activities. Being able to step quickly out of harm's way in a crowded shopping mall or jump across a mud puddle on a rainy day are examples of skills that are necessary for safe and efficient movement for her.

17.6 Using Physical Therapy Modalities and Equipment with NDT

PTs learn how and when to use many different interventions in their practice, including modalities and equipment. These can include but are not limited to electric muscle stimulation, taping, ultrasound, bracing, and various walking devices, such as walkers and body-weight-support treadmills, balls, bolsters, and so forth. PTs and PTAs working within an NDT framework may include any of these modalities or equipment in a client's care plan. The inclusion of each or any of these would be based on a client-specific evaluation and determination that this component would contribute to a more optimal outcome. When viewed from the perspective of the ICF model, modalities are intervention strategies selected as part of the plan of care to achieve outcomes, and equipment is assistive technology that is a facilitator to outcomes.

17.7 Summary

All PTs who work with individuals with neuromuscular, musculoskeletal, sensory system, cardiovascular, respiratory, and integumentary impairments as a result of a neurological condition must understand how impairments in these systems, including multisystem posture and movement impairments, influence clients' abilities to function at the participation and activity domains of the ICF. This knowledge, when combined with the knowledge of the NDT Practice Model, expands the clinician's ability to help clients optimize their functional outcomes.

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18 The Practice of Speech-Language Pathology from a Neuro-Developmental Treatment Perspective

Rona Alexander

This chapter outlines the history of when and how the profession of speech-language pathology became an integral member of the Neuro-Developmental Treatment (NDT) team. The mutual information and skill exchange between the two entities, specifically in the areas of feeding and swallowing, speech/sound production, and language, cognition, and communication, is presented. Clinical examples of how the practice of speech-language pathology within the NDT Practice Model demonstrate the problem solving and decision making used to address clients' activity and participation domains of the International Classification of Functioning, Disability and Health (ICF).

Learning Objectives

Upon completing this chapter the reader will be able to do the following:

- Define who a speech-language pathologist (SLP) is in terms of professional responsibilities and functional outcomes addressed in client management.
- List at least three skills NDT education enhances in the professional skills of SLPs.
- Analyze a speech-language pathology outcome with a specific participation or activity of a client in his or her own practice using the NDT Practice Model.

18.1 Historical Perspectives on Speech-Language Pathology within NDT

Speech-language pathologists (SLPs) began exhibiting interest in the work of Dr. and Mrs. Bobath in the mid-1960s. Helen Mueller came from Switzerland where she was working as a speech therapist in a school for children with cerebral palsy to study with the Bobaths in London and was instrumental in defining the focus of practice for speech-language pathology within Neuro-Developmental Treatment (NDT). She developed the basic NDT speech curriculum, which has been included in the NDT/Bobath approach since 1968 (Helen Mueller, NDTA Award of Excellence videotaped acceptance, May 2001). This core curriculum included information in the areas of oral motor development and treatment, feeding and swallowing development and treatment, respiratory-phonatory development and treatment, early sound/speech production development, and prelinguistic and cognitive development and their relationships to children with cerebral palsy.

Suzanne Evans Morris was the first SLP from the United States to successfully complete an NDT basic pediatric course in London in 1964. Since that time, Dr. Morris has had a significant influence on the speech-language pathology curriculum taught in NDT courses and used within NDT in the United States. She has played an important role in advancing knowledge in the principles and practice of NDT and speech-language pathology in the examination of and intervention for children with neuromotor impairments through her extensive writings and workshop presentations (Suzanne Evans Morris, PhD, personal communication, March 2010).

The early and continuing connection that exists between NDT and speech-language pathology has helped to solidify the focus within NDT on the importance of teamwork and on a holistic approach to the examination of and intervention for children and adults with central nervous system (CNS) pathophysiologies. In addition, this relationship between NDT and speech-language pathology has played a role in reinforcing the need for SLPs to be actively engaged in services, especially in the areas of feeding and swallowing function, oral motor and oral sensory function, respiratory-phonatory function, and prelinguistic and early cognitive function as they relate to infants and children with neuromotor problems.

According to the American Speech-Language-Hearing Association's (ASHA's) "Scope of Practice in Speech-Language Pathology" policy document from 2007, "Speech-language pathology is a dynamic and continuously developing profession."[1] It has had a strong presence in both educational settings as well as medically based settings. "The overall objective of speech-language pathology services is to optimize individuals' ability to communicate and swallow, thereby improving quality of life."[1] Today, "speech-language pathologists address typical and atypical communication and swallowing"[1] in the areas of speech sound production (i.e., articulation, apraxia of speech, dysarthria, ataxia, dyskinesia); resonance (i.e., hypernasality, hyponasality); voice (i.e., phonation quality, pitch, loudness, respiration); fluency;

language (i.e., phonology, pragmatics, morphology, syntax, semantics, prelinguistic communication); cognition (i.e., attention, memory, sequencing, problem-solving, executive functioning); and feeding and swallowing (i.e., oral, pharyngeal, laryngeal, esophageal). These represent an expansion from the areas of traditional focus in speech-language pathology that existed in the late 1960s to today, when we include areas such as feeding and swallowing, which NDT has long viewed as essential as a focus for SLPs.

When SLPs begin their NDT education, they start with a general base of knowledge in areas that compose the practice of speech-language pathology. This, however, does not mean that they may practice in all areas of speech-language pathology with children and adults with neuromuscular impairments. They “may practice only in areas in which they are competent (i.e., an individual’s scope of competency), based on their education, training, and experience.”[1]

With NDT education, SLPs learn to analyze and understand the influences of postural alignment, postural control, body mechanics, kinesiological characteristics, typical movement development, atypical and compensatory patterns of movement, and body system interactions on all functional activities related to communication and feeding and swallowing. They gain new insights into the relationships among the feeding and swallowing problems, oral sensory and oral motor issues, respiratory coordination problems, voice and resonance issues, language and cognition issues, and the posture and movement problems that individuals with neurological pathophysiology may experience.[2,3] Therapeutic handling (i.e., graded movement facilitation provided by the therapist and one core element of intervention in the NDT Practice Model) provides the SLP with knowledge of a more extensive foundation of strategies to incorporate into intervention directed toward the learning of new movement experiences that influence the individual’s communication and feeding and swallowing function.[3,4,5] In the simplest terms, NDT helps SLPs become more competent in providing services for individuals with neuromotor problems. They see the individual as a whole, connecting his or her communication and feeding and swallowing function with all other aspects of that individual’s posture and movement during the variety of functional activities he or she participates in each day.

From an NDT perspective, the examination process requires extensive observation and analysis of the performance of functional tasks and the posture and movement behaviors used by the individual during these tasks. In accordance with the International Classification of Functioning, Disability, and Health (ICF), NDT-educated SLPs describe the abilities and limitations of an individual to participate in specific life situations (social functions domain) and to actively perform a task (individual function domain) as part of their examination process. Further evaluation will result in the delineation of specific body structure and function integrities and impairments in individual body systems, including the musculoskeletal, neuromuscular, sensory, gastrointestinal, cardiovascular, respiratory, and perception/cognitive systems. It is also necessary to identify environmental factors and personal factors that may be influencing an individual’s activities, body structure and functions, and participation. In addition, the NDT-educated SLP will collect information on effective and ineffective posture and movement behaviors (e.g., head control, trunk control, symmetry, balance, alignment) that are influencing the child or adult’s communication and feeding and swallowing function. This information can then be used to create an intervention plan of care that reflects the needs of the individual and his or her family.

The NDT-educated SLP brings to examination and intervention a strong foundation in typical developmental characteristics as well as in changes in body biomechanics and kinesiology over time. Understanding the typical development of oral, pharyngeal, and respiratory function as they relate to feeding and swallowing, speech/sound production, language and cognition, and communication development is not sufficient for the SLP working with individuals with CNS impairments. To fully understand how these areas progress and change over time, SLPs must relate their development to the changes that occur in general body movement activities, shoulder girdle and upper extremity function, and pelvic/hip and lower extremity function as well as the development and integration of all areas within sensory processing.[2,6] Through this more comprehensive knowledge of typical development, normal biomechanics, and kinesiology, the NDT-educated SLP recognizes the significant influences that changes in posture and movement behaviors can have on feeding and swallowing function and communication.

Through an NDT framework, the SLP gains greater knowledge about atypical development, the effects of aging, and the occurrence of compensatory patterns of movement as a consequence of body system impairments. Whether providing intervention services for children or adults with CNS pathophysiology, SLPs must understand the process by which atypical/compensatory movement patterns develop and the variety of factors (e.g., biomechanical, environmental, personal, alignment, sensory awareness) that may influence the atypical/compensatory patterns of movement used by an individual.[4,7]

For example, a child or adult with neuromuscular system impairments and retraction of the cheeks and lips may use head and neck hyperextension with shoulder girdle elevation when drinking liquids from a cup. An NDT-educated SLP will use his or her knowledge of typical and atypical movement when devising an intervention plan for the implementation of appropriate intervention strategies working toward changes in this individual’s cup-drinking activity. Initially, the SLP will observe the individual during activities other than cup drinking to determine if cheek/lip retraction and head/neck hyperextension with shoulder girdle elevation are evident during other functional activities. Selected handling strategies will be used to optimize the alignment of the body over the base of support in sitting, encouraging neutral head flexion, neck elongation, and shoulder girdle depression.[8] Strategies to elongate the cheek/lip musculature paired with sensory input to ready the cheeks/lips for activation will be provided.[9] The individual will be guided through oral activities that encourage active lip closure, lip protrusion, and lip opening that do not involve drinking before presenting cup-drinking activities. The SLP will assist in facilitating appropriate head, neck, and shoulder girdle alignment during the oral activities and cup drinking. As the individual begins to take over internal control of the head, neck, and shoulder girdle with increased cheek/lip activity, the SLP will reduce the use of handling strategies during the task.

Because SLPs have the potential to address so many areas, the areas that have had a long-term connection with NDT will be used more specifically to discuss what NDT brings to speech-language pathology intervention for children and adults with neuromotor challenges. Areas of speech-language pathology that will be discussed include feeding and swallowing, speech/sound production, and language, cognition, and communication.

18.1.1 Feeding and Swallowing

Today's SLPs receive basic knowledge in the area of swallowing and swallowing disorders (i.e., dysphagia) as a requirement in their college/university programs. The focus of the majority of these university courses is on adult swallowing and swallowing disorders, with limited information provided in the area of pediatrics. To competently work in the area of feeding and swallowing with adults or children, SLPs should obtain extensive supervised practical experiences in this area with the specific age groups they intend to serve. In addition, they should attend a variety of advanced-level continuing education seminars/courses to more fully understand all of the influences that affect an individual's feeding and swallowing function (i.e., gastrointestinal, respiratory/airway, oral sensory and oral motor, pharyngeal sensory and pharyngeal motility, neuromotor, musculoskeletal, behavioral) and how to incorporate this knowledge into the examination and intervention services they provide. These services generally focus on the oral, pharyngeal, and respiratory coordination issues that influence feeding and swallowing.

SLPs, with knowledge of NDT for adults or pediatrics, expand their knowledge and experience to better understand the activity limitations, the body structure and function integrities and impairments, and the influence of posture and movement that an individual with CNS pathophysiology and feeding and swallowing issues may experience. Ineffective posture and movement behaviors impact on all areas of feeding and swallowing and must be addressed by the SLP if progress is to be made.

SLPs have a special knowledge of the structures and functions of the oral and pharyngeal mechanisms. The NDT-educated SLP also understands oral and pharyngeal functions as they relate to typical movement development, postural alignment, postural control, biomechanics, and body system interactions and impairments. This NDT perspective provides a foundation from which a more comprehensive evaluation of an individual's functional abilities and limitations can be conducted in the areas of feeding and swallowing. In addition, it provides a foundation of understanding in posture and movement that expands the areas in which intervention strategies must be directed as part of the individual's intervention plan of care to improve oral, pharyngeal, and respiratory function during eating, drinking, and saliva management activities.

For example, a 2-year-old boy has a primary diagnosis of cerebral palsy, athetoid quadriplegia. He is held at a 60° angle on his mother's lap for bottle drinking and spoon feeding during mealtimes because she does not believe that he eats as well when he is put in his high chair. Cheek/lip retraction, forward/backward suckling movements of the tongue with a thick tongue contour, and unstable, poorly graded jaw movements are evident throughout bottle-drinking and spoon-feeding tasks. It is difficult for the boy to keep his head in midline generally, and he often turns his head to the right when he is working with food or the bottle's nipple in his mouth. He prefers to hold his body in a more extended posture with significant shoulder girdle and rib cage elevation during feeding and other functional activities (e.g., dressing and undressing, diapering, biting on a biter). Deep bouncing on his mother's lap helps him to calm and organize periodically during mealtime as well as during other activities when he becomes disorganized.

The SLP with a foundation in NDT will further analyze the relationship between this boy's oral, pharyngeal, and respiratory activity during general movement activities as well as upper extremity activities and compare these activities to what is seen during feeding and swallowing tasks. In intervention, therapeutic handling will be used, working toward changes in the child's postural alignment and body movements that will provide a better foundation for changes in oral, pharyngeal, and respiratory coordination function. Handling strategies directed toward increasing rib cage mobility, activating the abdominal musculature, activating the hip musculature against the base of support in sitting, stabilizing the shoulder girdle complex on the rib cage, and increasing elongation of the neck with shoulder girdle depression as part of an active base of postural control and movement on the part of the child, will provide the foundation on which changes in oral and pharyngeal function can be stimulated.[10]

As the child exhibits more active symmetrical postural control and movement, these more effective postures and movements can then be integrated into establishing a more supportive, stable postural foundation for eating and drinking tasks at mealtime. Equipment can be adapted to assist in maintaining a more appropriate postural alignment with the least amount of effort on the part of the child so that the focus can be on modifying oral and pharyngeal activity to improve nutritional intake.[11] Intervention continues to be used as a time to integrate advances in postural control and movement with advances in oral and pharyngeal function during a variety of activities, including feeding and swallowing tasks. Mealtime continues to be a time to incorporate and practice oral and pharyngeal skills that have been gained in intervention that now result in improved nutritional intake and hydration. With a foundation of more active postural control and movement, as well as more active oral and pharyngeal control and movement, the child will progress in the use of his lips, cheeks, jaw, anterior tongue, and posterior tongue, resulting in advances in eating and drinking.[12]

When an adult has feeding and swallowing issues as a result of a stroke, immediate attention is classically drawn to the implementation of compensatory strategies to assist the individual in coping with oral and pharyngeal dysfunctions. However, the NDT-educated SLP will direct the interventions toward the underlying body system impairments and system interactions (i.e., neuromuscular, musculoskeletal, sensory, perceptual/cognitive, gastrointestinal) and posture and movement behaviors that are resulting in the individual's activity limitations.

Mr. J is a 72-year-old man who had a stroke affecting his left side. He was fully independent prior to his stroke and had been very active in his retirement, working out at the gym three times per week. Mr. J's left hemiplegia resulted in left-side neglect as well as head, neck, and trunk asymmetries whenever he would look toward the right side of his body. He did not maintain symmetrical weight bearing through his hips when in sitting, revealing a posterior pelvic tilt with increased push toward extension with his right arm and right leg.

Mr. J had a left side facial droop with flaccidity throughout his midface musculature. He was able to activate the masseter muscles of his jaw, but the left side was weaker than the right. When bringing his lips toward closure, he revealed a significant downward droop and rollout of his lips on the left. There was loss of saliva and food from the left side of his mouth. The lateral border of the left side of his tongue was thick, weak, and unable to turn upward, which kept him from being able to maintain pieces of food on his tongue surface. A tongue protrusion pattern led by the right lateral tongue border was used to move food back for swallowing. Significant oral asymmetry and a partial oral sensory loss made the control of pieces of food throughout the mouth very difficult.

Due to his poor oral and pharyngeal sensation and musculature activity, it was recommended that Mr. J be started on a pureed diet with liquids thickened to a honey consistency. Although Mr. J disliked the diet and heavy consistency of his fluids, he understood the need to implement these procedures to help him to better control his food and liquid intake.

Mr. J worked with an NDT-educated SLP who understood that the effect of his oral motor and oral sensory impairments on his eating and drinking skills could not be worked on in isolation. It was necessary to initially focus on Mr. J's head, neck, and trunk asymmetries and his neglect of the left side of his body. Initial work emphasized achieving and maintaining a neutral, symmetrical pelvic and trunk alignment. Physical therapy, occupational therapy, and speech therapy were closely coordinated to obtain an increase in his acceptance of midline toward left-side visual stimulation as well as tactile input and musculature activation on the left. He was encouraged to accept biting activities and left lateral tongue border activities using tooth brushing and tasks that focused on age-appropriate oral stimulation. As his head and neck alignment, facial musculature activity, and oral control improved, more work on specific oral motor, eating, and drinking tasks could be integrated into intervention and functional activities. All oral motor and feeding/swallowing activities were preceded by and combined with therapeutic handling strategies focusing on increased active trunk control, improved head and neck control, and the gradation of muscle activation throughout the body to provide the foundation for sustained symmetrical activity and sensory alertness and organization within the oral and pharyngeal areas. Mr. J gradually began exhibiting greater tongue, jaw, and lip control during eating and drinking tasks, allowing for modifications in his food and liquid intake.

The strong relationship between postural alignment and control and the oral and pharyngeal movements used during eating and drinking tasks must be addressed by all SLPs providing feeding and swallowing services for children and adults with CNS pathophysiology. The SLP with NDT training is prepared to analyze this relationship and provide intervention that focuses on discipline-specific feeding and swallowing functional outcomes. She or he implements strategies that work toward improving the postural foundation necessary for improved oral and pharyngeal function as well as those that directly influence tongue, jaw, cheeks/lips, and pharyngeal sensory and motor activity. These problem-solving analyses and intervention strategies result in integrated oral and pharyngeal activity during eating and drinking that the individual learns to control in many different settings and under varying conditions.

18.1.2 Speech/Sound Production

Infants begin creating sound with their first cry. A baby's body movements help to generate the muscle activity that supports respiratory function and changes in oral and laryngeal activity, often resulting in the baby's production of sounds. As the infant and young child's posture and movement behaviors advance, they develop greater abilities to coordinate their respiratory function with more intricate oral and pharyngeal activities. This coordination is reflected in their production of sounds of longer duration with variations in loudness and intonation and with more efficient production of a greater variety of sounds that will later be organized into intelligible words and phrases.[3,10]

SLPs understand the progression of sound/speech development and the oral motor factors that influence articulation and speech intelligibility. However, it is essential when working with individuals with neuromuscular, musculoskeletal, and sensory system impairments to also incorporate into examination and intervention an understanding of how posture and movement, respiration, and sensory factors influence the ability to produce sound and speech.[13] NDT-educated SLPs will recognize the relationship between posture and movement, respiration, and sound/speech production. They have the skills to integrate strategies into their intervention plans that reflect the important effects that body movements, postural alignment, structural and kinesiological changes, and respiratory changes as well as oral and pharyngeal motor and sensory influences have on an individual's speech/sound production.

For example, a 3-year-old boy with a diagnosis of moderate-to-severe spastic quadriplegia produces a limited variety of sounds when he attempts to speak. He uses head/neck hyperextension and increases in stiffness to initiate sounds. His sounds are soft, short in duration, and nasal in quality. Throughout his body, he generally exhibits asymmetry that is greater on the left, shoulder elevation with internal rotation, an elevated rib cage with a flat anterior chest contour and a rounded posterior rib cage contour, a flared lower rib cage contour with minimal active rib flaring, a posterior pelvic tilt, and hip adduction with internal rotation. His arms and legs increase in stiffness with active body movement, which is evident whenever he attempts to make sounds. Orally, he reveals limited lip movements with cheek/lip retraction, limited tongue movement with some tongue retraction and a consistently thick tongue contour, and poor grading of jaw movements with asymmetry to the left.

The SLP with NDT education will know that to improve this boy's sound production, it will be necessary to implement strategies that assist in increasing rib cage mobility, elongating chest wall musculature to increase thoracic cavity space, and modifying rib cage alignment within the trunk while encouraging integration of these changes into body movement activities that encourage active changes in posture, movement, and respiratory coordination. Sound production is encouraged and stimulated in coordination with these changes in head/neck, shoulder girdle, rib cage, trunk, and pelvic/hip activity. As the abdominals become active, stabilizing the rib cage from below, and as the shoulder girdle descends, stabilizing on the upper rib cage, strategies directed toward active neck elongation with neutral head flexion can be combined with strategies to encourage changes in cheek/lip, tongue, and jaw movements. Activities to stimulate the use of these new oral movement experiences in coordination with improved postural and respiratory musculature activity and control will result in the initiation of sound production without increased hyperextension and stiffness as well as the production of sounds with longer duration and improved quality.

Dysarthria and apraxia of speech are motor speech disorders affecting both children and adults. They may be caused by stroke, cerebral palsy, traumatic brain injury, progressive neurological disorders, or other conditions that are a result of CNS pathophysiology. People with dysarthria have weakness of the musculature of the mouth, face, and respiratory system. Speech may be very soft; slow or rapid in rate; and nasal, hoarse, or breathy in quality. Tongue, lip, and jaw movements are limited and not well coordinated with respiration.[14]

Apraxia of speech may be characterized by problems in saying sounds as well as in planning and sequencing the sounds in syllables and words. "People with apraxia of speech know what words they want to say, but their brains have difficulty coordinating the muscle movements necessary to say those words."[15] Individuals may have both dysarthria and apraxia of speech, which will also negatively affect the intelligibility of their speech for effective communication.

Classically, speech-language pathology intervention for individuals with dysarthria has focused on improving breath support, increasing oral activity, improving articulation, modifying speech rate, and strengthening oral muscles. Intervention for individuals with apraxia of speech has emphasized the repetitive practice of sounds, syllables, words, and sentences while "improving the planning, sequencing, and coordination of the muscle movements for speech production."[16] In the most severely involved cases, alternative and augmentative systems of communication may need to be introduced.[17] The NDT-educated SLP would, in addition, analyze the influences of posture, movement, and sensory factors on the person's dysarthria or apraxia of speech and incorporate strategies into intervention that would address these impairments' influences on the individual's speech/sound production.

An 8-year-old girl diagnosed with moderate athetoid quadriplegia with dystonia and dysarthria wants to use speech to communicate with her friends in her classroom rather than using her augmentative communication system. Some individual word or two-word phrases are intelligible to those who know her well, but if she tries to say longer phrases or sentences, she is frequently misunderstood. Her tongue movements are slow and limited in variety. Her jaw movements are poorly graded. She appears to use mild cheek/lip retraction to provide some stability for her tongue and jaw movements as well as shoulder girdle elevation with internal rotation whenever she speaks. Her lower extremities push out into extension with increased stiffness when she talks while sitting in her wheelchair. She is a bright girl and tries hard to be understood. However, it is evident that the harder she works to talk, the less intelligible she becomes.

The NDT-educated SLP who works with this girl recognized that several issues had to be addressed. First, it was important to look at her wheelchair and other equipment she used in the classroom to make sure that they were appropriately adapted for her. Her wheelchair needed to be modified to provide her with better pelvic/hip and lower extremity/foot alignment and proprioceptive input so that she had a lower body foundation that would provide better support for her speech and respiration. She had grown since she was originally fitted for the wheelchair, and her wheelchair needed to be adapted to meet her present needs. The tray on her wheelchair also needed to be raised to provide better trunk and upper extremity support.

In intervention, the NDT-educated SLP focused on strategies that helped the girl to use her rib cage and diaphragm more efficiently to sustain better breath support and respiratory coordination with her oral and pharyngeal activity while talking. Therapeutic handling directed toward improving rib cage alignment and increasing abdominal musculature activity with active upper body control on a more stable foundation at the pelvis and hips in sitting and standing were implemented at the start of each therapy session. Tasks (e.g., singing) that stimulated more sustained duration of sound on a base of better active upper and lower body control were integrated into the session. Oral sensory and motor activities, such as biting and holding onto different sizes and flavors of biters, were also incorporated to help increase oral musculature activity, strength, and control, especially of the tongue and jaw on a foundation of neutral head flexion, neck elongation, shoulder girdle depression, trunk elongation, a neutral or slightly anteriorly tilted pelvis, and hip flexion with neutral rotation and abduction in sitting. Speech tasks were practiced that encouraged use of specific sound combinations in different words and phrases while maintaining the active postural alignment and control needed to support improved oral and pharyngeal musculature activity. Small group tasks with her siblings and other children her age were arranged for the practice of her speech activities under different environmental situations and with more spontaneous speech experiences. This progression of activities provided a foundation for improved speech intelligibility that made conversation with her friends more successful except in times of significantly increased stress and excitement. At these times, she was encouraged to use her augmentative communication system to make sure she was understood whenever possible.

A second example is Mrs. Z, who had a stroke resulting in left hemiplegia. Her speech was frequently described as "mumbling," although she was intelligible in all situations except when in a crowded auditorium with many distractions. Examination of her oral function revealed poor left lateral border lifting of her tongue. During eating, this poor control resulted in the collecting of food in her left cheek. When speaking, it also resulted in "sloppy" vowel productions, poor elevation of the back of the tongue for specific sounds, and slowed speech. Mrs. Z generally held her head up with upper cervical hyperextension and a slight rotation of her jaw to the right side.

In intervention, the NDT-educated SLP focused on strategies that initially helped Mrs. Z become more stable over her base of support in sitting so she could more efficiently weight shift to both her right and left, while maintaining a more appropriate postural alignment. As she gained better dynamic control in her trunk in sitting, her lateral head and jaw movement to both sides began to improve. She was encouraged to maintain slight head flexion as she controlled her head and jaw movements to both the right and the left. The coordination of these body, head, and jaw movements with controlled weight shift over her base of support helped facilitate greater activation of the styloglossus muscle (one of the extrinsic tongue muscles) on the left. This improved muscle activity further improved Mrs. Z's head and oral control, resulting in improved postural activity as well as more precise speech articulation.

A third example is Mr. X, who demonstrated receptive and expressive aphasia with severe dysarthria after his stroke. He could not imitate or approximate any phonemes or any fine motor activities throughout his body. He was not able to use gestures or words. Oral control was poor for both foods and liquids, with more pronounced weakness on the right resulting in a right facial and lip droop. His intervention plan of care called for traditional aphasia therapy, the use of augmentative communication, as well as the use of honey-thick liquids for drinking and a pureed diet consistency for eating.

During his first week in inpatient rehabilitation, Mr. X made some mild gains in receptive language comprehension in response to a program of traditional speech-language intervention strategies. Further examination revealed that a critical barrier to his progress was his significant fear of movement in space. The only sounds he was heard to produce were moaning or crying out with movement as an expression of his fear for this activity. Therefore, Mr. X's speech-language pathology intervention program was modified to include therapeutic handling strategies in coordination with respiratory and phonatory strategies (e.g., inhalation/exhalation exercises; activities requiring varying durations of vowel productions).

Volitional phonations/sound productions were encouraged during functional movements, such as lying to sitting, sit to stand, pointing activities, and standing activities. Gradually, Mr. X began to sequence his exhalation effort with phonation and movement. Strategies to assist Mr. X in modifying his oral motor activity and the timing of this activity with phonation were incorporated. With repeated practice, he was able to achieve vocal pitch changes as well as some oral approximations of words. Within 6 months, Mr. X was using short phrases and sentences to communicate with others, exhibiting good receptive language skills, and eating regular foods and drinking thin liquids safely.

Active body movements, rib cage and respiratory musculature activity, and the development of postural control and alignment have a direct influence on sound/speech production in both children and adults with CNS pathophysiology.[18] SLPs with NDT education recognize the importance of using therapeutic handling to influence an individual's posture and movement, respiratory support, and oral and laryngeal function when problems in speech and sound production exist. Speech is a multisystem activity, and this must be reflected in each individual's plan of care and the intervention strategies implemented to improve speech/sound production.

18.1.3 Language, Cognition, and Communication

Within the profession of speech-language pathology, the study of the development of communication skills has moved steadily downward in the life span to early infancy and the influences of attachment and the earliest interactions between infants and their parents on later communication and social skills as well as play skills. Nowadays, speech students are exposed to this new expanding area of knowledge and research in their university programs in addition to the more traditional area of language development in school-aged children. This study of early communication development, the development of play skills, is included and is now the basis for the role that the SLP plays in early intervention programs. The SLP works with the young child and family within the context of the family and home environment, facilitating development of play skills for early language development as well as facilitating early communication interaction between the child and family.

The SLP with NDT education is aware that early development of postural stability and movement skills forms a critical foundation for these early communication behaviors and play skills.[19] Later language development is based on concepts that are learned through early play experiences. These play experiences are based on an infant's growing ability to move and explore space and manipulate objects within that space. The SLP working within an NDT framework is able to assess a young child's early communication skills, including the postural stability and movement skills, the early gestures and vocalizations, and the early social awareness and interactions that are the result of these different areas of development.

In addition to the knowledge base of posture/movement development and the development of respiratory support, the NDT-educated SLP also has experience working within a team that includes physical and occupational therapists as well as early educators. With this team approach, a child is treated as a whole and a family as a member of the team.

For example, an 18-month-old girl has a diagnosis of short gut syndrome secondary to necrotizing enterocolitis, bronchopulmonary dysplasia, and developmental delay secondary to prematurity. She has low postural tone base with asymmetry, is more active on the left, and does not move off midline. She is not sitting independently and does not explore toys beyond mouthing objects placed in her hand. Her high chair is slightly reclined so she is able to rest her head back without requiring the effort of holding her head up. She does not use eye gaze or reaching to make choices, but she will vocalize in response to people talking to her. When placed on the floor, she exhibits no active movements.

The SLP with NDT education will take into account this child's low postural tone, asymmetry, and reluctance to move off midline as she assesses the child's early communication and play skills. She will explore the child's play skills within the context of the child's movement skills, providing stability and support to elicit play and communication behaviors at a higher level whenever possible. Within the home, with a physical therapist or occupational therapist if possible, the NDT-educated SLP will assess available seating equipment, such as a high chair or booster seat, with a particular focus on the postural support provided, adapting these as needed to maximize the child's stability for functional play and communication. The SLP may recommend that this child be seated more upright so she can see the toys on the tray and be encouraged to reach forward to touch and explore them. This positioning would be made possible in the high chair with the addition of foam blocks to provide lateral trunk support for postural stability.

During intervention sessions in the home, working with the child in play on a blanket on the floor, the SLP would use therapeutic handling to encourage more active participation during play and interaction with family members. With the support provided for increased postural stability and alignment, the child would be encouraged to move off midline to reach for objects, actively supporting weight through one arm, while reaching with the other. The SLP would be aware of pacing the movement so the child is also able to coordinate her eyes with her movement, maintaining eye contact with the object or the person on whom she is focused. With her hands supporting the rib cage, the SLP would be facilitating movement that would also affect rib cage mobility and respiratory functions, increasing not only stamina but also the child's ability to make sounds for communication. As her overall activity increases, the child's increased attention to play opportunities and her communication partners will result in increased success in her communication efforts that, in turn, will stimulate more attempts in a positive spiral of energy and communication.

This approach to intervention requires that the SLP be aware not only of the development of early communication and cognition but also of the entire foundation on which communication and cognition are based. The NDT-educated SLP brings this breadth of knowledge, including the importance of postural stability and movement as the foundation for the development of early cognition and communication skills, to the examination of and intervention for infants and young children with suspected or diagnosed problems in the areas of language, cognition, and communication.

Whether providing services for infants and children or adolescents and adults, SLPs must be aware of the close relationships and interactions among language, cognition, and communication in regard to both development and function. Impairment in any one of these areas can negatively affect an individual's function in another. When neuromuscular and musculoskeletal system impairments also exist, an individual's ability to integrate changes in the areas of language, cognition, and communication are even more significantly challenged.

A language disorder is characterized by impairment in comprehension and/or impairment in the use of spoken, written, or other symbol systems. It may involve the form of language (i.e., phonology, morphology, syntax), the content of language (i.e., semantics), and/or the function of language in communication (i.e., pragmatics).[20] Individuals may have difficulties understanding and answering questions, following directions, finding the words they want to say, repeating or generating sentences, understanding what they have read, or writing words/sentences.

Cognitive disorders reflect impairments in the cognitive process and systems that include attention, perception, memory, problem-solving, organization, and executive function.[21] The functional areas of "behavioral self-regulation, social interaction, activities of daily living, learning and academic performance, and vocational performance"[22] may all be affected by impairments in cognition.

Communication may be verbal or nonverbal and intentional or unintentional. It may be composed of conventional or unconventional signals. It includes, but is not limited to, listening, speaking, gesturing, pointing, reading, and writing in accordance with the form, content, and function of language.[22,23]

Over the past 30 or more years, services for individuals with impairments in language, cognition, and/or communication function have expanded with growth in the area of augmentative and alternative communication (AAC). AAC requires the involvement of a multidisciplinary team that includes the AAC user, professionals, family members, and other caregivers if all factors are to be considered that develop "a set of procedures and processes by which an individual's communication skills (i.e., production as well as comprehension) can be maximized for functional and effective communication."[24] NDT-educated SLPs have learned that this team approach to providing services is essential to an individual's progress in intervention, especially when impairments in language, cognition, and communication exist.

For example, Joey is an 8-year-old boy with severe spastic quadriplegia who has cognitive abilities that have been described as low normal. He has been receiving physical therapy, occupational therapy, and speech services since he was an infant and continues to receive these services privately as well as through his school programming. His private therapists are all NDT educated. Joey's private SLP has established functional outcomes for him in intervention that reflect his language, cognitive, and communication needs as well as his feeding and swallowing needs.

Neuromuscular system, musculoskeletal system, and sensory system impairments significantly influence his postural alignment and control during all functional activities. He presently uses an adapted power chair with a joystick placed on the right for access. He uses his right upper extremity to control the joystick as well as to access his dynamic display augmentative communication system, which is mounted on his power chair. His private therapists and parents were all involved in the selection of his seating, standing, and mobility equipment, keeping in mind his augmentative communication, feeding/swallowing, postural alignment, and mobility needs.

Joey's private SLP, who is NDT educated, treats him in his home and while out of his power wheelchair to assist him in gaining greater active postural control and upper extremity control for augmentative communication access. Mobile surfaces and body movement experiences, such as bouncing, swinging, and rocking, are used initially in intervention for sensory organization and arousal. Therapeutic handling strategies are incorporated to encourage more active postural work through his trunk and upper body as he works his lower body off a more active base of support in prone, sitting, and standing. Activities are introduced to stimulate the use of his right upper extremity for reaching and his left upper extremity for active stability. Because Joey's volitional movement is primarily in a sagittal plane, therapeutic handling strategies are used to facilitate postural activity in the frontal (i.e., lateral movements) and transverse (i.e., rotational movements) planes of movement. As Joey exhibits greater active postural control and alignment, he is challenged to sit on a bench with a table in front of him while working on using his augmentative communication system. He is encouraged to answer questions using a minimum of three-word phrases/sentences that are syntactically correct. He is being taught to program new words into his augmentative device so he can keep his vocabulary up to date, incorporating new words he is learning in school.

The initial work done in intervention, which provides Joey with the opportunities to combine greater postural control and alignment with upper extremity activities, prepares him for better and more accurate use of his right arm and index finger when using his 40-location augmentative communication device screen with a keyguard. He can more accurately shift weight in the frontal plane, including across midline, as he points while maintaining a more stable alignment posturally. Without consistent practice in these areas, he will have more difficulties with the use of his augmentative communication system over time as he gets taller and has to work even harder to maintain the postural foundation he requires to use his upper extremities for system access.

Adult clients poststroke often exhibit problems in the language and cognition areas. Such a client was a 64-year-old male executive who was seen for a thorough speech-language evaluation upon arrival at an inpatient hospital rehabilitation department. He averaged 75 to 90% accuracy on both formal and informal testing and was, therefore, not recommended for specific speech intervention services. No more than a week later, his physical and occupational therapists noted their frustration with what appeared to be his limited cognitive abilities and poor safety awareness and organization.

Upon reevaluation by an NDT-educated SLP, it was discovered that he could process and organize information in a quiet environment and while seated. However, he did not know where his body was in space and exhibited significant problems organizing and processing information when he was standing and moving. Since he was being asked to follow specific verbal directions and safety instructions while using a walker and other adaptive equipment, he was having difficulties following and executing instructions being given to him. This inability to follow verbal instructions was not a problem of distraction in his environment; rather, it was a problem with his ability to process internal or external language while moving (i.e., multitasking).

Strategies incorporated into intervention focused on higher-level problem solving and math calculations and were performed in standing. Activities that emphasized deep proprioceptive and tactile input through the upper and lower extremities, such as pushing against a wall with arms extended or marching in place, were included at the beginning of every intervention session. He was encouraged to talk during activities describing where his body was as he moved. Describing barriers to movements in his environment and challenges that existed while he was walking helped him to develop greater safety awareness and organization. By integrating cognitive, sensory, and motor tasks, this individual was able to learn to significantly improve his cognitive performance during movement activities.

Postural control and ability to move in space directly influence an individual's functional abilities in the areas of language, cognition, and communication. Children expand their language, cognitive, and communication skills as they move and investigate all aspects of their environments. As they get older, they learn to use their language and cognitive skills to communicate in a variety of environments whether they are sitting, standing, walking, or running. When there are impairments in language, cognition, and communication, intervention programming must reflect an understanding of the influences that postural control and body movements can have on the success and progress made by an individual in these important functional areas.

18.2 Summary

All therapists who provide evaluation and intervention services for individuals with neuromuscular, musculoskeletal, and sensory system impairments must understand how posture and movement influence the functional abilities and activity limitations of their clients. SLPs working with children or adults with CNS pathophysiology must acquire the special skills required to incorporate appropriate strategies into intervention that address the influences of posture and movement on discipline-specific functional goals, especially in the areas of feeding and swallowing, speech/sound production and language, cognition, and communication. SLPs with NDT education possess the expanded knowledge and experience that is needed when working with such a complex population.

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Case Reports

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Introduction

Mary Rose Franjoine

Unit V provides the reader with clinical illustrations of Neuro-Developmental Treatment (NDT) in action. The case reports presented in this unit are written by clinicians and provide real-life examples of how the NDT Practice Model can serve as a decision-making framework for daily practice. This unit of the text features 15 case reports. Additional video-based cases are available on Thieme MediaCenter. To facilitate the review process, this unit is subdivided into two sections: Adult-Onset Case Reports and Pediatric-Onset Case Reports. The NDT Practice Model serves as the structural framework for organization of each section of this unit. The area of the NDT Practice Model emphasized within each case report has been selected as the mechanism for the ordering of case reports within each section.

What Is a Case Report?

A case report is a description of clinical practice, often providing detailed information about a patient or client as a person, a unique individual. Case reports can enhance our understanding of a client's clinical presentation; describe a novel clinical scenario; provide examples of intervention strategies; explore the use of new, innovative, or creative interventions; explore the application of clinical practice theories; and serve as a springboard for future scientific and clinical research. The conclusions drawn from a case report should not be generalized to the population as a whole. However, the clinical insights gained from a case report can expand our knowledge and understanding of the diversity of clinical practice, that is, the uniqueness of individual-based care. In this text, case reports can provide a detailed picture of a client, illustrating his or her unique clinical presentation, and they can detail the challenges encountered by both the client and the clinician. These case reports can illustrate the application of contemporary practice principles to address the unique needs of a specific individual. They can also provide valuable insights into the clinical decision-making process, exploring in depth the process used by the expert clinician.

The case reports presented in this text provide detailed and specific information related to a clinical question. Some can serve as a vehicle to illustrate and document clinician or client preference for examination or intervention strategies. Ultimately, case reports can stimulate a clinician's mind, provide new insights into old problems, and propose new clinical ideas for consideration. A case report or collection of case reports, such as these, can serve as a methodological foundation for future research.

Case Reports in the Evidence-Based Practice World

Case reports are unique contributions that clinicians can make to the professional literature.[1,2,3] Rothstein,[3] McEwen,[1,2] and others have advocated for the publication of case reports in the physical therapy literature for many years. Case reports written by clinicians for clinicians are believed to be valuable teaching tools and are reported to have a positive influence on the training of young medical professionals and in the advancement of clinical practice.[4] Case reports serve as a form of anecdotal evidence. By design, a case report is less scientifically rigorous than a randomized, controlled, double-blinded clinical trial.

Randomized, controlled trials (RCTs) often have large sample sizes and a narrow focus of investigation; thus the researcher's ability to comprehensively describe a complex set of clinical circumstances is limited. By contrast, the sample size of a case report is very small, often one subject, thus affording the author the opportunity for an in-depth exploration and analysis of numerous variables that may affect the client's diagnosis, prognosis, plan of care, and response to specific interventions. The findings from RCTs, when published, are often authored by teams of researchers, who may have limited contact on a daily basis with clinical practice. Case reports are generally authored by the practitioner who was directly involved with the individual featured in the case report. Often, the authors of case reports are full-time clinicians who have an understanding of the rapidly evolving challenges of clinical practice.[2] It may take a team of researchers years to develop and refine the research question, design the study, attain institutional review board approvals for research with human subjects, secure funding, recruit subjects, complete data collection, analyze the data, and disseminate findings. Case reports are generally retrospective in design; thus findings are often submitted for publication within months of the client–therapist experience.

Case reports have a place in the schema of evidence-based practice (EBP). Sackett proposed a widely accepted definition of EBP in1996. He stated that EBP "is the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual clients."[5] The implementation of EBP requires the integration of individual clinician expertise, patient values, and the best available clinical evidence from systematic research into the decision-making process for care of the individual. Clinician expertise includes the therapist's educational background, clinical experience, and clinical skills. The person seeking therapy services brings his or her unique needs, wants, values, and expectations to the therapeutic relationship. The identification and analysis of best evidence may be undertaken by both the individual seeking therapy and the therapist.

In 2000, Sackett and colleagues proposed five hierarchically ordered levels of evidence and a methodology to guide practitioners in their review of the evidence[6] (**Table V.1**). A detailed discussion of EBP and research methodology is beyond the scope of this text.

Table V.1 Sackett's levels of evidence

Level of evidence	Types of studies
1A	Systematic review of randomized, controlled trials (RCTs)
1B	RCTs with narrow confidence intervals
1C	All or none studies
2A	Systematic review of cohort studies
2B	Cohort studies, low-quality RCTs
2C	Outcomes research
3A	Systematic review of case-controlled studies
3B	Case-controlled studies
4	Case series, case reports, poor cohort case-controlled studies
5	Expert opinion

Case Reports as a Basis for Best Practice

The case reports presented in the two sections that follow in this unit provide the reader with concrete, specific examples of *NDT in Action*. Each case report began with a clinical question. The question then guided the critical inquiry and framed the design of the case report. The focus of the case reports differs because each explores the needs, wants, and expectations of the individual featured within the case report. All therapists used the NDT Practice Model and the International Classification of Functioning, Disability and Health (ICF) framework to guide their clinical decision making and clinical practice. Each therapist's educational background is different, each has different clinical experiences and expertise, and each has a different set of clinical skills. As one would expect, based on the differences between individual clients and therapists, the process of information gathering, examination, evaluation, formation of a plan of care, and intervention varies among case reports. Each case report illustrates an aspect of NDT-based practice; when viewed in their entirety, the case reports begin to frame the scope of NDT as a practice theory.

Case report authors include occupational therapists, physical therapists, and speech-language pathologists who have had formal training in the practice of NDT and who are NDT-certified clinicians. The case reports illustrate practice in a wide variety of settings, such as the client's home, school, and community settings, including medical-based facilities. The clients featured in the case reports range in age from infancy to adulthood. Severity of disability, as well as time from onset of disability, varies among the individuals featured in the case reports. The case reports depict the richness of diversity of clinical practice; application of the NDT Practice Model to a diverse group of individuals with varied needs and expectations illustrates the robustness of NDT as a framework for clinical practice.

The scope of NDT practice is one factor that creates challenges for the researcher who wishes to investigate the efficacy of NDT. The critical inquiry and investigation of effectiveness must begin with discrete, focused questions. The refinement of the research question and the identification of the population to be investigated are the next steps in the process. Case reports as a form of evidence can help to clarify the research questions and define the target populations. The explicit purpose of the case reports that follow in the next two sections of this unit is to illustrate *NDT in Action*, depicting the depth and breadth of NDT.

Adult Onset Case Reports

The six adult-onset case reports featured in the first section of this unit illustrate for the reader the use of the NDT Practice Model in daily clinical practice. The case reports feature individuals whose pathophysiological etiology and time from onset varies, who have a wide array of capabilities and challenges, who sought therapeutic services across a spectrum of clinical practice settings, and whose goals, wants, and dreams differ. Case reports presented in this section explore the examination, evaluation, and identification process of functional movement impairments in the context of outpatient therapy services.

Case Report A1 features Mark, who at the age of 51 years sustained a left stroke (right side more involved), following him through a 12-week course of outpatient physical and occupational therapy. This case report illustrates the NDT-based clinical decision-making process exploring the use of functional movement analysis in impairment identification, goal/outcome setting, and intervention planning.

Case Report A2 of JW follows. She was also 51 years of age at the time of her right stroke (left side more involved). The reader meets JW in outpatient therapy and follows her progress through 8 months of physical and occupational therapy, including her transition back to work. This case report provides detailed insights into the NDT problem-solving process through the systematic analysis and synthesis of functional movements. It also provides insights into the intervention planning process and the selection and progression of intervention strategies.

The case report of PW, A5, is written from the perspective of the occupational therapist, it provides insights into the collaborative process with the physical therapist and speech-language pathologist. PW is a 65-year-old woman with a right stroke (left side more involved) who presented with significant cognitive impairments and shoulder pain. This case report follows PW's outpatient therapy program for 4 months and provides examples of active intervention strategies for stretching and strengthening in functional postures and activities.

These three case reports, when viewed together, enhance the reader's understanding of the collaborative process of NDT-based care, as well as the spectrum of care provided in an outpatient clinic environment.

The practice setting for two other case reports is in the home of the individual seeking therapy services.

Carol, in Case Report A3, presents with contraversive pushing behavior. At the time of her right stroke (left side more involved), Carol was 62 years old. This case report chronicles a 14-month episode of care, guiding the reader through the process of impairment identification, prioritization, development of a plan of care, and the systematic implementation and progression of intervention strategies.

Case Report A4 features Ernie, a 20-year-old male who suffered a severe traumatic brain injury (TBI) secondary to a motorbike accident. The reader follows Ernie for 21 months of home-based physical therapy. Ernie presents with bilateral involvement with his right side more involved than the left. In addition to significant impairments of the neuromuscular system, Ernie presented with significant impairments of the musculoskeletal system, specifically in his lower extremities. Ernie's intervention program focused on obtaining improved range and alignment in his feet and ankles through active, upright stretching activities (i.e., in functional postures and activities) along with better trunk and head control. Ernie's family was very involved in his therapy program and implemented all home program recommendations.

The case reports of Carol and Ernie allow the reader to explore the functional possibilities and challenges of working in the home. The reader gains insight into the ongoing process of examination, evaluation, and progression of an NDT-based plan of care.

The outpatient clinic is the practice setting for the final case report in this section. Case Report A6 features Dennis, a 62-year-old man, who was 57 at the time of his stroke. Clinically, he presents with a right stroke (left side more involved). This case report follows Dennis over a 5-year period, providing insights into the long-term management needs of an individual poststroke. This case report also provides detailed examples of analysis of impairments and their relationship to intervention strategies over time.

The six adult-onset case reports, when viewed individually, provide the reader with insights into an aspect of NDT-based care. When viewed collectively the case reports expand the reader's understanding of possibilities. To further enhance the reader's depth and breadth of knowledge of NDT practice, each case report is followed by an alternative reflection. The alternative reflections are short, focused commentaries, providing an alternative view from the perspective of a different discipline or practice setting. On Thieme MediaCenter, the reader will find additional photos and videos that augment and expand the content of the case reports, enriching the reader's understanding of the dynamic nature of NDT-based care, providing a frame of reference for *NDT in Action*.

Pediatric Onset Case Reports

Nine pediatric-onset case reports are featured in the text with two additional video-based cases presented on Thieme MediaCenter. Each case report explores an aspect of NDT-based practice. This section of the unit begins with Case Report B1 about Mya and Maddison, identical twins who were born at 26 weeks of gestation. Each infant faces her own unique challenges and has her own unique strengths. This case report illustrates the individualized process of information gathering, examination, evaluation, formation of a plan of care, and intervention from the perspective of the NDT team, which included the twins' mother as well as occupational therapists (OTs), physical therapists (PTs), and speech-language pathologists (SLPs). Using the NDT Practice Model, the reader will gain insights into the discipline-specific roles of the PT, OT, and SLP in the development of an NDT-based plan of care as well as a greater appreciation for the collaborative nature of the intervention process when care is provided using the NDT team approach. This case provides specific examples of NDT-based intervention planning, intervention, and home programming. On Thieme MediaCenter, the reader will find a video that chronicles the process of examination and intervention with each infant, comparing and contrasting the needs of each infant, and the development of unique plans of care for Mya and Maddison.

Case Report B2 features Russell, who sustained an open head injury, and is set in an inpatient pediatric rehabilitation hospital. At the time of his injury, Russell was 14 years of age and living the life of a typical teenager. This case report also explores the concepts of the team, the information-gathering process, and the examination-evaluation phases of care provision. This case, written from the perspective of an SLP, explores the use of NDT-based knowledge and therapeutic handling skills to guide her daily clinical practice and empower her clinical decision making. This case report follows Russell during his 9-week inpatient rehabilitation admission, chronicling his progress of recovery, emphasizing the evaluative process used to progress his speech therapy programming, including the recovery of oral feeding and communication skills. To aid readers in their understanding of the damage caused by the bullet that caused the open head injury, the diagnostic imaging of Russell's brain immediately postinjury is provided on Thieme MediaCenter. Additionally, Russell's swallow studies during his inpatient rehabilitation stay are also available for review.

The next three case reports presented in this unit explore NDT-based intervention from the perspective of the PT and emphasize the NDT-based planning process within-and between-session decision-making processes. In Case Report B3, readers will meet Perry, who is 9 months old and has begun a new episode of care. This case report describes the examination, evaluation, and development of a physical therapy plan of care using the NDT Practice Model and the ICF framework for a young child with hemiparesis. The reader will follow Perry in physical therapy for approximately 2 years, gaining insights into the ongoing process of examination, analysis, synthesis, and intervention program planning. This case report illustrates the importance of considering the unique sensorimotor and emotional needs of a young child living with hemiparesis. On Thieme MediaCenter, the reader will find a video that illustrates NDT-based intervention strategies.

Makayla's case report (B4) follows and provides the reader additional insights into the NDT-based planning and implementation process of a physical therapy intervention program. At the beginning of the case report, Makayla is 23 months of age and is learning to sit and transition to sit in a child-sized chair to play with her twin sister. Specific NDT-based intervention handling strategies are explored and rationales provided for their selection, modification, and fading. The photos and videos on Thieme MediaCenter provide specific examples of, and insights into, NDT-based therapeutic handling and sequencing of strategies within a single intervention session.

Case Report B5 focuses on a child's ability to transition to sitting. In this report, the reader will meet Jamie, a child living with cerebral palsy spastic quadriplegia, when he is 10 years of age and will follow him during a 10-week physical therapy episode of care. This case report chronicles Jamie's gains in skill and confidence in his ability to transfer from his wheelchair. The reader will gain insights into the examination and evaluation process aimed at enhancing task-specific function and will explore the selection and sequencing of specific NDT-based intervention strategies. Thieme MediaCenter provides an expanded table of intervention plans and results with photos that illustrate the progression of intervention strategies.

Together, the three case reports featuring Perry, Makayla, and Jamie provide a wide array of examples of *NDT in Action*, illustrating key concepts of NDT-based physical therapy intervention that were introduced to the reader in chapters on physical therapy and Chapter 9 on intervention. These case reports explore their specific application with children of different ages and functional abilities.

The case report featuring Jagraj (B6) also focuses on the examination-evaluation components of NDT-based intervention planning and the progression of a plan of care. When the reader first meets Jagraj, he is 5 months of age, recently discharged home from the hospital, and is recovering from thoracic surgeries that were necessary to correct congenital heart defects. As is too often the case, Jagraj's recovery process was complicated and led to his inability to feed orally. As with Russell in Case Report B2, the reader will follow Jagraj's progress in speech therapy. Summaries and the linked videos allow the reader to follow his progress toward oral feeding and his development of communication skills. Additionally, the reader has the opportunity to reconnect with Jagraj at 4 years of age as he enters a feeding group. The reader will gain insights from the perspective of an SLP into the NDT-based clinical decision-making process that drives the development and progression of intervention. The videos that accompany this case report provide specific examples of positioning, NDT-based therapeutic handling, and oral motor intervention strategies.

The next two case reports in this section of the unit explore the application of principles of NDT practice, the NDT Practice Model, and the ICF framework to enhance participation, minimize participation restrictions, and improve the quality of life for children and families living with cerebral palsy. Case Report B7, featuring Patty Grace, explores the role of the NDT clinician as a consultant. When the reader first meets Patty Grace, she is 9 years of age and has mastered downhill skiing on Vail Mountain. This accomplishment for many may seem insignificant, but when one considers that she lives in a ski community, her family are avid skiers, and at the age of 4 years when her family moved to Vail, Colorado, her primary means of mobility was a wheelchair, she is remarkable. Patty Grace lives with a diagnosis of ataxic cerebral palsy, and during the 4 years while she was learning to ski in standing, she mastered walking, becoming an independent community ambulator. This case report describes the problem-solving process and the selection and adaptation of ski equipment used by the adaptive ski instructor to develop Patty Grace's physical abilities and her confidence to ski in standing.

The case report that follows (B8) is very different in its scope and focus, but it too embraces the spirit of inclusion and participation in life and family activities. This case report introduces the reader to Brandon and his family. Brandon has multiple complex medical needs, participation restrictions, activity limitations, and impairments in all domains of motor development, communication, and cognition, and is considered severely and profoundly disabled, as well as medically fragile. This case report explores the intervention process from the perspective of enhancing Brandon's ability to participate in life. It also explores the interrelationships of direct therapy and assistive technology, focusing predominantly on participations occurring in supported sitting and standing, enhancing the quality of life for Brandon and his family. The reader will gain insights into the NDT-based decision-making process for a child with multiple complex medical needs beginning at age 2 years and continuing throughout his life. Thieme MediaCenter features photos and a video of Brandon engaged in participations with his family in his home and within the community through the use of a variety of assistive technologies.

The case reports featuring Patty Grace and Brandon were selected for inclusion in *NDT in Action* because they embrace fundamental constructs of NDT and in the hope that they would empower the clinician to think beyond the boundaries of the traditional therapy setting and outcomes, to see the possibilities, to look beyond the diagnosis and prognosis, and to empower children and their families to embrace and live life to its fullest.

The final case report in this section (B9) challenges the reader to question service delivery models and modes of intervention, and it explores alternative dosing paradigms. This case report features Sam, who is 6 years of age and has a medical diagnosis of spastic quadriplegia cerebral palsy and dystonia. It explores the design and implementation of a 2-week therapy intensive episode of care. Thieme MediaCenter provides a video of occupational and physical therapy intervention sessions and Sam's gains in physical capabilities during his 2-week therapy intensive.

In summary, the 15 case reports that follow and the two video cases on Thieme MediaCenter illustrate *one* aspect of care for *one* individual at *one* moment in time. The therapy services provided would be different if the individual were younger or older, had different comorbidities, lived in a different geographic area, and had different needs, wants, and dreams. The case reports are examples of the NDT Practice Model in action; they are not intended to provide a prescription for care or a recipe for success. It is hoped that this collection of case reports can inspire future research, clarifying the clinical questions that should be asked and systematically investigated. For clinicians, it is hoped the case reports inspire all practitioners to think outside of the traditional therapy box, to reflect on the process of information gathering, methods of examination, the process of evaluation, and formation of a plan of care to consider the focus of intervention; to ultimately ask the questions about how, what, when, where, and why. How might using the NDT Practice Model enhance clinical outcomes? What knowledge and skills might we gain from studying NDT Practice Theory? When should the NDT Practice Model be used? Where in the continuum of care is it appropriate to use NDT decision-making frameworks? Why not NDT?

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Section A Adult Onset Case Reports

Case Report A1 The Application of Posture and Movement Analysis to Accurately Evaluate, Plan Intervention, and Achieve Functional Outcomes for an Individual Poststroke

Marie Simeo

A1.1 Introduction

An accurate examination and evaluation are critical for identifying the effect a neurological event has on a client's social participation and activities and for identifying the system impairments contributing to the activity limitations. It is essential to link system impairments to activity limitations to establish functional outcomes with specific performance criteria that reflect changes in the degree of impairment.

The clinician improves the client's quality of life by minimizing disability, optimizing activities, and remediating system impairments. The development and implementation of the intervention plan reflect how functional outcomes are achieved and system impairments are reduced. The clinician considers the client's goals, objective findings, as well as didactic information from the neuro- and movement sciences, applied kinesiology, and evidence-based clinical trials to guide the clinical decision-making process. Clinical outcome measures are used to determine the changes in the client's abilities and the intervention's efficacy.[1]

The examination begins with evaluating the client's activities and activity limitations. Assessing the client in function is consistent with the dynamical systems approach for motor control.[2] How a person functions reflects how multiple systems, such as the musculoskeletal, neuromuscular, visual perceptual, and cognitive systems, organize to produce a desired outcome following a neurological event.

Although general descriptors of a client's functional status provide an overall picture of an individual's activities and activity limitations, it is critical to analyze posture and movement during functional tasks to identify specific system impairments.[3,4,5] A client's movement strategies for completing functional tasks should be analyzed and compared to the those of a healthy individual to correlate impairments to activity limitations, determine the most significant impairment affecting all areas of function, establish outcomes that reflect both the desired functional outcome and neurorecovery, and develop interventions that specifically address the impairments limiting the client's activities.

Physical therapists are expected to demonstrate a basic level of competency in observational gait analysis, and the clinical application of the Neuro-Developmental Treatment (NDT) Practice Model extends this expectation to clinical competency in observational posture and movement analysis of functional tasks. For occupational therapists, posture and movement analysis is a critical extension of task analysis.

Because functional tasks are complex, identifying the component parts or subtasks first (task analysis) and then the movement components necessary to efficiently and successfully complete each subtask (posture and movement analysis) helps to more specifically identify the differences between the standard performance criteria and the client's current level of performance.[6] When simplifying tasks into subtasks, the clinician should consider whether these subtasks are arbitrarily defined components of a continuous activity, such as the stages of gait or whether the subtasks have a discrete beginning and ending. Differentiating between discrete and continuous tasks will influence how the motor skill should be taught to maximize learning.[7]

As clinicians observe and analyze the movement strategies used to complete functional tasks, they can begin hypothesizing or differentiating possible system impairments that may be limiting the client's activities.[8,9] The clinician pursues answers to the following questions: How does the client's movement strategy differ from that of the healthy population? Are the client's differences within the range of normal variations observed between individuals in the healthy population? If the differences are outside the range of normal variation, why are the client's options for movement limited?

To compare the client's movement strategies to those of a healthy adult, the clinician must understand the typical movement components of various functional tasks. Researchers have identified in the healthy adult population discrete invariable movement components for basic functional tasks. These are considered typical and are used as the standard or norm for such activities as sit to stand, gait, stair climbing, and upper extremity (UE) function.[10,11,12,13,14,15,16,17]

Although the invariable events in these functional tasks are the foundation for what is considered the norm, in the healthy population there is significant movement variation between individuals of the same age and within the same individual repeatedly performing the same task.[18,19,20] These variable events may be due to several factors, such as the method of motion analysis used, the intrinsic characteristics of the individual performing the task, the environmental conditions, and the context in which the task is performed.

Unfortunately, there isn't a resource that identifies the invariant events or the standard performance criteria for a wide range of functional activities. The clinician must integrate information from a variety of resources, such as motion analysis studies and applied kinesiology and biomechanics, as well as human movement studies, motor learning principles, and motor control theory, to develop an expectation for the standard performance criteria.

The following case report demonstrates the clinical application of the NDT Practice Model. It focuses on the critical role of posture and movement analysis in the examination and evaluation of a client—establishing functional outcomes, developing an intervention plan, and implementing intervention strategies. It also illustrates the integration of information from the neuro- and movement sciences and the application of motor learning principles within the NDT problem-solving framework.

A1.2 Case Description

Mark is a 51-year-old, white man with a past medical history (PMHx) of uncontrolled type 2 diabetes mellitus, coronary artery disease with status poststent in 2006, and hypertension. He reported to the emergency department on May 27, 2010, complaining of right-sided weakness.

A1.2.1 Health Condition/Diagnosis

Acute left frontoparietal ischemic stroke with mild subcalcine shift and resultant right hemiparesis.

A1.2.2 Course of Care

- Acute care hospital neurology floor for 1 week.
- Acute inpatient rehabilitation unit; received physical therapy, occupational therapy, speech-language therapy; 5 days/week for 3weeks.
- Skilled nursing facility (SNF); received occupational therapy, physical therapy 5 d/wk for 8 weeks.
- Outpatient therapy (OP therapy); physical therapy and occupational therapy 3 d/wk for 12 weeks.

A1.2.3 Social History

Mark was unemployed prior to his stroke. He has a degree in finance and previously worked in the financial field. He is presently working on developing a Web site for a financial venture.

Prior to his stroke, Mark resided with his grandmother and returned to her home following his discharge from the SNF. The home is on one floor and accessible. Mark is an avid golfer and played on a regular basis prior to his stroke. His plan was to relocate to Texas in 12 weeks after his OP therapy to temporarily reside with his parents while continuing to work on his recovery.

A1.2.4 Personal Goal

His primary activity goal was to resume golfing, using both hands on the club as he did prior to his stroke. When questioned about additional goals, Mark replied, "I figure if I can resume golfing, then I would be able to do most anything else."

A1.2.5 Examination and Evaluation

Several general descriptions of Mark's functional activities and activity limitations provided an overall impression of Mark's functional status at the initial evaluation. Observational posture and movement analysis was used to describe three functional tasks Mark was asked to perform during the initial evaluation. These descriptions reflected more specifically Mark's current level of performance and helped identify his system impairments. The three tasks were: (1) ambulating without an assistive device, (2) opening an upper kitchen cupboard door with his right hand, and (3) grasping and releasing a cylindrical container.

Activities

1. Ambulated independently in indoor environment with a wide-based quad cane on low-pile carpet, stopping frequently due to right lower extremity (RLE) muscle fatigue and difficulty clearing the RLE in swing. Demonstrated a step-to gait pattern; at velocity.
2. Independently ascended three to four steps, placing quad cane on step, initiating step up with unaffected left lower extremity (LLE), followed by placement of RLE on same step.
3. Independently descended stairs using the left handrail, stepping down with RLE first while shifting weight back onto LLE until right foot was placed foot flat on step below; supported body weight on left upper extremity (LUE) as he stepped down to the same step with LLE. Assistance of another person was necessary to transport Mark's cane to the bottom of the steps.
4. Independently placed golf club in affected right hand, by using unaffected left hand to passively extend his right fingers, abduct the thumb while wrist was flexed and ulnarly deviated. Once club was positioned in right hand, fingers involuntarily flexed around golf club handle, thumb adducted, and wrist remained flexed and ulnarly deviated.

Activity Limitations

Activity 1

Mark was unable to ambulate functional distances (> 60 feet) in indoor environment on low-pile carpeting without an assistive device and close supervision.

Mark's gait was assessed without an assistive device, since using the quad cane allowed him to use compensatory movement strategies that masked his gait deviations. His compensatory strategies made it difficult to accurately identify system impairments and the extent to which the impairments limited Mark's mobility.

Current Level of Performance for Task 1

Task: Ambulating a short distance without an assistive device. Functional stages of gait (RLE reference limb) were as follows:

- Weight acceptance (WA) with initial contact (IC) and loading response (LR)
  - Upper trunk flexed forward, laterally flexed to right, rotated back on right.
  - Lower trunk, pelvis rotated back on right.
  - Right hip, knee slightly flexed.
  - Right scapula elevated, abducted on thorax.
  - Right upper extremity (RUE) anterior to hip at client's side; shoulder internally rotated; elbow flexed; forearm pronated; wrist flexed, ulnarly deviated; fingers and thumb fully flexed (fisted).
  - Initial contact lateral aspect foot; foot flat.
  - As weight accepted, increased upper trunk right lateral flexion; lateral shift to right; increased right hip and knee flex.
- Single limb support (SLS): midstance (MST), terminal stance (TST).
  - Upper trunk, pelvis rotated back on the right; increased right hip, knee flexion with unweighting LLE for quick step forward up to R foot.
  - Upper trunk laterally flexed, laterally shifted to right.
  - Hip, knee move between small ranges of flexion and extension.
- Swing limb advancement (SLA): preswing (PS), initial swing (IS), midswing (MS), and terminal swing (TS).
  - Weight shifted forward and laterally onto LLE (lateral greater than forward); upper trunk shifted left, rotated forward.
  - Right upper trunk and pelvis rotated farther back on the right.
  - Right hip externally rotated; progressed RLE forward with hip adductors, minimal right knee flexion; ankle dorsiflexion assists with foot clearance; ankle inverts slightly; foot contacts floor up to or slightly behind L foot.

Activity 2

Unable to open an upper kitchen cabinet with his RUE while standing at the counter.

Current Level of Performance for Task 2

Task: Open a kitchen cabinet located overhead with his right hand.

- Starting alignment.
  - Feet greater than shoulder width apart; right foot slightly behind left; pelvis rotated back on right; right knee slightly flexed.
  - Left hand on quad cane; upper trunk shifted laterally to left, rotated forward; thorax flexed forward.
  - Right scapula winged, abducted, elevated on thorax; shoulder internally rotated, adducted; elbow flexed 20°; forearm pronated; wrist flexed, ulnarly deviated; fourth and fifth fingers, metacarpophalangeal (MCP), interphalangeal (IP) flexion; first and second fingers MCP, IP flexion; thumb end range metacarpal (MC) opposition; MCP, IP slightly flexed.
- Movement strategy: transport stage of reach.
  - Shifted weight onto LLE.
  - Flexed upper trunk laterally to left; rotated L upper trunk forward.
  - Elevated right scapula; rotated right upper trunk back.
  - Abducted, internally rotated and flexed right shoulder 30°; elbow remained flexed; forearm pronated; no change in wrist and fingers.
  - Rotated right upper trunk forward; flexed hips R greater than L to position hand closer to handle.
  - Repeatedly moved right upper trunk between forward, back; initiated first and second finger IP extension until he hooked first and second fingers on handle
- Opening cupboard door.
  - Moved from left lateral upper trunk flexion toward right upper trunk lateral flexion; rotated right upper trunk back; increased weight shift onto LLE.
  - Released hand from handle; rotated trunk back to the right, extended thumb IP joint; initiated extension first and second IP joints to release handle.

Activity 3

Unable to use his right hand to grasp and release a cylindrically shaped container he was attempting to move while standing in front of the kitchen counter.

Current Level of Performance for Task 3

Task: Grasping and releasing a cylindrical container with his right hand.

- Starting alignment.
  - weight supported on LEs (L greater than R); upper trunk shifted laterally to left, rotated forward ; upper trunk, pelvis rotated slightly back on the right.

  - LUE on countertop.
  - RUE positioned at side—trunk, scapula, UE alignment same as noted above in the description of the starting alignment of the second activity limitation.
- Movement strategy.
  - Elevated right scapula; rotated right upper trunk back; forearm moved from pronation toward supination (does not reach midposition); wrist and fingers remained flexed.
  - Used left hand to take object to right hand.
  - Pushed cylinder in left hand between right thumb and index finger.
  - Initiated release of right grasp by flexing upper trunk to the right, rotating upper trunk forward and back; initiated forearm supination; elbow, wrist, and fingers remain flexed; unable to release cup without help of other hand.

Interpreting Observational Postural and Movement Analysis

Movement analysis of the second task Mark performed, opening an upper kitchen cabinet door with his right hand, was compared with the typical or standard performance criteria used to accomplish the task. The standard performance criteria are based on the kinesiology of the shoulder girdle complex, the biomechanical and musculoskeletal requirements determined by the context and environment, and the neurophysiology of reach.

There are invariant events that occur with forward reach, but there is also significant variation in the possible movement strategies that could be used to accomplish the same task. In Mark's case, factors such as his height, distance from the cupboard, the type of cupboard handle, and the direction the door swings were all variables the clinician considered when trying to identify the invariant standard performance criteria for opening the cupboard door.

To correlate system impairments to activity limitations, the clinician compared the movement strategy Mark used to position his hand on the cabinet handle to the standard performance criteria for the activity. The proximal UE movement strategy he used differed from the standard performance criteria in the following way: Mark's thoracic spine was flexed rather than extended, his upper trunk was shifted to the left and the right scapula abducted further from the already abducted starting alignment and moved into end range scapula elevation. The glenohumeral joint moved into abduction and internal rotation without a change in elbow flexion or forearm pronation.

The movement strategy Mark used proximally to initiate RUE forward reach suggested that there may be either a limitation in range of motion (ROM) and/or weakness in the thoracic spine, scapula, and/or glenohumeral joint. To differentiate between musculoskeletal or neuromotor causes for the activity limitation in forward reach, a more specific assessment of the trunk and shoulder girdle complex was indicated. Because the shoulder girdle complex does not function in isolation, further evaluation of the shoulder girdle complex considered all related body segments and, in particular, the base of support (BOS). In Mark's case, his LEs served as his BOS, as he reached forward to open the cabinet.

The interrelationship of the shoulder girdle complex to other body segments is clear from a strictly anatomical perspective and is supported by kinematic studies.[21,22,23] Muscles attach from the pelvis; lumbar, thoracic, and cervical spines; and the rib cage to the shoulder girdle complex. The strength, alignment, and ROM of these body segments affect UE function. A more specific assessment of Mark's trunk and LEs was performed to determine possible impairments contributing to his limitations in UE reach.

Identifying Client-Centered Goals

In establishing functional outcomes, a primary consideration is identifying the activity or activities that are meaningful and significant to the client. The client's motivation and participation in the learning process are essential for motor skill learning.[24] In Mark's case, at his initial evaluation, his personal goal was to resume golfing. His rationale was that if he had the physical abilities to golf, he would most likely be able to do almost anything. Mark recognized that if he could golf, it meant he would have a functional grasp and release of his right hand, adequate strength and coordination of his RUE to move through extreme ROM with selective movement at each joint, adequate RLE strength for balance and power needed to drive the ball, and also adequate strength and balance to walk the greens and maneuver over uneven terrain.

Mark's personal goal was addressed in intervention; however, due to the activity's complexity, number of subtasks, and specificity of training, an alternative goal will be used as an example for establishing functional outcomes. In preparing for his move to Texas, Mark wanted to assist with packing the contents of his office. The following example illustrates task and movement analysis to identify the standard performance criteria for lifting a box and Mark's current level of performance when he attempted this activity.

Functional Activity Analyzed

The activity identified was stooping to pick up a lightweight box off the floor using both UEs, carrying it to a nearby countertop, and placing it on the surface. The standard performance criteria compared with Mark's performance of this activity is outlined in Table A1.1.

A comparison of Mark's performance to the standard performance criteria for this activity and the previously described activities demonstrated noticeably limited variety in the movement strategies Mark accessed. Each task had different requirements, and in each task, Mark consistently established the same BOS in standing and demonstrated the same UE movement strategy for forward reach; or as in this case, he failed to use the affected UE in this bimanual task. Based on this analysis, the analysis of his golf swing, and other functional tasks observed throughout the evaluation, as well as more specific evaluation of individual systems, Mark's system impairments were identified. The impairments listed refer to Mark's right side unless otherwise indicated.

Table A1.1 Comparison of performance criteria

Standard performance criteria	Mark's performance
Subtask 1: Stoop to the floor while reaching toward the box, placing hands on opposite sides of the box.	
Movement analysis	Movement analysis
Stooping	Stooping
• Establish BOS; feet in stride.	• Feet parallel, wider than shoulder width apart in same plane; weight shifted more onto left LE; rotation of pelvis forward on left; back on right.
• Trunk stable, eccentric release of extensors as trunk flexes.	• Trunk alignment: increased lumbar extension; flexed thoracic spine; upper trunk rotated back on right; forward on left.
• Front LE—hip muscle force (primarily eccentric) to support body weight moving through large ROM toward box on floor.	• Right scapula elevated and abducted; slight downwardly rotated.
• Back LE—role varies depending on width of stride; shorter stride supports body weight; wider stride used as assist for balance.	
Forward reach while stooping	Forward reach while stooping
• Scapula approximated on thorax; eccentric release into abduction as trunk flexes.	• RUE alignment: GH internal rotation; slight elbow flexion; wrist flexed and ulnarly deviated.
• Initiation of humeral flexion, elbow extension as body moves in direction of reach (weight shift forward onto front LE, flexion of the trunk; abduction of the scapula contribute to forward reach; therefore less active shoulder flexion is necessary to position the hand on the box).	• Fingers flexed; fourth, fifth fingers > second, third; thumb flexed into palm of hand.
• Forearm moves from pronation to midposition.	• Shifts weight further onto LLE; flexes hips and knees L > R; rotating left pelvis and upper trunk forward.
• Wrist and fingers extend to open hand in preparation for placement on the sides of the box.	• As he flexes trunk, hips, knees forward, RUE moves forward and across his body into GH adduction
	• Attempts to position right hand near box by continuing to flex trunk forward, elevating scapula and rotating right upper trunk forward as humerus internally rotates.
	• Unable to move forearm from pronation to midposition, extend wrist, extend fingers or thumb for hand opening.
	• Flexes at trunk, hips, and knees one-third way to floor. Stops attempt to move further toward floor to place right hand on box when unable to open right hand.
	• Since box is large and requires placement between both hands to lift and carry it, patient stops reaching toward box with left hand. Returns to an upright posture. Does not complete task.
Subtask 2: Return to standing holding the box	
Movement analysis	Movement analysis
• Initially generates increased stabilizing isometric muscle force in trunk, UEs in anticipation of lifting a weighted object.	• Unable to perform.
• Next uses concentric trunk extension, LE hip extension, knee extension to move against gravity; hip abduction for stabilization laterally.	• Returns to standing moving right upper trunk from forward rotation and flexion toward trunk extension and rotation back to the right while extending hips and knees (L > R).
• Concentric ankle plantar flexor muscle force to assist in moving out of knee and ankle flexion toward standing.	• End alignment: weight shifted onto LLE > RLE with forward rotation of upper trunk and pelvis on left; LLE hip and knee slightly flexed.
• Scapula approximation, adduction; shoulder extension; elbow flexion to bring box close to body.	
Subtask 3: Walking while carrying the box	
Movement analysis	Movement analysis
• Increase trunk stability; sustained isometric UE muscle activity to hold the box steady close to body.	• Unable to walk and carry any size object between both hands.

(continued)

Standard performance criteria	Mark's performance
• LEs in normal biomechanics of gait (stance and swing).	• Gait mechanics as described previously without object in hands.
Subtask 4: Placing the box on the countertop	
Movement analysis	Movement analysis
• As stepping toward counter; weight shift onto front LE as flex shoulders 0–30° with eccentric release of biceps to lower box to the surface; scapular muscles act primarily as stabilizers (primarily isometric).	• Unable to complete task.
• GH abduction and external rotation, fingers and wrist extend to release hands from box.	
• Shoulder extension; eccentric release of biceps to lower hands to side; wrist and fingers relax.	

Abbreviations: BOS, base of support; GH, glenohumeral; L, left; LE, lower extremity; LLE, left lower extremity; R, right; RLE, right lower extremity; ROM, range of motion; RUE, right upper extremity; UE, upper extremity.

System Impairments

Musculoskeletal

- Decreased passive range of motion (PROM) lumbar flexion.
- Decreased PROM end range thoracic extension.
- Decreased muscle length.
  - Scapula elevators; abductors.
  - Shoulder internal rotators, especially > 90° flexion.
- Decreased PROM into wrist extension (0–30°) secondary to the following:
  - Decreased muscle length wrist, long finger flexors.
  - Decreased mobility proximal carpal arch.
  - Decreased mobility distal radioulnar joint toward pronation.
  - Decreased carpal joint mobility—proximal row radially deviated; distal row ulnarly deviated.

Neuromuscular

It should be noted that muscle weakness is defined as the inability to generate sufficient tension in a muscle for the purposes of posture and movement.[25]

- Decreased right upper trunk strength (all groups); cannot increase/sustain muscle force.
- Decreased initiation muscle force scapula depressors, adductors, stabilizers.
- Decreased initiation muscle force shoulder external rotators.
- Decreased shoulder flexion and abduction strength.
- Decreased selective movement RUE (UE Fugl–Meyer 22/66).
- Increased muscle tone right wrist flexors; third, fourth finger lumbricals; opponens pollicis.
- Decreased hip extension and abduction strength: cannot increase/sustain to support body weight in single-limb support phase of gait.
- Decreased hip flex strength > 10° antigravity for initiation swing.
- Decreased hamstring strength between 30 and 60° antigravity.
- Decreased ankle eversion strength.
- Decreased ankle plantar flexor strength.
- Decreased RLE selective movement (LE Fugl–Meyer 20/34).
- Unable to sustain adequate muscle force simultaneously in RUE, RLE, and trunk to engage RUE in functional activities in standing and gait.

Sensory

- Decreased proprioception RUE and LE.

Cardiovascular

- Compromised cardiovascular endurance to sustain activity.

Prioritizing Impairments

Given the list of specific system impairments, it was important to identify the impairment(s) that most significantly influenced all aspects of Mark's functional activities; that is, the impairment(s) that, if responsive to intervention, would most significantly improve his functional abilities. In Mark's case, the most significant impairment that contributed to his activity limitations was his right hip weakness. Mark's hip weakness limited his ability to transition from sit to stand, increase his gait speed, manage the stairs with a step-over-step pattern, stoop to pick up objects off the floor, generate adequate power for a golf swing, and use his RUE for support, balance, or to perform functional activities in standing.

Mark's ability to generate and sustain muscle force in his right hip as well as his trunk was imperative to achieving and maintaining postural control necessary for RUE function. A prerequisite of UE function is postural control.[26]

In standing, a stable lower extremity (LE), one with adequate strength to support a person's body weight, contributes to postural control, freeing up and allowing the upper extremities to engage in functional activities without displacing the body.

This relationship has important implications for clinicians attempting to promote UE recovery for a client in standing. In Mark's case, before the RUE was successfully engaged in function, the clinician, regardless of the discipline, had to address the right hip weakness. Adequate postural control had to be established before the potential for UE recovery was realized. Although hip strength is a prerequisite for functional use of the UE in standing, it is not addressed in isolation, sequentially, or to the exclusion of other system impairments. This control will be explained in more detail in the section on intervention.

A second impairment that significantly affected Mark's activities was his right scapular weakness, specifically decreased approximation, depression, and adduction strength. Scapular muscle weakness alters muscle length–tension relationships of the shoulder girdle complex, limiting the ability to use the UE for support, balance, or reach.[27] Scapular weakness also influenced Mark's ability to sustain trunk and hip extension in standing because the weight of the unsupported RUE created a forward and right lateral flexion moment of the upper trunk and a forward flexion moment at the hips.

Identifying the most significant impairment(s) did not minimize the effect of Mark's other impairments on his activity limitations. Prioritizing impairments allowed the clinician to establish meaningful functional outcomes with specific performance criteria and to develop intervention strategies that consistently targeted Mark's primary impairments.

Establishing Functional Outcomes

The following is an example of a long-term (LT) and several short-term (ST) functional outcomes established for Mark to measure achievement of the first subtask in the activity previously described. Identifying the performance criteria for these outcomes served as a frame of reference for determining the impairments targeted during the intervention session. Other variables that affected Mark's potential for recovery, such as the site and extent of the lesion, comorbidities, type and degree of system impairments, his motivation, and his ability to learn, were also considered when identifying performance criteria.

Because the objective was to achieve the desired functional outcome(s) and to promote neurorecovery by reducing system impairments, the functional outcomes included both quantitative and qualitative components of task performance. Inclusion of the qualitative performance criteria allowed the distinction of improved functional abilities due to neurorecovery versus compensation.[28] The specific performance criteria reflected the anticipated change in the degree of impairment necessary to achieve the outcome.

The motor learning principle of adaptive training was applied to determine the short-term outcomes.[29] The short-term outcomes were modifications/adaptations of the functional activity. They were structured to require movement strategies similar to those of the long-term outcome, challenge Mark's abilities, and require the remediation of system impairments for successful completion. Each of the three short-term outcomes outlined for physical therapy and occupational therapy progressively challenged Mark's abilities by manipulating variables that made the activity more difficult to perform.

The variables are identified for each discipline-specific outcome in the sequence.

Functional Activity

The functional activity consisted of stooping to pick up a lightweight box off the floor using both UEs, carrying it to a nearby countertop, and placing it on the surface.

Subtask 1

Stoop to the floor while reaching toward the box, placing hands on opposite sides of the box.

Long-Term Outcome

Mark will stand in stride with the right foot ahead of the left, shifting weight from the LLE to the RLE as he reaches down toward the floor with both UEs, placing his hands open and flat on opposite sides of the box.

Key Performance Criteria

- Sustained dorsal and ventral trunk muscle activity; graded eccentric release of trunk extensors.
- Generate RLE hip extension and knee extension muscle force moving eccentrically into gravity; activate hip abduction muscles force for lateral stability; generate hip external rotation muscle force to align LE.
- Approximate scapula on thorax; initiate shoulder flexion 0 to 45° in neutral scapular rotation as elbow extends; forearm moves from pronation to midposition; wrist extends past neutral; fingers and thumb extend.

First Short-Term Outcome

Physical therapy: Mark will squat to a low surface (50% of distance to the floor), narrow stride position (in the frontal plane), right foot ahead of left, assistance for sustaining right hip extension and abduction muscle force as he weight shifts forward onto the RLE and eccentrically moves into gravity using both UEs for support on a surface, with assistance to maintain the right hand on the surface.

Occupational therapy: Mark will use the RUE for support on a flat surface, tabletop height, in squat position with assistance for scapula approximation; isometric glenohumeral external rotation, shoulder flexion, elbow extension; right hip stability while stepping forward and back with LLE and minimal LUE support for balance.

Second Short-Term Outcome

Physical therapy: Mark will squat to the floor with his feet in the wider stride position in the sagittal plane (5–6 in apart), the right ahead of the left, with assistance sustaining right hip extension and abduction muscle force as he weight shifts forward onto his RLE while he eccentrically moves into gravity, sliding the LUE toward the floor in contact with a surface for balance with assistance maintaining the RUE for support on a surface.

The variables manipulated were an increased width in stride; increased ROM for LE weight shift; increased demand of RLE strength; decreased BOS by moving the LUE on a surface.

Occupational therapy: Mark will use the RUE for support on a flat surface, tabletop height, with assistance for scapular approximation; isometric glenohumeral external rotation and eccentric release of shoulder flexors, elbow extensors; right hip stability while stooping (50% distance to the floor), sliding the LUE toward the floor in contact with a surface for balance; with assistance to initiate right concentric shoulder and elbow extension to move against gravity.

The variables manipulated were to alter the type of RUE muscle contraction from isometric to eccentric; initiate concentric activity; increase the ROM the entire body is moving through; increase the demand for RUE postural adjustments.

Third Short-Term Outcome

Physical therapy: Mark will squat to the floor with his feet in a wider stride position in the sagittal plane (8–10 in apart), right ahead of left, independently sustaining the right hip extension and abduction muscle force as he weight shifts forward onto his RLE while eccentrically moving into gravity, reaching to the floor to pick up a golf ball with his left hand with assistance, maintaining the RUE for support on a surface (Fig. A1.1).

The variables manipulated were to increase the width in stride; increase the ROM required for LE weight shift; increase the demand for RLE strength; decrease the BOS by taking the left hand off the support surface.

Occupational therapy: Mark will independently use his RUE for support on a flat surface, tabletop height, eccentrically releasing shoulder flexors and elbow extensors as he reaches toward the floor to pick up a golf ball with his left hand, returning to a squat position with concentric shoulder and elbow extension, and assistance to achieve balanced muscle activity between wrist flexors and extensors for initiation of finger extension with his hand on a surface with assistance for hip stability.

The variables manipulated were to decrease the amount of manual feedback, increase the number of degrees of freedom to control, and increase neuromotor demands of the right wrist and hand segments.

The performance criteria in these functional outcomes addressed Mark's most significant impairment—right hip weakness. Additional impairments that limited Mark's ability to perform this activity, such as decreased ability to sustain trunk stability; weak scapula depressors, adductors, and serratus anterior; weak shoulder external rotators, flexors, and abductors, were also addressed.

Fig. A1.1 Preparation for stooping to pick up a golf ball.

The short-term functional outcomes were developed to address several impairments in multiple body segments, emphasizing the interrelationship and coordination of multiple body segments organized around the requirements of a functional activity. Although the physical therapist (PT) and occupational therapist (OT) were working with Mark in the same functional activity, the goals for each were discipline-specific. In the activity of stooping and reaching as already described, the OT established the RLE as an active part of Mark's BOS but more specifically addressed the demands placed on the trunk and the RUE. In this same activity, the PT emphasized the task requirements of the trunk and RLE but had to address the RUE as part of the BOS. UE alignment and strength affected the alignment and the ability of the trunk and RLE to generate force.

A1.2.6 Intervention

The primary objectives are to achieve functional outcomes that are meaningful to the client and to promote neural recovery by reducing system impairments.[28,30] The objectives are consistent with the evidence for neuroplasticity and the clinician's role to positively affect the client's quality of life.[31,32,33] Therapists can manipulate intervention variables to enhance the client's ability to learn a motor skill and to drive neuroplastic changes.[34,35]

The clinical application of evidence-based practice and the use of outcome measures to determine the effectiveness of intervention is imperative. Within our profession, however, evidence may be contradictory and consensus sometimes elusive. Just as in other areas of medicine, available clinical evidence guides but does not necessarily dictate clinical decision making. Evidence-based practice is the integration of the best available clinical evidence with the experience, education, and skills of the clinician and the client's unique expectations and values.[36] Ultimately, it is the clinician's responsibility to assimilate information from multiple sources to develop and implement an intervention plan based on the evaluation of each individual client.

The intervention plan developed for Mark, like the evaluation, illustrates the integration of information from the neuro- and movement sciences and the application of motor learning principles within the NDT problem-solving framework. As previously illustrated, in evaluating Mark and establishing functional outcomes, posture and movement analysis continued to play a critical role in developing and implementing effective intervention strategies.

The NDT Practice Model advocates teaching clients more normal movement strategies to complete functional activities. The objective is to promote motor recovery and reacquisition of movement components present prior to CNS injury.[28] At the same time, motor compensation, the use of alternative degrees of freedom and/or muscles to complete a task, is inhibited or discouraged because compensation can limit recovery.[37,38,39]

Initially, when Mark attempted to reach forward with his RUE, he used additional degrees of freedom in the trunk and scapula to compensate for weakness and limited selective UE movement.[23,39] He initiated overhead reach with lateral upper trunk flexion away from his affected UE, scapula elevation and abduction, and glenohumeral internal rotation and abduction. He lacked adequate muscle strength to stabilize the scapula on the thorax and to balance the force couples for scapula upward rotation and humeral head depression to lift his arm. The intervention plan therefore addressed strengthening the weak muscles that were identified, reducing the degree of impairment so that Mark could achieve his functional goal of overhead reach without incurring secondary impairments.

Prior to strengthening the scapula depressors and adductors, the shortened antagonists, muscles that elevate and abduct the scapula, had to be lengthened. Additionally, the shoulder internal rotators were lengthened to maintain the humeral head in the glenoid fossa as the scapula adducted on the thorax. If the humeral head was not maintained in the glenoid fossa while the scapula was adducted, the anterior joint capsule would be overstretched, contributing to the shoulder subluxation and stretch weakness of the external rotators.

To limit the degrees of freedom in the RUE as shortened muscles were stretched, Mark's hand was positioned open and flat on a firm surface in a closed chain position. With the RUE stable on the surface, the therapist provided manual feedback to assist with scapula adduction and depression and shoulder external rotation as Mark rotated his trunk away from his RUE, stretching the shortened muscles (see **Fig. A1.1**).

As ROM was achieved into scapular depression, adduction, and shoulder external rotation, the muscles needed to maintain this alignment were strengthened to oppose the muscle force generated by the shortened antagonists. Strengthening began with an isometric muscle contraction once the weak shoulder girdle muscles were in an optimal length–tension relationship.

In the intervention scenario described, while the therapist provided manual feedback to strengthen the weak shoulder girdle muscles, manual feedback was also provided to prevent Mark from accessing compensatory movement strategies. The therapist used manual feedback to both facilitate strengthening weak muscles and inhibit compensatory movement strategies. Limiting or restraining compensatory movement strategies used for forward reach has been demonstrated effective in enhancing otherwise untapped potential for selective UE movement.[37,38]

The NDT Practice Model focuses on the contribution of multiple body segments necessary to complete functional tasks. The interrelationship of body segments is not only apparent from an anatomical perspective but is well documented in describing mechanisms of postural control, UE reach, and gait.[22,23,40] During intervention, therefore, individual body segments or impairments were not targeted in isolation. Intervention activities were structured to strengthen muscles over multiple body segments in functional synergies.

For example, to achieve the subtask of stooping to the floor to pick up a box or golf ball, Mark had to generate muscle force in his right hip, knee, and ankle to use the RLE for support as he lowered his center of mass (COM) toward the floor. Additionally, he had to sustain trunk extension, stabilize the scapula on the thorax, and initiate shoulder flexion and elbow extension for forward reach. The activities in the progression were structured to activate functional muscle synergies in all body segments within a functional context to meet the postural requirements of the task.

A more advanced intervention activity structured to achieve the same objectives required Mark to recruit and sustain graded muscle force in the RLE while sustaining muscle force in shoulder flexion and elbow extension with the scapula stabilized on an extended thorax. Generating and sustaining muscle activity in multiple body segments in a coordinated, functional synergy was achieved by instructing Mark about the intended outcome—moving the couch several feet. Rather than providing explicit instructions about the specific movement components of the task, Mark was learning implicitly how to grade muscle force in multiple body segments to accomplish the goal[41] (**Fig. A1.2**).

The intervention activities selected for Mark by either the PT or the OT were structured to address his primary impairment(s). In Mark's case, this was generating and sustaining muscle force in key muscle groups of the right hip. The OT addressed RUE strengthening in a standing activity so that Mark's most significant impairment, right hip weakness, could be targeted simultaneously. Establishing adequate right hip strength in standing with sustained trunk extension contributed to scapula

Fig. A1.2 Recruiting and sustaining muscle force in multiple body segments.

stabilization on the thorax, a prerequisite for UE reach. Although the most significant impairment is the primary consideration, activities are structured to target remediation of additional musculoskeletal, neuromuscular, and sensory impairments of other muscle groups and/or body segments.

Movement strategies are organized around the requirements of the task; therefore, tasks were identified and structured based on Mark's interests and degree of impairment. Mark's personal goal was to return to golf. This goal was the anticipated outcome and guided the selection of activities included in the intervention progression. Because engaging in golf and golf-related activities was motivating to Mark, those functional tasks that had similar movement substrates were selected. The initial intervention activities were directed toward acquiring the substrates of movement strategies necessary for various related activities rather than those specific to one particular task.

For example, the movement strategy used to pick up a golf ball on the green is similar to the strategy Mark used to pick up keys if he dropped them. The invariant components of movement are the BOS with feet in stride; a weight shift forward onto the RLE; eccentric release of the trunk, hip, and knee extensors as the body moves into gravity in the direction of reach; and shoulder flexion and elbow extension to position the hand near the object.

Examples of the components of movement that may vary depending on the environment and context in which the task is performed are the width of the feet in stride, the amount of weight supported on the front LE, the role and position of the back LE for either balance or support, the degree of flexion at each segment—trunk, hips, and knees, and the degree of hand dexterity needed to manipulate the object on the floor. Mark was able to transfer what he learned practicing picking up the golf ball to tasks with similar requirements.

At a certain point during intervention, the unique movement components, such as ROM requirements, force demands, as well as timing and sequencing of muscle activation had to be practiced in the particular activity being learned. Each movement strategy was specific to the task and environmental context in which it was performed. This type of practice is consistent with the motor learning principle of task specificity.[24] For example, in Mark's case, the UE movement strategy for the golf backswing, downswing, and follow-through are unique to golfing. The movement strategies for reaching into a cupboard, washing his hair, or putting his hat on and taking it off also needed to be practiced because the details of the movement strategies are different from those associated with golfing (Fig. A1.3).

To address multiple body segments in function, by necessity, requires the inclusion of the affected upper and lower extremity and trunk in the intervention activities. Integration and task-specific use of the affected UE in functional activities is supported by constraint-induced movement therapy (CIMT), modified CIMT, and kinematic studies demonstrating the relationship of the UE to other body segments in functional activities.[21,22,23,42,43,44,45,46]

In Mark's case, his more affected, dominant right UE was integrated in all functional activities during intervention to promote motor recovery but not to the exclusion of the left, less affected UE.

Fig. A1.3 Facilitation of grasp specific to putting on a hat.

Early in Mark's intervention progression, his right UE was consistently placed on various surfaces and positioned in specific alignments to optimize muscle length–tension relationships, creating a demand for muscle activity, either automatic or volitional. Where Mark's UE was placed and how it was aligned affected other body segments in the kinematic chain. For example, Mark's resting scapula was elevated, abducted, and downwardly rotated on a flexed thorax. Positioning Mark's right UE in slight abduction and external rotation biomechanically biased the thorax toward extension and the scapula toward depression and adduction. Additionally, shortening the overstretched thoracic extensors, scapula adductors, and depressors increased the potential for these muscles to fire by placing them in an optimal length–tension relationship.

The UE was positioned in a closed chain, weight-bearing position with the hand in contact with a surface. Having the hand rather than the forearm in contact with the surface with the elbow slightly flexed allowed adjustments in muscle activity at the elbow as Mark moved his body in relationship to the more stable UE. The closed chain position limited the degrees of freedom Mark had to control and promoted a balance between isometric, eccentric, and concentric muscle contractions while increasing proprioceptive feedback. The therapist structured intervention activities to facilitate muscle recruitment as prime movers, synergists, and stabilizers, or as antagonistic muscles in functional synergy patterns.

Strengthening and coordinating the glenohumeral joint with associated movements of the trunk and scapula were initiated in closed-chain positions as Mark moved his body on a relatively stable UE. The therapist structured an activity, determining the direction and degree of movement of the body in relationship to the UE, to target specific muscle groups, elicit the desired muscle contraction (isometric, eccentric, concentric), and activate muscles working in functional synergies.

In the activity described previously, the strength and coordination of the distal components—elbow, forearm, wrist, and fingers—are being addressed, as well as the proximal components. Change in muscle activity and type of muscle contraction varies in each of these UE segments, depending on the amount of support the UE is providing, where the movement is initiated, and the direction the body moves in relationship to the arm.

Postural control and proximal UE strength and coordination are necessary for the transport stage of reach, moving the hand toward an object.[47] Transitioning the hand from a closed- to open-chain position for placement on or manipulation of an object significantly changed the demands on both the proximal and the distal UE segments. To progressively grade the requirements for additional muscle force, coordination, and selective movement at multiple joints, several intervention variables were modified to continually challenge Mark's abilities. Based on his motor recovery and ability to control an increasing number of degrees of freedom, the amount of contact the hand has on a surface, the type of surface (stable or mobile), and the degree of UE support required in the activity were graded.

Initially, Mark's hand was positioned open on a firm, flat surface with the heel of his hand, first and fifth metacarpals, lateral surface of his thumb, and the finger tips contacting the surface. As Mark made the necessary UE postural adjustments and developed the ability to control increasing degrees of freedom with progressively less feedback from the therapist, activities were modified so that his UE supported less of his body weight.

The hand remained in contact with a firm, flat surface, but as the position of the forearm changed from pronation toward supination, the ulnar border of the hand rather than the palmar surface was in a weight-bearing position. Maintaining the ulnar border of his hand in contact with the surface to stabilize the lateral column was important since Mark did not have adequate strength of the fourth and fifth metacarpal extensors to overcome the resistance of the flexors. Transitioning the hand to less contact on a surface while maintaining ulnar stability allowed the initiation of active finger extension for hand opening in preparation for a functional grasp and release.

Proximally, movement strategies that strengthened the scapula depressors, adductors, shoulder external rotators, humeral head depressors, and elbow extensors were emphasized to oppose the stronger involuntary muscle force in the antagonists. Creating a balance in muscle activity around the shoulder girdle complex was necessary for Mark to initiate shoulder flexion for functional reach with the hand in open chain. Rather than initiating shoulder flexion concentrically, Mark's UE was assisted overhead into a closed chain position. The demand was then for an isometric muscle contraction to maintain the UE overhead before grading muscle force to eccentrically lower the arm through small ranges of motion, still in contact with a surface.

Mark developed adequate strength for forward reach with the hand in open chain between 0 and 60° of shoulder flexion. Although Mark developed adequate strength to move the UE above 60° with the hand in contact with a surface, he was unable to develop adequate strength in the serratus anterior, middle, and inferior trapezius to balance the forces necessary for upward rotation of the scapula and humeral head depression with the hand in open chain.

There was overlap in developing strength and selective movement of the proximal and distal UE segments. While working on developing proximal UE strength and coordination, the demand for strength and selective movement of the hand was intentionally decreased. Likewise, as distal hand function was being focused on in intervention, there were fewer demands placed on the proximal UE segment.

For example, when developing distal selective movement, Mark was sitting on a tall stool, decreasing the amount of force he needed to generate at the right hip compared with the muscle force necessary for stability in standing. Mark's forearm was also supporting lightly on a surface to provide stability, since, initially, he could not simultaneously manage the degrees of freedom of both proximal and distal segments.

This overlap continued with functional activities Mark performed independently at home. For example, while sitting, Mark was tearing out pages from financial records and scanning them into the computer. He was able to stabilize the magazine with his right hand as he tore out the page with his left hand. To position his right hand on the page required forearm pronation and supination with wrist and finger extension and elbow extension to hold the page in place. The demands of the proximal UE were not as significant in this activity.

Developing the ability to open his hand and extend his thumb was integral to developing a functional grasp. Grading flexion to grasp an object was difficult for Mark, and if too much strength was generated in the finger flexors, he could not oppose the flexors with the weaker wrist extensors to stabilize the wrist. Without stabilization of the wrist, the finger extensors were at a mechanical disadvantage to extend the fingers and open his hand.

Developing graded finger flexion balanced with eccentric finger extension to grasp an object was initiated on larger cylindrical objects that required Mark's hand to shape along the oblique arch. This was the type of grip required, although on a larger object during the beginning of intervention, that Mark would need to hold a golf club in both hands. Starting from a position with the fingers more extended, graded flexion was facilitated through a limited range followed by reciprocal finger extension. The ability to initiate right hand grasp and release was incorporated in functional activities with modification of the surface size as Mark's abilities improved.

As demonstrated in this intervention sequence for Mark, there is significant overlap in developing strength and selective movement *within* the affected body segment, such as in the trunk and the right lower and right upper extremities, *between* the affected right upper and right lower extremities, and *between* both the left and right lower extremities and the left and right upper extremities. The type of activity chosen, how it is structured, and when it is modified to challenge Mark's abilities are decisions the clinician makes based on the client's goals, activity limitations, type and degree of impairment, and his response to intervention. There was an intervention plan in place, but how Mark responded to the intervention ultimately determined the next step in its sequence.

A1.2.7 Outcomes

Objective measures and standardized testing were performed periodically during the course of intervention to document a reduction in impairments and an improvement in activities. The initial and discharge measures are recorded in Table A1.2, Table A1.3.

Table A1.2 Outcome measures

Initial	Postintervention
Orpington = 2.4 mild stroke	
Fugl–Meyer LE = 20/34	Fugl–Meyer LE = 26/34
Fugl–Meyer UE = 22/66	Fugl–Meyer UE = 39/66
Berg Balance = 40/56	Berg Balance = 49/56
10 m walk test = 0.26 m/s Household ambulation	10 m walk test = 0.60 m/s Limited community ambulation

Abbreviations: LE, lower extremity; m, meter; s, second; UE, upper extremity

A1.3 Discussion

The NDT Practice Model does not exclude intervention strategies, such as electrical stimulation, resisted weight training, splints, or lower-extremity orthotics because strategies are the tools chosen as part of an entire client management process. In Mark's case, electrical stimulation was used early in his course of OP therapy to assist in developing strength in the wrist extensors to overcome the significant resistance of the wrist and finger flexors. Electrical stimulation was also used later in the intervention progression to assist with initiating thumb extension for hand opening. Electrical stimulation was used as an adjunct to direct intervention and was therefore provided before or after Mark's scheduled physical therapy or occupational therapy sessions.

Early in the intervention process, Mark wore a hand splint during the day to assist in maintaining the PROM achieved in wrist extension and radial deviation. The splint was designed to increase the distance between the first and fifth metacarpals, to limit flexion, to maintain the position of the wrist in slight extension following mobilization of the wrist and forearm, and to achieve adequate ROM in these directions. When Mark developed adequate wrist extensor strength to balance the wrist and finger flexors, use of the splint was discontinued.

Resisted weight training played a role in Mark's recovery. However, since Mark did not have access to strengthening equipment outside of intervention sessions, his home program was established to increase strength in key muscle groups within a functional context. During intervention sessions, Mark used the elliptical trainer with assistance for balance, to increase his RLE strength, specifically hip and knee extension and ankle plantar flexion. Having the right foot in a modified chain position allowed Mark to increase the speed of reciprocal LE movement patterns without jeopardizing potential instability at the ankle while moving quickly as is needed from terminal swing to initial contact in gait. If Mark had had access to this equipment outside of therapy, it is possible that resisted weight training could have played a more significant role in his recovery.

The clinical skill of therapeutic handling was not emphasized in the description of Mark's intervention progression. However, its importance in enhancing motor recovery, decreasing compensatory movement strategies, and assisting him to coordinate more effective strategies within a functional context cannot

Table A1.3 Stroke Impact Scale physical domains

Difference between initial and discharge stroke impact score (SIS)[48]
Strength 37.5[a]
Hand 30.0[a]
Mobility 11.1[a]
ADL 10.0[a]

Abbreviation: ADL, activity of daily living.

[a]Indicates clinically important difference (CID).

be underestimated. Just as the manual skills of an orthopedic therapist are critical to assessing and treating specific orthopedic conditions, the manual skills of therapists treating clients with neurological deficits are equally critical. A clinician's skill in applying manual feedback to elicit a desired response and to monitor changes in muscle activity as a client moves is a variable affecting a client's functional outcome.

In summary, the intervention plan developed for Mark, like the evaluation, illustrates the integration of information from the neuro- and movement sciences and the application of motor learning principles within the NDT Practice Model. NDT is not a series of techniques or procedures; rather it is an analytical thought process using the clinical skill of posture and movement analysis as a basis for promoting neuro-recovery through the reduction of system impairments to achieve functional outcomes.

See Thieme MediaCenter for an extensive photo gallery of Mark's intervention.

A1.4 Alternate Reflection

Kris Gellert

In this case report, Mark had not identified cognitive impairments that may impede his performance of the various tasks he was asked to do, for example, when lifting a box or swinging a golf club. Imagine how his examination and intervention program may have looked if cognition had been a significant area of impairment for Mark.

Cognition plays an important role in a person's ability to pay attention to detail, to follow commands, to show awareness and insight into impairments, and to formulate and execute a given plan of action. Cognition can also play a role in an individual's ability to regain and relearn motor skills, specifically in how declarative information can be used by the individual and in how the scheduling of and structure of the practice environment are established.

For the individual with cognitive deficits following a neurological insult, the clinician needs to consider several factors, such as safety or the need for supervision and/or verbal or environmental cueing, for the best performance. Cognitive impairments often lead the clinician to create an intervention plan that may be longer and may require the active role of a care partner compared with that of an individual with purely motor impairments.

Mark was able to establish a goal for his rehabilitation—he wanted to return to golfing. He could also reason that the skills needed for golfing would help him with several other functional activities as he prepared to pack and move to Texas. Mark was able to problem-solve through fairly complex information. It would likely be challenging for this level of processing to occur in an individual with significant cognitive impairment.

Mark was also able to use abstract information to help him work toward his stated objectives. He was able to work with his rehabilitation team on the requisite physical skills that would help him to obtain his overall goal of returning to golf and coordinating a move to Texas. These activities involved the tasks of safely lifting a box, packing items from cupboards and closets, or swinging his golf clubs. He could generalize skills and activities used in a clinical setting and apply such skills within the context of a functional task. Therefore, his therapy program allowed for exercise-like activity as well as intervention within the functional tasks.

In the case of the individual with significant cognitive impairment, the ability to generalize can be diminished. For this individual, practice within familiar functional tasks, environments, and contexts would be critical. If Mark had suffered significant cognitive impairments, he likely would not have been able to generalize from exercise-like activities into real-world performance or process an abundance of verbal information about his performance. For example, in Mark's identified goal of golfing, the clinician would be challenged to incorporate both the tools of the activity (golf glove, club, ball, etc.) as well as practice of the movement substrates required for the subtasks of golfing into a variety of movements and tasks within each session. Mark's focus would remain on the activities, such as the golf swing, bending to pick up his golf tee, walking and carrying his golf club, and so on, rather than on the stabilization required at the hip or the timing of the distal aspect of the UE in conjunction with the proximal shoulder and core. The movement substrates required for each of these tasks/subtasks will help Mark in several functional situations, whereas repeated practice of swing influences only the swing. Time spent on isolated practice of movement substrates in contexts not related to a meaningful task for Mark would not be as effective for generalization as practice within familiar and motivating activities.

The clinician, when working with an individual post-stroke, needs to complete a comprehensive examination and evaluation to ascertain the presence of even minor cognitive impairment. The knowledge of the level and specificity of cognitive impairment helps to personalize the plan of care for each individual.

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Case Report A2 Intervention to Promote the Functional Recovery of the More Involved Side with the Goal of Return to Work

Karen Guha and Sherry Rock

A2.1 Introduction

Stroke is a leading cause of disability in adults. Recent evidence with neural plasticity leads us to understand that, despite a neurological injury, there is plenty of potential for recovery following a stroke. The existing data of the last several decades provide significant evidence to support that the brain continuously changes its neural circuitry to encode new experiences and promote changes in behaviors.[1,2] This research has been demonstrated in the healthy brain[3,4,5] and has been expanded to demonstrate neuroplasticity in the injured brain.[6,7] In both the healthy and the injured brain, research has demonstrated functional reorganization of the brain when an optimal environment is created for learning to occur. There is evidence indicating differences in how learning occurs in a healthy versus an injured brain.[8] To promote rehabilitation, one must understand the principles required to promote learning in an injured brain.

Understanding the principles supporting optimal experience-dependent plasticity guides clinicians in the rehabilitation of an individual with an injured brain. Some of these factors include concepts around promoting use of the affected limbs. Studies have demonstrated improvements in the functional use of the involved limb and activation of the motor cortex in the damaged brain when rehabilitative training was combined with constraint of the ipsilesional arm in humans.[9,10,11,12,13] There is some suggestion that negative plastic changes occur if the individual continues to compensate and use only the less involved limbs.[14] Over an extended period of time the neural circuits are not engaged in tasks the circuits begin to degrade.[8] Rehabilitation strategies that promote the use of the involved limbs enhance neuroplasticity.

Substantial evidence suggests that focusing on meaningful, functional tasks enhances neuroplasticity and thus recovery because the individual is more engaged.[15,16] Richards et al[17] noted "many clinical reports and motor learning–related findings indicate the best way to learn an activity is to practice that activity, which means task-specific training." The constraint-induced movement therapy (CIMT) research suggests that upper extremity (UE) function in individuals after a stroke can improve when therapy involves intensive, task-specific training using activities that are challenging to the individual and relate to real-life scenarios.[18]

In Lennon and Ashburn's study,[19] therapists recognized that it was important to focus on movement components, such as alignment, transfer of weight, and pelvic tilt, within a functional task. These components of movement are required within many functional tasks. To work within a functional task with our clients who suffer from neurological injury, we need to understand the components of movements for a given functional task. We need to determine what prevents efficient task performance.

Dean and Shepherd[20] demonstrated that individuals poststroke who practiced seated reaching had improvements in their ability to reach, as well as increased loading through the involved foot and increased activation of leg muscles. Dean et al[21] also found these improvements carried over to standing up. They concluded this was likely because there are similar biomechanical demands between reaching forward beyond arm's length and standing up.

Wu et al[22] indicated that, when patients participated in reaching activities that were goal directed, there were improvements in the quality, accuracy, and efficiency of the reaching movement in the involved UE. Working within the functional task in all of the foregoing studies thus demonstrated improvements in the performance of the specific task, as well as increased activation in the involved UE and lower extremity (LE).

In Ling and Fisher's[23] case report, the subject's goal was to do his laundry at the community laundromat. To reach this goal, he needed to walk carrying the laundry basket and ascend and descend a curb. Based on this goal, they analyzed his movements and determined the specific system impairments that prevented him from achieving this goal. The intervention involved working within the task by breaking the larger task down into smaller subtask components. The specific subtasks practiced were chosen to address the specific impairments limiting him from obtaining his goal. Knowledge and skill in movement analysis allowed clinicians in the study to understand the sensory and movement demands of tasks. With this task-specific training, the therapists were able to assist this individual to make functional gains and achieve his goal. Although it is not always possible to practice within the exact task or within the exact environment the task is typically performed in, or to use the limb in the way it is typically used for the task with an individual who has minimal to no functional use of the involved UE, there are strategies to assist with task-specific training.

As demonstrated in both Ling and Fisher[23] and Davis,[16] real-life tasks can be broken down into mini- or subtasks. Simulating the task as closely as possible by choosing intervention strategies that incorporate practice of the same or similar movement substrates/components, as well as setting the task and environment up in a certain way and choosing the most appropriate functional subtasks to be practiced, can address specific impairments and promote desired UE and LE movements and trunk control.[16,23] Thus it is also critical to evaluate individuals poststroke within functional tasks to determine the specific single-system impairments that are contributing to the individual's activity limitations and participation restrictions.

Tasks that involve excessive effort can frequently cause overrecruitment of muscles and inefficient altered movement patterns.[16] Ensuring an individual has an appropriate and stable base of support and an efficient alignment is essential to promoting UE and LE recovery.[16,20] In addition, proximal stability can influence functional UE and LE outcomes.[20,23]

Based on these findings, using tasks, subtasks, and the appropriate environments that both match the ability of the body and limb movement and appropriately challenge within a functional context can help to promote improved UE movement patterns.[16] Using either closed or modified chain tasks (see Chapter 9 on session intervention for further discussion of closed, modified, and open chain practice) can moderate the effects of gravity and the recruitment demands necessary for the limb movement. For example, stabilizing on a counter with the more involved hand while the other one reaches into the cupboard for a glass is an example of a closed chain use, and holding a cloth in the more involved hand and wiping a counter or holding a cup in the involved hand and sliding it up an inclined surface toward a higher cupboard are examples of modified chain movements for the UE.

These concepts were also clinically applied by Ling and Fisher[23] where closed and modified chain tasks were used to train proximal control. The subject in this study demonstrated improvement in both proximal and distal control. This work supports the idea of obtaining proximal control to promote more distal function of the UE.

Research supports that individuals who suffer from stroke need practice and repetition to learn or relearn functional activities. The exact amount of repetition each individual requires to make functional improvements is unknown. In Wolf et al[18] patients in the CIMT group received 6 hours of therapy per day over a 14-day period and demonstrated functional changes in motor recovery in the affected UE. Taub et al[24] suggested that, when conventional physiotherapy is administered 6 hours a day for 10 consecutive days, there is an increase in arm use similar to that seen in CIMT therapy. The conclusion was that some individuals with subacute and chronic stroke changes/deficits could benefit from physiotherapy if they received multiple hours of motor skill practice per day.

Our health care systems are not set up to provide 6 hours of therapy a day to each individual who suffers a stroke. Practicing skills outside of or beyond the therapy session is critical to help with skill acquisition.[19] Therapists need to consider how clients will practice skills outside of the therapy session to achieve long-term and functional changes.

There are many strategies to consider when working with individuals who suffer from stroke, including the volume of practice, incorporating the more involved limbs into the function, the neuroplasticity potential, and task/subtask practice that is meaningful and targets specific impairments. All these strategies can be applied toward the functional goals the individual has identified and the tasks chosen within these goals.

Often in research and in clinical practice, the tendency is to use standardized measures to measure change. Examples of these include the Functional Independence Measure (FIM), Barthel Index, Chedoke McMaster Stroke Assessment (CMSA), Fugl–Meyer, Berg Balance Scale, grip strength, and passive and active range of motion. Using standardized measures is important in research and therapy practice, but using only standardized measures does not necessarily allow clinicians and researchers to capture change in tasks that are functional and meaningful to each individual. As evidenced in Ling and Fisher,[23] standardized measures do not always detect functional changes nor do many of them consider the quality and efficiency of movement of individuals after a stroke.

The importance of quality of movement when performing functional tasks, its contribution to efficient biomechanical function, and the magnitude of its contribution to functional recovery of the involved UE and LE are often overlooked.[23] In the study by Ling and Fisher,[23] no changes were noted in the Fugl–Meyer UE motor assessment or grip strength, yet the individual demonstrated changes in the use of his limbs, including his hand function, and he achieved his functional goal. These changes were demonstrated through the use of observational movement analysis as part of the pre- and posttesting assessments and as measurements to detect changes in function over time.

This case report describes how the Neuro-Developmental Treatment (NDT) Practice Model can be used with a patient poststroke to guide clinical decisions about implementing physiotherapy and occupational therapy interventions that promote functional use of and recovery of the more involved side by incorporating the more involved limbs into the performance of functional tasks and assisting this individual to return to her participation roles.

A2.2 Case Description

JW is a 51-year-old woman who sustained a large right parietal intraparenchymal hemorrhage with associated mass effect on September 21, 2009, resulting in left-sided hemiparesis. JW had a significant cardiac history, including mitral valve replacement in 2004, atrial fibrillation since she was 23 years old, aortic valve endocarditis, and a bicuspid aortic valve. She had no other known risk factors and was previously active.

JW's acute inpatient stay was complicated by treatment for the endocarditis, and as a result, she spent 6 weeks on an acute unit. JW was transferred to inpatient rehabilitation on November 2 and was discharged home on

December 10, 2009. Prior to her stroke, JW had worked full time at a Canadian university as an information technology (IT) training and support coordinator. She engaged in activities of moderate intensity for at least 30 minutes on 5 or more days a week. Her interests included gardening and yard work, participating in Pilates classes, aerobics, canoeing, dragon boat racing, running, and regularly walking her dog. JW described a history of scoliosis but reported no physical symptoms associated with the condition.

JW is married and lives in a multilevel home with her husband and their dog. At the time of her admission to this outpatient program, she was walking independently in her home using a rollator walker and relying on a wheelchair for outdoor mobility. She was ascending the stairs using a hand rail on the right and a step-to pattern, and she descended the stairs backward. JW was independent with all self-care activities but without using her left UE. JW initially used a handheld shower and sat on a shower chair in their walk-in shower. Prior to her stroke, she showered in a tub but was not able to negotiate the step into the tub safely after her stroke. JW dressed herself independently from a seated position and needed assistance to tie shoes and to manage buttons. She therefore avoided wearing pants and shirts with button enclosures. Tasks that required bilateral UE function, such as cooking, laundry, and housekeeping, were deferred to her husband and a hired housekeeper. JW was not able to work or drive and required transportation for outside appointments, grocery shopping, and entertainment purposes.

JW's expressed goals were to improve the use of her left upper extremity (LUE) for functional activities, such as stabilizing food objects so she could chop food for cooking, using her left hand to assist with folding laundry and dressing, and walking indoors and outdoors without relying on a walker or wheelchair. She wanted to return to work at the university and perform her specific job as soon as possible. To achieve this last goal, JW needed to be able to walk indoors and outdoors across campus in a timely manner to get to meetings at various locations. She also needed to ascend and descend stairs multiple times throughout her work day to get to her office and other campus buildings. JW would have frequent meetings during the day requiring her to don/doff a jacket multiple times, especially in the fall and winter months. Her job required her to multitask using the computer and phone simultaneously to support staff/students with IT issues.

Because JW's nondominant LUE was the more affected from her stroke, she needed her LUE to, at minimum, act as an active support to perform her responsibilities, but she was interested in eventually using her left hand to type as well. JW attended physical therapy and occupational therapy at our outpatient program (OP) two to three times a week beginning in December 2009. This case describes her intervention from December 2009 until September 2010.

A2.2.1 Examination and Evaluation

A significant life role for JW involved her career. She had worked at the university for more than 20 years and held a senior position in the IT department where she supervised several staff members. Her job required her to walk, travel across campus to other buildings for teaching purposes, ascend and descend stairs, type, carry teaching equipment during lectures, develop and give lectures and presentations, and support staff/students in various functions, including answering e-mails and phone calls, problem-solving computer issues, and instructing staff/students in using computer software. Prior to her injury, she had worked more than 60 hours a week. JW indicated she was passionate about her career and loved the challenge, responsibility, and high-paced environment of her position. Returning to her position at the university was her greatest goal. As such, the focus of this intervention was to help JW return to her position as soon as possible but with minimal accommodations. She was insistent that she would only return to work if it meant not compromising the gains she had already made and would potentially facilitate further gains in her function.

Facilitators—the Positives

There were many positive factors that would facilitate a successful transition back to her place of employment. JW was highly motivated and an active participant throughout her rehabilitation. She consistently transferred suggestions/recommendations from therapy into her home and community environments. Despite significant light touch and proprioception impairments in her left limbs, she readily incorporated her more involved extremities in all functional tasks. JW had an extensive support network, including her husband, family, friends, and colleagues, and her employer. She had no cognitive or visual perceptual system impairments. Her heart condition and scoliosis placed minimal restrictions on our interventions.

In regard to her environment, JW was able to access therapy and the community using accessible transportation and family/friends. She was able to independently access her home environment with assistive devices. JW had the flexibility in her work environment to set up her space to ensure involvement of her more involved limbs. Her employer was accommodating in helping her return to work.

Barriers

The predominant environmental barriers were within her community. She required a hand rail on the right side to ascend and descend stairs. JW required physical assistance to access various places within her community secondary to curbs and doors. She walked slowly

Table A2.1 JW's most significant system impairments and activity limitations

System impairments	Activity limitations
• Inability to sustain activity in upper abdominals • Weakness of left hip extensors (primarily gluteus maximus) • Weakness of left knee extensors (primarily quadriceps) • Weakness of left knee flexors (hamstrings) • Weakness of left ankle dorsiflexors (tibialis anterior) • Tightness of shoulder internal rotators (primarily pectorals) • Inability to sustain activity in left scapular approximators (serratus anterior) • Inability to sustain activity in left scapular adductors (rhomboids) • Weakness of left scapular upward rotators (upper/lower trapezius, and serratus anterior) • Weakness of left shoulder external rotators • Inability to sustain activity in left elbow extensors (triceps) • Tightness of wrist flexors and long finger flexors • Weakness of left wrist extensors • Weakness of left finger extensors • Inability to initiate activity in left ankle evertors • Absent light touch and proprioception throughout left side • Decreased cardiovascular endurance	• Unable to use left upper extremity to stabilize vegetables to cut with right upper extremity • Unable to use left upper extremity to stabilize bowls and dishes when preparing meals • Unable to sweep, wash floors, clean high surfaces • Unable to put hair in ponytail or barrette • Unable to drive (i.e., manipulate the steering wheel and use controls for turn signal, operate windshield wipers) • Unable to carry grocery bags and get items out of wallet • Unable to type with left hand • Unable to talk on phone and make notes simultaneously • Unable to push/pull wheelbarrow for gardening/yard work • Unable to use paddle for rowing • Unable to carry laundry basket • Unable to walk dog • Unable to do Pilates or aerobics activities • Unable to open containers • Unable to run and go hiking • Unable to walk community distances in a timely way • Unable to walk at speeds to keep up with friends, family, peers • Unable to walk on uneven terrain

using a rollator walker and found it difficult to navigate in crowded environments. JW also required frequent standing or sitting rests due to fatigue. She could tolerate walking continuously for only 10-minute intervals. The university has a large campus with many students rushing to classes; thus there were concerns about her ability to safely ambulate in this environment.

Activity Limitations and Body System Impairments

At the time of this initial evaluation, JW presented with the following impairments and activity limitations as outlined in Table A2.1.

Outcomes and Outcome Measures

The following objective measures were used both as baseline measures and as outcome measures to demonstrate ongoing change. They were also related to JW's impairments and identified functional goals.

Standardized Measures

1. *Berg Balance Scale*: The Berg Balance Scale was developed to measure balance among older people with impairment in balance function by their ability to perform various movement and functional tasks.[25] Table A2.2 lists JW's Berg Balance scores.
2. *Chedoke McMaster Stroke Assessment Scale (CMSA)*: The CMSA is a 7-point scale that classifies motor recovery. The impairment inventory is used to classify the severity of physical impairments in individuals with stroke. It is divided into six dimensions, in which smaller scores indicate greater motor impairment.[26,27] Table A2.3 lists JW's CMSA scores.
3. *Grip/pinch strength*: Grip and pinch strength were measured with the Jamar Hydraulic Hand Dynamometer (Patterson Medical Holdings, Inc.). Refer to Table A2.4 for JW's Jamar dynamometer measures.
4. *Two-Minute Walk Test*: This test was conducted and timed in the hallway of the therapy area in our rehabilitation hospital. After each 33 m, JW had to turn 180° and walk in the opposite direction. Table A2.5 contains JW's 2-Minute Walk Test results.

Table A2.2 JW's Berg Balance Scale scores

Date	Score
December 9, 2009	41/56
March 23, 2010	52/56
September 30, 2010	54/56

Table A2.3 Chedoke McMaster Stroke Assessment Scale (CMSA) scores

Date	Postural control	Leg	Foot	Shoulder	Arm	Hand
December 9, 2009	5/7	5/7	3/7	6/7	3/7	2/7
March 23, 2010	5/7	6/7	3/7	6/7	4/7	2/7
September 30, 2010	5/7	6/7	3/7	6/7	5/7	4/7

Table A2.4 Jamar dynamometer measures for JW

Date	Grip	Grip	Pinch	Pinch
	Right (average)	Left (average)	Right (average)	Left (average)
December 9, 2009	39.3 kg	6 kg (right hand assisted to hold dynamometer)	5.6 kg	Unable to perform
September 30, 2010	31.3 kg	8.3 kg (right hand assisted to hold dynamometer)	4.8 kg	0.5 kg

Table A2.5 Two-Minute Walk Test results for JW

Date	Distance traveled	Gait aid
December 9, 2009	58 m	Single-point cane
March 23, 2010	80 m	Single-point cane
September 30, 2010	99 m	No aid

Self-Referenced and Norm-Referenced Objective Functional Measures

Self-referenced measures, norm-referenced measures, and movement analysis were used to demonstrate changes in a selection of some of the functional activities that were required for JW to reach her goal of returning to work.

Observational Movement Analysis Descriptions

These movements were photographed and/or videotaped on three dates. The measures are outlined in the following six tables along with the observational movement analysis description for four of the tasks.

Putting on a Coat (Table A2.6)

December 9, 2009: The following describes how JW performed the task of putting on her coat. She completed this task sitting on a therapy mat, one-half femur length on the bed, feet hip width distance apart.

JW's starting alignment is described as follows:

- Sits toward front edge of mat; one-half femur length on mat.
- Feet hip width distance apart.
- Hips slightly higher than knees.

Table A2.6 Time measures for putting on a coat

Date	Time (before zipper)	Time (after zipper)
December 9, 2009	40 s	100 s
March 23, 2010	34 s	59 s
September 30, 2010	13 s	32 s

- Trunk in slight lumbar extension.
- LUE at her side in slight glenohumeral (GH) abduction, slight internal rotation.
- Right (R) hand grasping collar of jacket and holding it in front of LUE.

JW dons the left sleeve:

- L foot forward of R.
- Weight shifted more to R.
- Trunk in lumbar extension with thoracic flexion, cervical flexion looking at sleeve.
- R hand brings L sleeve to L arm, feeds left hand into sleeve, and slides sleeve up to shoulder with RUE.
- As slides sleeve up LUE, JW laterally side flexes in R lower trunk, pushing through RLE.
- LUE in 30° GH abduction, internal rotation, scapular abduction.

JW dons the right sleeve:

- Trunk rotated to the R with thoracic flexion, cervical flexion, and moving toward posterior pelvic tilt.
- Weight on R ischial tuberosity greater than L.
- L foot forward of R.
- RUE moved into GH extension and adduction, scapular adduction, downward rotation to grasp R sleeve behind her back.
- Once sleeve grasped, RUE then moves into GH abduction, external rotation and elbow extension to slide arm through sleeve.
- Trunk rotated back to midline, moves into posterior pelvic tilt, increased thoracic flexion.
- LUE positioned during this segment as follows:
    - Scapular abduction and slight elevation.
    - GH abduction ~30°.
    - GH flexion ~20°.
    - GH internal rotation.
    - Elbow flexion ~110°.
    - Wrist flexion ~20° with fingers in slight flexion.

JW does up the zipper:

- Cervical flexion, lateral trunk flexion on the L, increased thoracic flexion and posterior pelvic tilt.
- L foot forward, weight bearing primarily through RLE.
- L wrist and finger flexion used to grasp zipper with L arm stabilized by holding it against stomach.
- Once zipper started, L forearm placed across body to stabilize coat with wrist in flexion, forearm pronation, ulnar deviation, and fingers in flexion.
- Movement into neck extension and some thoracic extension with increased L lateral trunk flexion observed as right hand zips up coat.
- Weight bearing through lateral side of R foot.

March 23, 2010: JW completed the task in standing. Feet shoulder width distance apart, L foot forward of R throughout activity. Toed out bilaterally L > R. Weight on RLE > L.

JW's starting alignment is described as follows:

- Trunk in slight lumbar hyperextension and neutral thoracic extension.
- R hand grasped collar of jacket and brought to LUE.
- LUE in slight GH abduction with slight elbow flexion, wrist, fingers slightly flexed.

JW dons the left sleeve.

- R hand directed sleeve to L hand.
- L elbow extended to direct L UE into sleeve.
- RUE brought sleeve up to L shoulder.
- LUE positioned in GH abduction, internal rotation, scapula abducted, downwardly rotated with wrist neutral with fingers slightly flexed.

JW dons the right sleeve (Fig. A2.1):

- To reach for R sleeve: trunk rotated to the R with thoracic flexion and cervical flexion.
- JW flexed at hips, R knee in slight flexion, L knee hyperextended, increased contact on lateral side of L foot.
- RUE moved into GH extension, internal rotation and adduction, with scapular adduction and downward rotation to grasp right sleeve behind back.
- Once sleeve is grasped, RUE then moved into GH abduction, external rotation and elbow extension with scapular adduction and movement toward upward rotation to slide RUE through sleeve.
- LUE positioned during this segment as follows:
  - L scapula in relative abduction and elevation.
  - GH abduction ~30° with internal rotation.
  - L elbow in ~70° flexion.
  - Wrist flexion ~10 to 20°, fingers flexed.

JW does up the zipper:

- Trunk maintained in some thoracic flexion and flexed in cervical spine to look at hands to do up zipper.
- Hips moved toward extension but still in slight flexion.

Fig. A2.1 March 2010: JW reaching with right upper extremity for jacket sleeve.

- LUE in ~20° GH abduction with internal rotation and ~80° elbow flexion with 45° wrist flexion and forearm supination to grasp bottom of zipper with a lateral pinch (involving all digits) to steady zipper.
- Grasp and elbow flexion sustained with L wrist in ~45° flexion and forearm in pronation to stabilize the coat while R hand pulls the zipper up.
- As JW pulls up the zipper, she moves into neutral hip extension, thoracic and cervical extension.

September 30, 2010: JW completed the task in standing with feet hip width distance apart. L foot slightly forward of R with feet slightly toed out bilaterally. Weight on RLE greater than L throughout activity.

JW's starting alignment is as follows:

- Trunk in neutral lumbar and thoracic extension.
- Slight hip flexion.
- R knee extended to neutral, L knee slightly flexed.
- R hand grasps collar and brings sleeve to LUE.

- LUE in slight GH flexion, abduction with elbow extended, wrist and fingers slightly flexed.

JW dons the left sleeve:

- Moves into thoracic flexion and cervical flexion to look at sleeve.
- Right hand holds left sleeve and left elbow flexed to get into sleeve and then extended with scapular abduction, GH flexion and internal rotation to push LUE into sleeve; wrist positioned with ~35° wrist flexion and ~5 to 10° metacarpophalangeal (MCP) flexion and 45° proximal interphalangeal (PIP) flexion.
- RUE pulls sleeve up LUE as LUE is pushed into sleeve.

JW dons the right sleeve:

- Trunk rotated to the R to reach for R sleeve.
- Increased hip flexion, flexion in thoracic spine and cervical flexion compared with starting alignment but less than in March 2010 while reaching for R sleeve.
- RUE moved into GH extension, internal rotation and adduction with scapular adduction and downward rotation to reach and grasp right sleeve behind back.
- Once sleeve is grasped, right upper extremity (RUE) then moves into GH abduction, external rotation, scapular adduction, toward upward rotation and elbow extension to slide arm through sleeve.
- LUE positioned during this segment as follows:
  - L scapula in relative adduction.
  - GH extension (5°), abduction ~10 to 20° with slight internal rotation (less than March 2010).
  - L elbow in ~80° flexion.
  - Wrist flexion ~20°, fingers slightly flexed.

JW does up the zipper:

- Increased hip flexion, thoracic flexion, and cervical flexion to look at hands to do up zipper.
- LUE close to neutral GH rotation and ~0° abduction to assist in stabilizing hand to hold zipper.
- L elbow is 45° flexion with wrist in flexion of ~10° and forearm pronated to grasp bottom of zipper with a lateral pinch (involving all digits) to steady zipper.
- Grasp is sustained with L wrist in ~10° flexion, 10 to 20° of ulnar deviation, and forearm in pronation.
- LUE is tucked close to body with little to no humeral internal rotation and ~80° elbow extension to stabilize the coat while right hand pulls the zipper up.
- As zipper is pulled up, JW moves into neutral hip extension with thoracic and cervical extension.

Typing on a Computer Keyboard with Her Left Hand (Table A2.7)

December 9, 2009: JW was unable to perform the task at all.

March 23, 2010: JW completed the task at a desk sitting on a wheeled desk chair.

JW's starting alignment is as follows:

- JW sits in lumbar hyperextension with cervical flexion.
- Slight rotation of trunk back to L.
- L elbow in 90 to 100° flexion with GH internal rotation.

JW brings left fingers to keyboard using right hand to assist left hand throughout task to do the following:

- Maintain L elbow in ~90° flexion.
- Hold L wrist in relatively neutral wrist extension.
- Support L MCPs in neutral extension.
- Direct L hand/second digit to appropriate location on keyboard.

Left hand performs as follows:

- MCPs in ~20° flexion.
- PIPs in ~90° flexion with second digit extending slightly to ~80° to touch keys.
- Second through fourth digits have some distal interphalangeal (DIP) flexion making it difficult to get pad of second digit onto keys.

Trunk and neck alignment are similar to starting alignment.

September 30, 2010: JW completed task at a desk sitting on a wheeled desk chair.

JW's starting alignment is similar to that of March 23, 2010.

- Trunk in lumbar hyperextension and cervical flexion.
- Slight rotation of trunk back to the left.
- Left elbow in ~90 to 100° flexion with slightly less GH internal rotation compared with March 23, 2010.

The left fingers are brought to the keyboard.

The right hand performs as follows:

- Assists to bring left hand above keyboard.

The left hand performs as follows:

- Elbow ranges between 90 and 100° elbow flexion to help lift fingers off keyboard.

Table A2.7 Time measures and accuracy in typing task with left hand

Date	Time to type the words *A CAT* with left hand	Letters typed
December 9, 2009	Unable to perform	
March 23, 2010	27 seconds	AA XXCZArrrrrrrrrrrrrrrrrrt4
September 30, 2010	20 seconds	AVCZZCSAT

- Some humeral internal and external rotation is used to direct second digit to the keys.
- Wrist moves between 30 and 45° flexion.
- MCPs move from neutral extension to slight hyperextension (~5°) to assist with lifting fingers off keyboard.
- Second, third, fourth PIPs move from ~40 to 90° of flexion, hitting some of the keys as the second digit attempts to hit the correct keys.
- Slight DIP flexion noted in second through fifth digits.
- Second digit remains in ~80 to 90° of PIP flexion when touching the keys.

Trunk and neck alignment is similar to the starting alignment.

Walking

The following results were collected using a GAITRite mat (CIR Systems, Inc.). The GAITRite system is a level walkway, pressure-sensitive mat.[28] For the self-paced trial, JW was instructed to walk at her own pace. During the fast-paced trial, she was instructed to walk as fast as she could, safely. During the cognitive distraction trial, JW was asked to count backward by 3 from 100. She was asked to begin counting prior to starting to walk and continue until off the mat. JW was instructed to begin walking several steps before hitting the mat and to continue walking after off the mat for several steps. For the self-paced and fast-paced walking trials, data for 18 footfalls were collected, which meant two to three passes across the mat. For the cognitive distraction trial, only one pass across the GAITRite mat was collected.

Speed of walking was measured in m/min. The swing time symmetry ratio is a measure of the time JW spent in swing phase. This was measured for each leg. A longer swing time on the left corresponds to a longer single-limb-support time (stance) on the right leg and vice versa.[29] A ratio of 1 represents equal time in swing with each leg. Step width was measured in centimeters, and the distance from the heel of one foot to the heel of the other was measured. The step length was also measured in centimeters. A step length–symmetry ratio that is out of the normative range indicates that the step lengths are asymmetric.[29] See Table A2.8, Table A2.9, Table A2.10 for gait measures taken at three times during intervention.

December 9, 2009: JW was walking in her home using a rollator walker, and she used a wheelchair for outdoor mobility. She walked in therapy without a device for short distances. Her gait was characterized by the following:

- Initial contact on L: Contact with lateral forefoot, knee extended.
- Loading response to midstance on L: L knee was hyperextended as weight loaded onto leg. L hip remained flexed, L knee hyperextended, and ankle in plantar flexed position at midstance.
- Swing phase on L: Hiked L pelvis and circumducted hip with knee extended with ankle plantar flexed and inverted to advance L foot forward.
- Trunk alignment throughout all phases: Hyperextended in lumbar spine, upper trunk side flexion to the L.
- LUE alignment throughout all phases: Abducted to ~40° and internally rotated at GH joint, with elbow and wrist flexed.

March 23, 2010: JW walked in the community using a rollator walker for community distances and was walking at home and in therapy without a device. Her gait was characterized by the following:

- Initial contact on L: Contact with lateral forefoot, knee extended.
- Loading response to midstance on L: Knee flexed slightly, inconsistently achieved neutral hip and knee extension during midstance. Within a few minutes of walking, L hip flexed and knee hyperextended at midstance.
- Swing phase on L: Minimal flexion at knee, hip flexed with some circumduction to advance L foot forward.
- Trunk alignment throughout all phases: Lumbar spine hyperextended, upper trunk side flexion to L.
- LUE alignment throughout all phases: Abducted to ~40° and internally rotated at GH joint, with elbow and wrist flexed.

September 30, 2010: JW was walking in her home without a device and used a standard cane for all outdoor mobility.

Table A2.8 Gait measures—December 9, 2009

Condition	Step width (cm)	Velocity (m/min)	Swing time–symmetry ratio	Step length–symmetry ratio
			Norm (1–1.06 s)[26]	Norm (1–1.08 cm)[26]
Self-paced—no device	19.47	23.52	1.64 (0.63/0.38:L/R)[a]	0.812 (29.49/36.30:L/R)
Fast paced—no device	20.85	29.22	1.06 (0.51/0.48:L/R)[a]	0.913 (29.49/36.30:L/R)
Cognitive	22.81	23.52	1.77 (0.66/0.38:L/R)[a]	0.905 (28.48/31.48:L/R)

Abbreviations: L, left; R, right.

[a]JW spent more time in left swing phase and therefore greater time in right single-limb support.

Table A2.9 Gait measures—March 23, 2010

Condition	Step width (cm)	Velocity (m/min)	Swing time–symmetry ratio	Step length–symmetry ratio
			Norm (1–1.06 s)[26]	Norm (1–1.08 cm)[26]
Self-paced—no device	20.05	54.48	1.15 (0.47/0.41:L/R)[a]	0.92 (49.12/53.69:L/R)
Fast paced—no device	17.90	61.14	1.21 (0.48/0.40:L/R)[a]	0.85 (51.86/61.03:L/R)
Cognitive	21.10	44.34	1.26 (0.49/0.39:L/R)[a]	0.85 (41.02/48.08:L/R)

Abbreviations: L, left; R, right.

[a]JW spent more time in left swing phase and therefore greater time in right single-limb support.

Table A2.10 Gait measures—September 30, 2010

Condition	Step width (cm)	Velocity (m/min)	Swing time–symmetry ratio	Step length–symmetry ratio
			Norm (1–1.06 s)[26]	Norm (1–1.08 cm)[26]
Self-paced—no device	17.42	47.7	1.42 (0.62/0.44:L/R)[a]	0.94 (52.61/55.75:L/R)
Fast paced—no device	16.33	62.82	1.87 (0.74/0.39:L/R)[a]	0.94 (58.40/61.86:L/R)
Cognitive	18.15	49.56	1.39 (0.61/0.44:L/R)[a]	0.89 (50.69/57.07:L/R)

Abbreviations: L, left; R, right.

[a]JW spent more time in left swing phase and therefore greater time in right single-limb support.

She reported that, in mid-May, she had been walking in the community and rolled over laterally on her left ankle. At her next therapy session, she had pain and swelling in her left ankle with pain on weight bearing. She appeared to have a lateral ankle sprain and was treated for this. Immediately following this incident, JW was limited in her ability to walk longer distances and avoided walking on uneven surfaces. JW returned to walking with her rollator walker to off-weight her left ankle for approximately 2 weeks. She then slowly returned to walking short distances with a cane and then eventually with no device indoors. In May, she was also prescribed an AirSport Ankle Brace (Aircast, DJO Global) to support her ankle. She wore this support all day from May until July and then began to gradually wean herself off this support.

In September 2010, JW continued to wear the AirSport Ankle Brace when walking outside in the community but had stopped wearing it in her home environment. On September 30, 2010, when her walking was reassessed on the GAITRite mat, she removed the AirSport Ankle Brace just prior to walking on the mat. JW felt that her walking was worse on this trial as a result.

In our opinion, the quality of JW's gait improved from March until September, but the observed and measured magnitude of this change was less significant, likely as a result of this ankle injury. Her gait was characterized by the following:

- Initial contact on L: L heel but hindfoot and midfoot struck on the lateral border, with knee extended.
- Loading response to midstance on L: Knee flexed slightly, consistently achieved neutral hip and knee extension during midstance.
- Swing phase on L: Approximately 40° flexion at knee, flexed at hip to advance L foot forward.
- Trunk alignment throughout all phases: Lumbar spine slight hyperextension, upper trunk side flexion to L.
- LUE alignment throughout all phases: Neutrally external rotation at GH joint, forearm supinated, elbow flexed, wrist in neutral extension, fingers slightly flexed.

Ascending and Descending Stairs (Table A2.11)

December 9, 2010: The following is a description of how JW ascended and descended the stairs with supervision.

Holding R hand rail, ascended as follows:

- Steps with R leg to first step.
- Single-limb support on L: Hip flexed, knee hyperextended.
- Swing phase on L: Leans heavily on handrail on R side. Hikes L pelvis, circumducts at hip to bring L leg to same step as R.
- Trunk alignment: Hyperextended in lumbar spine, upper trunk lateral flexion to the L during stance and swing.

Table A2.11 Stair measures

Date	No. of stairs	Amount of assist	Time to complete (s)
December 9, 2009	8	Supervision, step to with right leg leading up and down. Ascends forward and descends backward.	51
March 23, 2010	8	Independent with right hand rail, step to with right leading up and down. Ascends and descends forward.	34
September 30, 2010	8	Independent with right hand rail, reciprocal pattern, forward up and down.	20

- LUE: GH abduction, elbow flexed to 90°, wrist and fingers flexed.

Holding R hand rail, descended backward as follows:

- Stepped down with R leg to step.
- Single-limb support on L: Hip flexed, knee slightly flexed.
- Swing phase on L: Rotated trunk back to L, hip flexion, circumducted L hip with minimal knee flexion. Placed to same step as R.
- Trunk alignment: Hyperextended in lumbar spine, upper trunk side flexed to the L during stance and swing.
- LUE: GH abduction, elbow flexed to 90°, wrist and fingers flexed.

March 23, 2010: The following is a description of how JW ascended and descended the stairs independently.

Holding R hand rail, ascended as follows:

- Steps with R leg to first step.
- Single-limb support on L: Hip slightly flexed, knee neutral extension.
- Swing phase on L: Circumducted at hip with some hip flexion and knee flexion to bring L leg to same step as right.
- Trunk alignment: Hyperextended in lumbar spine, upper trunk side flexed to the L.
- LUE alignment: Slight GH abduction, elbow flexed to 30°, wrist and fingers in neutral extension.

Holding R hand rail, descended forward as follows:

- Stepped down with R leg to step.
- Single-limb support on L: Hip and knee flexion.
- Swing phase on L: Extended knee quickly, ankle inverted.
- Trunk alignment: Hyperextended in lumbar spine, upper trunk side flexed to the L during stance and swing.
- LUE alignment: Slight GH abduction, elbow flexed to 30°, wrist and fingers in neutral extension.

September 30, 2010: The following is a description of how JW ascended and descended the stairs independently. JW carried her standard cane in her left hand for both ascending and descending.

Holding R hand rail lightly, ascended with a reciprocal pattern as follows:

- Stepped with R leg to first step.
- Single-limb support on L: Hip and knee neutral extension as R foot stepped up to next step.
- Swing phase on L: Hip > knee flexion. As she placed L foot on stair above, foot was briefly caught on riser of stair in six of eight steps.
- Trunk alignment: Slight hyperextension in lumbar spine during stance and swing.
- LUE alignment: Scapular approximation, relative adduction, depression and upward rotation. GH external rotation to neutral, flexion/abduction to 20°, elbow flexed to 90°, forearm in neutral supination/pronation, grasping cane shaft with L hand independently.

Reciprocally holding R hand rail, descended as follows:

- Stepped down with R leg to step.
- Single-limb support on L: Hip hyperextension on two of eight steps, otherwise neutral extension with knee flexion as right foot lowered to next step.
- Swing phase on L: Hip then knee flexion to initiate swing. Extended knee with control, neutral ankle position to place foot on lower step.
- Trunk alignment: Slight hyperextension in lumbar spine during stance and swing. Rotation back on right side on three of eight steps when hand would stay too far back on hand rail.
- LUE alignment: Scapular approximation, relative adduction, depression and upward rotation. GH external rotation, flexion/abduction to 20°, elbow flexed to 90°, forearm in neutral, grasping cane shaft with L hand independently.

A2.2.2 Intervention

JW attended physical therapy and occupational therapy in an outpatient neurological setting of a Canadian rehabilitation hospital. She attended each discipline for 45 minutes two to three times a week from mid-December 2009 until September 2010. Following our initial evaluation, which included analyzing the requirements of the tasks JW needed to complete to return to work as well as considering her impairments, we established a care plan that was directed toward her goals.

Initially, her most significant specific system impairments were related to reduced proximal stability around her left scapula, trunk, and hip. As such, our focus was directed on improving this proximal stability through handling and environmental setup and manipulation while engaging her in practice of meaningful tasks that both were important to her and targeted her impairments.[30] Our intervention progression follows.

December 2009–March 2010

Initially, both physical therapy and occupational therapy used primarily closed chain tasks for JW's LUE, keeping the limb in active support on flat surfaces to facilitate JW's ability to sustain scapular approximators, depressors, and elbow extensors. (Refer to Chapter 9 for definitions and more detailed descriptions of closed, modified, and open chain practice.) With this arm in active support, we used body-on-arm strategies to stretch her tight shoulder internal rotators (Fig. A2.2). For most of her therapy sessions, JW was working in standing and squatting postures, emphasizing stance activity and alignment on her left leg to work toward more active midstance control. She required a therapist's assistance to work in these more challenging postures and to ensure she was using her more involved limbs in the activity. We chose postures that would also challenge her to sustain activity in her abdominals, obliques, and left hip extensors. Within each individual therapy session, we increased the challenge by doing the following:

- Changing aspects of the functional task.
- Changing postures (high perched to squat to standing).
- Manipulating her base of support (stepping on stable to less stable surfaces with the less involved leg).
- Varying the direction of the movement for reaching or stepping with her R limbs.

Examples of these include the following: standing at a counter with her LUE in active support on the counter while stepping forward with R leg and reaching with R arm into cabinet above shoulder height for her work manuals and working within a squat position with her LUE in active support on a stable, lower surface while reaching forward with her R arm to a lower shelf in a closet for her shoes.

Fig. A2.2 February 2010: Challenging JW's left upper extremity (UE) in active support while reaching to close curtain with right UE. Occupational therapist facilitating scapular depressors and triceps for active support.

In these examples, JW needed to sustain an active trunk in various ranges of flexion, extension, and rotation. The demands placed on her left upper and lower extremities were primarily isometric holds or movements through small ranges. We used handling (distally or proximally) as needed to her abdominals, elbow extensors, scapular stabilizers, humeral external rotators, and hip extensors. The environmental setup and the tasks were chosen to ensure that JW was adequately challenged to demand activation in the trunk and more involved extremities as described in Howle.[30]

As her left upper and lower extremities' proximal control improved, we introduced modified closed chain tasks. Initially, JW required handling to assist in completing these activities. Some examples follow:

- Walking while pulling a wheelbarrow behind her down the hall.
- Walking while carrying a laundry basket with both hands.
- In standing, sliding her arm up an inclined surface toward a cupboard while holding a cup.
- In standing, opening and closing a hydraulic door with her left arm.

Within this incline setup, we first focused on placing isometric demands on the extremity. Examples for JW included actively holding her LUE at various ranges on a stable table while she stepped with her right lower extremity (RLE) or rotated her trunk on the midline to the right. As previously stated, we refer to this type of activity as *body on arm*, indicating that the body moves while the arm remains stable.

Within a modified closed chain setup, we progressed tasks to place eccentric and then concentric demands on the limbs. We did this with JW by having her slide her arm down an incline surface using an arm on body movement. This eccentric control would be required when JW needs to take a cup from the cupboard and bring it down to the counter level. To challenge JW further within this same functional task of reaching, she then put the cup back into the cupboard by sliding up an incline with concentric demands on her elbow extensors and shoulder flexors.

Arm on body movements occur when the arm is moving but the body is stable. These same principles were used for her LE to challenge the LE eccentrically before concentrically. An example is during stair climbing; she stepped to the first step with the right foot, followed to the same step with the left, and then stepped down with the right leg. In this way she challenged her eccentric left leg extensors (hip, knee, and ankle) as she stepped down with the right. To challenge the concentric control of her left leg extensors, JW then stepped with her right leg to the step above her left foot. To challenge the concentric control of her left leg flexors (hip, knee, ankle), she then stepped up with her left leg to the next step. Initially, JW required significant handling to work within these functional activities in a modified closed chain, but as JW improved, we gradually reduced the amount of handling to the point that she eventually was able to do these activities without the assistance of a therapist.

Throughout our sessions, we worked with JW within various tasks that were meaningful to her. Some examples of these included climbing and descending the stairs initially with a right hand rail, but later with a left hand rail only, so that she could negotiate stairs in the community, walk and carry a laundry basket, push and pull a wheelbarrow while walking (Fig. A2.3), sit while working on the paddling motion with the paddle, and run. We worked with JW to assist her in completing these activities but constantly decreased our assistance so that JW was maximizing her abilities.

We worked on bimanual subtasks and increasingly challenging tasks to prepare her to walk while pulling a work bag, open and walk through doors, and ascend or descend stairs while carrying teaching supplies in her right arm. These activities all placed increased demands on her trunk and LUE and LLE. A concept we continued to focus on was incorporating objects into JW's hand so that, in addition to addressing the more proximal impairments, we were addressing her distal impairments as well. She had some distal control in her hand but still needed assistance to maintain grasp. By using different sizes, shapes, and textures of objects in her left hand that were specific to a task, we worked on improving graded grasp, radial wrist extension, movement of and between supination and pronation, and subcortical sensation in her hand. It was important to focus on both proximal and distal impairments in her UE because efficient UE function requires both proximal and distal control.

In addition to her regular attendance in therapy, a home program was established with JW. On a weekly basis, we problem-solved with JW about how she could incorporate her more involved extremities into her day-to-day functional tasks without any assistance. This included assisting JW to modify her home environment so that she could optimize the activity in her trunk and more involved extremities. For example, JW used her LUE to actively support on stable surfaces while standing in the midline while her RUE performed activities of daily living, such as meal preparation and folding laundry. She also maintained active support through her left arm and hand while sitting and working on the computer with her right hand, watching television, and reading. These activities were progressed at home so that she eventually began to use her left arm as a gross assist to carry pots in the kitchen, assist to steady food and items associated with activities of daily living, and stabilize the zipper with her left hand to zip up her jacket. She was also encouraged to walk as much as possible and to spend some time practicing walking with an improved pattern. For example, one initial home strategy related to JW's gait was for her to focus on keeping her left hip "forward, so her hips were level," meaning her left hip achieved a neutral extended position in midstance, which then decreased her knee hyperextension.

Fig. A2.3 March 2010: Working in function—JW walking while pushing wheelbarrow, incorporating left upper extremity into activity in preparation for gardening goals. Physical therapist facilitating left hip extensors and abdominals via distal cue.

March 2010–September 2010

We continued to use some of the intervention strategies as already described. During this phase, the therapy sessions primarily focused on modified closed chain tasks, but we also began to open the chain in the limbs. As we increased the challenge to the limbs, JW required handling from a therapist. As before we continued to monitor and gradually decrease the amount of assistance we provided.

Controlling movement with an open chain is more difficult. When considering open chain, we initially made it easier by using shorter-level arms to open only part of the chain in the UE. For example, because JW had more range of motion and strength around her shoulder girdle, we had her slide her arm up an inclined surface so that her forearm or elbow remained in contact as a point of stability while her wrist and hand moved off the surface to reach for her canoe paddle. This resulted in the wrist and hand link to be open (a short lever) while the rest of the limb was still in support.

Initially, the movement demands in an open chain were within small ranges and using smaller levers. Depending on the task and the setup, we could selectively challenge different UE movements by opening the chain at the elbow, forearm, and wrist or finger links.

The same rationale and intervention decisions were made for her left lower extremity (LLE) to work on swing phase of gait impairments. We could selectively open the chain to target knee flexion with short levers. We placed a therapy ball in front of her left knee and had her keep her knee on the ball as a point of stability while the chain was opened with movement of the distal leg.

Our handling also progressed in general from proximal to more distal key points of control. Initially, our more direct handling was to her abdominals, scapular stabilizers, elbow extensors, and hip extensors. As she progressed, we were able to move to more distal key points. For example, in the reaching example described earlier, as we progressed to working in open chains, our handling moved more distally to the forearm and wrist, while still monitoring the alignments and movements of the scapula and trunk.

In the LE, we moved away from contact on the hip extensors to a more distal contact on the upper trunk to influence the hip alignment for midstance alignment. We used handling to activate postures and movements in an anticipatory way. Within a therapy session and over time, we continually assessed and monitored JW's alignment/postural control and decreased our feedback (verbally and with handling) until eventually there was little to no feedback by the latter sessions. Our handling and verbal cueing moved from immediate to summary and was more sporadic.

We also allowed JW to make errors. We strove to strike a balance between not allowing too much error so that the error wasn't what was learned but, rather, a reasonable amount so that JW could identify the error and begin to correct it on her own. This withdrawal of our input within a session and over time, as well as allowing for errors within certain boundaries, allowed JW to internally organize and problem-solve her movement and enhanced the opportunity for learning and carryover to occur. This strategy ensured a more optimal environment for learning.

At this stage in her recovery and OP therapy, JW continued to have impairments proximally at her scapula, shoulder, trunk, and hip, but these impairments had improved significantly such that her limitations in using her left limbs in function were now more influenced by her distal impairments. These impairments included tightness of long finger flexors; weakness of radial wrist extensors, finger extensors, thumb extensors, and abductors; weakness of knee flexors and ankle dorsiflexors; an inability to initiate ankle evertors; and an inability to isolate and grade the flexor and extensor activity in her hand and with wrist movements. Given JW's improvement in her proximal impairments, we then more specifically targeted the selective aspects of distal limb function, including wrist and hand function as well as distal control at her left ankle. For example, we began to focus on her goal of typing as JW was getting closer to her return-to-work date. We did this by starting with her forearm and heel of her hand in contact with the desk and isolating finger movements using a modified closed chain. JW would flex, extend, abduct, and adduct at her MCP joints by sliding her fingers on the top of the desk. We then incorporated flexion and extension at her PIP joints by sliding her fingers into and out of PIP extension. Next, we then progressed to having her slide her fingers in a similar fashion on the keyboard with the extension at her MCP joints.

For her LE, to improve the quality of her functional walking, we focused on the impairments that affected the swing phase of gait. We worked on strengthening her knee flexors, ankle plantar flexors, and evertors by initially selectively isolating these movements at each joint before working on combined movements, such as knee flexion/extension with ankle dorsiflexion, which is required for swing phase of gait. For example, JW stood in stride position with her right leg forward. She worked on shifting her weight onto her right leg, allowing passive knee release on the left leg, and then rolled her left leg over a cylinder roll. Later, JW stepped over various items on the floor (e.g., books and poles) where she had to flex at her knee and dorsiflex at her ankle to clear the object. We also worked on walking up and down inclined surfaces. We again used concepts such as increasing the range of motion and gradually opening the chain from shorter to longer lever arms. For example, before JW could completely step over the cylinder roll, we worked on specifically strengthening her left knee flexors in a variety of ways. Early on, these strategies included having JW sit on a high plinth with her left foot on a rolling stool and asking her to pull the stool under the bed so that she focused on flexing her left knee. We also worked in standing and specifically in stride with the right leg forward to simulate trailing limb alignment in the preswing phase of gait on the left. We placed a Theraball in front of her left knee, and she maintained neutral hip extension while she flexed her left knee, keeping it on the ball. Her lower leg and foot were now open chain. We then added hip flexion while her knee was still on the ball. This worked components of initial to midswing in a modified closed chain so that initially JW focused on flexing her knee and then combining hip and knee flexion.

In May 2010, JW began to plan for a return to work by mid-July. We spent some time in therapy problem solving with JW to set up her home office environment so she could use her left hand for typing to increase the practice of this skill. She continued to attempt to use her left hand on keyboard keys despite the ongoing difficulty. We suggested JW set up her desk space at home so that her forearm was supported, which allowed her to more easily isolate finger movements for typing. JW was not able to type at a speed or efficiency required for her job at this stage. As such, we problem-solved with her to set up her desk space so her LUE could be actively supported on a contoured, domed surface while she used her right hand for typing and answering the phone. JW had tightness of her wrist and long finger flexors and had difficulty keeping her hand on her flat desk surface with her wrist extended for active support. The contoured, domed surface supported her MCP joints and allowed JW to actively support through her hand with some wrist extension and accommodate for the shortening of her long finger flexors. We recommended a community occupational therapist to assist with her return to work plan and to facilitate any necessary equipment for JW to use at work.

With her return to work date set, JW also wanted to walk at faster speeds to get to various scheduled appointments across campus. At this point, the impairments at her knee and ankle still limited her ability to walk safely at faster speeds. We assisted JW to walk without a gait aid, both forward and backward, changing directions and speeds, running, jumping, squat walking, and side shuffling, to increase the challenge and address the impairments most interfering with this ability. We also worked with JW on walking outdoors without a gait aid on various surfaces, including grass, hills, up and down curbs, and reciprocal stair climbing with a left or right hand rail or without a hand rail so that she could access all stairs in the community. She continued to need assistance in therapy to perform these challenging activities.

As mentioned previously, in mid-May, JW was walking in the community and injured her left ankle. She had subsequent swelling and pain for the next 8 weeks with weight bearing on her left ankle. Because of this injury, we recommended she wear an AirSport Ankle Brace to provide lateral stability to her ankle. This injury was a minor setback in her recovery because she was more reluctant to shift weight onto her left foot and leg. To promote activity of her ankle evertors and to decrease the swelling, we used electrical muscle stimulation for 15 minutes each session for a period of 2 months. Once she was able to consistently initiate activity of her ankle evertors, this treatment was discontinued.

A2.2.3 Outcomes

JW made meaningful functional improvements from December 2009 to September 2010. In September 2010, she was completely independent with all activities of daily living using her LUE as a gross assist for dressing, bathing, washing her hair, reaching, cooking, and carrying. JW was now showering in her tub, stepping independently in and out, and standing while showering. She only used a shower chair to sit while shaving her legs.

JW incorporated her LUE into all her activities despite continued limited fine motor control and dexterity. She was able to complete all household tasks, including day-to-day cooking as well as fine dining preparation for their dinner parties. She was independently doing the laundry, shopping at the grocery store and market, and performing other community tasks, but she did require more time than before her injury. JW continued to use a housekeeper because housekeeping was not one of her goals.

She was walking independently without a device indoors and continued to use a standard cane when walking outdoors. Her endurance and speed of walking improved so that she was able to go out for the day with friends and keep up with them without requiring rests. JW was able to ascend and descend stairs using a reciprocal pattern with or without a hand rail, and she was able to go up and down curbs independently. She got her driver's license back in September but was reluctant to drive much in the winter months and thus still required assistance for transportation during this season. She did purchase a vehicle with automatic transmission because she had previously driven one with a manual transmission. JW was freely and independently accessing the community, including shopping, going to movies, socializing with friends, and hosting dinner parties.

JW's significant cardiac history affected her circulation. Initially, her circulation was poor in both her LUE and LLE with discoloration proximally in her arms and legs, worse distally. Her left foot and hand were purple in color. This discoloration was not present on the right. On formal testing, JW initially had absent light touch and proprioception sensation throughout her left side. As JW improved in her motor function, her sensation and circulation also improved. Her circulation improved such that the color in her left extremities was almost identical to that on the right side by September 2010. JW began to notice improvement of sensation in both extremities beginning proximally and progressing distally as well. By September, she had some light touch and proprioceptive sense in her left foot, although this was still reduced compared with the right. Her sensation in her hand remained more impaired than in her leg. JW felt this was a significant limitation in her ability to use her hand without visual feedback.

In July, JW returned to her previous position at the university. She returned to work in 4-hour intervals initially before progressing over a 6-week period to full days. Her employer was very supportive of her return-to-work plan. JW had a community occupational therapist perform a job site analysis. Modifications were made to her workstation and equipment was provided to enable her to be efficient in her job. She was provided with voice recognition software and a Bluetooth device to assist in her job. She was able to access her computer and phone simultaneously using these devices because typing using her left hand was not fast or accurate enough. Consequently, her workstation was set up so that her LUE could still be active in a support function.

When JW first returned to work, she used her standard cane to walk outside around campus and in busy areas indoors. She did not use her cane in her office. Initially, JW attempted to book her appointments in close proximity to her office so that she didn't need to walk across the entire campus under time pressures. If her appointments were too far away or the weather was inclement, she did use a university transportation service. Because she relied on using a standard cane for mobility, she was unable to walk and carry her teaching supplies. She used a back pack or briefcase bag to carry her supplies and placed her left hand in her pocket or on the strap of the bag when walking across campus. She had no difficulty ascending or descending the stairs using a hand rail or her standard cane.

By September 2010, JW had reached her goals. She was working full time without compromising the gains she had made in therapy. She also continued to make positive gains with regard to her ability to use her more involved side in all functional activities.

Please see video segments of JW's intervention sessions on Thieme MediaCenter.

A2.3 Discussion

This case report describes how JW was able to incorporate her more involved side while performing functional tasks and return to participation roles, including her main goal of returning to work. Our assessment and intervention applied NDT principles. We performed task analysis, movement analysis, and ongoing reassessment of her impairments and their influence on her ability to perform functional activities and participate in life roles. We worked within various functional tasks that were subcomponents of her larger goal to return to work. We did this by starting with small, specific functional tasks that would address her impairments and were linked to the goal of returning to work. Some of these initial activities included using her left extremities in active support. With hands-on facilitation, we were able to challenge her more involved side in therapy sessions beyond what she was able to do on her own. We initially focused more on proximal control (trunk, scapula, hip), and as this control developed, we increased our focus on distal function (wrist, hand, foot). These concepts were critical to her systematic progress toward her main goal of return to work.

JW suffered a left ankle sprain in mid-May 2010, which was a minor setback in her recovery. Given the lateral instability of her left ankle, she started wearing an AirSport Ankle Brace and continued to wear it inconsistently beyond September 2010. For the final GAITRite data collection, she took this support off her left ankle just prior to walking. We wonder if this factor contributed to her decreased performance on this test date compared with the results on March 23, 2010, because she had to acclimate to walking without the support. To verify this assumption, it would have been beneficial to compare the GAITRite results with and without the AirSport Ankle Brace support.

JW was an active participant throughout her outpatient therapy and problem-solved with us on how to incorporate her more involved extremities into functional activities at home and in the community. We considered her home and work environments and assisted her in modifying these environments to enable her to effectively incorporate her more involved extremities. Examples of this were using her work bag to facilitate her LUE in active support while walking across campus and using a domed surface to facilitate active support of her LUE while working at her workstation. She provided ongoing feedback on her successes and challenges so that we were continuously able to modify her intervention, home program, and environment so that the level of challenge was optimal.

In this case report, we used some standardized measures as well as norm and self referenced measures (e.g., gait speeds, step lengths, and movement analysis descriptions). JW showed improvements in most of the standardized measures. However, on the CMSA, JW improved by no more than 2 points on the 7-point scale, but she made functional gains in both UE and LE motor recovery. The standardized measures were an important part of our evaluation, but they, on their own, did not reflect the magnitude of her functional gains. In the descriptions of the self-referenced measures, it became clear to us that JW's impairments improved, which contributed to more efficient and effective movement patterns. These more efficient movement patterns then resulted in JW being able to successfully resume functional activities and participation roles with the least amount of compensation.

In future therapy sessions (after September 2010), we continued to challenge JW by focusing on more complex outcomes. Some of these complex tasks included reciprocal stair climbing while carrying a laundry basket, walking on varied outdoor surfaces (like those required for hiking) with less hands-on assistance, paddling for dragon boat racing, typing, using her left hand only to carry glasses, dishes, teaching supplies, and other items. By focusing on these outcomes and their subcomponents, we further addressed her impairments so that her daily tasks were performed with greater ease and efficiency. We continued to work with her on activities such as walking on uneven surfaces and slopes, sitting on less stable surfaces like a canoe and using a paddle, walking and carrying various items with increasing speeds and changing directions, and walking while pushing and pulling to simulate walking her dog. Over time and with practice, JW required less assistance until we were mostly providing verbal feedback. JW began to experience further cardiac complications resulting in medical interventions, including cardioversion several times and medication changes. These complications did alter our intervention from time to time. During these times, she was not able to tolerate walking with increased speeds or distances and running, and she needed more frequent rests with UE intervention as well. Despite these complications, JW continued to work hard during and outside of therapy. JW was discharged from outpatient therapy in January 2012.

We feel this case report highlights the importance of the following points:

- Identifying the critical impairments that impact a patient's functional activities.
- A logical sequence of progression from closed chain → modified chain → open chain challenges for limb recovery.
- Working within tasks that are relevant and important to the patient.
- Consistent and varied practice of the patient's involved limbs in various meaningful functional tasks.

We demonstrated how working within an NDT framework enabled JW to progress from requiring assistance with many functional activities (laundry, cooking, doing up buttons, walking in the community at community speeds, walking and carrying objects such as her briefcase and coat) to being independent with these activities. As a result of these activity limitations, she initially had many participation restrictions (unable to work, unable to socialize with friends in the community or host friends in her home), but as intervention progressed, JW was able to resume these roles. By using NDT principles to guide our decisions, we challenged JW and assisted her to achieve her goal of return to work.

A2.4 Acknowledgment

We would like to acknowledge the assistance of the Heart and Stroke Foundation, Centre for Stroke Recovery, and specifically Madison Martin, Research Associate.

A2.5 Alternate Reflection

From the Client, JW

On Monday, September 21, 2009, my life changed. I went from a multitasking, physically active 50-year-old to discovering that I had somehow lost the left side of my body. I was unable to coax the part of my body, that I could no longer feel, to move. I became aware of how much I had taken my physical functionality for granted.

Initially paralyzed on my left side, I anticipated that it was only a matter of time before I slowly regained those “innate” skills that I had honed since I was a toddler. Left to my own devices and in the hands of less skilled and dedicated therapists, I would have developed horrendous muscle patterns designed to accommodate my inability to call on those innate skills and atrophied muscles. I would have developed exaggerated movements to accomplish everyday tasks. Instead of engaging correct muscle groups and pushing through the movement, I would have defaulted to larger muscle groups and would never have achieved successful movement and muscle strength.

My outpatient physical and occupational therapists worked together to devise a plan that would require me to use *closed and modified chained* movements to develop smaller muscle groups (especially significant as I have never regained full feeling in my left hand or foot). Each week, I was given homework and, in many cases, a prop (e.g., a small foam ball) to continue to work on small movements and strength exercises between therapy sessions. Working as a team, my therapists collaborated on combining occupational and physical exercises to help prepare me for returning to work where I would need to multitask once again. I still employ many of the activities prepared by my therapists, and I know that my successes are a reflection of the time, dedication, and NDT approach to my stroke rehabilitation.

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Case Report A3 Identifying and Addressing the Impairments in an Individual Who Demonstrates Contraversive Pushing Behavior

Cathy M. Hazzard

A3.1 Introduction

Pusher syndrome was first clinically described by Davies[1] in her book *Steps to Follow* in 1985. Contraversive pushing, also referred to as pusher syndrome, pushing behavior, or ipsilateral pushing, is defined when an individual who has had a stroke actively pushes away from the nonparetic side, leading to a loss of postural balance and falling toward the paralyzed side.[2] Clinically, these individuals strongly resist passive correction to midline in both the frontal and the sagittal planes, especially if this correction is done abruptly or without any functional or task context.

Most authors cite the incidence of pushing behavior as ~10% of the acute stroke population (5.3% of the entire stroke population and 10% of the stroke population who receive rehabilitation).[3,4] However, other studies, including Danells et al,[5] in 2004 (63% of the stroke population), and Lafosse et al,[6] in 2005 (40–50% of the stroke population), report the incidence to be higher. Initially, the pushing behavior was believed to occur almost exclusively in individuals who had right brain lesions.[1] However, it is now widely accepted that pushing behavior may be present in individuals with lesions in either hemisphere.[2,3,7]

Karnath and colleagues[2,7,8,9,10,11] have been conducting extensive research with this population with various collaborators to determine the origin of pushing and to develop management strategies and techniques for its treatment. This research has determined that pushing is associated with unilateral lesions of the left or right posterolateral thalamus and leads to an altered perception of the body's orientation in relation to gravity.[2,7,8,9,10,11]

In the Karnath et al[2] study of 2000, both the visual and the vestibular systems were determined to be intact in these individuals. In addition, these researchers determined that, on average, these individuals perceive their upright middle at ~18° to the ipsilesional, nonparetic side. This finding led the researchers to describe a second pathway for organizing movement in gravity (separate from the one for perception of the visual world). They call this second pathway the graviceptive system.

Spatial neglect and other neuropsychological impairments were traditionally suspected to be the causes of this pushing behavior, but investigations have ruled these causes out.[3,9,11] There are, however, strong correlations between pushing behavior and spatial neglect after right hemisphere lesions (incidences from 100%,[2,12] 80%,[13] 67%,[10] 62%,[5] to 40%[3]) and between pushing behavior and aphasia after left hemisphere lesions (incidences from 100%,[9] 80%,[6,14] 60%,[10] to 47.1%[3]). These strong correlations (spatial neglect with right hemisphere lesions and aphasia with left hemisphere lesions) occur because the relevant brain structures associated with these functions lie in close proximity to each other.[7]

There is some debate among researchers about which group of individuals should be classified as pushers based on the amount of motor recovery present on the more involved side of the body (limbs and trunk).[5,9,10,15] Some believe that there are two different categories; if there is severe involvement, including essentially no motor recovery on the more involved side of the body, these individuals are categorized as pushers.[3,5,9,10] If there is relatively good motor recovery on the more involved side, these individuals are *not* categorized as pushers, despite their very active pushing away from the less involved side with active resistance to correction to vertical midline.

Danells et al[5] and others[2,3] suggest that the recovery of pushing is not strongly associated with the recovery of motor control. Pushing is often completely resolved by 3 months (71% of subjects in the study by Danells et al[5] in 2004) or by 6 months (100% of subjects in Karnath et al[9,10] 2002 and 2005, respectively, and the work of Pedersen et al[3] in 1996), yet profound motor deficits/paresis in all these groups still existed.

In 2007, Santos-Pontelli et al[15] published a case report that examined pushing behavior in an individual poststroke but with only minimal paresis. Their results showed that, as the pushing behavior decreased, the functional outcome measures increased (using the Barthel Index), yet the paresis level did not statistically change. Thus it appears that the resolution of the pushing behavior is associated with improved functional outcomes but not with resolution of paresis or whether the paresis is mild or severe.

From a motor stabilizing perspective, clients who demonstrate pushing behavior do the opposite of what clients with stroke who don't push do. Pederson et al[3] in the Copenhagen Stroke Study concluded that "ipsilateral pushing did not affect functional outcome, but slowed the process of recovery considerably." In the same report, the subjects required ~3.6 weeks longer to reach the same functional outcomes as individuals without ipsilateral pushing behavior.[3] In 2004, Danells et al[5] found the length of stay (LOS) to be 4.57 weeks longer to reach the same functional levels for individuals who push compared with individuals who do not push.

Currently, with shorter LOSs in most Western countries and the pressure in these health care systems to move people along the continuum of care as fast as possible, it could be that individuals who push poststroke may no longer be given the opportunity to achieve the same functional outcomes given that they require more recovery and practice time. Also, as already discussed, given that their paresis is typically more severe, these individuals require more manual effort to mobilize and/or require the use of mechanical lifts for transfers and in therapy. Thus these individuals may be more likely to be directed to long-term care facilities from acute care without being considered for other programs, such as slow stream rehabilitation. It is also possible that, in acute care, they are not stood, transferred, and generally mobilized in therapy and on the medical units as often as individuals who do not demonstrate pushing behavior.

Understanding and applying strategies to help those who demonstrate pushing behavior integrate and resolve the pushing as early as possible in the recovery phase may enable clinicians to assist clients with shortening the period of pushing and may thereby facilitate earlier return to the same levels of functional independence as clients who do not push poststroke.

Pushing behavior and its management are not consistently described and taught in therapy schools. Novice therapists, if they have limited or no didactic knowledge or practical strategies for evaluating and working with these individuals, typically have to rely on what more experienced colleagues teach them when they first encounter an individual who demonstrates pushing behavior.

The following case report demonstrates the clinical application of the Neuro-Developmental Treatment (NDT) Practice Model to severe contraversive pushing behavior. It also shows that determining the underlying cluster of system impairments contributing to the pushing behavior plays a critical role in establishing functional outcomes and developing intervention strategies for this individual who pushes. A broader discussion of contraversive pushing behavior in individuals poststroke can be found in Chapter 11 on stroke.

A3.2 Case Description

Carol R. is a 62-year-old woman who suffered a large right ischemic frontoparietal infarct on November 17, 2008, with resultant left hemiparesis. Her comorbidities are hypothyroidism (well controlled by medication) and a past stroke (~20–25 years previously). Carol and her husband report that she fully recovered from this past stroke and had no residual deficits.

Carol experienced several complications while in the hospital. Her hospital course included a pulmonary embolus, pneumonia, and insertion of a percutaneous enterogastric tube (PEG) on February 4, 2009, for nutritional purposes. This replaced the nasogastric tube she had in situ since her admission. She was moved to the inpatient rehabilitation unit ~2 weeks after her stroke and remained there until her discharge home on March 4, 2009. The stroke team encouraged Carol's husband, Bob, to pursue complex care placement instead of taking her home—Bob refused.

On discharge, referrals to home and community care occupational therapy and physical therapy and to home support (twice a day for personal care) were made. There were no options offered for outpatient therapy; the team felt Carol's prognosis for further recovery was minimal. Carol's swallowing abilities improved gradually once home such that the PEG could be removed by approximately May 2009 (2 months postdischarge from the hospital). Carol began private physical therapy in April 2009.

A3.2.1 Personal Goals

Carol (and Bob's) goals are to "fully regain her function so that she can sew, walk/hike, and work out at the gym, travel, and drive." She wants to be "normal again and get her life back."

A3.2.2 Examination and Evaluation

Social, Environmental, and Contextual Factors

Carol was healthy and active prior to this stroke. She is married to Bob and has three grown children and two grandchildren. Their children and grandchildren live in different provinces. Her children provide emotional support but are not able to provide or assist in any physical care for Carol.

Carol's husband, Bob, is supportive and determined to keep her at home. He is willing to assist in any way that helps her improve, including encouraging her to do as much as she can on her own.

Carol and Bob live in a one-story home in a small town in British Columbia. There are two steps to get into the home from outside. The house is all on one level indoors and is in a community with paved sidewalks and large green spaces. Their yard is full of fruit trees and flowers, and they have a small herb garden.

Participation and Participation Restrictions

At the time of her stroke, Carol had retired from nursing. She owned a one-woman sewing business for children's clothing and rag dolls that she ran from her home. Carol had begun this sewing business while still working as a nurse. She sold these items on consignment at local retail stores and at craft sales and fairs. Her hobbies included reading, swimming, working out at the gym, running and hiking, traveling to see her children and grandchildren, and yard work. She shared the cooking responsibilities with her husband but not cleaning (she happily left this to her husband).

Poststroke, Carol had no cognitive deficits and was able to participate in her partnership with her husband in decisions about the house, family, finances, and so forth. She is chatty and social. Presently, she is not able to participate in her occupational and social activities, such as working out at the gym, walking/hiking with her friends/spouse, performing any aspect of her sewing business, driving to the clothing stores and craft fairs where she sells her products, assisting with the gardening and lawn care, assisting with the grocery shopping, or traveling alone via plane to visit her children and grandchildren.

Activity and Activity Limitations

The following general description of Carol's activity and activity limitations give an overall impression of Carol's functional status at the time of the initial evaluation.

Carol is totally physically dependent on one person for all home and community tasks except for the following:

- Eating at the kitchen table with her right hand once set up and wearing a bib (in a supportive wheelchair).
- Wiping drool from her mouth with a cloth with her right hand when propped up in bed or in her supportive wheelchair.
- Watching TV and reading books while propped up in bed or in her supportive wheelchair.

Observational posture and movement analysis was used to establish and document Carol's baseline functional performance level in functional tasks she performed during the initial evaluation. These same activities were reevaluated and measured periodically, as will be shown later in this case report.

Baseline Functional Performance Measures as of April 2009

1. Transfers (wheelchair bed, lying ↔ sitting, wheelchair ↔ commode, wheelchair ↔ car)
    - Required maximum assist of one person.
    - Helper (always her husband Bob).
        - Performed all wheelchair setup including brakes, footrests, and armrests and positioning of her feet.
        - Braced her feet and used a transfer belt around her midtrunk to pull her to standing and pivot from seating surface to seating surface.
    - Carol (Fig. A3.1).
        - Pushed backward and to the left with right arm > leg during the transfers.
        - Right foot tended to reposition constantly to the right and forward of her center of mass (COM).
        - Trunk remained in marked thoracic flexion with shortening and posterior rotation of the rib cage on the left side, forward head posture with left neck side flexion.
        - Left upper extremity (UE) hung at her side with palpable three fingerwidth glenohumeral subluxation.

    Note: Home and community care home support staff (the care aides) were not allowed to transfer Carol because her transfers were deemed to be too heavy for them to perform. Based on their WorkSafe policies, she would be classified as needing a mechanical lift if the care aides were to perform the transfers.

Fig. A3.1 Carol's sitting posture on initial examination and evaluation.

2. Sit to stand for pulling pants up.
    - Setup, alignment, and assist are as described in list item 1.
    - Once in standing, Carol grabbed onto a clothes dresser or braced her self against the wall so Bob could use one of his hands to pull Carol's pants up.
3. Sit to lying to get into bed to right side.
    - Alignment as described in list item 1.
    - Fell backward and to the left if left unsupported in sitting.
    - Attempted to assist with right arm on bed for sitting to side lying but pushed away and back from the right side and thus was only successful ~20% of the time, requiring constant verbal and tactile cueing to use this arm in a helpful way.
    - Helper lifted full weight of both legs from floor into bed and repositioned legs for comfort.

   - Helper assisted with upper body positioning once in supine.
4. Indoor mobility.
   - Nonambulatory.
   - Occasionally wheeled wheelchair with right hand and right foot/leg short distances only; ~2 to 3 m on smooth, level surfaces in a forward or backward direction.
   - Unable to make turns or negotiate carpets or ramps in wheelchair.

   Note: Carol reported that she stood only once during her inpatient rehabilitation stay.
5. Toileting.
   - Used bedside commode chair only for toileting (not going into bathroom at all) with assistance of husband and caregivers.
   - Assisted as in list item 1.
   - Required supervision of one for balance while sitting on commode.
6. Applying makeup.
   - Wipes her face with a cloth and applies the makeup with her right hand when sitting in a supportive wheelchair in front of a mirror.
   - Trunk alignment is as described in list item 1.
7. Other performance.
   - Once her feeding tube was removed, Carol began once-weekly tub baths at a nearby assisted living facility. A mechanical lift was used to transfer her in and out of the tub. The home support workers bathed her.
   - Carol used a cloth to wipe drool from her mouth with her right hand approximately every 2 to 3 minutes while sitting.

Equipment

Bob built a ramp to accommodate Carol's wheelchair getting in and out of the house. They installed a bedrail under the mattress on the right side (Carol's side) and purchased a lightweight wheelchair with a Quadtro Select Cushion (ROHO, Inc.) and a Personal Backrest (Invacare Corp.). Carol and Bob also purchased a commode chair for toileting because both bathrooms were too small for her wheelchair and a caregiver and a safe transfer.

Carol's Most Significant System Impairments

Neuromuscular

- Inappropriate overrecruitment of right lateral trunk flexors and limb extensor muscles (UE > lower extremity [LE]), specifically, concentric activity of these muscles. Does not accept weight onto the right limbs, with eccentric > isometric muscle contractions. (This is an impairment specific to individuals demonstrating contraversive pushing.)
   - Inability to sustain activity in spine extensor muscles (thoracic >> lumbar and left [L] >> right [R]).
   - Weakness in left hip abductors, extensors, and quadriceps muscles.
   - Weakness in left lateral trunk muscles.
   - Inability to initiate activity throughout left UE, including all of the scapular muscles.
   - Inability to initiate activity in all left LE muscles other than hip abductors, extensors, and quadriceps as described.

Sensory/Perceptual

- Decreased perceptual awareness of midline frontal plane > sagittal plane. (This is an impairment specific to individuals demonstrating contraversive pushing behavior.)

Musculoskeletal

- Tightness in the following:
   - All neck muscles for side flexion, rotation and long pivot extension (L > R).
   - PF muscles; L >> R, and soleus > gastrocnemius muscles.
   - Left lateral trunk muscles (including rotators).
   - Left glenohumeral (GH) internal rotators and adductors.
   - Left metacarpophalangeal (MCP) and proximal interphalangeal (PIP) extensors (fourth digit especially).

Cardiovascular

General Cardiovascular Deconditioning

Clinical Scale for Contraversive Pushing Score = 5.5 (See Chapter 11 on stroke for more details on the Scale for Contraversive Pushing.[2])

Individuals poststroke who demonstrate pushing behavior have system impairments similar to those of individuals poststroke that do not push. These include impairments in the neuromuscular system, such as the inability to initiate or sustain activity and weakness in the muscles on the more involved side of the body (trunk and limbs); the musculoskeletal system, such as shortening of muscles and other soft tissues, typically on the more involved side of the body (trunk and limbs); the sensory/perceptual system, such as loss of or diminished awareness of proprioception, light touch, and midline orientation; and the cardiovascular system, such as decreased endurance. However, as was discussed in Chapter 11, individuals who demonstrate contraversive pushing poststroke also have a subset cluster of impairments specifically related to the pushing behavior. In Carol's case, the impairments specifically related to her pushing behavior are the inappropriate overrecruitment of activity in the right lateral trunk and limb extensor muscles (UE > LE); specifically, concentric activity of these muscles (she does not accept weight onto her right side (trunk and limbs) with eccentric greater than isometric muscle contractions, and her decreased perceptual awareness of midline in the frontal greater than sagittal planes.

A3.2.3 Intervention

Private home-based physical therapy began April 10, 2009. She was seen approximately twice a week for therapy sessions between this time and the fall of 2010. After this time, the frequency was approximately once a week until the spring of 2011. This case report covers the time up to the end of May 2010. Carol's therapy continues (after the spring of 2011) with bursts of sessions on an ongoing basis. She continues to make steady, slow gains. Included at the end of this case report is an addendum with Carol's progress after the spring of 2010.

Individuals who demonstrate pushing behavior have system impairments similar to those of individuals who demonstrate more typical poststroke impairments, plus a subset of impairments specifically related to the pushing. This subpopulation of individuals poststroke who demonstrate contraversive pushing behavior requires a further collection of intervention strategies and ideas to address their specific collection of impairments. A more detailed collection of these strategies can be found in Chapter 11.

Examples of the intervention activities used with Carol during her therapy sessions follow. Throughout the therapy sessions, the therapist strived to keep Carol's left hand/arm in closed chain setups where possible; this occurred more during the mid to later time frame when the need for trunk and leg cues and support decreased and the therapist had a free hand occasionally.

Therapy sessions occurred in her kitchen, sewing room, outside in the yard and garden when the weather permitted, in her bedroom, in her two bathrooms, and at the community pool. The activities were varied to keep her and the therapist's interest. Her husband was present during all the sessions (other than when in the pool—he used this time for respite). Bob both helped as needed and also learned from what was done during the therapy sessions so that he could carry over the practice strategies between therapy sessions. Fig. A3.2 shows a kitchen activity working in the postures of liftoff and squat.

The intervention activities are divided into three phases; early-, mid-, and late-phase time frames to show some of the intervention progressions made as Carol's pushing tendencies decreased and as her strength and function improved.

Fig. A3.2 Functional tasks in the kitchen in liftoff and squat.

Intervention Strategies for Carol

Early-Phase Strategies (April 2009–August 2009)

1. High sit ↔ liftoff from various surfaces including the following:
   - Wheelchair.
   - Kitchen chair.
   - Armrests of the couches.

   While lifting off, she was reaching for objects
   - On the floor (to keep the right leg extensors working more in flexion and with eccentric activity).
   - Forward and at shoulder height level (that is, shoulder height from a sitting position).
2. Rising and lowering small distances from a midsquat position.
3. Scooting forward and low pivot transfers to the right (only to the right in the early phase) between the following:
   - Wheelchair ↔ kitchen chair.
   - Wheelchair ↔ commode chair.
   - Wheelchair ↔ bed.
   - Wheelchair ↔ sewing stool.
4. Walking around her house with either a straight cane or an adapted two-wheeled walker (Fig. A3.3). This activity required maximum assistance of one person. She had an AirSport Ankle Brace (Aircast, DJO Global) on her left ankle and a curling slider on her left shoe. Curling slid-

Fig. A3.3 Walking in her home with a straight cane, an AirSport Ankle Brace (Aircast, DJO Global) for ankle stability and a half curling slider to decrease the effort of swing phase. Use of a flexible ankle support to provide stability during standing, transfers, and walking activities, such as the AirSport Ankle Brace versus using a rigid or articulated ankle-foot orthosis early on in rehabilitation allows for motor recovery to occur without restricting mobility. A half curling slider decreases friction, thus decreasing the effort for the patient to bring the foot through in swing phase (assists the helper too if he or she is bringing the foot through).

ers are hard plastic pieces that attach to the soles of shoes used in the ice sport of curling. They slide on the ice with very little friction. One of the tasks the helper needed to do was swing and place her left foot 100% of the time.

Home Practice Strategies during This Phase

- Carol and Bob borrowed a recumbent bike from a neighbor in the late summer of 2009 to address her deconditioning. Her right foot needed to be tied to the pedal, and Bob frequently needed to help initiate the revolutions. She pedaled ~10 to 15 minutes every other day.
- Reaching to the floor toward the right front wheel of her wheelchair when sitting in her wheelchair.
- Sticky notes were place around her house to cue her orientation to midline. These were placed on walls or objects in locations where she typically sat during the day, such as on the kitchen wall across from her at the kitchen table and on the TV stand.

Midphase Strategies (September 2009–December 2009)

1. Carol continued with activities as in the early phase plus added the following activities.
2. Swimming at the community pool once a week. Carol had been a regular pool attendee for exercise prior to her stroke and wanted to return to the pool for walking practice, exercise, and to enjoy the hot tub. The children's pool at the community recreation center was used. This had warm water, a sloped entry, was only 3 ft at its deepest, and had benches around the sides in the deeper end. If there were others in the pool, jets could be turned on that created waves. There were also benches in the hot tub. Activities in the pool included the following:
   - Floating on her back and kicking her legs (flexion/extension and abduction/adduction).
   - Floating on her sides and trying swimming strokes.
   - Moving from floating on her stomach to standing.
   - Sit to stand from the benches in the pool water.
   - Squats and squat walking.
   - Trunk stretches.
   - Leg pushoffs from the side wall of the pool → lying on her back.
   - Arm pushoffs from the side wall of the pool → lying on her stomach.
   - Walking at different speeds and turning.

   Note: All the activities in the pool required assistance of one or two people. In the early sessions in the pool, she required maximum assistance of one (and sometimes the assistance of a second person) to get in and out of the pool, for the standing and walking activities, and for the showering and dressing aspects of the pool visits. She sat on a bench or chair during the showers in this phase and used a water wheelchair to get to and from the pool and hot tub from the change room.

   The last 15 minutes of each session were spent in the hot tub. Early on, Carol transferred from a water wheelchair to the edge of the hot tub and needed one or two people to help her in and out of the hot tub.
3. High sit ↔ stand while reaching for objects up high and slightly to the right.
4. Standing to squatting low while reaching for objects down and to the right.

   For both items 3 and 4, her right arm was often doing the reaching while in contact with an object in a modified chain activity, such as using a cloth to dust the furniture or to slide her hand along a door or door frame.

   Standing and tapping/stepping with her right leg; again, the right arm/hand was usually busy with a task, such as reaching for or holding an object relevant to the environmental context.

5. Sit ↔ stand from a raised toilet seat in her en suite bathroom. As described earlier, Carol's wheelchair did not fit into her bathrooms but she was able to walk into them with the therapist's assistance to practice transfers on and off the toilet and later, into and out of the shower.
6. Walking around her house; a little outdoors walking on the grass and sidewalk was added in this phase. She used primarily a straight cane versus the modified two-wheeled walker because of the tight spaces indoors and the uneven surfaces outside in the yard. She continued to wear the AirSport Ankle Brace and the curling slider. She was now able to swing her left leg through about half of the swing distance ~20% of the time.
7. Stairs—she attempted to work on the two steps in the garage to house entrance and the one step from her sidewalk to deck outside in the yard, but Carol would panic, and her pushing would increase to the point of becoming unsafe for herself and the therapist.

   Note: The therapist wanted to work on the stairs with Carol because they were functional for her and a useful activity to decrease pushing tendencies by challenging the legs, in particular, to coordinate their activity reciprocally. However, work on the stairs, even two small steps, was so stressful for Carol that the decision was made to leave this for later.

Home practice strategies during this phase included activities as described in the early phase plus the following:

- Sit to stand very slowly for a few repetitions at the kitchen table before and after meals (this occurred more than 10 times a day).

Later-Phase Strategies (January 2010–May 2010)

1. Carol continued with some of the activities from the midphase and added the following.
2. Sit ↔ stand from gradually lower surfaces.
   - Lower couches (beginning with pillows on them to make them a little higher and then gradually removing the pillows until she was sitting to and from the regular height of the low couches).
   - Regular toilet seat.
   - Built-in seat in the en suite shower.
3. Stepping into and out of the bathtub (in one bathroom) and the shower stall (in their en suite bathroom).
4. Wheelchair ↔ van transfers through standing and stepping up and down to and from the van level on the passenger side.
5. Pool progressions—Carol was now able to walk to the edge of the hot tub from the pool, sit on the raised wall, and perform a scoot transfer across the wide wall and down into the water with one person assisting. She used the stairs (up and down over the edge) to leave the hot tub. These were the first stairs Carol could and would do without panicking. As she was motivated to get into the hot tub, the stairs were the means to the end. Carol was also highly distractible; the activity on the pool deck with other swimmers functioned to distract her from her fear of the stairs.

   Note: The activities in the pool during this phase required the assistance of only one person. Most days she would walk from her wheelchair at the entrance to the pool deck, into the pool (down a ramp), to the hot tub from the pool, and from the hot tub into the changing room. She typically stood during her shower and for dressing. The helper would do all the showering and dressing tasks while Carol balanced herself using a wall grab bar with her right hand. She would sit in her wheelchair in front of the mirror and brush her hair and put her makeup on using her right hand.
6. Stairs
   - In and out of the hot tub at the community pool (Fig. A3.4).
   - The two steps from the garage into their home.
   - From her sidewalk in the backyard up onto the deck.

   Once Carol realized she was safe on the hot tub stairs, she was able to overcome her fear and would go up and down the stairs into their home and in the yard.
7. Walking—when the weather allowed, Carol walked longer distances in her yard on the grass and sidewalk, in their driveway, and on the sidewalk in front of their home toward the neighbor's house. The outside

Fig. A3.4 Practice at the community pool—a regular activity of Carol's from before her stroke.

walking was all with a straight cane. She continued to wear the AirSport Ankle Brace and the curling slider on her left ankle and shoe, respectively. She was now able to swing her left leg/foot through with occasional assist for final accurate placement ~50% of the time on smooth indoor surfaces.

Home practice strategies during this phase included activities as described in the early and midphases plus the following:

- Bob took Carol for walks in the house one or two times a day.

On days when Carol was challenged significantly with respect to being perceptually shifted (i.e., actively), increasingly loaded on the left side of her body, she would become diaphoretic, come close to fainting, and usually vomit. This occurred one or two times a month during the early and midphases of intervention. The frequency of this response decreased over time, occurring only very occasionally and usually when she resumed therapy sessions after a break period.

A3.2.4 Outcomes

Observational posture and movement analysis was performed periodically during the course of intervention to document improvements in Carol's function and a reduction in her impairments. Carol's functional performance measures as of May 2010 are listed in Table A3.1.

Comparing Carol's baseline functional performance of April 2009 to the same activities listed in Table A3.1 from May 2010, it is of significance to note that, as of May 2010, she had made the following improvements:

- Required less help from her husband and caregivers in all tasks, but particularly for transfers, dressing, toileting, and bathing.
- Was able to walk into their bathrooms with her husband's assistance and use a raised toilet seat for toileting versus relying solely on a bedside commode.
- Was able to walk indoors and short community distances with the assistance of one person (she was nonambulatory at the time of the initial evaluation).
- Was beginning to return to her hobby of sewing, with assistance.
- Was regularly attending the community pool for therapy.
- Was no longer drooling.

A3.2.5 Addendum on Further Gains after May 2010

- Showering at home once a week with Bob's assistance. Carol steps into the shower stall and sits on the built-in shower chair. Bob provides maximum assistance with the transfer in and out. Once seated, Carol assists with the showering using a handheld shower.
- Sit ↔ stand from a wheelchair with setup (left foot and hand placement), close supervision, and verbal cues only.
- Standing unsupported (i.e., without the use of her right hand on a grab bar) for brief periods in the bathroom and shower areas and while a caregiver retrieves items.
- In the pool and hot tub, she can now sit on her own on the benches when the jets and waves are on.
- Carol is able to volitionally extend and flex her left knee and dorsiflex her left foot in about half the available range—examples of continuing motor recovery.

A3.3 Discussion

In today's health care environment, clinicians in acute care settings are being asked to make recommendations and decisions about where to discharge or transfer individuals who have suffered a stroke. These tasks are often required within hours to a few days after the stroke event. Clinicians are being asked to decide who should be transferred to home, to an inpatient rehabilitation bed, or to a slow stream facility, or who should be discharged to a long-term care facility where active rehabilitation rarely occurs. Individuals who demonstrate contraversive pushing tendencies often present with profound paresis and are heavy and challenging to work with from a physical perspective. Positive outcomes are possible and should be expected with this population but are often not anticipated and thus not pursued.

When clinicians do not understand the subset cluster of impairments of the individual who presents with contraversive pushing behavior, they may struggle to make effective and efficient intervention choices. As discussed in the introduction section of this case report, improvement in functional outcomes can be expected with this population of individuals poststroke with therapy, even with persisting paresis. The sooner the pushing behavior is minimized or resolved with these individuals, the greater the opportunity is for them to make significant functional gains. In Carol's case, there was a delay of 5 months for the initiation of therapy to specifically address and to mediate her pushing behavior impairments. However, as demonstrated in Table A3.1, meaningful functional gains occurred and are continuing to occur on an ongoing basis. This case report adds to the clinician's examination and intervention toolbox when working with individuals who demonstrate contraversive pushing behavior.

A3.4 Alternate Reflection

Bonnie Jenkins-Close (Acute Care Physical Therapist)

The outcome might have been different in this case if, during Carol's acute rehabilitation stay, she had been provided multiple opportunities to stand. An environ-

Table A3.1 Functional performance measures for Carol—May 2010

Activity	Functional performance measure
1. Transfers (wheelchair ↔ to kitchen chair, wheelchair ↔ to bed)	• Required assist of one for many verbal cues. ∘ For movement/sequence needs. ∘ To position left foot and maintain left hip/thigh alignment. ∘ To provide light contact on left lateral thoracic area to keep weight shifting forward and to the right. • Moved to right side only (intervention strategy). • Used right arm on wheelchair armrest or seat of chair/bed. • Intermittently pushed through left arm if placed and maintained in place by helper. • Surface heights were similar. • Typically took two to three increments to complete transfer.
2. Sit to stand for pulling up pants	• Required assist of one for frequent verbal cues. ∘ For movement/sequence needs. ∘ To position left foot and maintain left hip/thigh alignment. ∘ To provide light contact on left lateral thoracic area to keep weight shifting forward. • Needed verbal cues once standing to guide right hand to pull left side of underwear and pants up. • Required close supervision once standing and frequent light contact to regain balance (two to three times during the entire task) while pulling pants up. • Used right hand only for task; left hand/arm hung passively at side. • In standing, left hip deviated laterally with left knee hyperextension 10/10 times. • Took ~10 minutes to complete entire task.
3. Sit to lying to get into bed	• Independently sat at side of bed and lowered upper body to mattress with verbal cueing. • Able to initiate lifting of legs onto bed. • Brought right leg into bed on own but required assist of one to lift left leg over mattress lip and to finish positioning legs under covers. • Did not use left arm at all; hung at side.
4. Walking (indoors)	• Required assist of one on left side to swing foot through 50% of the time and to provide verbal and light tactile cues on right shoulder for alignment of trunk in the frontal and transverse planes. • Without tactile cues on left hip abductors, the left hip deviated laterally and left knee hyperextended 10/10 steps. • Typically used a single point cane, curling slider, and AirSport Ankle Brace (Aircast, DJO Global) on left foot. • Walked indoor distances—walked around house for 30–40 minutes without resting if interspersed with squat, reaching, and standing activities. • Step lengths were right 12 in, left 11 in (helper placed left foot 50% of the time). Width of base of support = 31 in (outside of left foot to tip of cane).
5. Walking (outdoors, public places)	• Walked between the change room at the community pool, the pool, and the hot tub on pool deck surfaces (distances of 15 m each). • Began walking short outdoor distances in therapy sessions on grass, paved driveway, and community sidewalks.
6. Sitting down on toilet with a 6 in raised toilet seat	• Required frequent verbal cues to flex forward at hips and descend vertically over her center of mass (COM) versus descending posteriorly behind her COM and falling against toilet tank. • Required assist of one on posterior thoracic area to keep hips and knees flexing and COM over feet versus posterior to feet. • Descended with control until final 3 in and then rapidly and roughly landed on raised toilet seat without control. • Used a wall-mounted grab bar on the right side; required frequent verbal cues to position her right hand on bar.
7. Showering at the community pool	• Stood with right upper extremity support (on wall grab bar) for duration of shower while helper performed all other tasks, such as removal of bathing suit, donning clothes, applying the shampoo and conditioner, and toweling her off. Her shoes and socks were put on by the helper while Carol was sitting. • Able to let go of wall bar on right for short durations to assist with washing and rinsing hair and to put right arm in sleeve with close supervision and verbal cues for alignment before releasing. • Entire task took ~10–15 minutes.

(continued)

Activity	Functional performance measure
8. Sewing tasks (stitching lines, threading needle, pinning and cutting material on patterns)	• Stitching material with machine. ◦ Sat in wheelchair, using right hand only, able to turn machine on and guide material through needle for stitching lines, unable to thread needle. • Pinning and cutting material on patterns • Sat on high stool and able to lay out material on patterns on table for cutting. • Required one person to hold material while she pinned pattern paper to material and cut material out with her right hand. • Left arm hung at side unless helper placed and maintained hand on table. • Left arm occasionally actively assisted with support/balancing once placed on table.
Others	• Had not used her “drool cloth” since October 2009 despite frequently requesting it just in case she still needed it.

Note: Trunk remained flexed during all activities (thoracic flexion > lumbar flexion).

ment organized to structure her space might have provided internal orientation to the upright posture. The setup, which might be difficult at first, becomes easier in subsequent sessions. There are many options available in the clinic to enforce “no-lift” policies, and when used in conjunction with the Neuro-Developmental Treatment Practice Model, they can be beneficial with the more complicated, dependent client, including the individual who demonstrates contraversive pushing. Overhead lift systems run on ceiling tracks and use slings that can provide partial-body-weight support in upright postures and through transitions to upright. In addition to all the documented benefits that being upright provides, individuals who push also lack the ability to move in a forward direction over their base of support. This lack of ability to move forward often results in limited ability for the tibia to move over the talus, resulting in a supinated hind foot and decreased ability for the first ray to contact the floor. This inability for the tibia to translate over the talus can lead to soft tissue shortening in the calf muscles, further compromising the ability to passively and actively dorsiflex at the ankle.

Carol’s fear of moving forward was reinforced by this limited ankle mobility, contributing to her increased assist level in transitioning between sitting and standing from various surface heights. When the tibia cannot translate forward, increased lateral weight shift is necessary, leading to an inability to stabilize with the hip abductors and extensors, which, in turn, also contributes to foot supination.

With or without an overhead support system, Carol could have had practice moving in such activities as forward direction while stepping with her right LE, reaching forward and up with her right UE, and reaching up and backward with her right UE, to promote increased thoracic extension, and increased left hip stability, while moving over her base of support.

If Carol had had the experience of moving forward over her feet while stable and aligned in standing in the early phase of her recovery, it is possible that many of the impairments she demonstrated, such as gastrocnemius–soleus muscle shortening, hip abductor and extensor muscle weakness, and the inability to sustain thoracic extensor muscle activity, would not have developed or been as profound. Her functional outcomes may have progressed faster and may have been achieved with less effort on both Carol and her therapist’s part.

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Case Report A4 Addressing the Primary and Secondary Impairments of a 20-Year-Old Man with Traumatic Brain Injury

Teresa Siebold

A4.1 Introduction

Severe traumatic brain injury (TBI) may cause primary impairments, including reduced (or absent) muscle activation and motor execution as well as spasticity.[1] Depending on the severity and the conditions of the acute and subacute recovery phases, years of immobility and malalignments may be incurred and can lead to significant secondary impairments. Complete and partial bed rest, as a medical order and as a by-product of resources required to mobilize, is often an issue in the acute and subacute phases postinjury. However, immobilization of body segments, such as the affected feet and ankles or wrists and hands, is an ongoing concern. Unfortunately, well-meaning therapists often contribute to this immobilization with splints, braces, and positioning devices.[2,3]

Secondary consequences of the primary impairments and ensuing immobilization include joint deformities, muscle atrophy, soft tissue composition changes, further sensory changes, and cardiorespiratory compromise.[4] Physical therapists (PTs) and occupational therapists (OTs) understand these effects of immobility on the various systems of the human body, yet practitioners often intervene with these systems in isolation, focusing on one issue at a time.

This case report reviews the recovery of an individual with a severe TBI, highlighting the significant relationship between the musculoskeletal system and the neurological system.

A4.2 The Clinical Relationship between the Musculoskeletal System and the Nervous System

The muscles and joints of the ankles and feet are commonly affected by spasticity, overrecruitment or overflow activity, poor positioning, and immobility. Maintaining normal alignment and mobility in these areas is crucial for shock absorption, balance reactions, efficient weight bearing, and sensory feedback.[5] In addition, the foot and ankle complex influence the biomechanics of other joints and muscles up the kinetic chain because adults spend the majority of their day functioning in upright positions (sitting, standing, and walking activities). Neuro-Developmental Treatment (NDT) principles can be used in conjunction with orthopedic knowledge and strategies to address not only the primary impairments caused by TBI but the secondary joint and soft tissue issues related to reduced, absent, or abnormal movement patterns.

A4.3 Case Description

Ernie is a 20-year-old man who suffered a TBI as a result of a motorbike accident (MBA). He was 17 years of age at the time of his accident and was a healthy, active high school student who enjoyed history, politics, and snowboarding. The MBA left him with bifrontal contusions, a diffuse axonal brain injury, and a large arachnoid cyst. In addition, he had a left wrist fracture and multiple fractures of the spine with no spinal cord involvement. His family was given a very poor prognosis for any recovery of cognitive or physical function.

Although Ernie's family understood the prognosis, they chose to be supportive, hardworking, and devoted to any recovery he could achieve. As such, 15 months after the MBA, the family contacted an NDT-certified PT. This case study began in Ernie's home, after he had already received intervention in an acute neurology unit, rehabilitation from an inpatient unit, and a brief experience with an outpatient program. Intervention took place in his home once a week for 8 months, then once a month for ~ 5 months, and then once every few months until a total of 21 months had passed from our first meeting. This home-based functional physiotherapy approach, combined with the dedication of Ernie's family and home care worker in following through with recommended activities, ensured regular practice and thus his recovery and success.

A4.3.1 Examination

Client and Family Goals

The expressed goals of Ernie and his family were to decrease the amount of assistance required for transfers and mobility, as well as to increase his tolerance for activities and improve his quality of life (i.e., standing and walking activities).

Baseline Functional Performance

Ernie lives at home with his mother, father, and older brother. The family converted the television room on the main floor of the home into a bedroom for him. He had not been up the 12 stairs to his previous bedroom since before his TBI. Because the television room is sunken, the family built a ramp for Ernie's access. This ramp can be moved to the step into the kitchen or to the step up to the bathroom. Ernie is completely dependent for all of his activities of daily living (dressing, bathing, toileting, feeding) and mobility. He has been wheelchair dependent since the accident (Fig. A4.1).

The following paragraphs describe two of Ernie's functional activities to demonstrate his abilities at the time of initial evaluation: transferring from the wheelchair to the bed and standing for dressing.

Wheelchair to Bed Transfer

Ernie's mother first positioned him in sitting, close to the edge of the bed. Ernie attempted to help with some of the movements, mostly using a forward head and neck pattern and pulling his left upper extremity (UE) toward adduction and internal rotation. In sitting, he remained in a posterior pelvic tilt with a significantly rounded low back and thoracic spine. As a result, his neck was in suboccipital extension with his head dropping to the left and down to his chest.

Fig. A4.1 Ernie in a common wheelchair sitting position early in his intervention program.

Ernie's family and caregivers attempted to place his feet under his knees in preparation for the transfer. However, due to an equinovarus position, he was unable to bear weight on the plantar surfaces of his feet (Fig. A4.2). His weight-bearing surfaces were primarily the lateral borders of his fourth and fifth metatarsals toward their metatarsal heads. Left ankle dorsiflexion (after realignment and overpressure) was approximately − 8° and right was approximately − 10°.

One person was in front of Ernie to move him forward over his feet and help with lifting his buttocks off the bed. The second person to assist with the transfer was behind Ernie, helping to lift and guide his hips to the chair/wheelchair. The transfer was performed quickly, and Ernie remained passive during the movement. Throughout the transfer, his entire trunk was in flexion, including the cervical, thoracic, and lumbar areas. His ankles never achieved neutral alignment (in either dorsiflexion/plantar flexion or inversion/eversion).

Fig. A4.2 The equinovarus position of Ernie's bilateral lower extremities.

Standing for Dressing/Fixing Pants

Ernie stood with three people supporting him. One person was at Ernie's right lower extremity (LE) to ensure that his knee neither hyperextended nor buckled into flexion. A second person was required at the left leg to limit the overactivity that pushed him into extension and to the right. Repositioning of the feet was required to ensure at least partial weight bearing on the plantar aspects of his feet and to prevent injury to Ernie's ankles. As such, his feet tended to be placed far apart (hip abduction) and in toe-out positions (hip external rotation), increasing the width of his base of support (BOS) to ~ 35 cm (13.75 in) measured from the third digit of each foot. The third person was behind Ernie, in high kneeling on the bed, and supported him through his chest and shoulders, while also providing assistance at his gluteal muscles and hips to maintain hip extension. Later, a wall was used to support Ernie's trunk in standing, and the third person could then come in front of him and talk with him to work on head and neck alignment and control. Ernie's alignment was with trunk and hips behind his BOS and to the right (Fig. A4.3).

Table A4.1 outlines Ernie's level of functioning within the International Classification of Functioning, Disability and Health (ICF) framework at the time of initial evaluation. It is worth noting the additional positive features that contributed to his ongoing practice and success over time:

- Motivation.
- Body awareness.
- Strong family and friend support systems.
- Knowledgeable and dedicated home care support worker.

Fig. A4.3 Ernie's standing against a wall required three people for safety and alignment (photographer assisted at right foot and ankle). Note that Ernie's feet are toed out, abducted, and 18 cm (7 in) from the wall to accommodate the equinovarus restrictions.

Summary of Most Significant Single-System Impairments of the Neurological and Musculoskeletal Systems

Trunk

- Overlengthened trunk extensors.
- Weak trunk muscles; extensors > flexors.
- Unable to sustain activity in trunk extensors and flexors for stable, coactivated trunk.
- Tight but not fixed interspinal segments.

Head

- Weak cervical muscles; extensors > flexors.
- Inability to sustain activity in cervical extensors; long > short for stable, coactivated cervical spine.
- Shortened neck side flexors on R (scalene muscles and sternocleidomastoid).

Oral motor

- Weakness of oral-motor muscles.
- Inability to sustain activity in oral-motor muscles.

Left UE

- Recruiting most muscles in a cocontracting manner (agonist and antagonist contracting simultaneously)
- Inability to separate and grade muscle activity between agonist and antagonist, as well as synergistically.
- Weakness and inability to sustain activity in all left UE muscle groups.
- Tightness in long finger flexors.

Table A4.1 Using the International Classification of Functioning, Disability and Health (ICF) to outline initial clinical evaluation

Participation/restrictions	Functional activity/limitations	Observations of posture and movement
• Dependent for all mobility in home and community, including ambulation and transfers. Mother pushed manual wheelchair.	• Unable to sit without one-person assist on typical surfaces.	• Sat or stood in trunk flexion with post–pelvic tilt and suboccipital extension.
	• Required full wheelchair back support.	• Complained of pain and fatigue.
	• Required full assist of two people for low-pivot transfers.	• Hyperextended left knee in standing.
	• Required full assist of three people for standing (one on either side, one behind).	• Pushed into extension and to weaker right LE by overactivating left leg muscles.
		• Left pelvis in posterior rotation; hips behind BOS.
		• Left foot and ankle pulled into equinovarus pattern of ankle when standing (plantar flexion, inversion, talus abduction).
		• In sitting, left calcaneus rested in inversion, talus in abduction, with ankle in plantar flexion.
		• Able to actively move partially out of equinovarus posture for better positioning in wheelchair or in preparation for transfer.
		• Left passive dorsiflexion to neutral, with knee flexed and significant overpressure.
• Unable to engage in eye contact with family, friends, or therapists during conversations.	• Inability to right head on body.	• When one person supported head, neck pulled into position of suboccipital hyperextension.
	• Required one person assist to hold head up.	
	• Unable to scan his environment.	• Head fell to left and down to chest when not supported.
• Unable to eat out with family and friends.	• Unable to manage oral secretions.	• Mouth remained open with jaw dropping down; became wider with excitement or frustration.
	• Frustrated by family and friends using cloths to wipe away drool.	• Difficulty closing jaw.
	• Required one person assist for managing oral care.	• Drooled.
	• Unable to bite or chew food independently.	
	• Required one person assist for providing appropriate texture to diet, as well as feeding Ernie.	
• Unable to verbally communicate wants or needs—increased time and effort to communicate.	• Unable to show many facial expressions.	• Unable to gesture with right UE.
	• Required one person to ask specific, single-sentence questions.	• Able to reach with left hand for a "high five."
	• Communicated with left thumb extension for "yes,", pinky extension for "no."	
	• Gestured "hello" by raising left arm up (to head height).	
• Dependent for all basic activities of daily living.	• Unable to use left UE in functional reach (e.g., food, drink, or grooming).	• Able to partially relax tone in right UE to command for positioning and comfort.
	• Unable to grasp or manipulate objects (i.e., open lids on jars, operate pens, hold pictures).	• Rested in a position of significant humeral IR with forearm pronation, wrist and finger flexion.
	• Unable to use right UE for function.	• Elbow often extended.
	• Unable to use right UE for bilateral activities.	
• Unable to participate when ambulatory activities required.	• Unable to safely use (i.e., at risk of ankle or knee injury) right LE for bilateral weight-bearing activities, such as standing transfers, standing activities, or walking.	• When standing, locks right knee, or knee gives way into flexion.
		• Minimal active weight bearing through right LE.
		• Hips behind BOS in standing.
	• Caregivers concerned he may sprain his ankle during transfers or standing activities.	• Right ankle resting in equinovarus posture for prolonged periods of time.
		• Unable to actively recruit right dorsiflexors for positioning or preparation for function.
		• Passive right dorsiflexion to − 10° with knee flexed and significant overpressure.

Abbreviations: BOS, base of support; IR, internal rotation; LE, lower extremity; UE, upper extremity.

Right UE

- Weakness of bicep and pectoralis major muscles—only volitional flickers observed.
- Shortened long finger flexors.
- Inability to initiate activity in the other right UE muscles.

Left LE

- Shortened gastrocnemius/soleus complex, as well as other soft tissues surrounding foot and ankle joints.
- Weakness in left knee flexors, hip extensors and abductors, and ankle evertors and dorsiflexors.
- Inability to selectively recruit and grade muscles within the left leg (between flexors and extensors, between abductors and adductors).

Right LE

- Shortened gastrocnemius/soleus complex, as well as other soft tissues surrounding all foot and ankle joints.
- Weakness of all right LE extensors and flexors.
- Inability to sustain activity of all LE muscles.

A4.3.2 Evaluation and Plan of Care

Limited time for intervention (1 hour a week with an NDT-trained therapist), environment (his home), and stage of recovery (15 months post-TBI) demanded that Ernie's care plan be prioritized and function-based. There were expectations that the family and home care worker would be able to follow through with activities, as well as ensuring that Ernie remained motivated and engaged in the activities. To achieve both of these criteria, NDT principles of active, upright, and loaded (weight-bearing) positions while incorporating the more affected extremities during meaningful tasks were used.

To achieve these upright, weight-bearing positions, however, required better alignment of the LEs. Normal movement cannot occur in the presence of abnormal alignment.[6] As such, priority was placed on stretching, mobilizing, and realigning Ernie's feet and ankles using both orthopedic manual therapy strategies and functional postures and activities that used his body weight to assist with LE stretching while he was engaged in functional activities.

The significant malalignments of Ernie's feet and ankles were hypothesized to be primarily due to changes to the length of muscles and soft tissues. There were certainly adhesions of his joints and tendons; however, there were no fixed contractures or areas of heterotopic ossification (hard or bony end-feels). Overrecruitment of his plantar flexors and invertors caused his ankles and feet to assume the equinovarus position for the majority of the day. This prolonged poor positioning caused shortening of the intrinsic flexor foot muscles, plantar flexors (gastrocnemius–soleus complex) and invertors (tibialis posterior), and overlengthening of the dorsiflexors (tibialis anterior) and evertors (peroneals), thus making recruitment of the latter two muscle groups difficult.

The equinovarus positioning contributed to the poor alignment and impairments in muscles throughout the entire lower extremities, trunk, and upper extremities. Ernie stood with his left knee in hyperextension and his left pelvis/hip in posterior rotation. He had contraversive pushing tendencies and pushed into the lateral border and toes of his left foot. Thus his trunk was shifted to the right and back. However, the right leg was unable to support the weight, and he would either hyperextend the right knee for stability or it would collapse into flexion due to weakness. When in contact with the ground, the weight-bearing surfaces of the right foot were primarily the toes (third through fifth digits) and the lateral border of the foot.

As a result of this unstable BOS, asymmetrical alignment, and unequal weight bearing, Ernie did not feel safe or balanced. This led to even more overactivation of his left LE extensors and plantar flexors, feeding into the asymmetrical alignments, and causing the family and caregivers to provide significant support to him. Everyone, especially Ernie, was frustrated and fatigued.

A4.3.3 Intervention

Although the focus was on realigning the feet and ankles, the other impairments were not forgotten. The NDT Practice Model advocates addressing biomechanical and kinesiological principles to achieve the best possible alignment and conditions for appropriate muscle activity. Intervention began with closed chain activities and functional and meaningful movement patterns to achieve increased sensory feedback through joint compression and mechanoreceptor stimulation. It was important to activate the muscles of Ernie's LEs within normal synergies while performing the stretches and mobilizations to his feet and ankles. Active, closed chain positions balance agonist/antagonist activity, load the individual's own body weight into the limb, and use eccentric/concentric contractions.[7] In addition, the vertical orientation stimulates the reticular activating system, which increases the level of alertness and was motivating to Ernie.

Table A4.2 outlines the activities chosen and the progressions made for achieving the therapy priority of foot and ankle realignment during active, upright, and weight-bearing positions to allow Ernie to transfer more safely and with less assistance. Most tasks were performed with bare feet to allow the family and the therapist direct contact with his ankles and feet for safe alignments and facilitation (including mobilization of the joints and soft tissues) (Fig. A4.4, Fig. A4.5). All movements and activities were attempted from a position of talar neutral.[8] The feet were then placed on the floor while maintaining this alignment. Some ankle plantar flexion (PF) was necessary. However, due to hypertonicity and/or short plantar flexors.

Table A4.2 Activities performed during therapy including alignments and handling

Position	Activities performed	Handling/assistance provided
Sitting on edge of bed with UEs resting on the back of a wingback chair placed in front of Ernie. Placing his UEs on a surface increased his trunk activity and stability. To ensure a stable sitting surface, a 1-in piece of solid wood was placed on top of the mattress for Ernie to sit on. • Bare feet.	Looking at pictures of himself, his family, and friends. The pictures were positioned to encourage weight shift forward to the point of liftoff (lift pelvis/hips off bed to load feet and ankles). • Hold as long as tolerated (goal = 15 s). • Varied the amount of knee flexion (how high lifted up), the duration of the hold and the speed of liftoff and lowering. This variety ensured the type of muscle contraction was adjusted (concentric, eccentric, or isometric) and the ROM demands on the ankle and foot were altered.	• One person to facilitate forward weight shift over UEs and liftoff. • One person at each of right and left feet to ensure increased dorsiflexion as body weight shifted over foot (keep heels on floor) while providing calcaneal and navicular pronation mobilization/hold.
Prone standing (see Fig. A4.4)—using a massage table at highest setting, two pillows under Ernie's chest as he rests torso and UEs on massage table. Prone standing allows for loading and challenging of the LEs while reducing the demands on the trunk and LEs. Thus concerns related to balance or safety and the amount of work required of helpers are also reduced. • Bare feet.	• Standing with knees slightly flexed for as long as tolerated (for prolonged stretch to ankle plantar flexors [specifically soleus], invertors, and other soft tissues). • Progressively disadvantaged his less involved left LE, first in modified closed chain setups and then to open chain activities. Examples include tapped left heel (unable to toe tap), wiggled left foot out/in, step left foot out/in, step left foot forward/backward. This decreased the amount of pushing activity from the left LE, while increasing the demand and active loading activity of the right, weaker LE.	• One person required at Ernie's head and torso to ensure comfort and safety (neck position, breathing, swallowing, and UE position) • One person at each of right and left feet to ensure maintenance of ankle dorsiflexion (keep heels on floor) while: ∘ Therapist provided calcaneal and navicular pronation mobilization/hold (see Fig. A4.5). ∘ Also able to provide physical cues to left LE to ensure more typical movements achieved (i.e., limit amount of unwanted activity from left LE during stepping).
Standing against wall introduced at 18 weeks. • Heels placed ~1 in away from wall, BOS from third digit of each foot = 35 cm (13.75 in), knees flexed ~20°. • Bare feet.	Looking at pictures of himself, his family, friends, and motorbike (before and after the accident). Looking at brother, father, or mother when spoken to. • Weight shifting between right and left lower extremities—allowing Ernie to feel off balance to right with left LE pushing, then finding midline and recognizing this midline alignment and balance point. • Wall slides/squats to 20–45° knee flexion, hold for varying lengths of time; again, this modification encourages different types of muscle contractions through various ranges of motion. • Promote loading of more involved right LE during left heel tapping, wiggling left foot out/in. This also helped to decrease the amount of overactivity from left leg extensors (as was done in prone standing).	• Provided extrinsic verbal feedback to improve his awareness of being off midline as well as to improve his correction back to midline (i.e., he often overcorrected alignment and leaned to left with trunk but kept pelvis to right). • Downward and slightly medial physical cue to right gluteus medius muscle to increase, and then sustain, activity in hip abductors (to prevent collapsing into right Trendelenburg). • One person in front for trunk and head alignment and to provide physical cues to left LE (proximal cue at pelvis to maintain midline alignment and to quadriceps to load down into the foot) to decrease hip and knee extensor activity and ankle/foot plantar flexion pushing. • One person at each of right and left feet to ensure maintenance of ankle dorsiflexion (keep heels on floor) while providing calcaneal and navicular pronation mobilization/hold (see Fig. A4.5).
Standing, no wall support. He was able to begin standing without the wall for support after ~22 weeks. • Bare feet	Looking at pictures of family, friends, and his motorcycle to encourage righting head on body. Moved pictures to various positions of right, center, and left to further challenge balance and trunk control. • Shifted pelvis then shoulders and head forward off wall for brief periods. • Hold with verbal plumbline alignment as tolerated (15–30 s).	• One person required for torso support (through scapula and thoracic spine) as well as to assist with lifting head (verbal and physical cues to look forward at family member—father or brother, or at pictures). • One person at each of right and left feet to ensure maintenance of ankle dorsiflexion (keep heels on floor) while providing calcaneal and navicular pronation mobilization/hold (see Fig. A4.5).

(continued)

Table A4.2 Activities performed during therapy including alignments and handling *(continued)*

Position	Activities performed	Handling/assistance provided
Walking introduced at 14 weeks, but difficult to perform often because four people required to assist. • Socks, left CaligaLoc (ankle brace), and shoes were worn for first 6–7 months. • Bare feet or shoes (no brace) after ~ 7 months to the end of this case report intervention.	• Assisted weight shift forward to right LE midstance to terminal stance, step with left. Weight shift forward to left LE midstance to terminal stance, step with right. Repeat for ~15 ft, from front door of home to kitchen, over hardwood floor.	• One person in front of Ernie for trunk support and at posterior hips to facilitate forward weight shift to attain, and then maintain, midstance alignment at hips. • One person on each LE to ensure stable foot and ankle alignment during stance phase of gait; reasonable step length during swing; as aligned as possible initial contact to foot flat position for loading; support at knee as required (right knee required more than left to ensure knee flexion without buckling during loading, and soft extension in midstance). • Fourth person to follow with wheelchair for safety.
Stepups Introduced after ~ 8 months • Bare feet	Using the 6 in step from the sunken living area to the bathroom. • Weight shift forward to attain midstance on right LE, step up with left leg (began with disadvantaging left and increasing active loading response on right LE). • Maintain midstance on right LE without transferring weight onto left LE and step left foot back to floor again (continue to disadvantage the overactive left leg). Repeat as tolerated (initially 5 reps). • Weight shift forward to achieve left midstance, step up with right LE. • Maintain midstance on left LE without transferring weight onto right LE and step right foot back to floor again. Repeat as tolerated (initially 10 reps).	• One person in front of Ernie for trunk support and to facilitate slight forward weight shift to midstance alignment, then assist with maintenance of this position. • UEs around front assister's waist or shoulders. • One person on each LE to ensure stable foot and ankle of supporting limb; facilitation at stance knee as required (right knee required more than left); appropriate hip and knee flexion during stepups. Ernie was able to initiate left swing, but required moderate assistance to prevent hip hiking and ensure enough knee flexion to clear his toe from the step. Ernie could initiate right swing by releasing the knee, but due to severe weakness, required maximum assistance to lift the weight of his right leg to step up.
Ascending and descending stairs performed after 9 months of therapy. • Socks and shoes worn. • Left CaligaLoc (ankle brace) worn.	Ascending • Weight shift forward to right midstance alignment, step up to first step (6 in) with left. • Transfer weight forward onto left LE, lift right foot up with heel lifting first, then flex knee and hip, and dorsiflex ankle as lift right foot up to same step. • Repeated above sequence for ascending 12 steps—that is, used a step-to pattern with the left leg leading to set up the right LE as the trailing leg to facilitate right knee release for initiation of right swing.	Ascending • One person in front of Ernie for trunk support and to facilitate forward weight shifts then assist with maintenance of midstance position. • One person on right LE to provide handling at the right hip and knee extensors to ensure stability during stance, at the ankle and foot for as neutral an alignment as possible, and at the hip for adequate hip and knee flexion during swing. • One person on left LE for assisting with hip and knee flexion during stepup; safe ankle and foot alignment for loading phase when stepping up with right foot.
	Descending • Backed down stairs. • Used a step-to pattern with left leg leading down so right leg had to actively control the descent with eccentric muscle work as the working, loaded leg. • Performed 12 stairs.	Descending • One person in front of Ernie for trunk and head support and to cue backward weight shifts to midstance alignment on stable leg and to assist with maintenance of midstance alignment. • One person on right hip and knee extensors for facilitation of eccentric quadriceps and hip extensor control in stance phase and, to assist fully with swing phase to next step. • One person on left LE for guiding cues for hip and knee flexion (Ernie was able to initiate this), then hip extension (to prevent hip hiking) and ankle plantar flexion to reach to lower step for swing phase to lower step.

Abbreviations: LE, lower extremity; ROM, range of motion; UE, upper extremity.

Note: The timelines referred to in this table include the period after initiation of this home therapy intervention rather than from onset of his traumatic brain injury.

Fig. A4.4 Ernie in prone standing, one of the many ways his lower extremities were actively stretched.

Fig. A4.5 Providing a navicular pronation roll, while stabilizing the calcaneus, for appropriate standing alignment and a foot and ankle active loading stretch.

In general, the foregoing activities represent a progression over time. However, there was a considerable amount of progressing/regressing and overlapping between the activities depending on fatigue levels, motivation, frustration, and amount of assistance available. For example, walking was trialed during the sitting and prone standing phases. Walking was challenging and motivating for Ernie but initially required three people for alignments and one person for safety (i.e., the wheelchair had to be behind him). Although walking allowed for the assessment of his functional muscle activation (timing and sequencing) and range of motion, it was labor intensive and, therefore, was not practiced often.

Once he progressed to more frequent standing and walking activities, one of the tools used with Ernie was the Bauerfeind CaligaLoc brace (BauerfeindBraces) on his left ankle. This brace supported his ankle during transfers and while working in upright postures and thus significantly reduced his risk and fear of ankle injury. Another benefit of this brace is that it did not restrict his movement but preserved a safe ankle joint alignment so he could still move into various ranges and activate the muscles around the foot and ankle. After a few weeks of ankle-supported transferring and standing, he was able to progressively work without the brace and continue to improve his left LE control and alignment. By the end of this case report, Ernie was no longer wearing the brace on his left ankle.

The activities described occurred during our therapy sessions. Because his family was eager to help Ernie improve in any way possible, they and the home care worker also helped him with several bed and chair exercises on a daily basis. Such exercises included prone hamstring curls (active-assisted), bridging, four-point kneeling, and UE work. These exercises were important to ensure that one person could continue to work with Ernie on a regular basis. Functional activities of transfers and transitions (supine to sit and rolling) were also reviewed and modified regularly. The transfers and transitions were functional and helped both to increase Ernie's active involvement as well as decrease the number of caregivers required and the amount of assistance that they provided.

A4.3.4 Outcomes

Table A4.3 shows Ernie's outcomes and Fig. A4.5, Fig. A4.6, Fig. A4.7, Fig. A4.8, Fig. A4.9 show his body alignment when sitting and standing. Although Table A4.3 demonstrates that Ernie progressed in his active contribution to tasks and decreased caregiver work, there were also observable improvements in areas that were not formally evaluated. One of the most significant changes was in Ernie's attention. His ability to hold his head up and look at people while they were talking to him improved in duration, as did his focused attention during a conversation. In addition, Ernie's ability to close his mouth and manage his oral secretions was far better at follow-up.

Perhaps one of the most rewarding events during the entire episode of care was the day Ernie climbed the stairs in his home and spent the afternoon in his bedroom. He had not been to his room since the day of his TBI. After much hard work and preparation and with the assistance of three people, Ernie was able to climb the 12 stairs up to his bedroom. He and his mother spent some time going through his photographs, books, and posters. Ernie was excited about his physical achievement and further motivated to accomplish more. At the time therapy was finishing, Ernie's new goal was to climb stairs with only one person assisting (his mother) so he could visit his grandparents in Poland.

Table A4.3 Impairment and functional outcome changes over the duration of intervention

Impairment changes and functional outcomes	Initial assessment	8-Month reassessment	15-Month follow-up
Head control—during conversations or when in car.	Unable to lift independently.	Able to lift and hold for ~ 15–20 s to look at family members or when in car.	Able to hold for 4–5 min while someone is talking to him; self-corrects often.
Left ankle dorsiflexion (DF) range of motion.	Passive to neutral with knee flexed. Active to − 8°, with knee flexed.	Passive to 5°; active to neutral, repositions on wheelchair footrest when verbally cued.	Active to 5° with knee extended; during sit to stand, able to achieve 10°.
Right ankle DF range of motion.	Passive to − 10°, with knee flexed. No active motion.	Passive to neutral with knee flexed. Flickers of active DF.	Passive to neutral with knee near extension (standing and on testing); grade 1+ active.
Type of transfer performed	Low pivot	Standing pivot	Standing step around
Amount of assistance required for transfers	Two-person assist (full assist)	One-person (full assist)	One-person setup for positioning Ernie, the wheelchair, locking chair, removing leg rests, and then moderate physical assistance for weight shift and balance for the transfer.
Amount of assistance required for standing—during dressing or while looking at family or at pictures.	Three person	Two person	One or two person
Duration of standing/standing tolerance—for dressing, looking at family or at pictures.	About 3 min	10 min	Up to 45 min (when using wall); 5 min with one person assisting, no wall.
Walking—in home with family to get to wheelchair or massage table.	Unable	Three-person assist, short in-home distances.	Two-person assist, short in-home distances.
Ascending and descending stairs to go to his bedroom on the second floor.	Unable	Performing one stepup with two-person assist.	Able to perform step-to pattern on 12 stairs, with three-person assist.

A4.4 Discussion

The severity of Ernie's brain injury and the multiple systems affected (neurological, musculoskeletal, cognitive [attention and arousal], sensory/perceptual, and oral-motor) could lend itself to a variety of intervention options. However, upright postures were chosen to address his level of arousal and attention, and to use the NDT principle in recovery while working in familiar functional activities.

Some of the most effective alignments implemented included prone standing and sit to liftoff work. These postures combined the benefit of working into much needed foot and ankle ranges (by using his body weight to increase the stretch to soft tissue and joints), with the motor control benefit of activating his LE muscles in eccentric and concentric contractions. Due to his achieving more biomechanically efficient alignments, these were the first positions that Ernie could more effectively activate and use to sustain activity in his LE muscles. While working into more typical joint ranges, the sit to liftoff activity was challenging from a motor control perspective because Ernie had to grade his LE muscles while maintaining a coactivated neutral trunk. This highlights the fact that many functional activities will address the impairments of, and the relationship between, the musculoskeletal system and the central nervous system.

Unfortunately, although the prone standing and sit to liftoff work improved his LE control and alignments, he found them frustrating, and he sometimes refused to participate in them. It was difficult to make the prone standing posture interesting or engaging due to Ernie's lack of head control at that time. As such, he would get frustrated and overuse his stronger left side at the expense of his weaker right side. It was also difficult to control all the movement components and body segments during the sit to liftoff transitional movement, as well as keep it functional and engaging for Ernie. Although these alignments are effective therapy activities for addressing the impairments, their use was limited due to Ernie's lack of motivation to fully participate in them. Ernie challenged his therapist to continue to work him in both functional postures and functional activities to address his impairments as often as possible.

Ernie enjoyed the wall-standing posture and activities and would often work here when he refused the former two activities. Standing with his back against the wall allowed Ernie to work in upright alignments and grade his LE activity in concentric and eccentric ranges. With the assistance of one person at each foot and ankle, he could work on loading over his feet for improving range of motion and decreasing imbalances between his tendency to overrecruit his left and underrecruit his right LE muscles. In addition, this posture allowed Ernie to look at his

Fig. A4.6 After 19 months of therapy, Ernie's alignment allows him to be better positioned and supported in his wheelchair.

Fig. A4.7 After 19 months of therapy, Ernie was often able to stand with one family member with a base of support between 20 and 24 cm (8–9.5 in) (intermittently, a second person was required for realignment of his right foot and ankle).

family during conversations (with progressively less head control assistance required) and to look through pictures of himself or friends and family.

The wall also provided Ernie with trunk stability and therefore increased the amount of time he could work on his LE control and alignment because one of his most limiting impairments continued to be his inability to sustain activity in his trunk muscles, resulting in a less stable trunk. To not overwork himself in this setup, he needed to progress to standing without the wall support to further challenge his trunk impairments, as well as continue to work in activities in high-sitting postures. On follow-up, Ernie and his family were encouraged to continue to work away from the wall in standing and in high sitting or forward sitting with UE support to increase the demand for his trunk flexors and extensors to be active.

Other potential future strategies could include pushing or pulling activities to promote trunk activation. Ernie could work in high sitting, use the back of his wheelchair (with someone in it to provide resistance), and push it away from himself, then pull it toward himself. The activity could then progress to standing with wall support and then without it. Tipping chairs or stools to look at photographs or other collectables from his bedroom placed on the seat or lifting and lowering various objects, such as a brush, his shirt before dressing, or his towel after showering, would also achieve the benefits of a coactive stable trunk. Aligning him in front of bike magazines or bike parts would augment Ernie's motivation and engage him in the tasks as well as offer a multitude of activity options for the sessions.

With the increases in Ernie's movements and control, he may be able to try new avenues for ongoing therapeutic benefits. A trial of warm water therapy for standing and sitting activities was suggested. He might be able to play certain Wii games for head and neck control, UE coordination, and trunk control. Reviewing the way Ernie and his family perform their transfers or set up for meals would also be important to promote increased independence in function.

A4.5 Summary

The success that Ernie achieved and continues to achieve is due to his commitment to ongoing recovery and to his

Fig. A4.8 The near normal ankle and foot alignment achieved for standing activities.

Fig. A4.9 Ernie, getting a hug and kiss from his mom.

family's commitment to help him through it. In addition to working with the physiotherapist, the family has explored what massage therapists, chiropractors, and cranial sacral therapists can offer him. As well, the therapist made a referral to an outpatient clinic where he was treated for ~ 8 weeks by a PT, OT, and SLP. Although Ernie and his family are open to any area of practice that may benefit Ernie, their ongoing performance and commitment to the NDT strategies has been remarkable.

This case report covers a period of almost 2 years and began 15 months into his recovery. This therapist currently sees Ernie only every several months, and his recovery has not stopped. He and his family have been provided with the tools they need to continue to challenge him and allow him to progress.

There is an increasing body of evidence supporting neuroplastic changes secondary to specific rehabilitation activities.[9,10] However, more research is required to support the benefit of ongoing, long-term therapy for individuals who have suffered a severe TBI. Perhaps intensive rehabilitation programs for clients whose recovery is much removed from the date of initial injury would be an advantage compared with offering such a program in the early period postinjury. Health care practitioners need to continue to provide adequate medical and therapeutic care and protect joint integrity while maintaining muscle length as much as possible in the early postinjury periods. However, offering a period of intensive rehabilitation many months (or years) postinjury may allow the client time to sufficiently recover from significant medical issues, while providing families with the support they need to ensure recovery is possible over the long term.

A4.6 Alternate Reflection

Marybeth Trapani-Hanasewych

Ernie's case report illustrates how important establishing a stable BOS is for improvement in the fine motor skills, such as the drooling management and food chewing. Once he was able to obtain and maintain this BOS, he was able to work on his oral motor skills. An NDT-educated SLP may have assisted in the development of these skills by providing a more optimal alignment in the temporomandibular joint through active contractions. Just as he benefited from a more optimal alignment in and active weight bearing on his feet, he would have benefited from this in his temporomandibular joint. The oral-motor intervention activities may have best been offered immediately after his physical therapy sessions. He would have been able to use his improved trunk and LE alignment to support the refinement of the oral-motor skills to manage his secretions and chew foods. It is possible that these functions may have occurred sooner if an NDT-educated SLP had been available to collaborate in Ernie's care. Other activities might have included slurping from the side of a spoon with active forward movement of the lips and coordination of suck, swallow, and breath synchrony.

Ernie had many body linkages and motor pieces to keep aligned and active. Using controlled breathing to help him stay on task and focus may have helped in a joint intervention session. An SLP may have explored using diaphragmatic/abdominal breathing and voicing with him while he was engaged in tasks related to his hobby of motorcycles. Voicing could begin with sighing and then adding an easy vowel with consonant to voice. This may have developed into an ability to voice a sound to ask for help. The next focus would be to work on furthering his communication skills. Communicating with only thumbs up or thumbs down for yes or no is limiting. Augmentative communication devices may have been a viable option and could have been explored to allow Ernie greater access to interacting with his family and friends.

An SLP may have worked on language activities (such as identifying other motivators and interests) that would have encouraged him to maintain his head up with an active postural alignment in his trunk in sitting and standing during a joint therapy session. The SLP could also pursue cognitive activities that required him to plan and execute an activity, such as inviting a friend to watch a movie at his house. These kinds of activities, where he may be motivated to maintain his attention, may have helped to keep him aligned and active from a postural control perspective.

This young man has a lifetime of communication ahead of him and the potential to make further improvements. Ernie would benefit from SLP services at this time, despite how far he is postinjury.

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Case Report A5 Examination, Evaluation, and Intervention with an Individual Poststroke with Cognitive Impairments

Katy Kerris

A5.1 Introduction

The rate of cognitive impairment is high in patients poststroke. A study of 645 patients poststroke found 38% had cognitive dysfunction at 3 months poststroke.[1] Another study identified cognitive dysfunction poststroke at 3 months to be 39%, at 1 year 35%, at 2 years 30%, and at 3 years 32% (n = 163).[2] Researchers using 17 scored items measuring cognitive skills identified cognitive impairment in 35% of patients poststroke (n = 227) compared with only 3% of controls (n = 240).[3] Most recently, a study of life satisfaction poststroke found memory deficits in 32% of stroke survivors (n = 94).[4]

Coping with cognitive impairments presents challenges for survivors of stroke as well as their caregivers, adding to caregiver burden. Caregivers of persons showing memory impairment poststroke reported lower life satisfaction than caregivers of persons without cognitive problems poststroke.[4] Individuals who are cognitively intact are able to live independently and/or require less supervision at home than do those with cognitive impairment.[5]

The effectiveness of cognitive rehabilitation strategies following stroke has not been well studied. A recent review of medical databases found only 10 studies on this topic.[6] Still, identification of cognitive dysfunction at the time of evaluation can guide intervention planning and daily provision for intervention with patients cognitively involved poststroke. Intervention strategies blend the judicious use of handling, working within activities that are relevant and meaningful to the client, and careful selection of the environment and task setup to optimize outcomes. In individuals who have cognitive impairments poststroke or post–traumatic brain injury for instance, intervention strategies, including the therapist's handling strategies, need not be discussed and described in detail with the patient. This information requires high levels of attention, concentration, and understanding of language, which are all common cognitive system impairments in individuals after stroke.

Handling is still used but, if used correctly, requires only nonverbal interaction between the client and the therapist. The Neuro-Developmental Treatment (NDT)-educated therapist's use of familiar and relevant activities and specifically selected environmental setups to subcortically guide an individual into more efficient postures, alignments, and the automatic use of the more affected side need not involve a high degree of language and cognitive processing demands. The lack of awareness and error recognition often seen in these individuals can be addressed by enabling them to have more normal movement experiences and drawing attention to these when they occur.

Incorporation of family and caregivers during intervention is key for carryover to home and other functional environments. Constraint-induced movement therapy (CIMT) research has also demonstrated the importance of intensive practice in a person's recovery poststroke.[7,8,9,10] With this intensive practice in mind, educating and incorporating the family and caregivers in functional training practice and a home exercise program to remediate impairments is key to an individual's recovery poststroke.

The following case report describes the examination findings and intervention strategies chosen for a woman poststroke who demonstrated significant cognitive dysfunction, particularly in attention and judgment. Her care plan focused on movement practice in her clinic sessions and via a home activity program (HAP) within functional tasks that were immediately important and relevant to her, limiting the amount of verbal and cognitive information given to her. This case report also describes the strategies used in attempts to engage her husband and family in her rehabilitation program and the challenges encountered when these social factors proved complex.

A5.2 Case Description

PW is a 65-year-old woman with a past medical history that includes Bell's palsy, diabetes mellitus, hypertension, dyslipidemia, chronic anxiety, and circulation problems. She suffered a right anterior communicating artery (ACA) stroke on October 2, 2010. This case report outlines the details of PW's course in outpatient (OP) therapy over a 4-month period.

A5.2.1 Course of Care

- Inpatient rehabilitation for 5 weeks.
- Home health care services for ~2 months.
- OP therapy for ~4 months.

A5.2.2 Social History

PW is married and lives in a two-level duplex with her husband. Her prior functional level was complete independence, including working full time as a fifth grade teacher. She managed her household, doing most of the cooking and cleaning for her husband, and was relatively healthy. PW is right handed.

A5.2.3 Personal Goal

Her goal was to return to her profession as a fifth grade teacher by mid-March 2011.

A5.2.4 Examination and Evaluation

PW was admitted to OP rehabilitation on January 6, 2011, and received therapy for 4 months. Notes from home health care listed the following functional and mobility status at the time of admission to OP therapy:

- Sit to stand minimal assist.
- Stand pivot transfers with moderate assist (husband provides maximal assist, with PW grabbing around his neck).
- Walking with front-wheeled walker, 60 feet with moderate assist, including physical cues for knee control, foot position, and postural alignment.

During the course of her OP therapy, she had a fall at home on February 21, 2011, and spent 1 night in the hospital, undergoing a barrage of tests, including a left shoulder X-ray (showing mild degenerative changes at the acromioclavicular joint and a magnetic resonance imaging (MRI) scan showing the "old" right ACA infarct with encephalomalacia and volume loss as well as a trace subarachnoid hemorrhage in the left frontal lobe sulci and left sylvian fissure. She was discharged from OP rehabilitation during the recovery phase from this fall and stayed with family out of town. She returned to the OP clinic for reevaluation and continuation of intervention beginning March 21, 2011. At that time, it was felt her functional status and impairments were essentially the same as on initial evaluation. Thus the following details of her examination findings are from January 2011.

A5.2.5 Social, Environmental, and Contextual Factors

PW's husband expressed frustration with her lack of independence and progress and felt she was not trying to improve. He appeared to have limited insight into her deficits, especially her cognitive deficits. PW's sister, who lives nearby, was supportive, attended therapy with her, and attempted to integrate ideas learned in therapy in PW's home. The sister expressed concern about her sister's living situation. Other living situations were being considered, but none had worked out yet due to the desires of PW, her family, and financial constraints.

A5.2.6 Participation/Participation Restrictions

As already noted, PW had been a fifth grade teacher and was popular with her students. She was active in her church, and she and her husband had also assisted their daughter in daily child care while their daughter was at work. After her stroke, she was unable to return to work, babysit her granddaughter, or participate in her church activities without assistance.

She did not demonstrate any significant visual or communication issues. Her speech was clear. She was able to talk on the phone, write clearly and in a timely manner with her right hand, read documents the length of magazine articles only, and did not require glasses for vision. She was no longer able to drive and could access the community only with assistance. She required supervision at home at all times; she could not be left alone for even short periods.

A5.2.7 Activity/Activity Limitations

Observational posture and movement analysis was used in addition to standardized tests to determine PW's baseline performance measures. Her baseline functional status in January 2010 follows.

Observation of Activity with Posture and Movement Analysis

Dressing

- PW required minimal assist for setup to retrieve her clothing and to don her posterior leaf splint and left shoe.
- She attended adequately to the left side while dressing.
- She completed the task(s) using only her right hand unless cued. She could grasp, release, and pick up small objects (such as her underwear) with her left hand as long as these were positioned immediately in front of her such that she did not need to flex/abduct her glenohumeral (GH) joint past 45°.
- She complained of extreme pain in her left shoulder with lateral or posterior reach and any forward reach past 45° flexion. Pain levels in the arm were reported to be 8/10, with pain at rest and with movement.

Bathing

- PW required minimal assist to complete the entire task safely, especially to wash her lower limbs and bottom.

Indoor and Outdoor Mobility

- PW used a wheelchair as her primary means of mobility.
- The house was thickly carpeted throughout, except the bathroom and kitchen; she reported difficulty in propelling her wheelchair independently.
- PW was short in stature, making positioning for self-propelling less than ideal.
  - Her feet barely reached the floor in her hemi-height wheelchair.

  - She often sat forward, propelling with her right leg hooked under the left; she did not automatically use her left leg to assist with foot propelling.
  - She was unable to use her left arm in the task.
- Prior to admission to OP therapy, she had some training in the use of a front-wheeled walker but was not doing this because her husband felt it was more time consuming for him to assist her in walking than to allow her to propel her chair.

Ambulation

- PW walked with a front-wheeled walker and assistance of one person primarily in therapy, short indoor distances only.
- She was able to hold the walker with her left hand (i.e., her hand did not fall off).
- During stance phase, her left hip remained in hip flexion, and she either overflexed or hyperextended her right knee in the last 20° of knee extension. Throughout stance and swing phase, her upper trunk leaned to the right with observed left scapular elevation.
- There was increased supination of the left foot, especially when wearing the posterior leaf splint and shoe. Standing and walking with socks or barefoot showed similar patterns but to a lesser degree.

Stairs

- Most of the living space in PW's two-level duplex was on the second floor.
- She required minimal assist to ascend and descend 14 steps using a railing on the right side and a step-to pattern with the right leg leading.

Getting In and Out of Bed

- PW required standby assist (SBA) to get in and out of bed.
- PW frequently required assistance to get positioned in bed. Her mattress was soft, and they used flannel sheets as well as an incontinence pad. These conditions created too much friction for her to shift herself well. It was recommended that she avoid wearing pajamas and/or use different sheets along with a duvet style comforter to move more easily in bed.
- In the OP clinic, she was able to scoot on a mat with minimal assistance. She did not use her left limbs unless cued.
- Sit to side-lying to the left side required moderate assist due to shoulder pain.
- PW often complained of dizziness when moving from supine to sit.

A5.2.8 Standardized Test Measures of Body Structure and Function

- Berg Balance Scale score = 37/56.
- Lower extremity manual muscle testing: left hip flexors 3+/5; knee extensors 3+/5; dorsiflexors 0/5; plantar flexors 1/5.
- Reading comprehension, auditory attention, and visual attention all > 85% as measured by the Reading Comprehension Battery for Aphasia (RCBA-2).
- Repeatable Battery of Neuropsychological Status showed the following:
  - Immediate memory—73rd percentile (average).
  - Visuospatial skills—first percentile (extremely low).
  - Language—16th percentile (low average).
  - Attention—16th percentile.
  - Delayed memory—50th percentile.
- Motor-Free Visual Perception Test score = 32/36 (within the norm).
  - Processing time averaged 7.8 s per item, significantly above the norm.
  - Visual tracking functional.
  - Functional on visual fields testing; demonstrated midline shift to the right.

A5.2.9 Posture and Movement Observations

During the examination process, while an individual is performing or attempting to perform activities, it is important for clinicians to make observations of the posture and movement strategies used. Through this observation, the clinician is able to ascertain the body system integrities and impairments of the individual. By asking and answering the question *why* when inefficient strategies are observed or when the individual is unable to perform a movement/task, the clinician is able to hypothesize the underlying system impairments contributing to these observations and activity limitations. The following list describes the posture and movement observations made during PW's initial examination.

Alignment

- PW avoided weight bearing on her left leg; the left foot was often off the ground during transfers.
- In standing, she supported 10% of her weight through her left leg as measured by two floor scales.
- If assisted in placing and sustaining her left leg in weight bearing, her upper trunk leaned heavily to the right.
- The left scapula was rotated downward with limited rotation of the clavicle. Her head was turned slightly to the right.

Anticipatory Balance and Weight Shifting

- PW needed verbal cuing to maintain vertical, upright, and aligned positions with more equal weight distribution.

Other Observations

- PW required cuing and physical assist in all tasks involving standing, such as pulling up pants. This cueing was to put weight onto the left leg, which was underused to the extent that only her toe touched the ground, affecting her balance.
- She was often neglectful of her left limbs unless verbally cued.

A5.2.10 Body System Impairments

From these observations, the following body system impairments were determined.

Cognitive and Visual System Impairments

- Decreased cognitive awareness of deficits with impairments in judgment and safety.
- Slowed speed of processing impaired decision making and incorporation of environmental challenges.
- Visual field shift midline to the right.

Sensory/Perceptual Systems

- Severe impairments in visuospatial skills impacting midline awareness and position in space.
- Decreased attention to task as noted in functional situations in the clinic.
- Decreased midline awareness in sitting and standing, primarily in the frontal plane.
- Diminished light touch in the left foot and hand.
- Diminished proprioception in left foot joints.

Neuromuscular and Musculoskeletal Systems

- Inability to initiate activity in the left peroneal muscles.
- Weakness of the left quadriceps, anterior tibialis, and gluteus medius muscles.
- Decreased ability to sustain activity in the trunk muscles, specifically the extensors and abdominals in upright postures.
- Decreased ability to grade activity in the left quadriceps and hamstring muscles, especially in the end ranges of knee extension.
- Overactivity of the right scapular elevators.
- Left GH capsule tightness.
- Shortening of the left pectoralis and subscapularis muscles.
- Shortening of the right scalene and upper trapezius muscles.
- Decreased joint range of the midfoot joints on the left.
- Shortening of the left iliopsoas muscle.

A5.2.11 Evaluation Summary

Client Strengths

1. Fair to good motor return on the left.
2. Had specific goals in mind for return to valued roles and motivated to meet these.
3. Had improved from initial hospital stay to the present in all systems.

Contextual Factors

1. There were concerns about her home environment related to the consistency of care that may influence her ability to make steady gains.
2. Her specific cognitive deficits made consistency and carryover questionable and influenced her safety.

PW's most significant impairments limiting her function are listed and discussed in the context of their influence on her projected functional outcomes.

1. Sensory impairments in her left foot and her decreased awareness of midline were some of PW's more significant impairments. She would need to improve in these areas to be more independent and safe in mobility and function.
2. Visuospatial impairments affected her in all areas, including tasks that require attention and perception, reading, self awareness and decision making, and mobility. If improvement in these impairments did not occur, PW would be unsafe to transfer between surfaces and walk without supervision and would never be able to drive or return to work as a teacher.
3. Joint limitations, muscle hypoextensibility, and pain limited the use of her left arm and impaired her ability to initiate reach and position her left hand in space for functional tasks.
4. The imbalance of muscle control throughout her left lower limb affected her use of this limb in upright postures and her sense of security during standing and gait. She would need to improve

her use of and awareness of her left lower limb to improve in functional mobility.

A5.2.12 Establishing Functional Outcomes

If PW was going to return to work, assist her husband to babysit their granddaughter, and resume her church activities, she needed to be able to be independent at the activity level of the International Classification of Functioning, Disability and Health (ICF) in many tasks, including being able to walk independently indoors and outdoors in busy environments, dress in clothes appropriate to her roles (e.g., teacher, churchgoer), go to the bathroom and shower in an efficient time, walk and carry her teaching supplies, write on the chalkboard, and many more. Each of these activities is complex, requiring multiple steps, the ability to motor plan, attending cognitively to the salient aspects of the task(s), and producing movement in multiple body segments in a selective and coordinated manner.

When an individual presents with profound impairments, it is difficult to establish timely functional outcomes in activities that are as complex as these examples. Each of these tasks can be further broken down into subtasks. The benefit of this further analysis is to allow the establishment of reasonable and achievable short-term functional outcomes that will eventually lead to the long-term functional outcomes our clients wish for. The criteria chosen within these short- and long-term outcomes are based on the individual client's situation, including the type and severity of the client's system impairments, comorbidities, motivation, support system (including family and informal caregivers), access to professional services, financial resources, and many other variables. The therapist in PW's case weighed all these factors and established the following short-term functional outcomes (to be met in 2 months).

1. PW will stand in midline,
   a. with standby assist, and write a sentence on a white board with her right hand, incorporating both right and left arms into the task without loss of balance.
   b. independently, to prepare eggs and toast while standing in her kitchen, incorporating both upper extremities in the task. She will load the dishes in the dishwasher after completing the task.
2. PW will independently transfer in her bathroom using a walker and grab bars/tub seat to the toilet and the tub/shower.
3. PW will independently reach to head level to access items in the cupboard with her left arm and hand.
4. PW will demonstrate accurate prediction of ability in functional tasks, such as success rate in completing a reading assignment, tutoring assignment, and visual reaction time tasks.
5. PW will ambulate up and down a flight of stairs with standby assistance using the stair railing on the right with a step-to pattern.
6. PW will be independent in level surface transfers (toilet and tub transfers) with adaptive equipment and using a front-wheeled walker.

A5.2.13 Intervention

PW was seen three times a week for 4 months for physical therapy, occupational therapy, and speech-language pathology. Throughout the sessions, feedback was provided to PW via both verbal cues and handling for attention to task and movement information and problem solving.

Intervention activities included the following examples:

- Pre-gait training, including working in stance and stride phases of gait, incorporating an environmental constraint to increase the use of her left leg and arm. Examples of these activities include stepping up onto a step with the right leg and removing the right arm from the base of support. These activities were used in both physical and occupational therapy to improve strength, coordination, awareness, and function of her left lower and upper limbs. Setup included providing a raised surface for her left upper extremity to support through. This was placed in front on the left side, or behind as a cue to keep her hips forward.
- Functional mobility and ambulation training, including climbing stairs, walking on uneven ground, and floor recoveries. PW needed some support at her ankle during these activities. She used either an AirSport Ankle Brace (Aircast, DJO Global) or a fabric, lace-up ankle support. In addition, her ankle inversion improved with a more supportive running shoe.
- Gait training with a front-wheeled walker. Her environment at home was mocked up in the clinic (i.e., space, floor surfaces, obstacles, etc.). Over time, gait training moved toward using a four-wheeled walker with a seat for managing community distances.
- Transfer training using her walker to and from chairs and couches, toilets, beds, and a tub seat. Toilet transfers were an important activity for her because she had continence issues. PW's husband was reluctant to allow her to walk and use the bathroom by herself at home secondary to his fear of her falling.
- Bed mobility practice, especially after she had a fall trying to get up out of bed.
- Scapular and shoulder muscle stretches with the shoulder positioned in external rotation and flexion. We started with body on arm movements and head on body movements and then progressed to arm on body movements as soon as this was tolerated. These movements were used in conjunction with orthopedic joint-specific GH mobilizations.
- Reach training in upright postures with her left arm. This practice was often done in the kitchen

while standing at the countertop in tasks such as loading the dishwasher, rearranging the cabinets, and cooking food. Items were arranged to encourage use of her left limbs.

A home visit was performed for training in her home environment. During the home visit, observations were made about how her husband's decisions about what she could and could not do might impair her performance. For example, he placed her wheelchair and walker across the room from PW so she could not access them without his assistance to get to the toilet.

PW was given an HAP to practice some tasks independently and some tasks with her husband's or her sister's help. Her HAP activities included the following:

- A left upper extremity task strengthening program, including gripping and reaching activities. This program was to be performed at home under the supervision of a family member. Specific examples included reaching for her shoes to put them on and take them off, wiping off the table after each meal, and using a rubber band gripper to strengthen her hand and finger muscles while watching television.
- Visual perceptual tasks, including reading to her grandchildren and doing puzzles with them.

A care conference was held at week 10 of her OP therapy program when issues were identified with family dynamics as they related to care for PW. Attending were her husband, sister, brother, and a daughter. The family was encouraged to become more involved in her care by getting her out of the house and assisting with activities to speed her recovery. Examples of these activities included taking her on shopping trips into the community, visiting friends, and trips to her school. Each family member made a commitment to take her for 1 day a week. However, in the end, the family dynamics interfered with this plan, and eventually, it was decided that PW would move to Buffalo to live with her son and his family. This move occurred at 4 months into her OP therapy course.

A5.2.14 Outcomes

PW made meaningful functional improvements during her 4 months of OP therapy. Observational posture and movement analysis and standardized tests were used to document this improvement in her impairments and functional performance. Table A5.1 details these outcomes.

At the time of discharge from OP therapy and her move to Buffalo, PW was independent for all her indoor

Table A5.1 Outcomes of intervention for PW

Activity	Functional performance measures
Walking	• Independent with household distances with a front-wheeled walker.
	• Standby assist with four-wheeled walker for short community distances, such as walking into church or into the therapy clinic.
	• Demonstrated gait deviations and inefficient postures regardless of device, such as increased hip flexion in stance phase and ankle inversion.
Stairs	• Standby assist using a nonreciprocal gait pattern going up and down.
	• Continued to demonstrate problems with hip, knee, and ankle control.
Toilet and tub transfers	• Independent for toilet and tub transfers with the equipment listed previously, including handling clothing, diaper, and toileting hygiene.
	• She was still having daily issues with bladder continence.
Dressing	• Standby assist for retrieving clothing.
	• Independent for dressing except for donning the ankle brace.
	• Independent with tying her shoes with excessive time and effort using both hands.
Bathing/ showering	• Minimal physical assistance for completeness of task and safety in bathing due to continued cognitive decision-making and judgment errors.
Kitchen tasks	• Standby assist in kitchen tasks like emptying the dishwasher and preparing a simple meal with a walker for safety.
	• Improved ability to sustain weight bearing on the left leg but there was still unequal weight bearing.
	• Standby assist to reach to head-height kitchen cabinets with her left hand to retrieve food items.
	• Independent with opening the refrigerator with her left hand.
	• Able to manipulate and handle small items with her left hand.
Reading	• Able to read and discuss newspaper stories as well as novels.
Standardized measures	
1. Slow walking speed, ~25 ft/min (norm is 275 ft/min) measured during the 6-Minute Walk Test.	
2. Berg Balance Test = 41/56 (in the realm of "at risk to fall").	
3. Motor-Free Visual Perception Test score and processing time within normal limits.	
4. Pain scale—reported pain level in left shoulder was 3/10 at rest and in activity within available range.	

mobility using a front-wheeled walker, except for the stairs and bathing tasks. Being able to independently toilet was one of PW's most expressed goals during her OP therapy sessions. She required only standby assist with most kitchen tasks and was using a four-wheeled walker in the community to return to her church activities and visit her school.

PW was unable to return to work as a teacher due to her cognitive and mobility impairments, specifically, her lack of awareness of deficits and impaired self-monitoring. Managing an entire classroom of children is challenging cognitively and involves mobility components too challenging for her at the time of discharge from OP therapy. PW and her family hoped she could work as a private tutor for children because this work is less complicated cognitively and requires less mobility. This was her goal upon her move to Buffalo.

A5.3 Discussion

This case report described how PW was able to improve physically and cognitively in tasks that allowed her to become either independent or less dependent on assistance in her home and leisure activities. However, despite these improvements and improvements in her visual and cognitive functioning, her residual cognitive impairments interfered with her ability to return to her occupation as a fifth grade teacher. This outcome parallels the research outcomes as discussed in the introduction section of this case report: improved functional status for personal and home function but less successful in return to work outcomes. Managing an entire classroom of children is challenging cognitively. Having the responsibility for the supervision and safety of others, particularly of minors, in addition to herself, was beyond PW's cognitive abilities. For individuals poststroke with residual cognitive impairments, pursuing new activities that are similar to their previous occupation but without the ultimate responsibility for their own and other's safety and the expectation for financial remuneration can offer opportunities for further physical and cognitive practice. In PW's case, volunteering in a classroom or providing one-on-one tutoring in a quiet, nondistracting environment are examples of excellent activities to pursue.

Working within an interdisciplinary team is important in all cases but especially in cases when the client presents with cognitive impairments and challenging social and environmental factors. As productivity standards push clinicians to be focused on generating units, it is important that we strive for opportunities to collaborate. In the OP setting that PW attended, there are fewer formal meetings, but informal collaboration in the treatment areas occurs frequently to share ideas on what does and does not work for mutual clients. Each team member evaluates clients for accurate impairment identification and then develops intervention plans directed toward functional changes using the ICF model. However, each client evaluated possesses only one set of impairments and the same functional goals regardless of which discipline he or she is working with. It is critical that clinicians collaborate to optimize clients' outcomes.

In PW's case, working within an NDT framework helped to maintain the clinical team's focus on addressing PW's most significant impairments interfering with her activities and participation roles and guided choices for optimal intervention strategies, within functional tasks, and contexts that specifically targeted these impairments.

In PW's case, the team collaboration was also beneficial to problem-solve ways to address the family dynamics affecting PW's recovery. There were considerable observed differences in how her husband and her sister viewed PW's needs and how to best help her. At times, the intervention team was required to be involved in these family discussions to assist and guide with the decision making. The team had many discussions about how to manage the situation in a way that would ultimately help PW. At this OP facility, home visits and care conferences are rarely scheduled, but in PW's case, we did both. We feel both of these additional management strategies helped with PW's outcomes, despite the less than satisfactory outcome for her—she had to leave her home to move to Buffalo, New York.

A5.4 Alternate Reflection

Jason Knox

Returning to her role as a teacher was PW's only mentioned targeted goal with her being eager to get back to the classroom by mid-March. Basing her physical therapy on this participation role serves to offer valuable structure to her intervention plan. The classroom setting itself (or the like) could provide the backdrop for an enriched environment in which to assess and intervene with PW's cluster of impairments. Writing with a marker, erasing, or even pulling down a projection screen would incorporate her upper extremity impairments. Standing to teach, turning, pacing, or even sitting on the edge of a desk would address her trunk and lower extremity impairments. Also, writing math problems on the whiteboard would address her most limiting visuospatial, attention, and cognitive impairments, integrating her occupational therapy, speech-language pathology, and physical therapy goals. Multiple other possibilities exist by exploring the different subjects she may have taught (geography, history, science, etc.), other tasks performed in her duties as a teacher (collecting assignments, marking at her desk, computer work, reading aloud, etc.), and a variety of environmental factors (staff room, washroom, gymnasium, wheeled/stable chairs, stairs, etc.).

Physical therapy interventions have been traditionally focused on exercise and often out of functional contexts. However, to achieve optimal functional outcomes with PW, it is critical that a physical therapy examination be conducted within a host of these functional activities; moreover, this context also supports a nearly infinite array of varied intervention options to address PW's impairments in a progressively challenging, familiar, and motivating manner by exploring the richness of her own classroom environment. Limiting her use of assistive devices and braces (as able) would confirm impairments, linkages between her arm/trunk/leg impairments, and any substitutions that may be masking her true impairments.

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Case Report A6 Achieving Functional Outcomes with Neuro-Developmental Treatment for Chronic Stroke

Monica Diamond

A6.1 Introduction

A6.1.1 Rehabilitation for Chronic Stroke

Research is now beginning to demonstrate that individuals recovering from stroke can be expected to change and make progress for a long period of time after their stroke.[1,2] However, therapists treating clients with adult-onset neurological diagnoses such as stroke are frequently challenged because they treat these individuals for only short bursts of time within the scope of their work environment (i.e., acute care, inpatient rehabilitation, subacute care, home care, outpatient therapy, etc.). Even if the client remains in the same facility, a particular therapist may treat the individual for only a short period before the client is transferred to another program or service.

Recent research has attempted to determine the most effective setting for rehabilitation in the early poststroke period (rehabilitation unit, home-based, etc.).[3] In addition, research has begun to examine therapy outcomes in the time period referred to as *chronic stroke*, which usually includes up to 1 year after the stroke.[4,5] Information is lacking about therapy, recovery, and outcomes, or even about new problems or challenges, in the longer poststroke period that includes up to 5 or more years after the stroke.[6]

Due to the individual's changing need for care and the nature of the medical system, it is likely that the members of the client's therapy team will change throughout the recovery process. This change challenges the continuity of care from the client's perspective, and it makes it difficult for the therapist to fully understand or anticipate an individual client's progress or potential (i.e., how limited the individual was at onset, or how able and functional he or she is able to become 3, 4, or 5 years post onset.)

A6.1.2 Increased Acceptance for Case Study Research

It is difficult, for many reasons, to demonstrate potential for functional change in individuals with chronic stroke. One reason is the difficulty in compiling a homogeneous group of individuals with stroke to use for comparison. Inherent in the definition of a controlled trial is the idea that the intervention is standardized, and that, therefore, the randomized, controlled trials (RCTs) that have investigated intervention have generally addressed defined and discrete interventions that could be standardized.[5,7] However, the rehabilitation of an individual with impairments in many systems that change on a daily basis requires that the therapist create and implement a constantly changing plan to address those needs, not apply a standard set of procedures.

Studies that have purported to investigate the effectiveness of an approach have usually narrowed the approach to a few specific activities or techniques, eliminating much of the ongoing problem solving and modification that, by definition, is part of the approach. In addition, studies that have attempted to show the superiority of one approach over another have generally shown a small difference or no difference. We must proceed with caution when interpreting these studies because failure to show a difference between approaches does not mean that the approaches are ineffective. Both approaches may be effective, and it may not be clear that one is better than the other.[8,9,10]

Although case study research has recently gained legitimacy as an additional means to guide clinicians to successful interventions, clinicians may not have the time or resources to perform even formalized case studies. Use of a case report, with careful measurement of objective outcomes and delineation of the problem-solving process used to develop and modify the interventions, can provide additional information to increase the therapist's awareness and responsibility for the care plan's effectiveness, and it can also guide intervention with other clients.[11,12]

A6.1.3 Need for and Adequacy of Functional Outcome Measures

The clinician can measure intervention success in several important ways with an individual client. Sackett et al[13] remind us that we must consider current evidence as well as the subjective preferences of the individual being treated. Therefore, objective measures of functional change as well as the client's subjective opinions of what has changed and what is relevant to the client will determine effectiveness of the intervention to date and will guide further intervention, if appropriate.

Most research that examines progress and outcomes in individuals with chronic stroke focuses on the first year (+/−) poststroke. Furthermore, because stroke is often considered to be a problem of aging, research has not emphasized the progress and/or problems of persons living with stroke over the long term. Population studies to determine the causes of stroke at various ages have led to increased awareness of these long-term survivors of stroke and their physical, emotional, and vocational needs.[14,15]

Although there is increased awareness of the existence of long-term survivors of stroke, studies of interventions over a 5-year period have each generally focused on a specific intervention—whether it is effective and for whom.[5] Studies have not generally been designed to determine how to choose the best interventions or the optimal time frame, frequency, or duration of interventions for a particular individual. As Mant[16] states, “The paradox of the clinical trial is that it is the best way to assess whether an intervention works, but is arguably the worst way to assess who will benefit from it.”[16]

A6.1.4 Decision-Making-Process Research

Along with increased interest and emphasis on research-based intervention, there has been increased interest in the ability to define and describe the clinical decision-making process. Early in our professions, we recognized *expert* clinicians who seemed to have developed intuition that guided them to be especially effective with their clients.[17] Interest in defining this process of intuition and decision making has gradually provided use with models and schemes to guide our decision making. Use of an enablement/disablement model continues to help us to organize and link our data and thought processes. Current models describe the examination and evaluation processes in detail.[18,19,20,21] The process of linking the specific impairments that are most responsible for the activity limitations is being explored, although to a lesser extent.[19,22]

Neuro-Developmental Treatment (NDT) provides the therapist with tools to understand and address this linkage between functional activity limitations and the specific impairments that are most responsible.[23,24] Primarily, NDT provides the therapist with the ability to analyze tasks, movements, and postures from many perspectives and in great detail to determine the multisystem impairments or posture and movement problems that are present.[25] From here, the therapist determines and prioritizes the specific single-system impairments that are most responsible for a specific activity limitation.[26] In addition, a second major tool of NDT, the use of therapeutic handling, provides the therapist with additional information about aspects of an individual’s impairments, especially those of the neuromotor system that are particularly difficult to differentiate (e.g., the type and duration of muscle activation, location of initiation of muscle activity to perform a movement pattern, etc.) In this way, the therapist using NDT is more prepared to assess and intervene with the individual’s *specific* impairments most effectively and efficiently during the intervention phase, using NDT handling as well as other skills, to achieve the desired participation and activity outcomes as efficiently as possible.

A6.1.5 Purpose

This case report describes problem solving and decision making during episodes of care in physical therapy with Dennis, a 62-year-old man recovering from a stroke over a 5-year period. Particular emphasis will be on the use of the NDT Practice Model to (1) assess and treat his activity and participation limitations and (2) address the underlying system impairments that contributed to these limitations, particularly the specific limitations in the neuromotor system. Specific functional outcome measures as well as meaningful qualitative changes in function are reported, along with a discussion of the thought processes and prioritization that lead to these changes, to illustrate Dennis’s progress over a 5-year period.

A6.2 Information Gathering

A6.2.1 Client

Dennis had been treated in acute care and inpatient rehabilitation, and he had had some outpatient intervention when he was referred for an outpatient physical therapy evaluation in March 2006. His primary stated goal was to improve his mobility, especially his walking, to return to his previous activities, such as walking, biking, and traveling. He had been relatively healthy and active until July 2005, when he suffered a right frontal intracerebral hemorrhage (ICH) at age 57.

During the initial information gathering, Dennis’s physical therapist (PT) performed the objective portion of the examination and directed conversation toward assessment of contextual factors to determine what was important to him and what factors might enhance or limit Dennis’s progress in physical therapy. Most of Dennis’s time would be spent outside of therapy, so his PT needed to understand Dennis’s lifestyle, motivation, and family environment to help him achieve changes in function. Dennis’s wife, Marilyn, accompanied him during the initial session, and she gently helped him answer questions when he had trouble remembering parts of his recovery. Medical records of his hospitalization contributed additional details of his history.

A6.2.2 History

Medical

In addition to the ICH, Dennis’s additional medical diagnoses included hypertension, hypercholesterolemia, mild hearing loss, and mild depression in the past. His hospitalization for the ICH included 10 days in acute care and 5 weeks in inpatient rehabilitation. He initially received outpatient physical therapy, occupational therapy, and speech therapy, but at the time of this outpatient physical therapy evaluation (8 months post onset), he had been discharged from occupational and speech therapy. Dennis and his wife were interested in receiving a second opinion regarding whatever physical therapy options might be available to address his significantly increased tone and spasticity, especially in his left lower extremity (LLE).

Social Context

Dennis and his wife have three grown children and three grandchildren who are available to provide significant assistance. Both Dennis and his wife are retired school administrators, and Dennis had been continuing to work part-time until his stroke. Dennis had enjoyed walking, biking, reading, and watching movies prior to his stroke, and he and Marilyn planned to travel and spend more time with their grandchildren during retirement.

A6.3 Examination

Four important questions guided and helped organize actions and thought processes during the examination and evaluation: What? How? Why? So what? These questions guide physical therapy examination and evaluation through the NDT Practice Model to provide a basis for the plan of care.

A6.3.1 Activity and Activity Limitations

Because Dennis was a relatively high-functioning outpatient, his therapist collected data about activity through a combination of observation, hands-on assessment, and client report. She observed Dennis's posture and movement and let his answers to specific questions guide further assessment. Questions became more specific and focused as the PT learned more about his mobility, lifestyle, and goals.

To gather data about Dennis's functional/activity status, the PT initially asked *what* questions, such as, "What can you do?" "What activities are difficult or impossible for you?" Dennis's answers guided decisions about specific functional outcome measures that would effectively show his current status as well as his anticipated progress in functional activities (Table A6.1).

From the moment the therapist began escorting Dennis to the intervention area, she began to look for answers to *how* questions. She asked, "How is he getting his center of mass forward to shift from sitting to standing?" "How is he shifting weight and moving his center of mass forward when walking?" "How is he aligned when sitting unsupported?" "How much weight is on his left side versus his right side during each activity?" The answers to these questions described the characteristics of Dennis's posture and movement. These descriptions of *how* Dennis moved (e.g., left knee hyperextended, trunk rotated to the right) explain the multisystem impairments that, once analyzed, provided the critical link between data collection, evaluation, and subsequent intervention. Determining multisystem posture and movement impairments is the first step toward determining the underlying specific and significant single-system integrities and impairments that contribute to Dennis's current functional activities and activity limitations.

Although observation initially provided some information, the use of hands-on assessment, which is one of the hallmarks of NDT, enhanced the ability to answer *how* questions with hypotheses of how the specific single-system impairments contributed to Dennis's limitations in function and which impairments were the most significant. Questions such as, "When he shifts excessively to the right during sit to stand, do I feel a *push* from the LLE that pushes him right, or does the initiation of the asymmetrical weight shift feel like it is coming from a *forward lean initiated by the upper body*?" or possibly, "Do I feel that the force pushing him forward is coming from his use of his stronger right arm to push on the chair?" assisted in identification and prioritization of system impairments.

Table A6.1 Dennis's Status in the Activity Domain—Initial Evaluation[a]

Activities—"What can you do?"	Activity limitations—"What is difficult or impossible for you to do?"
• Independent in bed mobility.	• Bed mobility is slow.
• Walks independently in his home.	• Getting up from chair is difficult, often requires several attempts and cannot be done safely without the ankle-foot orthosis (AFO) due to severe inversion and plantar flexion of his left ankle.
• Goes out on short community outings with wife.	• Walking is very slow and requires use of AFO.
• Performs car transfer with supervision.	• Walking in community requires cane and close supervision.
Additional information:	
• Is left-handed—can do mostly what he needs to do with his left hand.	• Is unable to go for long walks.
	• Reports a recent near fall (onto couch).
• Reports that handwriting is "getting better."	• Needs assist for safety in the shower (foot twists, has difficulty getting leg over edge of tub).
	• Requires support from furniture and supervision for floor transfer.
	• Requires railing, supervision, and verbal cues for stair ambulation.
	• Doesn't drive.
	Additional information:
	• Reports problems reading.
	• Reports short-term memory problems.

[a]Answering the *what* question.

Using NDT eyes, Dennis's PT constantly looked for Dennis's contextual facilitators to use these strengths to enhance the intervention sessions and facilitate his overall progress.

Use of observation and hands-on assessment allowed comparison and reconsideration of findings during Dennis's evaluation. For instance, during observation of gait, Dennis's upper body was aligned slightly forward, and the left hip (affected side) was slightly flexed with his pelvis rotated posteriorly throughout stance. Initially, the therapist hypothesized that possible causes of this pattern might be insufficient hip extension strength or a limitation in hip extension range on the left. With continued hands-on assessment to feel movement, activation, and timing, the therapist was able to feel that Dennis was initiating the forward progression during gait incorrectly, attempting to pull his body forward by leaning forward with his upper body. His timing and sequencing for forward progression could be felt to be via upper body initiation rather than through use of the force of his LLE against the floor to provide forward propulsion. This upper body initiation, combined with Dennis's best attempt strategy for maintaining balance during stance on the left, resulted in a flexed, posteriorly rotated position of his left hip. When the therapist attempted to assist Dennis's hip extensors, she did not feel a limitation in hip extension range but felt that the forward movement of the upper body limited her ability to assist the hip to stay extended. Although the therapist felt less hip extension activity than expected, handling helped prioritize that the incorrect initiation of forward progression was a significant movement problem.

Table A6.2 delineates some of Dennis's other multisystem posture and movement integrities and impairments observed and felt during the initial evaluation. As his therapist assessed and provided intervention in the different positions and activities of the intervention plan, she continued to revise and update this list of multisystem integrities and impairments by comparing observations with what she felt through hands-on assessment.

A6.4 Evaluation

Once Dennis's therapist collected information about his multisystem impairments (as described in Table A6.2), it was time to ask *why* to determine which specific systems, as well as which specific underlying impairments within individual systems, were most responsible for his problems with function. For example, the multisystem impairment of decreased weight bearing on the LLE that was observed and felt during sit to stand could be caused by impairments in the musculoskeletal system, the neuromotor system, or the perceptual system, or by a combination of impairments in several systems.

The information gained about Dennis through observation and handling continued to be compared, associated, and linked to the different pieces of data, as in a jigsaw puzzle, to determine their relationships. Continuing to ask *why* resulted in organized, prioritized, and further testing to hypothesize the single-system impairments that were most responsible for his activity limitations. This examination and evaluation thought process continued throughout sessions with Dennis and provided the basis for the documentation included in the initial report, monthly plans of care (POC), daily notes, and correspondence with the physician and insurance company. Explanation of this thought process was one important way in which the therapist justified Dennis's need for skilled physical therapy intervention.

Part of the evaluation is gathering information about multi- and single-system impairments and then prioritizing them so that the intervention strategies designed are specifically directed toward addressing the single-system impairments that are most significant and limiting to Dennis's function. Addressing the *how* (e.g., just facilitating a more symmetrical weight shift) will not achieve results as quickly as determining the underlying *why*—addressing the cause of the asymmetry—and then reeducating use of a more symmetrical movement pattern for function. Strategies for remediating single- and multisystem impairments would be linked together to form an effective plan to achieve the activity and participation goals upon which Dennis and his therapist agreed.

Dennis demonstrated impairments in the neuromotor system, as expected, but also in the sensory-perceptual and musculoskeletal systems (as described in Table A6.3).

Dennis's musculoskeletal and sensory-perceptual systems were screened, rather than performing detailed tests and measurements during the evaluation session, because time to focus on these details would have detracted from other assessment that was felt to be more informative. To determine his progress it was necessary to obtain the desired objective measures early in the examination to establish an objective baseline. His specific problem areas were assessed in detail as needed in later sessions.

So what? This question relates to the participation domain, or to the things that are meaningful in the client's life. Because Dennis's cognition was relatively good, his wife was with him, and he was living at home (not hospitalized), it was relatively easy to direct discussion toward meaningful short- and long-term functional outcomes. This discussion also helped clarify the personal and environmental contextual factors that might influence Dennis's recovery (Table A6.4).

An individual contextual factor may be positive at some points and negative at others. Negative contextual factors can also sometimes be used as a source of meaningful functional goals. For example, Dennis and his wife lived in a two-story home with steep stairs. When Dennis was initially evaluated, his wife expressed concern regarding Dennis's safety while going up and down; she was providing hands-on guarding. This challenging mobility task later became an opportunity and a goal for Dennis. He gradually demonstrated progress, becoming able to negotiate the stairs using the railing with only supervision, and later without a constant hand on the railing, so that he was eventually able to carry items with one and then two hands while going up and down the stairs.

Table A6.2 Some of Dennis's multisystem posture and movement integrities and impairments

Multisystem posture and movement integrities	Multisystem posture and movement impairments
• Shifts weight onto affected side without support when cued in sitting and standing. • LLE supports weight in standing and walking. • Trunk alignment is relatively symmetrical; muscle activation is felt on both sides of the body. • Uses active movement of LUE functionally for a variety of tasks. • Head is aligned relatively in midline during most activities. • Moves his LLE actively through part range at most joints. • Balances in standing without hand support to perform two-handed tasks. • Shifts the upper body mass forward to begin sit to stand. • Controls most of movement lowering from stand to sit. • Alignment of the LLE in standing is relatively good, but better proximally than distally. • Activates muscles in the LLE for functional tasks such as sit to and from stand and gait.	Sit to stand:
	• Increased effort is observed with weight shift forward to come to stand; several attempts are needed, at times, to achieve standing position.
	• Weight shift is asymmetrical, with more weight on the right; movement forward is asymmetrical with the right side of body coming forward more effectively via hip flexion.
	• Dennis attempts to use momentum, including momentum of UEs, to assist with achieving forward weight shift (when not using UEs to push on surface to assist with the motion).
	• LLE abducts and externally rotates during forward weight shift and hip flexion.
	• Tibias do not translate forward with ankle dorsiflexion during the initial phase of sit to stand; left translation is less than right.
	• Dennis's upper body can be felt to be leaning more and more to the right as he comes to stand; this lean is exaggerated when he uses his right arm to push up.
	• When facilitated to stay in a more symmetrical posture, resistance to left hip flexion is felt; the LLE is felt to be actively pushing his mass to the right instead of forward toward his feet as he moves from sit to stand.
	• Left ankle strongly inverts during sit to stand and cannot be held in correct position through the transition by therapist using facilitation at ankle and foot.
	• When the therapist aligns Dennis's left foot and ankle in sitting, and when the weight shift is facilitated correctly forward, there is a passive resistance to hip flexion on the left—hip flexion feels "blocked"; more hip flexion range is available during forward weight shift if the hip is allowed to abduct and the ankle is allowed to invert, but the LLE is then not in a position to actively or safely accept weight for control/support in standing.
	Gait:
	• LLE appears stiff, with insufficient hip and knee flexion during swing (appearance of increased tone/tension).
	• Cadence is uneven, with stance time on left shorter than right.
	• Step length is longer on the left.
	• Trunk and shoulder girdles are asymmetrical, with left shoulder lower, and left arm hanging slightly more forward than right in standing.
	• Trunk laterally flexed to left with left side of pelvis rotated back; weight shift asymmetrical, greater to right than left.
	• Left toe drag is present approximately every fifth step.
	• Base of support is wide and is related to left ankle inversion; ankle inversion worsens with weight shift to the right.
	• Excessive lumbar flexion/extension is observed to occur at the points in the gait cycle and in the timing and sequencing pattern expected of hip flexion and extension; motion at the hip joint is less than expected.
	• When left hip extension is facilitated during late stance, active resistance to the pattern of "shoulders back, hips forward" is felt; during these attempts to realign the trunk, the upper body resists realignment more than the pelvis/hip.
	• When upper body initiation is prevented through handling, more effective hip extension can be facilitated, and better alignment of shoulders and hips over each foot during stepping can be obtained.
	Additional information:
	• Pelvis and lumbar spine are asymmetrical in sitting, with more lumbar extension on the right; pelvis slightly rotated back and tilted posteriorly on the left.
	• In sitting, Dennis's spine and rib cage are laterally flexed on the left; upper rib cage is flexed forward on the left; the scapula is tipped forward and downwardly rotated. • LLE spasms are strong enough to pop the night cast off almost every night.

Abbreviations: LLE, left lower extremity; LUE, left upper extremity; UE, upper extremity.

Table A6.3 Some of Dennis's known and hypothesized integrities and impairments of individual systems[a]

System	Integrities in individual systems	Impairments in individual systems
Neuromotor	• Able to activate muscles throughout both sides of his body. • Relatively good isolated control in LUE. • Good control of right side of his body.	• Excessive coactivation in most activities; coactivation limits mobility in many areas. • Activation that is too strong for the movement or task—muscles are overfiring. • Imbalance of muscle activity for movement at specific joints (LLE > LUE); for example, ankle plantar flexion occurs, but with inversion; hip external rotation and abduction occur but with hip flexion; and hip internal rotation and adduction occur, but with hip extension. • Faulty timing and sequencing of muscle patterns for sit to and from stand, for ambulation, and for other movements.
Musculoskeletal	• Can fairly effectively produce force against resistance in the LUE and LLE. • Strong right arm and leg. • No significant joint laxity. • Relatively good overall joint mobility and muscle length. • Relatively good alignment of joints of RUE and RLE; no history of arthritis or other joint pathology.	• Force production is varied, changes with position, and is more asymmetrical compared with the norm—i.e., adductors produce more force than abductors, plantar flexors produce more force than dorsiflexors. • Decreased muscle length in hamstrings (L more limited than R; medial more limited than lateral). • Muscle tightness limiting left hip flexion past 90° (more range is available if hip is allowed to externally rotate and abduct). • Muscle tightness that limits left hip extension with abduction on the left. • Tightness/shortness in muscles that externally rotate the tibia in a closed chain position (e.g., the medial hamstrings, ankle plantar flexors and calcaneal invertors such as tibialis posterior, and forefoot adductors), resulting in ROM limitations and resting posture of tibial external rotation, ankle plantar flexion, calcaneal inversion, and forefoot adduction. • Tightness/shortness of left pectoralis major and minor; malaligned left shoulder girdle. • Mildly limited and asymmetrical thoracic extension, L more limited than R.
Sensory-perceptual	• Generally aware of both sides of his body, in spite of his moderate sensory deficit.	• Preexisting mild hearing loss. • Sensory deficit in LLE (touch, pressure, proprioception).
Cognitive	• Able to understand and follow directions.	• Mild memory deficit. • Continued mild cognitive deficits for activities such as complex problem solving.
Cardiovascular	• Is generally physically fit. • No significant endurance limitations.	

Abbreviations: L, left; LLE, left lower extremity; R, right; RLE, right lower extremity; ROM, range of motion; RUE, right upper extremity;

[a]As identified at the end of the evaluation session.

Table A6.4 Personal and environmental contextual factors relevant to Dennis's recovery

Contextual factor	Facilitators	Barriers
Personal	Motivated	Impatient at times
	Well educated	"If a little is good, more is better" attitude
	Had history/experience during employment with activities that involved listening, negotiating	Tendency to overachieve
		History of mild depression
	Retired	Tendency to focus on instructions for what *to do*, does not focus as well on precautions—what *not to do*
	Had previous history of being active—walking, biking	History of working out; tends to prefer stretching activities versus movement/control activities
	Had previously done yardwork and some housework, was willing to consider performing these tasks as part of therapy homework	
	Has relatively good problem-solving ability	
	Demonstrates good follow-through, use of compensatory strategies as needed (i.e., makes notes to remember things to tell therapist)	

(continued)

Table A6.4 Personal and environmental contextual factors relevant to Dennis's recovery *(continued)*

Contextual factor	Facilitators	Barriers
Environmental	Good family support, wife also retired and therefore available if assistance is needed	Weather and climate associated with living in the northern United States provide challenges to mobility
	Adequate financial resources	Access to second floor in home is via steep stairs
		Yardwork and snow removal are necessary during certain parts of the year

At the initial evaluation, in answer to the questions posed to assess *So what?,* Dennis indicated an interest in returning to previous home and yard activities, interacting more actively with his grandchildren, resuming travel, and resuming a more active daily exercise and activity program. Knowledge of Dennis's situation, assistance available at home, interests, and previous lifestyle helped Dennis and Marilyn to formulate goals that were meaningful and motivating.

A6.5 Intervention: Goals, Outcomes, Intervention Planning, Implementation, and Progress Over Time

At the completion of the initial evaluation session, goals and outcomes were set, an intervention plan was formulated, and initial intervention strategies were designed. Because the focus of this case report is the management of an individual client over a period of 5 years, discussion of outpatient intervention is divided into two phases:

- The *early phase* from 8 to 16 months poststroke.
- The *later phase* from 16 months to 5 years poststroke.

A6.5.1 Overview of Intervention

Dennis was seen in a facility for outpatient (OP) physical therapy during the period from March 2006 to March 2011, beginning ~8 months after his stroke. Intervention frequency was twice a week for 6 months, then once every 1 to 4 weeks for an 3 additional months. After that, Dennis was seen for specific problems and goals approximately once every 1 to 2 months for ~2 years, with the frequency varying, depending on the problems being addressed. He was not seen for almost a year, and then he was seen for two short episodes of care during the fifth year, each time with a specific purpose.

Throughout the early phase of intervention, requirements of Dennis's insurance were addressed as needed, and at 12 months post onset, a formal appeal was made to the insurance company due to pending potential insurance denial. Additional therapy was approved following the appeal, and documentation continued as required by his insurance company and by Medicare, which covered the visits during part of the later phase of intervention.

Dennis continued to make progress in functional mobility throughout the 5 years covered by this case report. An overview of his functional progress from 8 months to 5 years post onset, as measured via objective functional outcome measures, is presented in **Table A6.5**.

Table A6.5 Functional outcomes—8 months to 5 years post onset

Months post onset of stroke	8–9	10	12.5	16.5	25	29.5	41.5	48.2
6-Minute Walk[27,28,29] (ft/device)	754/std cane	840/std cane	999/std cane	1240/std cane	1272/no cane	1428/ no cane	1250/ no cane (new AFO)	1312/ no cane
Timed Up and Go[27,30] (s/device)	22/std cane	16/std cane	13.6/std cane	12.1/std cane	9.6/no cane	9.5/no cane	10/no cane	NA
360° turn to R (no. steps/s)	13/9	11/8.3	9/6.3	8/6.1	6/4.8	8/4.7	8/5.0	8/3.8
360° turn to L (no. steps/s)	11/7	10/5.8	9/6.2	10/5.4	7/4.5	6/4.2	7/5.0	7/5.6
Dynamic Gait Index[31]	12/24	16/24	18/24	18/24	21/24	23/24	23/24	23/24
Functional Reach[32,33] (in)	8.75	11.6	10.1	10.3	8.5	10	NA	
Berg Balance[34]	45/56	51/56	53/56	54/56	53/56	54/56	NA	

Abbreviations: AFO, ankle-foot orthosis; ft, feet; in, inches; NA, not available; s, second; std, standard.

Note: All measures were assessed with client wearing current ankle-foot orthosis, except as noted.

Outpatient Intervention: Early Phase—8 Months to 16 Months Poststroke

Overview

During this phase of management, a considerable portion of each session was devoted to direct intervention. As Dennis walked into therapy, he reported on successes and problems since the last session while his PT listened, asked questions, and observed his movement patterns as he walked, took off his coat, and moved around the therapy area. Dennis's wife offered additional input and was consulted to verify Dennis's observations. Over time, she shared more of her observations because she had developed skill in objectively noting changes in her husband's movement. Marilyn was often able to correlate Dennis's perceptions of his movement with her observations of changes that occurred within the same time period or with specific events or activities. Her skill in observation continued to prove valuable in the later phase of outpatient intervention, when Dennis intermittently reported a new discomfort, changed his walking device or ankle-foot orthosis (AFO), began a new activity, or reported another change in his ability. The challenge for his therapist, along with Dennis and Marilyn's assistance, was to determine relationships between Dennis's reports of movement difficulty or pain with his changes in activities and movement patterns.

Anticipated Goals and Functional Outcomes

At the end of the evaluation discussed in the first part of this case report, short- and long-term functional outcomes were set and an initial intervention plan was established. Dennis's stated long-term outcome goal was to return to previous activities. When questioned further, he noted that he wanted to walk faster. The following additional anticipated short- and long-term outcomes were agreed upon, based on the results of the evaluation.

Short-term (1 month)

- Dennis will report no falls or loss of balance, due to improved motor control and stability.
- Dennis will move to and from sit to stand without use of his upper extremities with control and without use of momentum, for increased safety.
- Dennis will walk carrying a newspaper 25 feet without the cane, as a result of improved stability and balance.

Long-term (4 months)

- Dennis will safely walk several blocks with an assistive device without assist or supervision.
- Dennis will walk safely without assist in the community (e.g., stores, crowds) with an assistive device.
- Dennis will walk safely at home without a cane to be able to carry items in his right hand.
- Dennis will perform tub transfer and stair ambulation safely and independently.

Later in this phase, the following additional short-term (1-month) outcome goals were set, based on Dennis's progress and functional need.

- Dennis will walk safely without an assistive device on level surfaces for 100 feet with no more than two instances of his toe contacting the floor during swing (for increased safety on level and eventually also on uneven surfaces).
- Dennis will step up and down one step with supervision without use of an assistive device for eventual safe and independent community mobility without a device, including curb ambulation.
- Dennis will perform sit to and from stand with both feet flat on the floor without AFO (for safety and prevention of ankle injury) without requiring the use of his arms for support.
- Dennis will safely carry large items using two hands (without an assistive device) for eventual return to tasks such as carrying leaves or a garbage can.
- Additional goals related to the use of equipment (effective use of new night cast and AFO).

Intervention Planning and Implementation

During this early phase, the multisystem and single-system impairments described in the first section of this report were addressed. Neuromotor system impairments of faulty firing patterns, incorrect timing and sequencing of muscle activity, imbalance of agonist/antagonist muscle activity, and excessive coactivation were consistently addressed during all intervention activities because they were significant in limiting his function. Sensory system impairments were also addressed by making sure that Dennis was always aware of the movement pattern desired and that he was aware of both the correct and the incorrect performance of the movement pattern. This awareness included proprioceptive input to the left side, including weight-bearing activities whenever possible.

Secondary musculoskeletal impairments were significant and needed to be addressed intensively during this time. Dennis had developed several range of motion (ROM) limitations and malalignments, particularly in the hip and ankle on the left, but also in the trunk and shoulder girdle, even though his left upper extremity (LUE) had few functional activity limitations. Trunk and LUE impairments were addressed because they affected his overall alignment and control, and they significantly affected his potential to activate the desired movement patterns in the LLE.

Intervention strategies were developed to address Dennis's impairments within the context of a movement or activity and within functional activities to ensure carryover. Early in the intervention program, Dennis required reeducation of small portions of specific movement patterns (e.g., coming forward to get ready to stand with facilitation of specific movement components at the ankle, hip, trunk) to regain mobility of joints of his LLE and to relearn control of those movement components. As he progressed (within a session as well as over time), small movements were combined to reeducate whole patterns, such as forward symmetrical weight shift incorporating hip flexion instead of trunk flexion, eventually within the entire functional pattern of sit to stand. Facilitation of partial sit to stand using the LUE to correctly assist with the activity required integration of correct weight shifts for activation and for effective use of both the left arm and the left leg. In addition, facilitation was used to reeducate timing, sequencing, trunk control, rib cage alignment and movement, control of rotational components, and many other necessary parts of the sit to stand function that prepared Dennis for sit to stand as well as other functional tasks.

At times, individual single-system impairments needed to be addressed in isolation. As Dennis progressed, strategies were designed to address single-system impairments within movement patterns to remediate both single- and multisystem impairments. In addition, when possible, intervention strategies were designed to address primary and secondary impairments in different systems simultaneously to maximize the effectiveness of Dennis's intervention time. Strategies included addressing the neuromotor and sensory-perceptual impairments that most likely contributed to the musculoskeletal system problems to achieve a lasting change.

The following are just a few of the movement patterns that were incorporated into intervention strategies to address Dennis's most significant posture and movement multisystem impairments.

1. Forward weight shift in sitting, maintaining alignment of the LLE and using correct timing and sequencing of ankle dorsiflexion and hip flexion to achieve center of mass over feet, balanced activation of hip and knee extension, and symmetrical weight-bearing, without excessive plantar flexion. Fig. A6.1 and Fig. A6.2 demonstrate this strategy. See additional photos and videos of Dennis's intervention session on Thieme MediaCenter.

   Dennis's LLE is facilitated to maintain optimal alignment, to achieve optimal activation. Forward weight shift is controlled, making sure that dorsiflexion and hip flexion are sufficient to bring the body mass over his feet. Dennis is allowed to use both upper extremities, on his left knee in this instance, to provide some assistance to the movement and to help maintain symmetry.
2. Weight shift in standing with ankle/foot, tibia, knee, hip, and trunk correctly aligned (especially rotational components) to reeducate weight acceptance and correct activation of all LLE components for stability.
3. Reeducation of weight shift in standing and walking to promote a narrower base of support. Dennis tended to shift excessively to the right in attempts to clear his stiff LLE during swing. This exaggerated weight shift combined with his excessive activation as he tried to move his left leg resulted in a balance response and stiffening of the LLE with strong unbalanced plantar flexion and inversion at the ankle. A more correct weight shift allowed him to more easily gain control of complicated LLE movement components.

Fig. A6.1 This view shows facilitation of forward weight shift in sitting to prepare for sit to stand. Using Neuro-Developmental Treatment handling, the therapist can feel Dennis's activation pattern and notes that the weight shift forward is initially insufficient to bring his body mass fully over his feet. She can also feel incorrect timing and an imbalance of muscle activation at the ankle causing ankle inversion and plantar flexion, and limiting progression of the tibia over the foot. Upper body segments are not well coordinated to effectively shift the body's mass forward over the feet.
Optimal alignment during the movement is facilitated from the base of support (BOS) upward. The therapist prevents calcaneal inversion with her foot, and facilitates ankle dorsiflexion and progression of the tibia over the foot with her hand and leg. Pressure down through the tibia and toward the medial heel provides proprioceptive input and assists control of the foot and ankle position. The therapist's right leg positions Dennis's tibia in available internal rotation and prevents the tibial external rotation, thereby biomechanically helping to prevent the ankle inversion. Anterior pelvic tilt, hip flexion, and effective forward weight shift of the body's center of mass are facilitated. Control of Dennis's upper body mass is aided by the use of both of his upper extremities on his affected knee to assist with the movement and to create a closed chain upper body segment that the therapist can direct more effectively. In addition to the control of Dennis's left leg and foot, the therapist uses her right thigh, arm, hand, and shoulder, to provide dynamic control of many segments, including rotation, so Dennis can effectively shift his mass forward and rise partially to standing. At this stage, the movement is done slowly and is allowed to progress as the therapist feels Dennis's correct activation. Verbal and manual cues and guidance assist with reeducation, range, and direction. Assistance is graded to provide variability and repeated practice of activation of correct movement components.

Fig. A6.2 This lateral view shows Dennis being facilitated to achieve almost fully complete weight shift forward onto his feet with facilitation of correct biomechanics at the ankle and foot, hips, and trunk. There is some evidence of incorrect activation in the toe flexion noted on the left, but the therapist's control of other components is sufficient to keep the heel down, limiting Dennis's use of incorrect patterns. Balance responses can be observed in the right lower extremity. The therapist must feel whether Dennis's attempt to regain his balance is correct, or compensatory. In this case, Dennis's perception (through experience following the stroke) is that he is being shifted too far to the left. He will be assisted to relearn effective and correct shift to the middle and to the left leg for function, and the incorrect balance response can be expected to decrease as he gains experience. The toe extension seen in the right foot is actually a correct response, indicating that he's not quite far enough forward on his feet to gain his balance. Incorrect interlimb coordination is apparent because his left toes are flexing to push him back, and the right toes are extending because he *is* too far back. These activation patterns may be *observed* by the therapist, but she responds more to *feeling* the details of the components and the balance responses, making decisions about their accuracy and effectiveness and providing facilitation of more effective movement.

4. Activation and reeducation of dynamic stability patterns in the trunk and left shoulder girdle to promote more balanced alignment and correct activation during standing and walking activities. Better upper body alignment allowed the pelvic girdle and lower body to be more correctly positioned. (When Dennis's upper body was incorrectly positioned forward, his pelvic girdle and lower body remained back to achieve a center of mass [COM] over the BOS. This position resulted in undesired hip flexion and posterior rotation of the pelvis on the left.)
5. Reeducation of left hip control in sitting and eventually in standing to reduce the severity of his increased tone, which was felt to result from a combination of unbalanced firing patterns. Faulty firing and resultant instability caused Dennis to attempt to compensate with additional and excessive muscle activity. Subsequent malalignment of joints caused by tight and short muscles further contributed to Dennis's difficulty achieving correct muscle activation patterns for function. Dennis's hip problem was felt to contribute significantly to the more apparent and bothersome ankle inversion and plantar flexion pattern, since poor alignment and asymmetrical muscle strengths and lengths at the hip and pelvic girdle contribute to problems up and down the kinetic chain, especially in the rotational planes. For example, external rotation and abduction of the hip in sitting changes the relationship of structures that cross the knee (i.e., hamstrings, iliotibial band). Unbalanced forces across the knee contribute to rotation in the lower leg and, in Dennis's case, resultant external rotation of the tibia biomechanically contributed to inversion of the ankle. Evaluation included weighing the relative significance of these factors and forces through NDT-educated handling, feeling for resistance, and noting whether the resistance was active, changeable, responsive to changes or movements of other body parts, or nonchangeable. Facilitation in varying positions and different combinations of patterns provided further details and a basis for development of effective intervention strategies to activate, reeducate, and mobilize to achieve correct activation and incorporation of more effective patterns into function.

Home Exercise Program (HEP)

Dennis demonstrated motivation and sufficient cognition and communication skills to benefit from a carefully graded and progressed HEP. Each assignment was designed to contribute toward achievement of specific goals. HEP activities were reviewed regularly and modified, progressed, or discontinued as appropriate. Dennis was given activities that he could perform effectively without assistance, or in some cases, with the assistance of his wife when she was available.

It is important to assure that a HEP is meaningful, and it is often most appropriate to provide HEP activities that are done within the context of a functional activity (e.g., each morning and evening, while standing at the bathroom sink brushing your teeth). However, Dennis enjoyed pure exercises and was accustomed to exercising regularly, so his HEP included more exercises than might be given to another client. He was carefully instructed in the purpose of each exercise in relation to the functional outcome that was being addressed, and the exercises were reviewed regularly with him to assure that he was performing the movement effectively to achieve the desired goals (e.g., reeducation of a movement pattern vs. just stretching). Some of the activities and instructions that were incorporated into Dennis's early HEP included the following:

- Supine hip traction stretch, initially with assist of wife, later without assistance.
- Getting in and out of bed from the left side to increase left hip joint mobility and proprioceptive input during each transition.
- Four-point stretch to increase left hip flexion with adduction and internal rotation, use of this weight-bearing position to facilitate correct biomechanics of the hip joint during movement.
- Riding a recumbent bike, initially with the left foot strapped onto the pedal.
- Reminders to try each new activity or increase the amount of each activity *gradually*.
- Modified plantigrade activities to stretch hamstrings and gastrocnemius–soleus.
- Stretch to the bottom of the foot to increase soft tissue mobility.
- Wall pushups with shoulder external rotation and forearm pronation to increase muscle length and reeducate the rotational control of the LUE needed for selective and graded control of the shoulder and to improve Dennis's dynamic stabilization of the left scapula.
- Walking (where safe) with feet closer together (i.e., "try to slide your feet along each other as you walk forward slowly") to help Dennis learn to walk with a narrower base of support and relearn correct weight shifts.
- Walking in a pool, performing specific activities to reeducate motor control without use of incorrect/ineffective movement patterns.
- Reminders to relax, move gently, work less.
- Use of a night cast to regain ankle/foot mobility each night; short-term use of the cast intermittently during the day when needed to decrease tightness.

Toward the end of this phase, Dennis continued to exercise for ~45 minutes a day, with some assistance from his wife. HEP modifications and recommendations included the following:

- Continued use of the AFO during practice of sit to and from stand due to Dennis's continued inability to control the position and stability of the calcaneus and subtalar joint (AFO did not limit dorsiflexion).
- Modification of the hip stretch to stretch the entire LLE kinetic chain because stretching of one joint without control of the others did not effectively stretch two-joint muscles.
- Emphasis on motor control activities, not just the stretching that Dennis preferred and tended to revert to when not reminded.
- Reevaluation and recommendation regarding activation patterns while riding the recumbent bike, with instructions to actively *flex* and extend his LLE, and not just let the RLE push the LLE into a position of flexion.

Dennis's feedback and careful reporting concerning success or failure of the activities were essential aspects of making the HEP effective. As Dennis came to understand the importance of performing an effective HEP, he came to intervention sessions prepared with notes and questions for more effective follow-through.

Adjuncts

During the early phase of intervention, the following adjuncts were addressed and incorporated into the treatment to make the outcomes even more optimal:

- Botox (Allergan)—PT recommendations regarding muscle groups that might benefit from more or less Botox were incorporated into the physician's Botox treatment decisions.
- Stretching and casting for a new wraparound style AFO that provided better control of plantar flexion and inversion but allowed dorsiflexion. Taping and trials of smaller athletic-type braces helped determine how to provide adequate calcaneal control and helped prepare his ankle for casting.
- Repairing/replacing the night cast Dennis used to maintain ankle ROM. A spring-loaded passive stretch device was trialed but was ineffective in maintaining the desired joint alignment to address Dennis's excessive calcaneal inversion.
- Fabricating a small wrist splint to regain and maintain carpal alignment for pain-free wrist flexion and extension to allow weight-bearing during four-point activities. (To clarify, an occupational therapy evaluation was discussed, and in conjunction with Dennis and Marilyn and the occupational therapist, we decided that UE needs could be met while addressing physical therapy goals because Dennis did not have LUE functional deficits.)
- Trialing electrical stimulation to assist dorsiflexion during gait, which proved ineffective in addressing Dennis's active and passive excessive ankle inversion.

Direct intervention of relevant multi-and single-system impairments that limited activity and restricted participation, along with ongoing development and modification of the HEP, detailed recommendations regarding activities and adjuncts, and Dennis's consistent and focused attention to his recovery, resulted in his achievement of the short- and long-term functional outcomes that were set during this early phase of outpatient physical therapy treatment.

Outpatient Intervention: Later Phase—16 Months to 5 Years Poststroke

Overview

As Dennis continued his improvement and was increasingly able to manage his HEP and continue reeducation on his own, he needed to attend physical therapy less frequently. When seen, his primary goals included (1) addressing new problems directly or through modification of adjuncts or the HEP, to prevent small problems from causing more significant limitations; (2) reviewing his HEP activities to be sure he was performing them correctly; and (3) modifying and upgrading HEP activities to make them optimally effective. Dennis provided excellent information and feedback regarding his progress and difficulties at home, in verbal and sometimes written form, which made it easier to provide effective input and recommendations.

Several dilemmas may present themselves during intervention with individuals who are a year or more post onset of stroke. These dilemmas require that intervention frequency and the actual activities during the sessions change and vary to meet the individual's needs. The variable needs of clients, and of Dennis's in particular, included the following:

1. Insurance will usually not pay for continued progress that is slow and does not result in significant functional gains every month. Documentation, therefore, included careful evaluation and decision making to determine which functional activities might show progress in a short amount of time, so that treatment and HEP activities can be directed toward those functional goals. At times, when Dennis still had potential to make functional changes but functional progress was likely to be too slow to justify continued intervention, a carefully designed exercise program (with Dennis's input) to help him to continue to make progress (after discharge from a short episode of care) without continuous direct intervention and input became the emphasis.
2. An effective HEP at a level basic enough that the individual can perform it effectively and without compensatory movements that will result in it being ineffective. For example, Dennis was instructed in some HEP activities in closed chain positions to help assure that the alignment and activation would achieve the desired goals. Dennis was given specific written and verbal instructions regarding starting position and excursion of the movement to limit his tendency to perform undesired movements in his effort to overachieve.
3. Occasional visits, either at a decreased frequency or perhaps as one-time evaluation sessions, necessary for modification or upgrade of the HEP as the client improves or possibly as problems occur. Dennis was seen for several short intervention sessions to address specific problems, such as refabrication of the night cast when it broke, and reevaluation of possible causes of a new onset of left lumbar back pain. By addressing problems quickly, it is likely that we prevented or minimized the development of additional secondary impairments.
4. Therapy may be needed to provide recommendations for equipment, either to review something that is already in use but not functioning correctly or to provide recommendations regarding new or additional equipment or adjuncts. In Dennis's case, his physician recommended a trial of a spring-loaded ankle-stretching device as a complement to his Botox treatments. Dennis requested a physical therapy reevaluation, and we designed a process to compare the effectiveness of the new device with the night cast he had been using. In spite of modifications to the ankle-stretching device, ankle mobility was maintained more effectively with the night cast, and the use of the other device was discontinued.
5. That the therapist must address any new problems, such as pain, in the context of NDT problem solving. New problems are evaluated in the context of the entire scope of the individual's strengths and weaknesses, and with an attempt to determine the most significant multi- or single-system impairments causing the problem. Intervening with only the symptoms (i.e., in this case, the pain) is not likely to achieve lasting effects. Dennis reported new or increased pain at several points in his recovery. In each case, with Dennis and Marilyn's input, careful physical therapy evaluation assessed possible underlying causes and implemented specific interventions to address the hypothesized underlying cause. Some recommendations included the following:
   - *Changing intensity of an activity:* Walking backward was an exercise designed to activate hip extensors, but once he fatigued, he incorrectly used lumbar extensors to substitute for hip extensors. The intensity was then modified and specified—"Do only 3 sets of 20 steps backward, with rests between."
   - *Changing focus of a HEP exercise:* Shift to holding the end position of a four-point weight shift versus performing several repetitions, to address the need for mobility at the end range of hip flexion.
   - *Modifying his AFO and night cast:* Modifications allowed Dennis to more effectively control his ankle position.
   - *Resuming use of a HEP that Dennis had graduated from:* This included reintroducing a thoracic extension/scapular adduction exercise to improve his posture so that his upper body could stay upright, his left hip could be more extended, and his pelvis could be rotated forward toward neutral on the left in standing and walking to decrease low back pain.

As previously discussed, during the period of 16 months to 5 years poststroke Dennis was seen intermittently about once every 1 to 2 months for about 2 years, and then again for two short episodes of care during the fifth year.

In general, goals and outcomes during this period of time with Dennis related to the following:

1. Answering questions and making recommendations regarding equipment or other adjuncts, such as Botox treatment, the AFO, or the night cast.
2. Addressing new pain issues and attempting to determine and remediate the underlying causes of the pain.
3. Modifying the HEP as needed, to help Dennis advance as he gained control, to correct ineffective performance, or to design new HEP activities to address new issues.

Dennis had been active prior to his stroke and had exercised regularly, so some input was needed to prevent him from relying on patterns and exercises that had been effective and appropriate prior to the stroke but that now needed to be modified. He needed feedback regarding the proper balance of activity so that he did not overdo any one activity, especially as he learned a new exercise or activity. Frequently (we learned after some initial mistakes), he required specific written instructions, not only about how to do the exercise but how many times, how often, and for how long (e.g., "no more than 15 minutes"), and how to limit the exercise (e.g., "stop if you have any ankle discomfort"). HEP activities needed to be reintroduced at times—Dennis had graduated from some of the exercises but needed to return to them at times when he experienced specific problems. Critical exercises were emphasized, and, as mentioned, Dennis needed to be reminded of the goal of the activities, especially when the focus of the activity was to be on graded motor control. Without reminders, Dennis tended to revert to an emphasis on stretching, possibly due to his previous exercise history or to the fact that he was more able to perceive stretching than movement.

Anticipated Goals and Functional Outcomes

Each episode of an individual's care will have both short- and long-term functional outcomes, if that is appropriate. In Dennis's case, these outcomes were directed toward remediation of the specific problems that he reported. Examples include decreasing pain, addressing a problem with his equipment, or addressing a new activity limitation.

Treatment Planning and Implementation

During this phase of intervention, activities during sessions begin to be more client driven and usually involve more feedback and recommendation and less hands-on direct intervention, although hands-on assessment is still used to assist with problem solving; direct intervention is provided as needed on a short-term basis to assist with remediation of specific problems.

Problems, Intervention, and Progress

Dennis continued to make progress as measured by repeated evaluation via formal functional outcome measures (refer again to Table A6.5). Additional functional changes reported between 21 and 48 months post onset included the following:

- Able to safely step down curb without cane without supervision.
- Able to perform single-leg stance for 4 seconds on left with AFO, 14 seconds on right for safer stair/curb ambulation or to don pants or adjust socks or shoes while standing.
- Able to walk short distances without the AFO at night to go to the bathroom.
- Able to keep left foot on pedal of bike with only one strap at forefoot (previously had shoe bolted to pedal).
- Able to go from floor to and from standing without furniture support with occasional minimal assist.
- Able to go up and down four steps with no cane or railing with minimal assist.
- Able to eventually perform kneel to stand with no support for the first time since his stroke, to be able to get up in case of a fall in the yard or while crossing the street, or to pursue activities, such as gardening or playing on the floor or in the yard with his grandchildren with no external support available.

Summary: Later Phase of Outpatient Intervention

Dennis continued to progress during this phase of intervention, although there were setbacks. NDT handling was used more for assessment than for intervention during this phase, to help determine subtle movement and activation problems that were contributing to new problems with function. Remediation of these problems, such as the lack of left hip mobility and the difficulty with knee control, were addressed through specific revisions of Dennis's home exercise and activity program. An important part of modifying the HEP was to ask detailed questions and assess actual performance of selected activities to create an accurate picture of Dennis's activities at home. Along with the verbal and written instructions, NDT handling was an effective tool to help teach correct performance of the HEP activities.

Modification of the HEP included assessment of activities in which Marilyn's assistance was particularly critical, knowing that Dennis needed to manage as much of his HEP as possible and that asking Marilyn to be involved added stress to her life, although she was always willing to assist. Although Dennis demonstrated clear understanding of instructions and was able to repeat them back when instructed, both Dennis and the therapist realized the need for all instructions to be written. This was particularly evident when Dennis remembered the instructions for wearing the new AFO but forgot the wearing schedule that had been explained to him, even though he had been through the process before.

Dennis continued to improve in his motor control, in spite of receiving less direct intervention. As he improved, he developed new goals of decreasing his use of equipment (AFO, night cast). Careful monitoring and instructions were necessary to allow Dennis to try to decrease his dependence on equipment. For example, Dennis tried wearing the night cast every other night and for a short time not at all, and he was assisted to obtain a new, more flexible style of AFO to allow greater mobility in dorsiflexion and plantar flexion while maintaining subtalar stability. During these trials, movement assessment and determining cause-and-effect relationships between impairments and function were important skills used by the therapist to make recommendations to Dennis. The night cast was found to continue to be essential, and the new AFO style was found to be effective after some modification and a long and carefully managed break-in period.

Dennis had continued to request input on Botox injections, which he received every 3 months. Dennis and the therapist carefully recorded his subjective responses as well as changes in his movement patterns and function that were observed or felt. The physician and therapist discussed these responses, and at Dennis's request, the therapist continued to send written suggestions with him to each physician visit, requesting Botox to specific muscles, with suggestions as to which areas needed an increase or decrease in the dose. Two areas that were managed using Botox at the specific request of the therapist were the hip adductors and the small muscles on the bottom of the foot (flexor digitorum brevis and abductor hallucis). The use of Botox to selectively weaken the hip adductors appeared to restore a better balance of muscle activity around the hip, providing Dennis with increased freedom of movement and a decrease in effort required, particularly in walking. Botox to the foot muscles was used to help decrease the contribution of those muscles to Dennis's faulty foot position and movement.

Dennis and Marilyn continued to report that PT involvement during this period was beneficial. From a professional perspective, it appeared that a client like Dennis who did not receive professional recommendations based on skilled assessment of movement might choose to discontinue use of the night cast or AFO, change or discontinue performance of the HEP, or make other changes that would result in negative consequences. Therapist observations about the effects of changes, modifications to activity, equipment, or HEP were based on ongoing or intermittent assessment of his posture and movement. These observations also assisted Dennis's therapist to hypothesize potential progress or the potential for development or worsening of secondary impairments so that Dennis could continue his slow but steady progress without setbacks.

A6.6 Summary

Dennis and Marilyn's story demonstrates remarkable progress, motivation, and follow-through. Dennis's progress has been illustrated within the context of his goals, interests, and lifestyle. Skilled assessment and intervention with Dennis's movement impairments, based on the NDT Practice Model, have been shown to assist in his recovery of significant functional mobility over the 5-year period in which Dennis, Marilyn, and his therapist worked together to achieve his mobility goals.

A6.7 Alternative Reflection

From Dennis

Right from my very first introduction to NDT therapy at Monica's workshop, I felt strongly that this was an approach that would work for me. I remember thinking as Monica moved me through various exercises that I was *feeling* muscles that I hadn't felt being used since the time of my stroke 8 months prior. The next day, my wife contacted Monica to see if she had space for me in her therapy sessions. That was a turning point in my progress. Up until this time, I felt that I had reached a plateau that was nowhere near where I wanted to be in terms of quality of life.

Monica always made me feel like she was tailoring our sessions and the recommended HEP specifically to my needs, not merely methods that were generally accepted means to treat stroke victims in general. Her comprehensive style of providing therapy included clear explanations of the purpose of each exercise (e.g., which muscles we were working on and why). She used not only her own observations to develop my plan for therapy but also my observations and those of my wife. The written instructions (along with graphics) served to remind me of the appropriate methods. Over time, I developed a complete set of strategies to manage problem areas as they arose. I continue to use these strategies to this day with great success.

Thanks to Monica's dedication, I met the goals that we jointly identified. I would be nowhere near as self-sufficient as I am today without the ongoing therapy that I received. Over the years, I realized that Monica knew my body as well as anybody ever could, and I have continued to seek her assistance when minor issues arise.

A6.8 Alternative Reflection

From Marilyn

NDT therapy, to me, means intense, hands-on fine-tuning. I like to think of Monica Diamond as an artist, rather than a mechanic, as she patiently and creatively continues to treat my husband after his 2005 stroke (at the age of 57).

Following 8 weeks of in-hospital care and therapy, we were not ready to accept that Dennis's recovery was complete. Through volunteering to be a subject for Monica's NDT workshop at a neighboring hospital, we discovered new hope for much desired improvement.

Hands-on manipulation, detailed home exercises and supportive activities, careful attention to proper use of exercise and walking implements, detailed recommendations for Botox injection placements and timing, and hand-picked leg braces and shoes, all continue to advance both Dennis's hope and his recovery.

To me, the three most important specific elements of Den's progress are Monica's finely sculpted and resculpted HEP, her specifically requested and customized foot brace (through a child's brace company), and her ongoing upbeat and creative response to Den's various challenges.

Dennis and Monica make a strong team. Dennis's age, overall health, and determination make him a good student for NDT. Monica's problem-solving curiosity, her skills, her ongoing availability, and her attention to detail make her a highly effective teacher and trusted partner for him.

Seven years later, I continue to support Dennis's home activities and his connections to NDT. They have made such a positive difference in our lives!

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Section B Pediatric Onset Case Reports

Case Report B1 Multidisciplinary Examination and Intervention Planning for Identical Twin Infants with Extreme Prematurity

Gay L. Girolami, Diane Fritts Ryan, and Judy M. Gardner

B1.1 Background and Purpose

This case report illustrates a multidisciplinary approach to intervention with identical twin infants born prematurely. Each year in the United States, over half a million (1/8) infants, are born prematurely and develop complications that result in impairments impacting their growth and development.[1] For example, the effects of preterm birth may cause neurological sequelae resulting in delayed or atypical gross, fine, and visual motor development[2]; compromised processing and/or integration of sensory information[3]; impaired oral motor and respiratory control[4,5]; as well as reflux or other gastrointestinal conditions.[6] Infants who are identified as high risk or those who have delayed motor skills on standardized tests should be referred for a multidisciplinary examination to determine the need for ongoing therapy.

Performing an effective examination requires observation and analysis of these infants' sensory and motor behavior with respect to their environment, medical status, and family considerations. Input from the parent or caregiver is also vital to thoroughly evaluate the infant's needs. From our experience[7,8] and that of others,[9,10,11] there is evidence to indicate that Neuro-Developmental Treatment (NDT) offers a viable model to observe and analyze movement and the skills to evaluate the examination data, develop an effective intervention plan, and design strategies to address the functional goals of the family. In addition, the International Classification of Functioning, Disability and Health (ICF) provides an effective framework to organize clinical observations into hypothesized system impairments and to assess the influence of the impairments on functional activities and participation.

This case report illustrates the use of the NDT Practice Model (see Chapter 5) and the ICF (see Chapter 3) to examine and analyze the sensorimotor performance of high-risk preterm twins. This case report speaks to the value of a collaborative multidisciplinary process, which includes the parent as an integral member of the team. In addition, examination and intervention photos and videos are available on Thieme MediaCenter.

B1.2 Case Description

B1.2.1 Medical History

Mya and Maddison, the subjects of this case report, are identical twins born at 26 weeks' gestation. The infants were delivered by cesarean section to a 20-year-old single mother. At birth, Mya weighed 722.9 g (1 lb 9.8 oz), and Maddison weighed 737.1 g (1 lb 10 oz). The twins were respectively diagnosed with grade 3 and 4 intraventricular hemorrhage (IVH), mild bronchopulmonary dysplasia (BPD), stage 2 retinopathy of prematurity (ROP), and medical necrotizing enterocolitis (NEC). They remained hospitalized for 3 months and 3 days. During their hospital stay and following discharge, the twins had repeated feeding failures. Postdischarge, the girls were hospitalized three times for failure to thrive.

B1.2.2 Initial Examination

Prior to This Case Report

The initial examination was performed by an early intervention team (physical and speech therapy) when the infants were 11 weeks 5 days adjusted age (AA), which was a chronological age of 5 months 28 days. Weekly physical and speech therapies were recommended. Physical therapy was provided in a clinic setting, but medical appointments and frequent illnesses interfered with consistent physical therapy services. Scheduling challenges interfered with immediate access to speech therapy. An occupational therapist was not included as a member of the initial examination team.

B1.2.3 Case Report Examination

At 17 weeks 6 days AA (8 months chronological age), the infants began receiving all three therapy services in a clinic setting, and their mother consented to participate in our case report.

Parental Concerns

During our initial meeting, we talked with the mother and noted her concerns and questions to ensure they were considered during the analysis of the examination data and later addressed in the intervention plan and the goal-setting meetings. At this meeting, she expressed worries regarding the babies' feeding and sleeping patterns. She also informed us that her doctor was tracking the infants' growth, weight gain, and difficulties with feeding. The babies' mother also voiced fears about the twins' motor development and vision secondary to their diagnoses of ROP. In addition, the mother reported that Maddison failed the newborn audiological screening, and the mother noticed that Maddison did not startle when exposed to loud unexpected noises. Finally, the mother articulated difficulties with activities of daily living (ADLs), including bathing and positioning. She requested assistance with problem-solving solutions to all of these issues. These concerns, together with the responsibility of being a single parent to the twins and their 3-year-old sibling, left the mother feeling stressed and anxious.

Participation/Societal/Attitudinal Factors

Participation and societal factors were also identified. The mother was able to apply her previous parenting experience to identify concerns and advocate for her infants. The twins were also fortunate to have a large and supportive extended family. Although the babies were enrolled in the state early intervention program and many of the service providers came into the home, other services could only be accessed by bringing the infants to a clinic setting. This necessitated travel time and babysitting for the sibling.

Examination with Standardized Testing

Our initial examination consisted of a standardized assessment tool as well as clinical observations. In an NDT examination, the clinical observations include in-depth examination of base of support (BOS), alignment, and posture and motor control during spontaneous and elicited motor activities. Standardized testing provides a mechanism to benchmark infant performance with respect to normed scores for infants of similar ages and to assess changes in motor performance following intervention and outcomes relative to the infants' individualized goals.[12,13,14]

Both twins were assessed using the Test of Infant Motor Performance (TIMP). The TIMP evaluates functional motor behavior in infants between the ages of 34 weeks postconceptional age and 4 months postterm.[13] The TIMP is a test of the postural and selective control of movement needed for functional motor performance in early infancy. Research[12,13,15] has shown that the TIMP can effectively discriminate among infants with varying degrees of risk for poor motor outcome based on perinatal medical conditions and can diagnose motor developmental delay based on age standards developed from a sample of 990 U.S. infants of all races/ethnicities.

TIMP test scores at 3 months of age have been shown to predict 12-month motor performance with good sensitivity (92%) and specificity (76%).[12,13] Finally, the TIMP is sensitive to the effects of physical therapy provided to high-risk infants in the special care nursery and to home exercise programs taught to caregivers of premature infants following the infants' discharge from the hospital.[7,16,17]

Mya's raw score of 123 points placed her at the 50th percentile for her age. Maddison had a raw score of 111, which is in the 25th percentile and one point below the cutoff score (< 112) for referral. However, both infants qualified for early intervention based on their neonatal history. They also demonstrated difficulty organizing spontaneous movements in the upper and lower extremities (UEs and LEs) in multiple positions. In addition, at 8 months chronological age, they were unable to roll, sit, or push up on extended arms.

The standardized testing provided us with an overall view of the infants' abilities to move spontaneously and to organize movement with respect to items that were designed to elicit a range of motor performance in prone, supine, sitting, side lying, and standing. Clearly, Maddison is a candidate for intervention, but Mya's performance, while in the 50th percentile, is clinically worrisome because she is unable to organize her movements to explore her environment. In this case, as demonstrated from the next discussion of our clinical observations, Mya and Maddison would benefit from intervention. In addition, it was also vital to address the mother's concerns about feeding, handling, and positioning for both infants.

B1.3 Application of NDT and the ICF Model to Examination and Intervention Planning

The Examination Worksheet (**Fig. B1.1**) was used as a data collection form to capture information from the first three phases of the process: clinical observations, hypothesized body structure and function impairments, and functional activities.

B1.3.1 Phase One: Observations

The examination was initiated by gathering observational data that are evaluated to hypothesize body structure and function impairments, design intervention plans, and develop meaningful individualized intervention strategies. In the NDT framework of examination and intervention, it was important to observe the functional ability of the infant and compare it to functional activities consistent with the adjusted age. Next, it was critical to note the presence and/or absence of the components necessary to successfully achieve each identified functional activity. Thus it was possible to hypothesize the significant body structure and function system impairments (neuromotor, sensory, cardiopulmonary, etc.) that were interfering with motor acquisition and then identify the motor and sensory components necessary to achieve the next functional level.

Through the lens of NDT, we examined the infants in the following positions: supine, prone, rolling, pull to sit, sitting, horizontal suspension, protective extension, and standing to obtain a holistic overview of their sensorimotor competency. In each of these positions, it was critical to observe how the infants organized their posture, alignment, and BOS and how they initiated, graded, and terminated muscle activity to prepare for and respond to changes in their position relative to gravity. We also observed their spontaneous motor ability and changes in posture and movement in response to handling, to the environment, and with respect to an array of stimuli (i.e., visual, auditory, or tactile). Observing and examining spontaneous and elicited movement in various positions was important because babies are placed in or selectively choose these positions during the first year

Systems Consider these systems when identifying considerations that body structure and function.	
Musculoskeletal	Sensory
Neuromuscular	Gastrointestinal
Regulatory	Cardiopulmonary
Integumentary	

CHILD:	**EVAL DATE:**
BIRTHDATE:	**AGE:**
DIAGNOSIS:	**ADJUSTED AGE:**
REFERRING PHYSICIAN:	

Strengths (Include motor, cognitive, communication, behavioral, attitudinal and/or family related strengths)

OBSERVATIONS	BODY STRUCTURE/FUNCTION	ACTIVITY
Description of movement in various positions. (How they do it.)	Loss or abnormality of body structure or physiologic body function (systems). (Why are they doing it?)	Relate the body structure concerns (impairments) to discipline specific activities. This will assist you in directing treatment toward a functional outcome (What activities are important?)

Participation: (participation roles related to age)

Contextual Factors: (societal attitudes, architectural barriers, social policies, and other external factors to consider)

Fig. B1.1 Examination worksheet.

of life.[18] In addition, physicians routinely incorporate these postures in their examination of the infant when evaluating development and neurological integrity.[19]

Throughout our examination, we also gathered information regarding the babies' adaptive responses to various sensory inputs and the influence of the stimuli on movement, posture, and alignment in all eight positions. The infants' regulatory organization was also assessed. The regulatory system involves the ability to modulate the intensity of the arousal level while remaining engaged in the activity/interaction.[3] It was important for us to determine how the level of arousal supported or compromised the infants' motor and social behavior and their participation in daily activities.

There are a variety of ways to organize the examination observations. Refer to Thieme MediaCenter, which offers photos and videos of each infant in the above-described positions during their first examination and evaluation. These photos and videos allow for further examination of the twins' alignment, posture, and responses to spontaneous and elicited movement in each position.

B1.3.2 Phase Two: Body Structure and Function Considerations

After gathering the observation data, we next initiated the evaluation process. This process began by hypothesizing if and how each system might be interfering with the body structures and functional activities. Armed with these hypotheses, we met with the mother to develop the functional goals. This goal setting was followed by the creation of discipline-specific intervention plans and applicable intervention strategies. Based on the observations we made during the examination, we describe an example that demonstrates the process of hypothesizing body structure and function impairments.

Example

Both infants used extension and pushing strategies when placed in sitting. They had difficulty organizing and sustaining upright sitting and were unable to generate the protective, anticipatory, or compensatory postural responses to independently sustain this position.

Hypotheses

We discussed potential impairments in the musculoskeletal (i.e., weakness or range of motion limitations), neuromotor (i.e., inadequate ability to initiate or selectively control muscle activity or poor agonist/antagonist control), sensory (i.e., vision or vestibular issues), and gastrointestinal (i.e., reflux) systems. Through our range of motion examination and observations in different positions as well as conversations with the mother, we ruled out significant impairments in the musculoskeletal and gastrointestinal systems. However, in each position, we noted both infants had difficulty initiating activity in the trunk flexors and grading agonist/antagonist control of the trunk flexors and extensors. In addition, neither baby could selectively control shoulder, elbow, and wrist movements in the sagittal or frontal planes, and this lack of control interfered with their ability to use their upper extremities (UEs) for support. Therefore, we hypothesized that the most significant impairment was in the neuromotor system, specifically initiation, selective control, and grading of trunk and UE muscle activity.

The process described above was applied to each of the identified functional activities. After observing, discussing, and testing a variety of hypotheses relevant to our observations, we generated a hypothesized list of key system impairments for each infant (Table B1.1). Careful appraisal of the impairment list allowed us to identify the redundant body structure and function impairments that received greater consideration when the intervention plan and strategies were designed.

As we hypothesized and prioritized the challenges in the various systems, we observed redundant issues in each position that affected the infants' function. For example, consider the body structure (neuromotor impairment) of poor agonist/antagonist control of the head and trunk in Maddison (Fig. B1.2). She demonstrates this poor control in every position. After analysis, we concluded that her difficulty grading and controlling concentric and eccentric activity of the neck flexor and extensor muscles interfered with her ability to achieve adequate and symmetrical capital neck flexion to balance the strong neck extension. This predominance of neck extension biomechanically increased shoulder elevation, which, in turn, interfered with her ability to balance the trunk flexor and extensor muscles and also interfered with the scapular rhythm to support free UE movement needed for protective and support responses and sensorimotor exploration her body and the environment.

In addition, the imbalance of neck muscle activity prevented her from achieving optimal positional stability of the head and upper trunk necessary for the efficient timing and sequencing of bottle feeding. Therefore, by addressing the imbalance of agonist and antagonist control of her neck muscles' activity, we optimized her sitting posture and alignment and enhanced the use of the UEs for functional and sensory exploration while also addressing feeding, which was a concern voiced by her mother and pediatrician.

A similar thought process was applied to the observation for Mya, who demonstrated decreased ability to organize posture and respond to or anticipate postural perturbations. Based on our observations, we considered possible sensory and neuromotor impairments. For example, in facilitated rolling, she required external assistance/guidance to initiate the lateral weight shift of her center of mass over her BOS, and head righting was inefficient (left greater than right). In addition, Mya's ability to initiate, sustain, and selectively control movements was poorly developed.

Antigravity reach was limited in supine with strong scapular adduction, elbow extension, and intermittent fisting (Fig. B1.3). When Mya did bring her arms forward to the midline, she used shoulder circumduction, and the reach approach was ungraded and without intralimb disassociation. Mya substituted elbow extension and hand fisting for smooth elbow flexion, wrist extension, and open fingers. Once midline was achieved, she was then able to open the right hand but tightly clasped the left to provide increased trunk and upper limb stability for play. The stiffness of her movements decreased the proprioceptive feedback received, which is needed to assist with graded movement. However, Mya did realign her UEs toward the surface in anticipation of the position change as expected for her adjusted age.

Visual attention and engagement appeared fleeting and effortful in many activities and positions. Mya's mother reported that, in some situations, Mya appeared more relaxed during supine play. From our observations and discussion with the mother, we determined that the level of self-regulation demonstrated during examination may negatively contribute to Mya's ability to selectively initiate and sustain movement. Therefore, both neurological and sensory regulatory aspects were addressed during the intervention.

B1.3.3 Phase Three: Identify Functional Activities

This section outlines discipline-specific functional activities and illustrates how to write an intervention plan. These descriptions will provide additional examples of specific impairment areas that were hypothesized and addressed during intervention sessions and in the home programs.

The team identified the functional activities to emphasize for Mya and Maddison, while keeping in mind the mother's priorities. The therapists also focused on immediate expectations for movement transitions, play, ADLs, and interaction as well as underlying motor and postural control needs to advance the infants to the next stage of development.

Physical Therapy: Examples of Functional Activities for Mya

Physical therapy interventions were designed to progress the infants in the acquisition of the gross motor and transition skills needed for independent play and the

Table B1.1 Hypothesized table of system impairments

Body structure and function issues	Musculoskeletal	Neuromotor	Sensory	GI	Cardiopulmonary	Integumentary	Multisystem
Inadequate ROM in head/neck	X						
Inadequate strength in muscles of the trunk, UEs, and LEs	X						
Poor agonist and antagonist control of head, trunk, shoulder, and hip muscles		X					
Reduced ability to initiate and sustain muscles activity in trunk, UEs, and LEs		X					
Poor selective control of limbs		X					
Poor timing and sequencing of trunk, UE and LE muscles		X	X				
Decreased ability to organize posture, respond to, or anticipate postural perturbations		X	X				
Poor timing and sequencing of respiratory and phonatory control		X	X	X			
Questionable hearing in Maddison			X				
Decreased ability to organize posture, respond to, or anticipate postural perturbations		X	X				
Poor timing and sequencing of respiratory and phonatory control		X	X	X			
Decreased opportunities for vestibular, visual, tactile, and proprioceptive experiences typical for her age		X	X	X			Regulatory
Inefficient regulatory strategies (motor/sensory/state)		X	X	X			Regulatory
GI issues (reflux) cause concerns about nutrition and weight gain				X			
Decreased ability to anticipate the postural organization necessary for functional tasks		X	X				Regulatory

Abbreviations: GI, gastrointestinal; LE, lower extremity; ROM, range of motion; UE, upper extremity.

development of higher-level gross motor functional activities. Mya, who had more advanced motor skills than Maddison, was able to roll to her right side, but she could not independently make the transition to prone. With respect to rolling to the left, she was not as advanced, and she required assistance to initiate the supine weight shift needed to roll to side lying and continued guidance to complete the transition to prone. In prop sitting, Mya

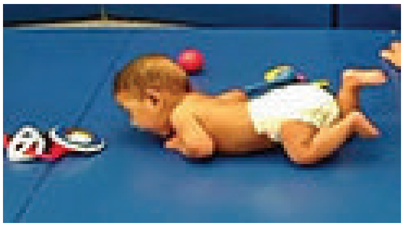

Fig. B1.2 Maddison is unable to extend the lower extremities. This shifts weight forward toward the upper extremities, making forward reach or propping on forearms impossible to achieve. This posture is static, and Maddie has little tolerance for prone positioning.

Fig. B1.3 In prone the extensor muscles of the trunk and lower extremities are strongly activated without antagonist control of the trunk flexors. Strong shoulder adduction and extension interfere with her ability to prop on forearms. Mya is unable to reach for a toy.

exhibited upright head control but recruited strong activation of trunk extensor muscles when attempting to sustain this position for play. When placed in standing, Mya supported on stiffly extended legs, causing a backward shift in her center of mass and an inability to align her trunk and hips over her BOS. In both supported sitting and standing, Mya demonstrated poor agonist/antagonist muscle activation, inefficient grading of muscle activity, and the lack of anticipatory and compensatory postural control to organize and sustain her posture over her BOS.

The mother voiced concerns regarding her infants' inabilities to roll to prone and to sustain independent sitting. She felt they were frustrated and irritable because of their limited capacities to explore and play with toys. She voiced a desire to see them progress in their rolling, sitting, and standing skills. Based on the mother's concerns, the following goals guided the physical therapy intervention.

1. Rolling from supine to prone to expand play opportunities and independent transitions.
2. Independently prop sitting to reach for and play with toys.
3. Maintaining supported standing for dressing, calming, and parent interactions.

Based on the physical therapist's observations and hypothesized impairments, the following activities support the development of the postural and motor control necessary to facilitate the acquisition of the functional skills identified by the mother.

- Mya will be able to reach for and play with her legs and feet when she improves her abdominal strength and postural control, allowing her to sustain antigravity UE extension and pelvic lifting in supine. In addition, she will gain the motor skills to support sensory experiences and improved body awareness. Mya would also develop the core strength and control needed to initiate and experiment with weight shifting to the right and left (crossing midline) and returning to the midline balance point. This activity is a precursor to rolling, improves control of agonist/antagonist trunk muscle activity, and grading and experience of eccentric and concentric control. The ability to roll independently would expand play opportunities and independence.
- Mya will sustain forearm weight bearing and exploring weight shifting in prone, so that she will begin to develop trunk elongation, which will lead to reciprocal LE movement and the strength and control for independent rolling.
- Mya will independently roll to contribute to spinal flexibility in the frontal plane. This flexibility will facilitate antigravity lateral head and upper trunk lifting necessary for efficient rolling and enhanced LE disassociation.
- Mya will independently prop sit, thereby improving strength and the ability to grade muscle group activity in the UEs and trunk. The ability to initiate head turning without losing balance will drive weight shifting over the BOS, improve postural control in the sagittal and frontal planes, and contribute to the emergence of compensatory postural control. Control of independent sitting will provide a solid base for Mya to use her hands for exploration of her body and playing with toys.
- Mya will stand supported, developing the strength and grading to achieve positioning of her center of mass over the BOS. Control of her posture in standing will permit Mya to strengthen hip extensors and abductors, learn to grade hip and knee flexion, and practice weight shifting, bouncing, and small stepping movements.

See Table B1.2 for a summary of Mya's physical therapy goals and body system impairment list.

Physical Therapy: Examples of Functional Activities for Maddison

The mother expressed similar goals for Maddison, although her gross motor skills in prone, sitting, and standing were not as advanced as those demonstrated by Mya. In addition, while Mya tended to use excessive and ungraded extension to maintain and play in these positions, Maddison used a strategy of flexing her limbs and holding her UEs together in midline. However, both infants required improved trunk and pelvic flexibility, muscle strength and grading, and the emergence of the compensatory and anticipatory control necessary to sustain balance. Therefore, the intervention plans for both infants looked similar, but the emphasis of the intervention strategies was altered to address their individual musculoskeletal, neuromotor, and sensory im-

Table B1.2 Physical therapy intervention planning worksheet

Name of Client: Mya Date: ____________________

Functional goals	Body structure and function impairment list

Mya will independently roll from supine to prone (over right and left sides) to play on her tummy.
When placed in prop sitting, Mya will exhibit trunk extension while turning her trunk 45° to the right and left sides to follow and object or person.
When placed in supported standing, Mya will align her trunk and hips over her base of support and bounce up and down, flexing and extending her hips and knees.
	• Insufficient spinal and pelvic mobility.
	• Insufficient strength and endurance in muscle groups in trunk, UEs, and LEs.
	• Poor agonist and antagonist control of trunk, shoulder, and hip muscles.
	• Poor selective control of limbs; repetitive limb movements.
	• Reduced variety of motor patterns in limbs.
	• Poor timing and sequencing of trunk, UE, and LE muscle activity.
	• Insufficient ability to initiate and sustain muscle activity
	  ◦ Upward rotation of scapula for arm movement overhead.
	  ◦ Trunk muscles activity in all planes.
	  ◦ Pelvis for stability while initiating UE and LE movements.
	  ◦ LE reciprocal control.
	• Decreased ability to anticipate and organize feedforward and feedback postural organization required for this task.

Interventions—sequence strategies relative to prioritized impairments	Expected impact on body structures and functions	Assess effectiveness of strategies: adapt, revise, or eliminate
1. Activities to improve trunk stability and rotation in supine, prone, sitting. 2. Activities to increase activation and agonist/antagonist control of upper and lower extremities in supine, prone, sitting. 3. Weight-shifting activities in supine, prone, side lying, and sitting to improve ability to initiate and sustain muscle activity for weight-bearing, reaching, and transition activities. 4. Activities in supine, prone, side lying, and sitting to encourage Mya to initiate weight shifting with reaching for objects in supine, prone, side lying, and sitting. See Thieme MediaCenter for a video clip that shows working on this strategy and addressing which impairments are worked with. 5. Incorporate sensory strategies. 6. Activities in supine, prone, side lying, and sitting to encourage Mya to initiate transitions into and out of supine, prone, side lying, and sitting. 7. Activities in supine, prone, side lying, and sitting to encourage Mya to anticipate and respond to internal and external perturbations.	1. Increased joint mobility and muscle strength in trunk, UEs, LEs. 2. Increased ability to sustain muscle activity in the UEs and trunk in all postures. 3. Improved ability to reach in all planes of movement while sustaining postures in supine, prone, side lying, and sitting. 4. Improved ability to initiate movement in the UEs and LEs for transitions, reaching, and UE weight bearing. 5. Improved ability to initiate UE and LE movements and weight shift outside the base of support without loss of balance. 6. Improved LE disassociation for weight shifting, rolling, and eventual transitions. 7. Improved ability to anticipate and respond to weight shift and to prepare for transitions.	

Abbreviations: LE, lower extremity; UE, upper extremity.

pairments. Thieme MediaCenter provides narrated videos that demonstrate how the intervention strategies were individualized for each infant.

Occupational Therapy: Examples of Functional Activities for Mya

Occupational therapy interventions were designed to address components of performance in activities needed for reach and hand function, visual motor skills, UE support, and play behaviors. For Mya, reach and grasp were deficient in all positions and interfered with her ability to contact, grasp, and play. Mya used her UEs to substitute for inadequate symmetrical head and trunk control. Movements, when initiated, were ungraded and lacking in variety. In both prone and supine, typical 5-month-old play positions, Mya held her arms stiffly, and her grasp was tense and lacked the fluidity to accommodate the variability and size of different toys. Therefore, Mya's ability to sustain a gross grasp and to learn through early reach and grasp experiences was limited. This lack of experience with reach and grasp limited Mya's ability to use the UEs for exploring her environment and compromised experiences gained from the visual, tactile, and proprioceptive systems.

The development of postural control, ocular motor skills, as well as arm and hand function will allow both Mya and Maddison options for self-play and visual exploration, which was a goal expressed by their mother. In addition, their mother also articulated concern regarding functional areas for Mya. The following goals were set for Mya.

1. Finding positions and activities to strengthen visual attention and visual skills is extremely important to improve ocular motor fixation, localization, and tracking in all positions.

2. Improving Mya's ability to sustain a posture and to independently play is critical to freeing the mother to pursue the needs of the other children.
3. Advancing UE skill and control to independently grasp and hold a rattle.

Activities that reflect achievement or will lay the fundamental groundwork for eventual achievement of the above goals included the following:

- The ability to easily and consistently reach up to mom's face or to a toy while in supine and when supported in a seating device. To do this, Mya would need to develop increased strength and control to stabilize and control her head, trunk, and shoulder girdle. This would effectively free her arms and hands for reach, grasp, and play. In addition, the ability to reach, grasp, and explore different body parts is a primary way that 5- to 8-month-old babies improve self-regulation and body awareness and develop security in their ability to weight shift around the midline. This exploration would also provide rich opportunities for integrating multisensory information for play and awareness of the environment.
- Developing the skills to play with toys placed within arm's reach when in prone. The ability to actively bear weight in forearm or extended arm propping while looking around in the environment will facilitate the weight shifting to develop reaching in space and eventually reach and grasp in prone. Reach and grasp will facilitate independence for play in prone, and this in turn will free up the mom's time to spend with the other children (e.g., helping her 3-year-old get dressed or diapering Maddison). Mya also required increased active weight bearing and weight shifting around the body axis (rotation in the transverse plane) as well as the ability to shift her weight caudally toward the pelvis to increase stability for UE play. Active UE supporting would also provide Mya the stability for prolonged head lifting and turning that would permit visual scanning of her environment. In addition, Mya would benefit from the tactile and proprioceptive input to her arms and body, promoting better grading and awareness of her extremities. The improved ability to support her body and engage in her surroundings will create viable options for independent play in prone.
- Grasping and beginning to investigate a rattle with either hand while in a supported sitting position. Addressing the fundamental areas of organizing and strengthening postural control with reach will begin to allow more opportunities for Mya to use her hands to play with objects. In addition, specific preparation of the hand to accommodate to various sizes and shapes should begin in well-supported positions. The ability to grasp and mouth a toy, as well as to sustain the grasp and interact with a person or object in the environment, would build the foundation for self-initiated play and the ability for Mya to entertain herself.

Based on the analysis of the body systems' structure and function, occupational therapy intervention strategies for Mya were prioritized. These are specifically outlined in the intervention section of Table B1.3.

Occupational Therapy: Examples of Functional Activities for Maddison

The twins' mother expressed the same functional areas of concern for Maddison. Therefore, when examining activities appropriate to address with Maddison, the occupational therapist developed the same functional goals already presented for Mya. However, the intervention strategies and the handling applied differed because Maddison demonstrated more sensory aversions, less strength, and lower muscle tone with decreased ability to initiate movements than Mya. Videos of individualized intervention strategies can be viewed on Thieme MediaCenter.

The mother faced additional challenges with Maddison. This twin was unable to tolerate and enjoy bath time. Sensory and handling strategies specific to bathing were incorporated in Maddison's intervention and home program activities. For example, deep pressure in a supportive supine flexed position was used by her mother to prepare Maddison for her bath. This position was carried over during bathing with supportive handling from her mother. Visual regard of her twin was also helpful.

Speech Therapy: Examples of Functional Activities for Mya

Speech therapy addressed oral motor, feeding, respiration, and language performance. For both Mya and Maddison, their mother was concerned about the growth and nutrition expectations outlined by her pediatrician. She also expressed the need to develop a manageable feeding schedule. Finally, efficient feeding and coordinated sucking, swallowing, breathing, and vocalizing were key areas of speech therapy focus.

For Mya, activities identified by the speech therapist that would reflect development of the foundations for accomplishing the above goals included the following:

1. Developing a consistent feeding schedule that the family could handle with correct calorie intake for growth and development.
2. Sequencing suck-swallow-breathe when bottle-feeding.
3. Maintaining sufficient airway clearance during feeding time.
4. Maintaining appropriate neck alignment and symmetry of head position to support swallowing.
5. Using sustained oral vocalizations to demonstrate communication intent.
6. Demonstrating improved respiration and phonation to transition from short nasal phonation to sustained oral phonation, through improved trunk alignment and control.

Table B1.3 Occupational therapy intervention planning worksheet

Name of Client: Mya Date:____________________

Functional goals	Body structure and function impairment list
1. Mya will reach up with either hand to Mom's face or a toy easily and consistently in supine and in supported seating without being held by Mom. 2. Mya will play on her tummy on the floor with toys placed within arm's reach for 5–10 minutes on her own. 3. Mya will grasp and mouth, grasp and engage in basic cause effect, entertaining herself for 5–10 minutes. 4. Mya will look, reach, and grasp a toy with either hand while floor sitting while Mom feeds twin for 5–10 minutes.	• Poor ability to initiate and sustain muscle activity in ◦ scapula depression/upward rotation with humeral flexion and with trunk control. ◦ abdominals, especially in frontal and transverse planes. ◦ pelvis for stability while activating UEs. • Poor selective control of muscle activation. • Poor dissociation of right/ left sides of body, upper and lower body, upper/ lower part of arm. • Poor timing and sequencing. • Decreased control of posture with vision. • Decreased control of posture with reach/grasp. • Decreased experiences using vision with reach and grasp. • Deficient strength of flexion/extension muscles in trunk, UEs, and LEs. • Poor agonist and antagonist control of trunk, shoulder, and hip muscles. • Decreased ocular fixation with postural control and with reach. • Decreased opportunities for this sensory motor experience. • Decreased ability to anticipate (feedforward) the postural organization necessary for functional tasks.

Interventions—sequence strategies relative to prioritized impairments	Expected impact on body structures and functions	Assess effectiveness of strategies: adapt, revise, or eliminate
1. Handling to improve sensory tolerance to using symmetrical trunk control with compensatory retracted UEs (deeper pressure, UE inhibition with aligned trunk and imposed weight shift, visual direction to match activity). 2. Activities to improve trunk stability, especially in frontal and transverse planes with UE compensatory patterns inhibited in prone, supine, and sitting while promoting head lifting and turning to visual and auditory inputs. 3. Activities to improve trunk control with scapular depression, shoulder flexion, and external rotation, such as unilateral WB and WS with active forward reach in prone, side lying, and sitting. 4. Activities to incorporate trunk, vision, and unilateral and bilateral reach to body parts and to objects. 5. Incorporate sensory strategies of increased proprioceptive/ tactile input with handling to improve modulation and attention during movement (e.g., try ball surface in sit, side lying, and prone with ability to impose weight shift to activate more balanced use of posture in all activities). 6. Incorporate activities (as able) to encourage exploration of toys using both hands and visual engagement while posture is supported (e.g., object placement/timing/choice to match motor and visual goals, texture to promote fingering, interaction to promote sustained attention). 7. Assisting Mom to find ways to increase visual engagement and attention; increase grasp accommodation experiences. 8. Adaptive positioning to carry over team goals of symmetry, midline postural control in play positions: bouncy chair, prone propping over a roll and Boppy Pillow, travel chair with insert and tray.	1. Decreased hyperalert response during movement and play. 2. Decreased stiffness in reach; graded UE and hand placement and exploration. 3. Increased variation in reach for play objects. 4. Sustained UEs in weight-bearing placement over open hand. 5. Increased fingering exploration of toys. 6. Grasp accommodation to varied shapes with active thumb movement. 7. Increased visual fixation and attention; increased cause–effect play. 8. Bouncy chair, prone prop over roll and Boppy Pillow, travel chair with insert.	

The mother's priority for Mya was improved calorie intake to maintain medically acceptable levels on all growth charts. Prior to this time, the twins had been hospitalized three times for failure to thrive and vomiting. In addition to the evaluation of movement control in a variety of positions, bottle feeding was also assessed. Mya's position of excessive shoulder elevation and neck extension made coordination of suck-swallow-breathe difficult. Alignment during feeding needed to be addressed, as did choice of bottles, nipples, and formula.

Positions that required more upright control were demonstrated and taught to the mother. These positions supported improved bottle feeding and they optimized the introduction of strained foods by spoon. Improved positioning also supported Mya's capability for communication and play. See Table B1.4 for a summary of Mya's goals, body structure and function impairments, and intervention strategies.

Speech therapy also addressed respiration and phonation. Mya could activate her diaphragm when the need for postural control was less demanding (e.g., supine). As the postural demands increased, she had difficulty coordinating respiration and vocalizing. As suggested by Massery,[20] "Trunk control, breathing and internal functions such as the GI tract, are dependent on the ability of the body to generate, maintain and regulate pressure in the thoracic and abdominal chambers."

Speech Therapy: Examples of Functional Activities for Maddison

The concerns for Maddison were similar to those already presented for Mya. However, Maddison had more asymmetry, less trunk strength, and a slower respiratory pattern than her twin. Feeding and positioning strategies were similar, yet had to be adapted to specifically address Maddison's differences. In addition, Maddison lacked the ability to consistently respond to and localize auditory stimuli and was suspected of having a hearing impairment.

B1.3.4 Phase Four: Developing a Plan of Care

The success of the intervention plan depends on a dialogue between the parent and the therapy team. In our case, the parent contributed information that augmented our observations and was instrumental in development of the functional goals written for each infant. Our next step was prioritizing the hypothesized impairments that interfered with goal achievement and designing intervention strategies to address all identified impairments.

NDT education provides the therapist with the theory and practice to develop the individualized intervention strategies to achieve optimal functional outcomes.[7,9,21] The NDT-educated therapist also possesses the handling and evaluation skills to expertly implement and modify each strategy based on the needs and performance of the infant throughout the intervention session.

In the case of Mya and Maddison, the parent-identified goals and body structure and function impairments were similar for each infant. Review Table B1.2, Table B1.3, and Table B1.4 to see the physical therapy, occupational therapy, and speech intervention plans for Mya. They also describe the intervention planning phase of the NDT problem-solving framework. The upper section of each table exemplifies the discipline-specific functional goals for Mya and the hypothesized body structure and function issues that interfere with acquisition of the discipline-specific goals. The lower section prioritizes the intervention strategies (column one) and their expected outcome (column two) on the hypothesized body structure and function impairments.

It was also critical to evaluate the effect of each strategy. This was accomplished through critical, online assessment (i.e., second to second) of the effect of handling based on the infant's sensory and motor responses. We also considered how handling effects positive or negative changes in posture and movement. This ongoing examination allowed us to adapt and revise each strategy throughout the session to ensure optimal responses in the infant's sensory and motor performance, thus creating a support environment for the attainment of functional skills. This online thought process is documented via the narrations for each of the intervention videos on Thieme MediaCenter which offer the opportunity to compare and understand how the intervention strategies were applied and modified based on the individual needs and responses of each infant.

B1.3.5 Phase Five: Home Programs

NDT encourages functional home programs that offer opportunities to practice the components necessary for skill acquisition in daily routines. Our team explored possibilities for meaningful home carryover of activities that supported the team goals. Initial home program ideas were directed toward the development of manageable feeding routines for both Mya and Maddison, which were critical due to concerns related to failure to thrive. Specific strategies have already been outlined in the section on speech therapy intervention.

It was also important to recognize the mother's environment and participatory constraints and to offer home activities that could be consistently implemented every day. Therefore, we developed viable positioning options that could be incorporated before and after feedings. These positions freed the mother to feed one baby at a time or to address the needs of the older sibling. In addition, these positions were safe, and they optimized alignment and supported the development of improved postural control. The positions encouraged symmetry and promoted head and trunk control, UE reaching, and engagement opportunities to support self-initiated play. Fig. B1.4 shows the twin's mother positioning her infants as instructed for feeding.

The following positioning options were recommended with the suggestion that they be rotated throughout the day.

1. An adapted feeding seat was recommended with a pummel and rolled towels to aid positioning. A tray was added to encourage forward weight bearing on UEs. This positioning provided effective practice for increased UE symmetry, visual interaction, and should girdle stability for exploration of toys using hands together in the midline.
2. For prone play, we suggested a rolled towel or small Boppy Pillow (The Boppy Company, LLC) to biomechanically shift weight backward toward the pelvis. This position facilitated the twins' abilities to lift and turn their heads and promoted midline UE alignment and opportunities to use the hands for play and exploration.

Table B1.4 Speech intervention planning worksheet

Name of Client: Mya Date: ____________________

Functional goals	Body structure and function impairment list
1. Mya will receive adequate nutrition for her adjusted age based on the guidelines established for infants with very low energy expenditure. 2. Mya will maintain a continuous suck-swallow-breathe pattern when drinking 6 oz of formula. 3. Mya will eat 4 oz of strained food when being spoon fed by a parent. 4. Mya will use sustained vocalizations to create a communication loop with her mother during play activities.	• Poor ability to initiate and sustain muscle activity while feeding with ∘ scapula depression/upward rotation with humeral flexion and with trunk control. ∘ abdominals, especially in frontal and transverse planes. ∘ pelvis for stability. • Poor selective control of muscle activation. • Tongue and jaw decreased stability. • Poor timing and sequencing of suck-swallow-breathe pattern. • Deficient in strength of flexion/extension muscles in trunk, UEs, and LEs to support alignment needed in head/neck while feeding. • Poor agonist and antagonist control of trunk, UEs, LEs. • Decreased ability to anticipate the postural organization necessary for this functional task (feedforward). • Mom's lack of information regarding prematurity and nutritional needs.

Interventions—sequence strategies relative to prioritized impairments	Expected impact on body structures and functions	Assess effectiveness of strategies: adapt, revise, or eliminate
1. While feeding with the bottle, support the baby's head at the base of the skull. Apply a slight elongation of the neck to flex the head slightly. 2. Place your finger in the lateral portion of the gum ridges. Allow the baby to munch on your finger. This will allow better tongue/jaw separation during feeding. 3. Use a bouncy chair with rolls to improve head and trunk positioning. Feed solids in this upright symmetrical position. 4. Provide opportunities to chew on her fingers, teething toys, or your little finger (placed on the lateral portions of the gum ridges). This activity will allow better separation of the tongue and jaw during feeding. 5. Feed in an upright symmetrical position for solid foods. 6. Thicken liquids with cereal to allow more time for the swallow. (Mya swallowed much faster with cereal added to thicken food). 7. Assist Mom to eliminate Mya's habit of grazing on bottle throughout the day. 8. Define nutritive versus nonnutritive sucking for Mom. 9. Help Mom establish routine feeding schedule. ∘ 7 a.m. 8 oz formula; 9 a.m. 4 oz stage 2 fruit or veggie. ∘ 11 a.m. 8 oz formula; 12 p.m. 4 oz stage 2 fruit or veggie. ∘ 2 p.m. 8 oz formula; 4 p.m. 8 oz formula. ∘ 6 p.m. 4 oz stage 2 fruit or veggie. ∘ 11 p.m. 8 oz formula	Improve head flexion during sucking and improve tongue position while bottle drinking and with solids.	

Abbreviations: LE, lower extremity; UE, upper extremity.

Fig. B1.4 The mother and the occupational therapist discuss positions that can be used to optimize postural control and alignment during bath and play time. Throughout their discussion the mom uses a feeding position recommended by the speech therapist. This position inhibits trunk and lower extremity extension and facilitates neck elongation and a chin tuck for improved sucking and swallowing.

3. A bouncy chair with rolled towels to support midline head positioning and improved trunk alignment also promoted opportunities to practice activation and balance of the trunk and pelvic flexor/extensor muscles. This position also promoted ease and opportunity to bring the hands together, to reach for play with hanging toys, or to explore parts of the body (e.g., abdomen, knees).

Home visits were scheduled to problem-solve strategies for improved attention, engagement, and play opportunities for the babies. During the visit, we showed the twins' mother how to minimize the environmental stimulation, helped her understand which toys fostered attention and engagement, and assisted her to create a designated quiet space for play and nap time.

Specific to Maddison's home program, we assisted the mother to organize a bath time routine that allowed Maddison to tolerate and eventually enjoy bathing as playtime. Strategies used to achieve this goal included reducing the speed of movement and providing deeper tactile pressure and prolonged tactile input as Maddison was placed in a bath chair, which provided additional postural support and security.

B1.3.6 Phase Six: Reevaluating Progress

Mya and Maddison were reassessed after 2 months of weekly physical, occupational, and speech therapy. Both infants demonstrated improved spontaneous movement and postural control in prone, supine, and sitting. These changes supported achievement of many of the mother's goals. Of primary importance was enhanced weight gain and nutritional intake consistent with standards set by the Centers for Disease Control and Prevention.[22] The infants' improved postural control also allowed them to be positioned in prone and supported sitting for longer periods of time and enhanced their ability to play independently, freeing their mother to attend to tasks around the home and to spend more time with her older daughter. Finally, their mother had an established routine for positioning and handling that supported the enjoyment and success of ADLs both for the infants and for her.

With regard to changes in the areas of gross, fine, and oral motor, each infant demonstrated progress in all of the goal areas, although Mya demonstrated greater posture and movement gains than Maddison. Unfortunately, the concerns their mother expressed regarding Maddison's hearing had been confirmed. Discipline-specific summaries describing the gains made by each of the infants are presented on Thieme MediaCenter.

Physical Therapy Reevaluation Observations

Mya's ability to sustain antigravity postures in prone and supine had improved because she was able to attain forearm supporting in prone and to initiate weight shifting in this position. This strength in the trunk and shoulder girdle set the stage for reaching for toys and the development of the reciprocal LE movements needed for creeping.

In supine, Mya could now reach out with both hands to grasp a toy. She no longer grasped and held her UEs on her chest to organize her posture. The ability to reach away from the body reflected increased strength and control of the neck and trunk muscles. This improved postural control created a foundation of stability in supine and allowed Mya the possibility to experiment with selective UE control for reach, grasp, and exploration of her body. She was also beginning to reach toward her knees and feet because lower abdominal strength and antigravity control had been developed. This improved postural control set the stage for independent rolling onto her side and the possibility of completing the roll to prone with minimal assistance and good lateral head righting.

Mya now sits independently when placed. She can reach forward to retrieve toys placed on the floor in front of her, and she can hold the toy while returning to upright sitting. This ability to grade sagittal plane movements in sitting will be the foundation for the development of compensatory and anticipatory postural responses. Mya is now prepared to practice reaching out for toys and developing the protective responses necessary to transition from sit to prone or into four-point position.

When placed in supported standing, Mya willingly accepted weight on her legs and was able to align her pelvis and shoulder over her LEs with good upright alignment. Mya could bounce up and down and explore the surface with her feet. She was secure and happy in this position.

Maddison's postural control and alignment also improved but lagged behind the level of Mya's motor abilities. In prone, she could prop on forearms, but her elbows were placed behind the shoulders. She could not yet weight shift side to side and consequently could not reach forward to retrieve a toy. Her weight was shifted back toward the pelvis, but full hip extension had not been achieved, and she continued to initiate movement by flexing her hips. Reciprocal LE movement was not observed.

In supine, Maddison could sustain midline grasp when given a toy but could not reach out and grasp a toy. She was able to lift her pelvis from the support surface, but varied UE and LE movement was not observed. In pull to sit, Maddison was unable to initiate the movement with a chin tuck and failed to align her head with her trunk until the last 30° of the maneuver. Mya, meanwhile, was able to tuck her chin, lift her head, and actively pull herself into sitting.

When place in sitting, Maddison required support at the trunk. To sustain this upright posture, she continued to recruit strong trunk extension, scapular adduction, and shoulder elevation and to hold her arms close to her body. This arm position interfered with her ability to reach for, grasp, or play with toys. This strategy of strong trunk extension, shoulder elevation, and scapular adduction was also observed when she was held in supported standing. In this position, Maddison was up on her toes and pushed into the surface using strong plantar flexion. This resulted in hip flexion with the pelvis positioned behind her BOS. This alignment made it impossible for Maddison to weight shift or move her lower limbs in standing. Until her trunk strength and control improve and she is able to align her hips over her BOS, standing will not be functional for Maddison.

Occupational Therapy Reevaluation Observations

Mya's strengthened postural control supported possibilities for better reach and grasp. While supine, Mya was able to reach up to touch her mom's face, explore her LEs, and reach for a toy. Her hands were open, and thumb abduction and extension supported a more optimal hand position for grasping. In prone, Mya reached forward and lifted her arms off the surface to reach for a toy while controlling the lateral weight shift. Forward reaching was consistently observed, but competency appeared refined and controlled when using the right UE. That said, her reach is not fully mature, and she lacks adequate grading at the elbow; however, the joint hyperextension observed earlier was no longer present.

In prone, supine, and sitting, Mya showed increased variation of forearm pronation and supination orientation during reaching. She was also able to support on one arm while reaching with the opposite hand. These strategies indicate emerging dissociation between the UEs and hands. In addition, the control developed through the shoulder girdle has increased Mya's ability to combine upright head and trunk posture with reach and grasp. Shoulder elevation was decreased in all positions, replaced by increased head and trunk control. This freed her head movement and enhanced her ability to investigate her environment in all visual fields.

When placed in sitting, Mya independently sustained a long sit position. This position created added postural stability, freeing the arms and hands to readily engage a toy. Hand movements were more relaxed and varied with thumbs out of the palms. With support at her pelvis, Mya engaged in emerging bilateral-reciprocal hand exploration (i.e., one hand stabilizes while the opposite hand manipulates). The ability to visually focus, sustain, and regain a gross grasp while also grading elbow flexion and extension was consistently demonstrated in her play. Visual awareness of her surroundings appeared to be improved, and Mya could be visually directed and redirected in structured play. Her play interests were consistent with those of a 5- to 6-month-old.

Maddison also made observable changes in her ability to reach and grasp, although her gains were not as varied or well developed as those of her sister. Maddison was more hypotonic than Mya, making antigravity movement more challenging. However, when given proximal trunk support in supine along with tactile cueing, Maddison could bring either arm up (left easier than right) and swipe at a toy held in midline. However, she continued to have difficulty maintaining reach in space without some distal contact (i.e., a tray or large toy).

When placed in prone, Maddison could not lift her arm to reach for a toy, but she could slide her arms forward toward a toy while maintaining head lifting and visual contact with the object. However, prone continued to be a difficult position to free her UE from the surface to reach for and play with the toy.

Unlike her sister, when placed in supported sitting, Maddison required tactile input to her extremity to induce a reach. She also required more proximal stability and assistance to sustain good alignment and upright sitting posture while reaching and grasping. When reaching for a toy with the left hand, Maddison continued to strongly retract the right arm and shoulder to increase trunk stability. As her trunk strength and control improve, we would expect the right arm will no longer need to be used as an assist for trunk stability.

When assisted with proximal support at her shoulders, Maddison's elbow and shoulder movement showed increased variability, particularly when distal stability was provided by a large object or toy. Improvement was also observed in the use of the hand with greater extension of the fingers and active thumb abduction. These strategies allowed improved exploration of objects and toys. Anticipatory organization of hands for varied grasp and ability to coordinate grasp with vision continued to pose difficulties for Maddison. However, with structure from the therapist, it was possible for Maddison to look at, reach for, and grasp a desired toy.

Speech Reevaluation Observations

Feeding, Respiration, and Communication

The feeding strategies outlined in the speech therapy intervention plan were emphasized over the past 2 months with noticeable improvements. Both Mya and Maddison showed improved coordination of the suck-swallow-breathe sequence necessary for efficient feeding. Their enhanced head control and alignment resulted in improved tongue and lip control during bottle drinking and spoon feeding. These improvements could also be attributed to the mother's consistent awareness of optimal positioning and alignment to support effective suck-swallow-breathe coordination during bottle feeding. With improved positioning and increased neck elongation while sucking, the twins required less support from their mother during feeding, and the reflux vomiting had stopped. The twins also improved in respiratory function and vocalizations as head and trunk control improved in upright positions.

In addition, the speech therapist consulted with a nutritionist, who determined the need for a formula change due to difficulty with milk protein. Along with the formula change, the following adjustments were also implemented, indicating better suck-swallowing control and ability to handle fluids.

- The nipple flow was changed to a slow flow.
- Formula was thickened to a nectar consistency.
- Feedings could be scheduled throughout the day to accommodate the family's schedule and time constraints.

One significant functional difference between the twins was in the area of audition. Maddison does not respond to auditory inputs unless paired with vision. Her visual response to auditory input is often with very wide eyes, and her responses to imposed tactile and movement sensations are initially overly cautious. Maddison enjoys supportive vestibular input but has difficulty pairing movement with visual attention. The family is now actively exploring a repeat audiology consult to determine if her hearing issues would be improved with an assistive device.

All of the changes just described are illustrated in a table of comparison photographs, which can be viewed on Thieme MediaCenter. This table visually underscores the discussion of discipline-specific gains observed during the reevaluation and allows for a comparison of each infant's posture and alignment with the photos and videos from the initial evaluation. In addition to clinical observation gathered during the reevaluation, the results of standardized testing and the mother's current concerns would be incorporated to formulate new goals, revise the intervention plans, and update intervention strategies for Mya and Maddison.

B1.4 Conclusion

In this case report, we described how the NDT Practice Model and the ICF model can be used to perform a multidisciplinary evaluation and to develop individualized intervention plans for twins born preterm. NDT provided the blueprint for the evaluation and the framework for developing intervention plans. The ICF model offered a format to analyze the clinical observations and to hypothesize the impairments interfering with their acquisition of functional skills. Following 2 months of intervention, the multidisciplinary collaboration of the occupational, physical, and speech therapists guided by the parent's insights formed the basis for a holistic intervention plan that resulted in improved functional outcomes for the twins and decreased stress and anxiety for the mother.

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Case Report B2 Examination and Evaluation of Oral Feeding and Communication after a Gunshot Injury to the Head

Marybeth Trapani-Hanasewych

B2.1 Introduction

A gunshot wound to the head is a devastating event for the victim and family. Shootings are the fifth leading cause of unintentional death among American children under the age of 15.[1] Firearm-related injuries are especially lethal; approximately two-thirds of these injuries result in death.[2] Firearm-related death rates are highest among persons aged 15 to 34 years (8.5/100,000).[2] In 2009, there were 76,100 emergency department visits for firearm-related injuries, 35% of which were for unintentional injuries.[3]

This case report explores what happened when a 14-year-old's cousin accidently shot him in the head. It chronicles the recovery process of Russell, following him for 9 weeks, beginning with his admission to inpatient rehabilitation and concluding with his discharge home (Fig. B2.1). This report provides an overview of the care provided during Russell's inpatient acute rehabilitation stay and explores the application of key principles of Neuro-Developmental Treatment (NDT) practice to the clinical management of an adolescent with traumatic brain injury (TBI) during the early phases of his rehabilitation program. It also provides an integrated view of Russell's therapy programs, describing the interrelationships of his occupational therapy, physical therapy, and speech-language therapy programs from the viewpoint of his speech-language pathologist (SLP) within the context of an NDT framework of practice.

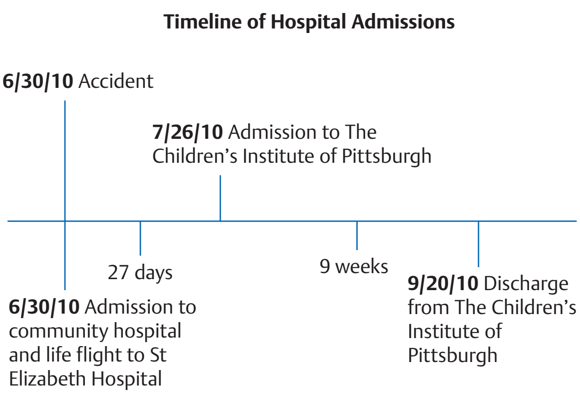

Fig. B2.1 A timeline of hospital admissions and discharge for Russell.

The report chronicles Russell's recovery process, identifying the sequential gains in abilities and the clinical decision-making process used by his medical rehabilitation team to enhance his functional independence. This case also explores the interrelationships of care provided by his SLP, occupational therapist (OT), and physical therapist (PT). From the speech-language therapy perspective, it explores gains in communication, feeding, and swallowing, and their relationships to the management of his tracheotomy tube, as well as the relationships to gains in locomotion and activities of daily living.

When a life-altering, traumatic injury occurs to a child, parents/families often have difficulty prioritizing their goals. They want all their goals to be successfully achieved, often immediately, but when asked, most families want eating and some form of communication restored as quickly as possible.

B2.2 Case Description

B2.2.1 Accident and Acute Care History

Russell was a healthy, active, typically developing 14-year-old boy who, on June 30, 2010, sustained an accidental gunshot wound to his head at 4:00 a.m. According to the parent's report, he was sleeping overnight with his cousin. A neighbor heard an explosion, came to the cousin's house, and called 911. The bullet had entered Russell's forehead, continuing through the frontal lobes, penetrating through the ventricles, and exiting the occipital area, creating an open TBI.

Russell was intubated at the scene and life-flighted to the hospital, where he underwent a computed tomographic (CT) scan of his brain (Fig. B2.2). He underwent surgical management for his head injuries on the date of admission. He was placed under sedation for several weeks (Fig. B2.3). His prognosis for recovery of any meaningful function was poor. The evidence cites that, when the wound is penetrating and enters more than one lobe and the ventricles, outcomes are poor with severe disability or death.[4,5] Outcomes are considered poorer for those with extensive bullet tracts, those that cross deep midline structures of the brain, or those that involve the brainstem.[6]

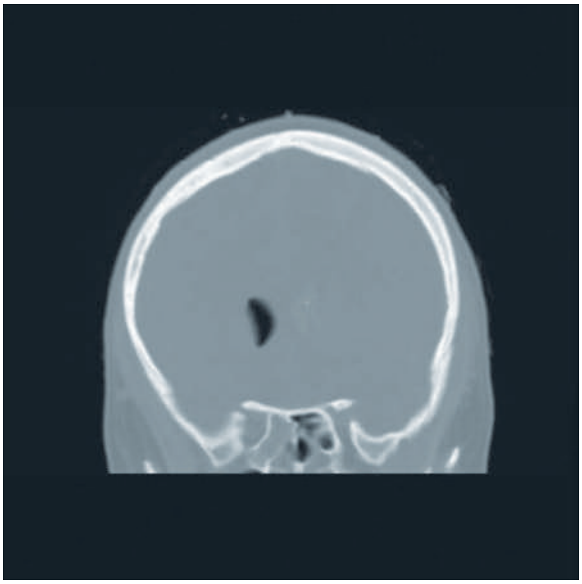

Fig. B2.2 Findings consistent with a bullet track are seen extending through the midportion of the brain. The track extends from the frontal bone just left of midline through the frontal lobe and left lateral ventricle, extending posteriorly just to the left lateral aspect of the falx and exiting posteriorly near the midocciput (per computed tomographic scan report).

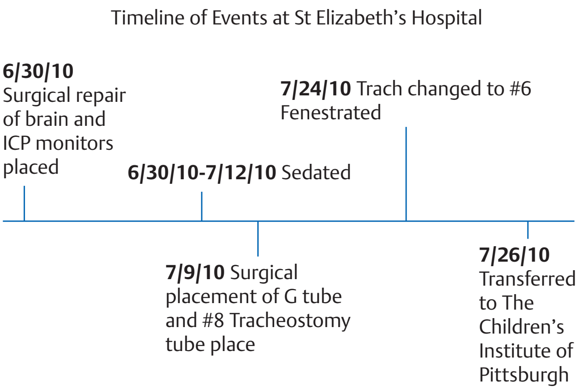

Fig. B2.3 Timeline of events at St. Elizabeth's Hospital.

Intracranial pressure monitors were placed, and his pressures were monitored while he was sedated. He had a gastrostomy tube (G-tube) placed 3 weeks into his acute care stay. Prior to this placement, he was nourished through intravenous therapy. He underwent a percutaneous tracheotomy 9 days into his acute care admission. He was treated with antibiotics for multiple fevers secondary to tracheitis and grew methicillin-resistant *Staphylococcus aureus* (MRSA).

When he was weaned from the sedation, his parents noted he was able to move his left extremities and inconsistently follow simple commands. His mother reported that at times he would shake his head *yes* and *no*, but this communication was not observed during the initial speech-language evaluation.

B2.2.2 Inpatient Rehabilitation Admission

Russell was admitted to The Children's Institute of Pittsburgh on July 26, 2010 (see timeline in Fig. B2.4). He was functioning at a Rancho Los Amigos Level III at admission.[7] This level is described as a patient showing localized responses to sensory stimuli and inconsistent responses to simple commands.

A person at this level will

- be awake on and off during the day.
- make more movements than at Levels I and II.
- react more specifically to what he sees, hears, or feels. For example, he may turn toward a sound, withdraw from pain, and attempt to watch a person move around the room.
- react slowly and inconsistently.
- begin to recognize family and friends.
- follow some simple directions such as "look at me" or "squeeze my hand."
- begin to respond inconsistently to simple questions with "yes" or "no" head nods.

Russell was not able to move in bed, transfer, or walk. He was totally dependent on others for any shifting of a position in bed. He could not sit without total support. Russell had no weight-bearing precautions upon admission. However he was at risk for falls. He had contact precautions, MRSA, and a left subclavian triple lumen catheter to deliver fluids and medications. He arrived with a fenestrated tracheotomy and gastrostomy tube. He was not able to communicate. He had no vision in his right eye and displayed a severe downward gaze secondary to bilateral cranial nerve, III, IV, and VI palsies. His parents were told that his right optic nerve was likely transected based on his CT scan. He presented with hyponatremia and was diagnosed with syndrome of inappropriate antidiuretic hormone secretion (SIADH). SIADH is an imbalance of sodium in the body. This is managed by restricting fluids and providing sodium supplementation. For months he required fluid restrictions and sodium supplementation. When he was able to safely drink, he was unable to do so due to SIADH.

Russell's past medical history indicated that he had been diagnosed with attention deficit hyperactivity disorder (ADHD) and attention deficit disorder (ADD) during childhood and was not currently on medication. He also underwent an appendectomy in 2008.

Russell's social/family history indicated that he lived with parents, two older sisters (ages 17 and 16), and an 18-year-old brother. Russell lived in a two-story home with 1 step to enter and 12 steps to the second floor. His bathroom was on the first floor, and his bedroom was on the second floor. The parents reported that a first floor bedroom setup was possible for him at home. Russell was entering the 9th grade at his local high school.

Status at Admission

Russell demonstrated the following activity limitations and impairments of body structures and functions at the time of admission.

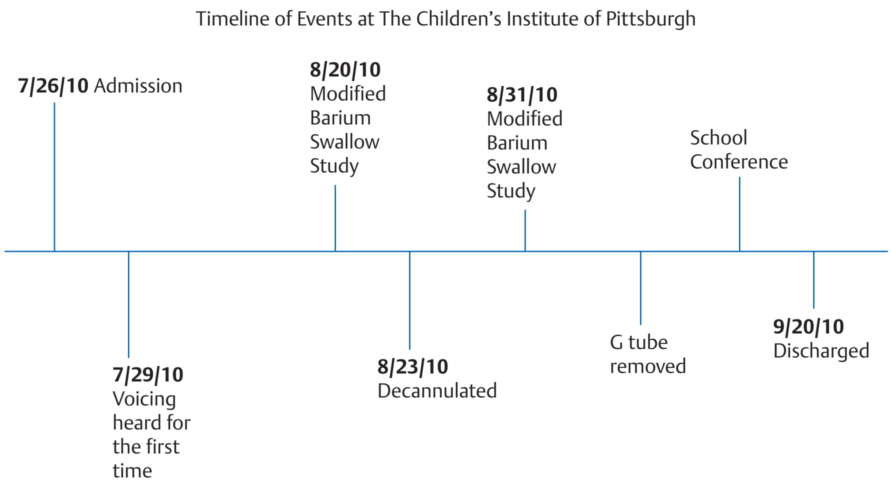

Fig. B2.4 Timeline of events at the Children's Institute of Pittsburgh.

- He was nonverbal and was unable to eat.
- He did not use vision and was unable to move and hold a position without total assistance of two people.
- Russell presented with weakness throughout the upper and lower extremities and trunk, along with right hemiparesis, and was scored as Rancho Los Amigos Level III. He had poor motor control and poor initiation of movement bilaterally, but the right side was more impaired then the left. He had poor coordination bilaterally; more focused on the right. He demonstrated abnormal motor patterns on the right with low postural tone with spasticity.
- He presented with proprioceptive and tactile impairments that were focused on the right side, vestibular impairments, and nausea when in upright positions.
- He had paralysis due to injuries of cranial nerves III, IV, and VI.
- He tired and fatigued easily.
- Cognition, expression, and receptive language were severely impaired.
- He had impaired memory.
- Russell had impairment of regulation that resulted in an increased heart rate.
- Russell had no transfer or mobility skills.
- He had no communication or self-care abilities.
- He had no leisure skills.

The parents and family wanted Russell to return back to his baseline function. However, at admission he was functioning with total care for all needs.

Analysis of Impairments of Body Systems

- *Neuromuscular:* Loss of postural motor control impaired his ability to initiate any movement. Hypotonic proximally with spasticity noted distally in the upper and lower extremities impaired his ability to move or maintain any postures against gravity.
- *Sensory:* Moderately impaired proprioceptive, vestibular, tactile, and visual systems.
- *Musculoskeletal:* Moderate to severe muscle weakness throughout the bilateral upper and lower extremities and trunk. Range of motion limitations for bilateral ankle dorsiflexion to neutral and popliteal angle of 43° on the right with hip flexed at 90°.
- *Respiratory:* Admitted with fenestrated cuffed tracheostomy. He had an abdominal binder that inhibited diaphragmatic/abdominal breathing. The binder was being used to prevent him from pulling his gastrostomy tube out.

View from the Perspective of a Speech-Language Pathologist

Russell was treated by all disciplines for intensive therapy. He received physical therapy, occupational therapy, and speech-language therapy services two times per day for each service. On the weekends, he received all services one time per day on Saturday and rested on Sunday. His mother was by his side constantly and was a key reason for his success. She attended therapies and practiced the skills during any down time. Some of the key transitions that occurred throughout his stay as observed by the SLP include the following.

Tracheostomy and Oral Trials

Russell wanted to eat orally but had been listed as receiving nothing by mouth since the accident. A fenestrated tracheostomy can cause more infections and adhesions and is usually reserved for use when someone is vented. Russell was no longer on a ventilator, so his tracheostomy was changed to a no. 6 Shiley tracheostomy tube (Medtronic). It was important to restore the pressurized system of the swallow by using a Passy-Muir speaking valve (Passy-Muir, Inc.). The speaking valve is a one-way valve that allows the patient to breathe in through the tracheostomy but forces the air up over the vocal folds and out the oral and/or nasal cavities. Restoring air to the oral and nasal cavities enhances taste and smell abilities.

Since the change to the Shiley no. 6 tracheostomy tube, the larynx was more free to move in an upward and forward position to swallow because it was no longer tethered with the inflated cuff in the trachea. Therapy started with oral stimulation activities that quickly moved to water-based trials of smooth foods, such as applesauce. He would tire quickly because he had to maintain a supported upright position.

Swallow Study

In week 4 of his admission, the first swallow study was completed on August 20, 2010, with the tracheostomy present. He was safe for regular foods but unsafe for thin liquids. Russell silently aspirated on thin liquids. He penetrated into the airway with nectar thick liquids but cleared with a double swallow or a cough and swallow. See the video of Russell's swallow study on Thieme MediaCenter.

He was able to tolerate the Passy-Muir valve at all times and was moving toward capping and decannulation. His mother clearly understood the value of using a speaking valve and provided the valve for all Russell's waking hours. The coordination Russell needed to adequately manage the thin liquid was emerging. See video on Thieme MediaCenter.

The following impairments were observed at this time:

- Decreased hyolaryngeal excursion.
- Premature posterior bolus spillage.
- Delay in initiation of a swallow.

Speech-language therapy focused on increasing the volume of regular foods to decrease the need for tube feedings. He drank nectar-thick liquids with meals and thin liquids with speech-language therapy only. In therapy, he practiced with small amounts of thin liquids with an increasing awareness of the liquid "going the wrong way" and coughing. Coughing is a sign that the sensory receptors in the trachea are recovering, and Russell could feel when the liquid was aspirated or had penetrated.

He also participated in activities to facilitate hyolaryngeal excursion range. This increased range helps to protect the airway from penetration and aspiration by pulling the larynx forward and narrowing the trachea, opening the upper esophageal sphincter to open the esophagus as the epiglottis rudders the bolus toward the esophagus. He was decannulated within a week of his first study. This decannulation helps because the laryngeal complex is no longer weighted by the tracheostomy tube. It was important to complete the modified barium swallow study as soon as it appeared that he would be successful with thin liquids. In this case, he was cleared within a week of tracheostomy tube removal.

The second swallow study was completed August 31, 2010. He was safe for thin liquids. He quickly moved to a regular diet with thin liquids. See the video on Thieme MediaCenter.

Use of Vision

Upon admission, Russell had no vision in the right eye and a severe downward gaze. His mother and the SLP reported that he seemed to be using some vision. Russell first used his vision by lifting his face toward the ceiling to look at things before his eyes could move closer to midline. When the SLP played cards with him, such as *Uno*, he was first able to discriminate the colors and then the numbers. When Russell was in joint intervention with physical therapy and speech-language therapy, the PT also noted his improved visual skills. This seemed to help build momentum for others to observe his improving visual skills.

Abdominal Binder

Russell wore an abdominal binder to protect his gastrostomy tube from being pulled out. In a joint intervention session when the PT was working on ambulation, the PT was having difficulty cuing Russell at his abdominals due to the binder. When the binder was removed, he began more active and accurate steps with improving speed. The SLP requested to the physiatrist to remove the order to use the abdominal binder because Russell was no longer pulling the gastrostomy tube. In addition, he no longer used the tube because he was meeting all nutritional and medication needs orally. This request prompted her to remove not only the binder but also the gastrostomy tube. This is an example of how each team member can positively affect the recovery process by looking at the whole person as a dynamic, responsive, and ever-changing being. NDT principles teach us to observe and identify those needs as they change throughout the rehabilitation process.

Medical Management

Cognitively, Russell was answering *yes* and *no* questions with better consistency and accuracy of correctness. However, his memory was so impaired that it was interfering with all facets of rehabilitation and learning. He was prescribed amantadine to stimulate his dopaminergic system and cognitive recovery. He tolerated the medicine well without side effects. After several weeks, he was weaned from the medicine without decline in memory or cognitive skills.

Metacognition

Russell had poor self-monitoring skills, with frequent outbursts of silly sounds or saying *burp* with no actual burp. He showed no embarrassment for the time or the audience that was present. The amantadine helped to reduce these incidents and increase his self-awareness to the inappropriateness of these behaviors.

Use of the Wheelchair—a Team Decision

Upon admission, Russell's medical status required that he be reclined in sitting due to impairment in the vestibular-ocular system; when upright for prolonged periods of time, he experienced nausea and fatigue. A reclining wheelchair allowed him to rest when needed, without enduring the difficulties of transferring back to bed. Medically, Russell required a reclining wheelchair for the first 2 weeks of his admission. However, once over the initial phase of fatigue and as his tolerance for upright activities improved, he was ready to be transitioned to a standard-back, nonreclining wheelchair.

This upright wheelchair was requested from the SLP. It allowed Russell to be more active in sitting, and, when in upright, he seemed more alert, with improvements noted in his cognitive and language skills. The other members of his medical rehabilitative team agreed the he was ready for less-supportive seating. Within the NDT Practice Model, all members of the team are encouraged to share their observations and insights and are empowered to make clinical recommendations to enhance the individual's overall functional potential. Communication, language, and cognition fall within the traditional scope of practice for an SLP. For an SLP practicing with knowledge of NDT, there is an enhanced understanding of the importance of postural control and biomechanical alignment and their influences on the ability to produce sounds and engage in communication. As a member of an NDT team, the SLP is able to step outside the traditional bounds of speech-language therapy and embrace the child as a whole person. When doing so, the therapist can consider the needs of the whole person to enhance discipline-specific functional capabilities.

Discharge

At 9 weeks after admission, Russell had changed from total assist in all domains of care to moderate assist in grooming, bathing, and toileting, as measured by the WeeFIM II Instrument (Uniform Data System for Medical Rehabilitation, UB Foundation Activities, Inc.). In the other domains, he primarily required minimal assist to supervision, while bowel and bladder management were rated as modified independence.

Russell was discharged at Rancho Los Amigos Level V, which is labeled Confused-Inappropriate, Non-Agitated.[7] A person at this level will

- be able to pay attention for only a few minutes.
- be confused and have difficulty making sense of things outside himself.
- not know the date, where he is, or why he is in the hospital.
- not be able to start or complete everyday activities, such as brushing his teeth, even when physically able, and often need step-by-step instructions.
- become overloaded and restless when tired or when there are too many people around.
- have a very poor memory; remember past events from before the accident better than his daily routine or information he has been told since the injury.
- try to fill in gaps in memory by making things up (confabulation).
- often get stuck on an idea or activity (perseveration) and need help switching to the next part of the activity.
- focus on basic needs, such as eating, relieving pain, going back to bed, going to the bathroom, or going home.

Russell was discharged home without any medications and with glasses and a gait belt. He could walk with some difficulty in clearing his right foot, which caused some balance issues when he did not clear it. He had not used a wheelchair in the last month of his stay. He could manage two flights of stairs with minimal supervision. Russell was very motivated to continue to improve his mobility skills. He would need to continue to work on improved gait and increased endurance. He was not appropriate for gym classes but would be continuing with physical therapy three times a week.

Russell needed supervision in dressing with T-shirts and elastic pants. He could don and doff his shoes with minimal to no supervision. He needed total assist for tying his shoes. He wore an articulated ankle-foot orthosis (AFO) on his right foot. His visual motor skills were evaluated using the Beery Developmental Test of Visual-Motor Integration (VMI), and he scored at 5 years 6 months for handwriting. The Test of Visual Perceptual Skills (TVPS) scores ranged from 4.6 to 8.2 years. He needed to be cued to write his name and address. He needed multiple rest breaks when doing higher cognitive skills, such as school work. He wore glasses but had decreased depth perception.

Russell was pleasant and cooperative. He performed best with 1:1 attention, especially when there were distractions or his attention was divided or he needed to shift between tasks. In academics, his reading and math skills were in the mildly impaired range of performance.

He interacted with people appropriately. He spoke in conversations with others. He had mild word-finding difficulty but could be cued by group, location, action, or properties of the word. He was often impulsive in quickly saying, "I don't know." If he was cued to think first, he could try another answer. It was suggested that he always go back and check his written work. His memory was improving but he did better if information was presented in shorter chunks that were concrete rather than abstract. It was suggested that comprehension checks be done when longer or more complex information was presented.

In terms of executive functioning, he could plan his own birthday party but had trouble organizing and retaining the information. Once strategies such as writing it down in a logbook were more habituated, he could use those tools to move on to the next planning phase, such as creating invitations.

It was recommended that he return home with intensive therapies, three times a week for each discipline. He had homebound therapy and then went to outpatient therapies three times a week at a local hospital. Once he was able to tolerate that routine, he was placed back in school for mornings with an aide and then went to his therapies in the afternoon. It is expected that he will have continued recovery for the next 2 to 5 years.

B2.3 Discussion of NDT

Berta Bobath said, "See what you see and not what you think you see."[8] We are sometimes so influenced by test results and professional observations that we may not take the time to listen to the families when they report that they are seeing better function. NDT teaches to listen to all that are involved with the patient and to try to be objective. In rehabilitation, the line between what is possible and what the evidence says is possible is a fine one. Russell arrived at The Children's Institute with a poor prognosis due to the severity of the brain injury. However, the intense therapies and strong support from his mother and family defied his odds of recovery.

NDT teaches us to be open to the possibility of change. You as a therapist may not expect change to happen just because the evidence tells you there will be a poor outcome; in this particular case the outcome was much better than the evidence would predict. If you allow past outcomes of others reported in the literature to dictate your prognosis, the child and the family will know that you do not believe in the possibility of success. Therefore, you will not look for the positives; instead, you will look for the things that will substantiate your belief that the outcome will be poor. In my mind, there were no limits to the possibility of a full recovery and to meet the goals of the family.

NDT teaches us to look at the whole person. We do not work with a person that is to be divided by parts or disciplines. This is why it is so important to allow your view of the patient to be widened and to make suggestions; for example, changing the wheelchair or looking at his visual skills.

We as therapists need to question and challenge each other and not see questioning as a threat or negative observation; rather, as a collaborative effort to meeting the needs of the patient. NDT offers the tools for an SLP to understand the whole physical aspect of rehabilitation and problem solving within a framework based on understanding in the movement sciences. Once an SLP understands the bigger picture and is able to integrate it into the field of speech pathology, the tool kit for therapy is greatly increased to meet the needs of the patients in the most efficient and effective manner.

B2.4 Outcome Measurement Tool

The outcome measure used during Russell's rehabilitation stay was the WeeFIM II instrument. The WeeFIM instrument was developed to measure the need for assistance and the severity of disability in children between the ages of 6 months and 7 years. The WeeFIM instrument may be used with children above the age of 7 years as long as their functional abilities, as measured by the WeeFIM instrument, are below those expected of children aged 7 who do not have disabilities. The WeeFIM instrument consists of a minimal dataset of 18 items that measure functional performance in three domains: self-care, mobility, and cognition.[9] Russell's admission and discharge scores are listed in **Fig. B2.5** and graphed in **Fig. B2.6**.

	Admission	Discharge
Eating	1	5
Grooming	1	3
Bathing	1	3
Dressing UE	1	4
Dressing LE	1	4
Toileting	1	3
Bowel	1	6
Bladder	1	6
Chair Transfer	1	4
Toilet Transfer	1	4
Tub Transfer	1	4
Walking	1	4
Stairs	1	4
Comphrension	1	5
Expression	1	5
Soc Interactio	1	4
Problem solve	1	4
Memory	1	4

Fig. B2.5 Russell's WeeFIM II scores at admission to The Children's Institute of Pittsburgh and at discharge.

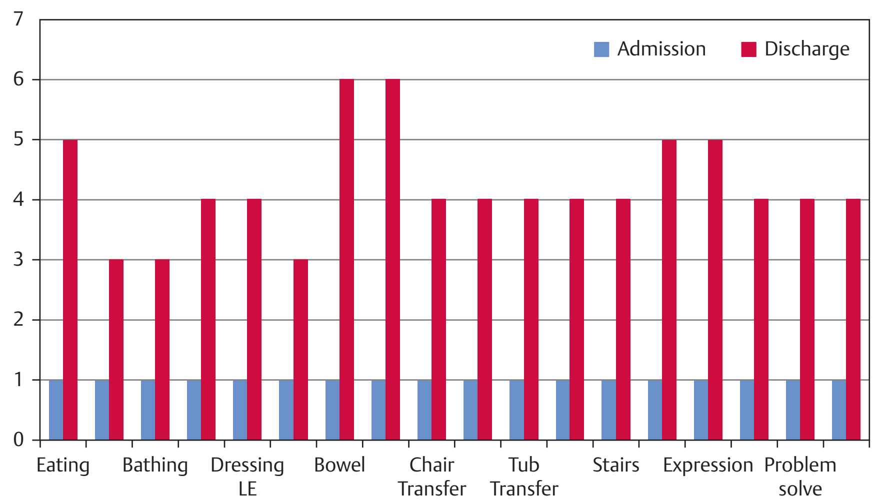

Fig. B2.6 Russell's WeeFIM II scores graphed.

The WeeFIM instrument is generally used to estimate the burden of care for patients that are seen in the rehabilitation setting. It is scored on a 7-point scale.

Independent
Modified independence
Supervision
Minimal assistance
Moderate assistance
Maximal assistance
Total dependence

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Case Report B3 Development of an Intervention Plan of Care for a Young Child with Hemiplegia

Pamela A. Mullens

B3.1 Introduction

When using the Neuro-Developmental Treatment (NDT) Practice Model in the formation of a care plan for a young child with hemiparesis, practitioners should consider the child holistically, within the context of his or her world. The world for many infants includes their parents and family, as well as care providers. As the child ages and develops cognitive, communication, manual-bimanual, and mobility skills, the boundaries of the child's world expand. The confidence and sense of self needed to venture away from the security and safety of a trusted caregiver evolve over time, with small successes laying the foundation for larger achievements. This case report explores the possible relationships among the body structures and functions, activities, and participation for a young child with hemiparesis, with a focus on the context of his psycho-social-emotional development.

The term ***hemiplegia*** is commonly used to describe the manifestation of a neurological insult to the brain resulting in sensorimotor deficits where one side of the body is more affected than the other. *Hemiplegia* may refer to a complete paralysis of the involved limbs and *hemiparesis* to a weakness. For the purposes of this case report, we will refer to hemiparesis, or weakness.

B3.2 Common Features of Congenital Hemiparesis

Identification and diagnosis of hemiparesis in early infancy can be challenging for the clinician. One of the earliest signs of the movement disorder is the presence of asymmetrical postures and movements; asymmetry may be seen in the infant who is typically developing up to 4 months of age, with the asymmetrical postures being most evident at ~2 months of age. Bobath and Bobath,[1] Bly,[2] and Kong and Quinton (lecture notes from a course in Neuro-Developmental Treatment conducted in Seattle, Washington,1978) have described the natural progression of the development of movement in children with hemiparesis from infancy to the mastery of upright function.

Fisting of the more involved hand has been reported as an initial sign of hemiparesis and is seen in conjunction with delayed motor milestones and increasing movement asymmetries.[1,2] Initially, the leg on the hemiparetic side is not as active in kicking as the less involved leg.[1] The trunk on the more involved side is also affected, initially appearing hypotonic,[2] and later may become shortened due to spasticity of trunk musculature as the infant begins to sit and stand.[1] Bobath and Bobath[1] also noted that, as motor development progresses and the child comes to sitting and begins to play using the less involved arm and hand, the arm on the hemiparetic side frequently tends to retract at the shoulder and may be held with elbow flexion and fisting of the hand.[1] Atypical movement synergies in the leg on the more involved side become increasingly apparent as the child develops the ability to stand and walk.[1] Hypertonicity in the more involved upper and lower extremities frequently increases as the child comes to standing and begins to walk.

Additionally, failure to progress through patterns of movement seen in typical development may result in biomechanical abnormalities. Due to atypical or restricted movement patterns, soft tissue structures, such as muscles, ligaments, and connective tissue, may not receive the lengthening provided by typically developing movement. This failure to lengthen, in turn, contributes to the development of secondary musculoskeletal impairments.[2,3,4]

Contractures may develop over time if muscles and joints are held consistently in static positions[4,5] and may lead to bony abnormalities.[2] Limb growth on the affected side may be reduced as a result of decreased and asymmetrical weight shifting and weight bearing and decreased muscle activation.[6] Reduction of weight bearing over the more involved limbs may result in osteoporosis,[7] and pain and arthritis may occur earlier in the population of adults with cerebral palsy than in the population at large.[7,8,9]

Sensory deficits, including tactile, proprioceptive, kinesthetic, and visual field deficits, are also reported in children with congenital hemiplegia,[10,11] contributing to neglect of the more involved arm. Neglect of the more involved arm may increase when the child engages in reaching activities with the less involved arm. The child attends to movement and function of the less involved arm while ignoring the more involved arm that cannot perform movement effectively. This neglect includes lack of visual attention to the arm and hand and decreased attention to tactile, kinesthetic, and proprioceptive sensation in the involved upper limb. The increasing activity of the less involved side frequently results in increased stiffness of the more involved arm, resulting in fisting of the hand, elbow flexion, and forearm pronation. Gradually, the child appears to ignore and reject the arm on the hemiparetic side. The child may refuse to look at the more involved arm and hand and dislike being touched on that side.[1]

Therapeutic management of the primary and secondary impairments associated with spastic hemiparesis in cerebral palsy in children requires an approach that takes into account and fosters the child's psychosocial development and the interaction between this development and body system impairments. NDT offers a viable clinical practice to the management of hemiparesis in young children. NDT's Practice Theory and Practice Model address the impairments underlying participation restrictions and activity limitations and stress the importance of the prevention of secondary impairments, including impairments in aspects of psychosocial development that may limit function as the child grows and develops. These models also strive to work with the child in the context of the family and to support parents/caregivers in understanding their child's integrities, impairments, capabilities, and functional limitations so that they can promote optimal function and participation.

Perry's intervention began in the first year of life. Early intervention beginning, if possible, in the first year of life is compatible with motor development principles of the NDT Practice Model. The earlier the intervention begins, the greater the opportunity for prevention of contractures and the attainment of functional goals. Basu[12] supports this principle and recommends continuing efforts to improve early detection of perinatal stroke so that intervention can begin at a time when activity-dependent plasticity in descending motor pathways is active and available.

B3.3 Case Report

This case report documents the diagnosis, the presenting problems, and the integrities of Perry, a young child with hemiparesis. It also documents the development and application of a plan of intervention specifically designed for Perry.

B3.3.1 Case Description

This case report follows Perry during a 2-year period of physical therapy beginning at the age of 9 months. His initial examination findings revealed delays in fine, gross, and oral motor function, as well as the emergence of impairments in the neuromuscular, musculoskeletal, and sensory-perceptual systems.

B3.3.2 Information Gathering

Perry was born at term; his mother reports that her pregnancy was typical, with no complicating factors. A medical evaluation was sought when Perry was observed not moving his left arm and his hand was held in a fisted position. At the age of 7 months, he was diagnosed with right middle cerebral artery infarct with cystic encephalomalacia. Within the first 2 years, there were reported concerns about the possible presence of seizure activity. On account of these concerns and because seizure activity frequently accompanies this diagnosis,[13] Perry was referred to a neurologist. Seizure activity did not present problems during this period of intervention.

Perry and his mother participated in an integrated infant/mother group at the University of Washington Experimental Education Unit (EEU) that provided Perry with educational services, occupational therapy, and speech-language therapy. It did not offer physical therapy, so these additional outpatient services were sought and began at the age of 9 months.

Perry is the youngest of three children in a two-parent family. His mother is not employed outside of their home, and his father is a professional employed in the field of special education. Additionally, the extended family was available for support. Perry's parents were willing to learn and do whatever was necessary to help their son.

B3.3.3 Examination: Observations and Initial Hypothesizing

Perry was first observed both in his home and at the infant/mother program at the University of Washington. The intent of the observation was to become acquainted with him and with his family, to determine his level of function, and to form initial hypotheses regarding impairments underlying observed activity limitations. These observations were made without handling by the therapist to obtain information regarding spontaneous behavior.

Participation and Participation Restrictions

Perry participated in the life of his family in the role of the youngest child. He also attended and participated in the infant/mother class at the EEU. Perry was unable to participate in the life of his family at the level expected of a 9-month-old child, primarily due to activity limitations preventing him from performing at an expected age level. He preferred not to leave his mother's lap, and he was carried by his mother, since he had no independent means of locomotion and could not actively explore his room and house independently.

Activities and Activity Limitations

Play

Perry played in a sitting position on the floor, supported in his high chair, or sitting on an adult's lap. His preference was to be on his mother's lap or to be carried by his mother. He liked to play with toy cars, noise-making toys (toys that made sound when shaken or banged or pressed), balls, and household items, such as pots and pans. He also enjoyed books and pictures. Perry used only his right hand to engage in play; no two-handed play was observed during the initial examination. When seated on the floor, Perry played with toys that were brought to him and presented either in front of him or on the right side. He ignored objects presented on the left. If toys went out of reach in front of him, he reached for them by bringing his trunk forward with hip flexion. Attempts to retrieve toys out of his reach on his right side were not noted.

Feeding/Nursing

Breast-feeding was Perry's main source of nutrition. He also sat in a high chair at the table for family meals but ate very little. He was offered pureed and some solid food. He ate pudding and ice cream from a spoon, and sometimes he held a cookie or other solid food in his right hand, brought it to his mouth, and ate small amounts.

Breast-feeding appeared to be a factor in self-regulation as well as in nutrition. When Perry became anxious, he gestured and indicated that he wanted to breast-feed. When Perry lay on his right side for breast-feeding, he brought his left arm and hand forward to touch his mother's body. He opened his left hand and held it against her; this appeared to be a purposeful movement and was the only voluntary movement of the left arm that was observed during the initial examination.

Communication

As expected for his age, Perry did not communicate verbally during the observation period. However, he demonstrated a well-developed gestural system of communication. He used facial expression, body movement, and vocalizations to indicate his emotional state and his likes, dislikes, and wants. He pointed with his right hand at objects he wanted and made sounds that drew attention to his gestures.

Locomotion

Perry had no independent form of locomotion. He moved around in the environment held and carried by his mother. Infants of 9 months of age typically have a form of independent locomotion.[3,14,15] Independent locomotion allows an infant to explore the environment and to gain competence in securing and investigating interesting objects in the environment. Without independent locomotion, these experiences were not available to Perry.

Lack of independent mobility prevented Perry from moving away from and toward other people and from developing age-appropriate separation from and reunion with his mother. He demonstrated no transitional movements, which further prevented him from experiencing independence in moving to upright positions.

Perry's inability to move away from his mother influenced his social development and his relationship with his mother. Children of 9 months of age are usually able to control their distance from the mother and use her as a secure base from which to explore the environment. They are able to return to her in the presence of perceived threats in the environment or for reassurance. This ability to control proximity to the caregiver allows the infant to consolidate and further develop the attachment relationship.[16]

Multisystem Integrities and Impairments

Given Perry's lack of self-driven environmental exploration and spontaneous movement transitions, he was placed in specific developmental positions to examine his movement capabilities, postural control, and motor control. Perry's mother moved and positioned him because he became easily agitated if he was separated from her or if he was moved or positioned by the therapist. These observations were directed toward determination of single-system and multisystem issues within the domain of body structure and function, underlying observed activity limitations.

Supine

In this position, Perry raised both legs from the surface to ~90° of hip flexion on the right and ~45° on the left. He reached forward with his right hand to touch his legs and toes (more frequently the right leg but occasionally the left). He did not reach forward with the left hand. When assisted to reach with his left arm and hand, he appeared frustrated.

Prone

Perry tolerated the prone position for less than 2 minutes. He could not move his arms forward for support or push against the surface to lift his upper body. He attempted to move, but he quickly became anxious and frustrated.

Rolling

From supine lying, he could roll to the right and left sides. He was unable to transition from supine to prone due to his inability to move his right or left arm out from under his body.

Sitting

Perry maintained static balance when placed in sitting. He could not transition to sitting from the supine or prone positions. Occasionally, he fell from sitting to lying. He did not attempt to correct for disturbances of balance or reassume the sitting position. During play, if a toy strayed to the right side, he reached to the right only as far as he could without losing balance. He did not reach toward the left. He sat with both legs in hip abduction and external rotation, with his left leg slightly more externally rotated than the right. His left arm hung at his side, with the left hand usually in a fisted position. When Perry performed effortful movement with the right arm and hand, the left arm assumed a position of elbow flexion, shoulder abduction, and slight retraction of the shoulder complex.

Postural Control in Sitting

Perry sat with his pelvis upright with apparently equal weight distribution on the right and left sides of his base of support. He demonstrated limited weight shifting in all directions. In the sagittal plane, Perry reached forward until his hips were at ~45° flexion and then returned to midline. Weight shifting and reaching backward in space were not observed.

Supported Standing

Perry took weight over both legs when held in supported standing. He enjoyed this position. He attempted to shift weight from side to side and took forward steps with support of a caregiver holding his right hand.

Balance in Sitting and Supported Standing (Demonstrating Integration of Postural Control and Limb Movement)

Perry exhibited protective and supporting behaviors in his right upper extremity (UE) in the sagittal and frontal planes but not in the transverse plane. Protective and supporting reactions were not observed to the left or in the left UE.

Fine Motor Control

Perry used his right hand for play, demonstrating a radial-palmar or scissors grasp pattern for small objects when positioned in sitting on the floor or in his high chair.

Control and Coordination of Left Upper Extremity (Integration of Posture and Movement)

Spontaneous movement of Perry's left UE was very limited and noted primarily during breast-feeding. At other times when sitting or held, Perry predominantly maintained his left arm and hand at his side with a slightly fisted hand. At times, he showed some degree of volitional movement in his left arm and hand. When his right arm was manually constrained, he opened the left hand and reached for objects with the left hand. The reach was grossly accurate, but he had no grasp or release with the hand. He became anxious and frustrated because the hand would not grasp. His behavior (crying and beating his head) was interpreted to indicate frustration and a desire that he wished his left arm to remain undisturbed. Additionally, Perry refused to look directly at his left hand and arm. When attention was drawn to his hand, he would not look in that direction.

The initial observations of activities/activity limitations and multisystem integrities and impairments led the therapist to hypothesize as to which single systems needed specific examination. The following systems were targeted for examination.

Body Structure and Function Integrities and Impairments

Muscle Tone and Activity

Perry's left arm displayed variable muscle tone ranging from low to high tone (measured by resistance to passive movement). At rest, tone in the trunk and arm musculature appeared low, although the left hand was frequently fisted with the thumb adducted. With strenuous use of the right hand, involuntary muscle activity in the left arm increased. The left arm assumed a high guard position—arm abducted at the shoulder and elbow flexed, forearm in pronation, wrist flexed, and hand fisted. Vigorous activity of the right arm also caused the left leg to exhibit increased hip flexion, abduction, and external rotation, knee flexion, ankle plantar flexion, and clawing of the toes. Additionally, in a supported standing position, strong excitement (annoyance or pleasure) or vigorous activity in the right arm resulted in clawing of the toes of the left foot.

Differences in muscle activity between the right and left sides of Perry's trunk were difficult to assess due to minimal differences between his right and left sides. Muscle activity in response to lateral weight shifting was present bilaterally but was slower on the left. This difference in response time between the two sides may be an indication that muscle activity was slightly lower on the left side when compared with his right.

Musculoskeletal System—Range of Motion

Perry showed full range of motion bilaterally in his shoulders, elbows, forearm, wrist, and fingers. Full range of motion was present in his hips, knees, and ankles.

Musculoskeletal System—Strength

There was weakness of the left elbow extensors. Strength was difficult to assess due to infrequent volitional movements of the left extremities.

Tactile System

Perry's perception of light touch, deep pressure, and sharp and blunt sensation in his left arm was examined when his visual attention was diverted. Perry did not respond to sensory input to his left arm if his attention was diverted. When he saw that his left arm was being touched, he objected, used the right arm to move the left arm to the right, and covered it with his right arm so that it could no longer be touched. Similar behaviors were not noted relative to touch of his left lower extremity (LE). Perry localized to touch of his legs and did not become upset. He also was observed to touch his left leg with his right arm. Perry responded to touch on both sides of his trunk.

Proprioception—Kinesthesia

Kinesthesia also appeared to be impaired on the left side with the upper limb more involved when compared with his lower limb. If Perry's arm was moved when he was looking away from the left side (when he could not see the arm), he did not react at all, giving the impression that he was unaware of the movement or touch. He reacted to passive movement or position change in the left leg when vision was diverted from the limb, by moving his leg and looking toward that limb.

Visual Tracking

Perry visually tracked objects in the vertical and horizontal directions. Visual fields also appeared to be intact.

Vestibular System

Perry's vestibular system was not formally examined, although it appeared to be functioning at an age-appropriate level, based on observations of the orientation of his head and body in space and the presence of righting responses.

Neuromuscular System

Perry's movements in the left arm and leg were slow, demonstrating limited control and coordination of muscle activity on his left more so than his right side and greater difficulty with control in his arm when compared with his leg. He had more difficulty in recruiting motor units in the left arm. Perry also had difficulty isolating motor activity on the left side and in the arm more so than the leg. The muscle synergies observed were more massed synergies, with less refined movement, particularly distally. Perry's left arm tended to pull into patterns of flexion, rather than extension, with stiffness varying from slightly low at rest, to increased with effort and emotion. There were no signs of clonus or tremor.

B3.3.4 Evaluation

The NDT Practice Model emphasizes the constant interweaving of assessing information from many sources to determine their meaning. With Perry, his family life and his personality, his integrities, the central nervous system pathology, and his participation, activities, and body systems were all considered in a holistic picture when determining the meanings of these factors and findings. Using the International Classification of Functioning, Disability and Health (ICF) model[17] of human functioning, an evaluation of findings was structured.

Contextual Factors: Facilitators and Barriers

Facilitators

Perry was surrounded by an immediate and an extended family who were interested in helping him. His mother was open to suggestions as to how she might encourage use of the left arm and hand, but she had not received instruction in doing this. She was an important resource. The father is a professional in the field of special education. He appeared to have a good relationship with Perry and to be effective in working with him to achieve the goals of therapy. He did not attend therapy sessions as frequently as the mother due to work responsibilities. However, he participated in meetings related to Perry's Individual Family Service Plan (IFSP) at the EEU and in doctor's appointments.

Perry was interested in play and was easily engaged in songs and activities that could be adapted to promote use of the left arm and hand. He also admired some fictional characters, such as Diego, and would perform activities and assume positions if they resembled Diego's moves. These moves lent themselves to adaptation promoting the goals of therapy.

Barriers

Perry was becoming proficient in learning to function using only the right hand. In extreme cases, the natural progression of development of children with severe hemiparesis is that they learn to move and function using the less involved arm and hand only. Perry seemed to be progressing in that direction. He discouraged any attention to his left arm, he showed anxiety and anger about weight shifting to the left, and he remained in sitting, playing only with the right hand. He showed passivity in that he ignored objects that moved out of his reach and made no active attempt to retrieve them or to move from one position to another. It was difficult to handle and move Perry because he preferred to be with his mother and his immediate family, and he became anxious if separated from her or if he was handled by anyone unfamiliar. He showed distress and anxiety regarding any attention directed to his left UE. This distress and anxiety made sensory testing and any form of intervention to the left arm difficult, even while he was on his mother's lap.

Body Structures and Functions

Tactile, Proprioceptive, and Kinesthetic Systems

Perry appeared to have severe loss of proprioceptive, tactile, and kinesthetic sensation in the left arm and hand and/or inability to attend to and process sensory information from the left arm. At 9 months of age, it was difficult to determine whether actual system impairments or inattention to sensory information was the major factor contributing to the neglect of the left arm and hand. Perry responded to tactile input to his left and right leg and to the left and right sides of his trunk.

Vestibular System

The role of the vestibular system as an underlying factor in the activity limitations was difficult to determine. The vestibular system together with vision and other sensory systems is purported to play a role in the development of protective and supporting reactions and the development of balance.

Visual System

No visual field deficits were reported in neurological evaluations, and Perry showed no difficulty with horizontal or vertical visual tracking. However, Perry did not have eye–hand coordination on the left because he did not look at his left arm and hand. He could look at objects on the left but diverted his gaze from his left hand.

Musculoskeletal System

Perry showed no asymmetry of upper or lower extremity length, and there was full range of motion in all joints. There was muscle weakness in the left elbow extensors.

Neuromuscular System

Perry demonstrated the greatest number of impairments of neuromuscular control and coordination in his left UE with some difficulties in the left LE and remarkably few expressions of the impairments in his trunk. In the left arm, the most obvious impairment was decreased isolated control (that was hypothesized to be due to involuntary muscle overflow and loss of selective motor control) within and between the arms, and to a lesser degree within the distal aspect of his left leg. At times, Perry's left foot assumed a position of plantar flexion at the ankle and clawing of the toes. He demonstrated slightly limited recruitment of postural motor units with his arm presenting with lower tone at rest but with the hand fisting, suggesting the ongoing recruitment of phasic motor units. In addition, Perry demonstrated decreased integration of postural functions and movement functions within his left arm with decreased use of the limb for support during transitions, and decreased use of the limb to move rapidly and then support as in protective reactions. Other signs of poor timing and sequencing of muscle activation were slow and imprecise movements in the left arm. The left arm was typically held in flexion, distally greater than proximally. Movements into extension were infrequent, demonstrating limited synergy or muscle group selection. The stiffness in his left arm varied from being lower at rest but increasing with effort and emotion. The hyperstiffness was greatest in the hand.

B3.3.5 Relationship of Body System Impairments to Activity Limitations

The following list exemplifies the body system impairments as they were hypothesized to relate to activity and activity limitations.

Activity Limitations

- Absence of transitional movements from prone to supine, supine to prone, sitting to lying, or lying to sitting.
    - Pushing away from the surface with the arm is a component of these transitional movements at the 9-month-old level of development.[3] Perry lacked the ability to push away from the surface with the left arm.
- No independent form of locomotion, such as creeping on all fours.
    - Support on an extended arm is a component of creeping. Creeping is a common method of locomotion at 9 months of age.[3] Support on the left arm and the ability to generate sufficient force to push with the left arm are necessary to perform the above transitional movements.

Possible Underlying Body System Impairments

- Sensory system impairments or sensory processing deficits leading to neglect of the left arm and preventing use of the left arm for support.
- Neuromuscular impairments.
    - Imbalance of flexor and extensor muscles and postural tone in the left arm resulting in difficulty maintaining extension of the left elbow.
    - Lack of ability to terminate flexor activity in the fingers and wrist preventing opening of the hand to grasp.
    - Limited recruitment of postural motor units, particularly of extensors throughout the arm. Poor integration of postural and phasic motor units. Stiffness varied from low to hyperstiffness. Limited isolated control within and between the arms.
- Musculoskeletal system.
- Weakness of elbow extensors.

Possible Underlying Multisystem Impairments

- Lack of lateral weight shifting to the left in sitting.
- Lack of protective and supporting reactions in left arm.
- Lack of bimanual hand activity and fine motor control.

In summary, Perry's sensory system deficits, neuromuscular impairments, and weakness of the elbow extensors on the left (musculoskeletal impairment) appear to be underlying factors in all activity limitations for Perry. His refusal to direct vision to his hand was a strong factor underlying deficits in fine motor control. The vestibular system may be a factor underlying lack of weight shifting to the left in sitting.

Hypothesizing the Relationships of Activity to Body Systems

One of the key features of the NDT Practice Model is to evaluate the possible effects of participation restrictions, activity limitations, and multiple system/body system impairments on the functioning of a person throughout the lifespan. For Perry, the following possibilities exist.

- Although Perry did not demonstrate musculoskeletal system impairments at this time, except for weakness of the left elbow extensors, he is at risk for secondary impairments including the following:
    - Asymmetrical limb length (due to reduced weight bearing on the left leg and left arm).
    - Restricted joint motion including
        - heel cord contracture due to increased stiffness in the left plantar flexor muscles.

- elbow and wrist flexion contractures and limited motion in forearm supination due to increased stiffness in elbow and wrist flexor muscles and forearm pronators.

B3.3.6 Intervention

Perry received physical therapy at his home once a week. The physical therapy program at home was coordinated with the infant program at the EEU. The physical therapist attended the meeting where the IFSP was created, and the occupational therapist visited Perry at his home and observed the physical therapy. This interaction promoted collaboration with the staff of the infant program. The infant program placed strong emphasis on promoting independent mobility, drawing attention to the left arm and hand, providing sensory input, and promoting use of the left arm and hand in play and other activities. The teacher, the occupational therapist, and the physical therapist collaborated on this goal, thus providing consistent and regular practice in a variety of settings.

The intervention program (plan of care) was created based on information from observation of spontaneous behavior, from examination and evaluation, from literature related to the development of children with hemiplegia and hemiparesis, and from an understanding of Perry's interests, preferences, and emotional reactions to his hemiparesis.

The reports from other team members, including the occupational therapist (OT), speech-language pathologist (SLP), and teacher at the EEU, were used to guide the intervention plan. Perry received a concentrated period of play therapy from a child psychoanalyst. The report of the psychoanalyst was another factor used to guide the intervention plan. The physical therapist did not address oral motor therapy because this was provided by the SLP at the EEU. The intervention program included a review of the targeted outcomes and provided specific examples of home program recommendations made for the parents, as well as specific examples of the therapeutic activities performed by the therapist with Perry.

General Aims of Intervention and Global Plan of Care

To assist Perry in developing transitional movements and an independent mode of locomotion

Desired Goals for Physical Therapy

Desired goals 1 and 2 are subservient or preparatory to goal 3.

1. To promote awareness of the left UE by encouraging visual attention to the arm and hand (getting Perry to look at his arm and hand) and by providing tactile, proprioceptive, and kinesthetic input to the arm and hand.
2. To allow muscle length to keep pace with limb growth during development, to prevent secondary impairments such as muscle shortening and joint capsule and ligament tightness leading to joint contracture.
3. To move independently from supine to prone lying, from prone lying to sitting, and sitting to either prone or supine lying, to creep on all fours, and to begin pulling to a standing position. As far as possible, weight bearing over the left arm and leg will be incorporated into the movements.

Desired Short-Term Physical Therapy Outcomes

- Perry will look at his left hand at least twice during a weekly physical therapy intervention session for 4 weeks in succession. This could include looking at the hand spontaneously while performing an activity with the arm and hand independently or with assistance, or when tactile, proprioceptive, or tactile stimulation is applied to the left arm or hand.
- Perry will incorporate the left arm in a simple two-handed activity, such as clapping hands, holding onto a handle bar with two hands, or holding a ball with both hands without assistance.
- Perry will transition from lying to sitting independently, incorporating weight bearing over the left arm during the transition.

Specific Examples of Direct Intervention

The home program was the initial focus of intervention. Later, other activities were included in therapy sessions. Since the intervention began with the home program, this program will be described first.

Family Instruction and Home Programs

Initially, Perry showed anxiety and was reluctant to separate from his mother. Although the aim was to help him to accept age-appropriate separation, it was important to provide effective intervention immediately to encourage the development of efficient posture and movement, to prevent secondary impairments, and to stem his present tendency to perform all activities without using the left arm and hand. In view of the urgency for initiating intervention parent instruction was integral to the intervention plan.

Initially, much of the intervention was given with Perry held by his mother or sitting on her lap. Having the parent carry out parts of the therapy program at home increased the intensity of the therapy. Perry's mother was advised of the need to maintain appropriate range of motion and muscle length, particularly in the left hamstrings, left heel cord, and left shoulder, elbow, wrist, fingers, and thumb.

The first step in the intervention program was to design a home program that was possible for the family and appropriate to the therapy goals. The parents were advised that the design of the home program was a collaborative effort between them and the therapist and that anything too difficult, uncomfortable, or in any way burdensome could be changed or replaced.

Perry's mother needed handling skills that would fit into her daily routine of bathing, feeding, diapering, lifting, carrying, and so on. At each home visit, intervention focused on an activity of daily living and worked on making this a time to optimize use of and attention to the left arm and hand and on other therapy goals. Perry's mother was creative in incorporating the goals of therapy into many play activities and activities of daily living. She was able to incorporate therapy in to a variety of settings, thus providing repetition and variability of practice.

Specific Suggestions for Activities during Diapering

During diaper changing, the mother and caregivers were encouraged to include the following:

- Encouraging activities to provide elongation of hamstrings, knee extensors, and heel cords.
- Bringing both arms into elevation above Perry's head and playing the game "So big."
- Flexing hips and knees toward the chest and then bringing both arms forward with hands on knees.
- Drawing visual attention to the hands and knees.

Bath Time Suggestions

At bath time, the mother worked on encouraging Perry to attend to the soap being rubbed on the left arm and in putting soap or lotion on the left hand and having him apply it to the right arm. He also rubbed soap and lotion on the left arm with his right hand. He played such games as splashing in the bath with hands and both feet and hiding the left arm under soap bubbles in the water and having his mother ask Perry where it was. He would then bring the arm out and show it.

Dressing

The left arm was incorporated into dressing to draw visual attention to the arm as in bathing and diapering. For much of the time, the movement was largely assisted movement, as in bringing the arms forward for pulling off socks.

Other Activities Outside of Therapy Sessions

Based on her understanding of the therapy goals, the mother invented and adapted games. She played pat-a-cake with Perry and facilitated use of both hands, and when he was on a hobbyhorse at home, she assisted him in holding on with two hands.

Perry's family enrolled him in a music class for preschool children. The activities of this class encouraged bimanual activity. For example, Perry held hands with children on his left and right sides when they formed circles for various activities. They also had a variety of bells and percussion instruments that needed bimanual activity. The class was also an opportunity for social interaction since Perry enjoyed being with the other children.

Physical Therapy Intervention Sessions

In addition to the home program and the school program, Perry received individual physical therapy sessions. These sessions included intervention strategies designed to achieve the established desired outcomes.

The following is an example of these strategies. Perry performed assigned tasks more easily with his left arm and hand when the arm and hand were prepared by giving sensory input at the beginning of the session. Due to Perry's age, this was done in a play situation. Perry was challenged to cover up the patterns on the rug at the entrance of the clinic. The therapist said that she hoped he was not going to cover up the patterns on her rug so that she could not see them. He gave an impish smile, opened his hands, and covered some of the patterns on the rug with both hands as seen in Fig. B3.1. Sometimes, he would do this in a hands and knees position and sometimes on hands and feet. In both instances, this activity provided weight bearing through the arms, and tactile sensation to the hands from the pile of the rug. In this and in the following activity, Perry was in control. He put his own hands on the rug. This sense of control was important in gaining his trust and cooperation.

The sensory input continued with an emphasis on the hands. Sometimes, the therapist would ask Perry to warm her hands. Again, the emphasis was placed on him doing something to her. As the activity progressed, a reciprocal pattern of the therapist and Perry doing something to each other's hands was introduced. For example, the therapist warmed her hands by rubbing them against Perry's

Fig. B3.1 Perry covers the carpet patterns with his hands.

hands, or Perry's hands were held against the therapist's hands and were rubbed.

Another way of warming hands was to hold one finger of Perry's right hand in extension and then to rub the therapist's fingers quickly and very firmly up and down the lateral sides of his finger. This firm input was done to each of the fingers and to the thumb of the right hand, followed by rubbing the anterior and posterior surfaces of each finger. Then the same activity was done to the left hand. It was important to begin with the right hand, because Perry accepted touch to the left hand if it was first applied to the right hand.

These activities focused attention and brought sensory input to the left hand and encouraged Perry to direct his attention and his vision to that hand. It was an opportunity to provide strong input to the left hand and arm. The fact that Perry's use of the left hand during therapy was more frequent after this preparation than when the preparation was omitted reinforced previous conclusions that sensory loss and/or sensory inattention was a factor underlying activity limitations and must be a major part of the therapy program. Perry's responses, therefore, guided the design of the intervention and were an ongoing part of the evaluation. This is an example of ongoing examination and evaluation occurring during intervention, an integral part of the NDT Practice Model.

Results of Intervention: 6-Month Review of Established Outcomes

Directing Visual Attention to the Left Hand

This outcome was achieved. Perry directed vision to his left hand at least twice (and usually more than twice) during each intervention session 4 weeks in succession.

Performing Bilateral Hand Activities

Perry clapped his hands, held onto a swing at school and a rocking horse at home with both hands, and performed the sign for *more* by bringing his right hand toward the left hand. Beginning sign language was taught to all children in the infant program at the EEU.

Coming from Lying to Sitting

This outcome was partially achieved. Perry was able to do this transition with assistance. He had difficulty initiating the movement from prone lying due to difficulty moving his left arm out from under his body. He rolled to the right side independently, but he then needed assistance in raising his upper trunk so that he could move the right arm in position to push up into a sitting position. Once the right arm was in position, he completed the transition to sitting by himself.

Coming from Lying to Sitting Independently

This outcome was not achieved.

Home Programs

During the first 6 months of intervention, his mother reported that carrying out activities in conjunction with dressing and diapering worked well for her, and she was able to do this ~90% of the time. However, bath time was so hectic with the other children around that she was unable to carry out activities during bathing. She understood the principles underlying the home program and devised games and activities that were directed toward the intervention outcomes in ways other than at bath time. She was also observant of the effectiveness of the intervention in achieving the desired goals of therapy.

Additional Gains

Perry became very interested in walking. Perry pulled to standing using his mother as a support, but he did not pull to standing holding onto furniture or similar supports. He walked with his right hand held by his mother or some other adult. Frequently, children with hemiparesis show an optimal gait pattern when held by the hand on the more involved side. In Perry's case, his gait pattern was smoother and more symmetrical when he was held by the right hand.

Revised Therapy Goals, Specific Outcomes, and Intervention

At the end of 6 months, the therapy outcomes were revised and reviewed to reflect Perry's progress and the remaining participation restrictions, activity limitations, and impairments.

- To gain a form of independent locomotion. It seemed likely that he would begin independent walking before either creeping or crawling.
- To come from lying to sitting and sitting to standing independently.
- To encourage use of the left arm and hand for tactile exploration (tactile exploration of his own body—touching legs, feet, right arm, trunk, ears, hair, etc., and putting fingers in his mouth) and tactile exploration of objects in the environment (i.e., feeling soft, rough, bumpy, smooth, etc.).
- To gain protective reactions of the left arm in the sagittal and frontal planes.

Specific Short-Term Outcomes

- When asked to do so, Perry will touch his legs, his right arm, his hair, and his left ear with the left hand and will reach forward and lay his hand flat on a surface in preparation for feeling the surface (rough, smooth, bumpy, etc.) at least once in a therapy session for 4 consecutive weeks.
- Perry will demonstrate protective extension of the left arm in the sagittal plane when his weight is shift-

ed forward in a sitting position, and/or he is lowered quickly toward the floor headfirst on four out of five trials at three consecutive therapy sessions.

- He will also demonstrate protective extension in the frontal plane when his weight is displaced sideways when he is sitting in four out of five trials in three consecutive therapy sessions. Spontaneous demonstrations of protective reactions in frontal and sagittal planes during functional activities would also be acceptable to show achievement of this outcome.

Intervention and Home Management

Home Management

The home program of managing hamstring and heel cord length, monitoring the elbow and forearm for full range of motion, and promoting lengthening of the glenohumeral muscles continued. There was a progression of the dressing program as seen in Fig. B3.2a, b. For example, his mother presented the shoe and expected Perry to bring his foot up to the shoe. When putting on a sleeve, she held the sleeve and waited for him to present his hand and attempt to push the arm through.

Climbing

Perry was interested in stair climbing. He went up stairs leading with the right leg and reaching for the stair above with the right hand. During therapy sessions, stair climbing was facilitated by leading with the left leg, but the limiting factor was lack of weight bearing over the left arm.

Gait

During this phase of Perry's intervention, he began walking independently. Walking became his mode of locomotion. However, he still needed to be close to his mother to come to standing. After ~6 weeks from the onset of walking, he learned to come from sitting to squatting and from squatting to standing. He came down from a standing to a sitting position by assuming a squatting position and then shifting his weight backward to transfer into sitting. These movement sequences gave Perry the ability to come to standing independently and to have independent locomotion. This, in turn, gave him access to independence in exploring the environment and in joining his peers in play activities.

In concert with all these advantages to independent locomotion, children with hemiparesis are at risk for secondary impairments when they begin walking.[1,2] Because of this, his gait pattern was monitored.

Fig. B3.2 **(a, b)** Perry becomes active with both hands in dressing skills.

Monitoring of His Gait Pattern

Perry walked with a wide-based but symmetrical gait pattern when he moved slowly. The toes of the left foot were clawed, but he showed dorsiflexion in the foot in response to displacement of his weight backward when standing. When his right hand was held, the gait pattern was optimal. Holding the left hand resulted in excessive forward movement of the right side of the pelvis during the swing phase of gait and a longer step on the right as compared with the left.

When Perry walked fast or was running with other children, he developed a slight inward rotation of the left leg accompanied by in-toeing on the left. The type of shoe he wore made a difference to this pattern. When he wore sandals, the in-toeing pattern increased but when he wore Oxford type shoes with a supportive insole, the pattern decreased or disappeared. Elongation to the heel cords, to the toe flexors, and to the plantar fascia of the foot, followed by weight bearing and weight shifting over the left leg, decreased the pattern temporarily. The pattern returned when walking speed increased.

Revised Plan of Care

Therapy sessions were now conducted twice weekly in the physical therapy office, not in Perry's home. This change permitted an arrangement of the environment to promote desired therapeutic activities, and it removed Perry from his own environment where he had preconceived ideas of how he would use the available toys and materials. He responded to the change positively, as he enjoyed intervention on a therapy ball, which was not available in his home, and he was interested in the available toys and equipment in the therapist's office.

Sample Therapy Strategies

To accomplish the outcomes related to bilateral UE use, play activities with a variety of toys that encouraged the use of two hands and activities providing sensory input to the left hand and arm were emphasized. These activities included putting bracelets on the left arm with the right hand, putting rings on the fingers of the left hand with the right hand, placing finger puppets on the left fingers and thumb, putting on a bracelet with beads that shook and made noise when Perry moved his left arm, and two-handed puppet play.

In addition, approximation was provided through each finger separately while reciting the "this little piggy" nursery rhyme and followed by movement to the thenar eminence. Perry looked at his hand intently during these activities.

With the mother holding Perry on a therapy ball (36 in diameter), the therapist leaned against the left side of the ball, and Perry was challenged to push her away. This encouraged weight shifting to the left. He was held on the ball in sitting, and weight shifting to the left was facilitated using the rib cage and pelvis as key points of control.

Other activities to encourage weight bearing and pushing with the left arm included playing with a bag of wind-up toys that were placed to his left side. Perry played with the toys sitting on a bench, with a table in front. Gradually, he accepted handling techniques designed to facilitate weight shifting to the left to reach for the toys. Initially, the therapist used the right side of the rib cage and pelvis as key points of control to shift weight over the left side. Later, placing one hand over the posterior aspect of the left side of the rib cage and pelvis provided more effective control.

Results of Intervention: Age 2 Years 3 Months

At this age, Perry developed expressive language. His level of receptive language enabled him to follow verbal directions, and he appeared to understand most of the communications offered to him.

Independent Locomotion

Perry walked independently. At home and at his 2-year birthday party, he followed the other children who were guests at his party as they moved around the house, and he did not need to be near his mother the whole time. In the office, he moved freely to collect the toys he wanted that he could see, rather than pointing and asking his mother to retrieve them for him. He continued to ask for toys that were on high shelves out of his reach and for toys that he remembered but could not see.

Perry came from supine to prone and from prone to sitting independently. He turned to the right side to come up, but he also put the left hand down and used the left arm and hand to assist in the movement. He also came from sitting to standing by transferring to squatting and then coming to standing without assistance or support. He returned to sitting by transferring from standing to squatting and then to sitting.

Perry climbed stairs on hands and knees. When asked to put his left arm up on the step above, he did so, but he did not bear weight on the left arm and hand as he ascended the stairs.

Use of the Left Hand and Arm

The goals were partially achieved. Protective extension in the sagittal plane was present but was not consistent enough to meet the goal of occurring in four out of five trials at each therapy session. He brought the left hand forward in the sagittal plane consistently but not always with an open hand. This reaction was emerging. The hand was open in protective extension in the sagittal plane approximately three times in each therapy session. Spontaneous protective extension on the left was important because it gave Perry confidence in weight shifting to the left. Without this protective reaction, fear of falling limited free weight shifting beyond stability limits. In addition, weight shifting over the arm promoted proprioceptive and kinesthetic input to the arm, which works to reduce neglect. Supporting reactions over the arms prepared him for use of the arms in transitional movements, such as coming from lying to sitting. This activity also provided sensory input to the arm and promoted strength in elbow extensors.

Additional Gains

On occasion, Perry grasped and released with the left hand. He would take a small, dowel-shaped object with the left hand and pass it to the right hand. He had difficulty maintaining the grasp, so it was difficult for him to hold an object in the left hand while walking. He has, however, done this on one or two occasions during therapy.

B3.3.7 Summary of Intervention and Discussion

Perry's therapy began when he was 9 months of age when he had severe disregard of his left arm and hand, little or no voluntary movement in the left arm, no independent transitional movements, and no independent form of mobility. His chief mode of mobility was to be carried by his mother. He played in sitting on the floor using only his right hand. He seemed intent on learning to function in this world without movement of his left arm and hand, and he became upset and frustrated if the left UE was touched or brought to his attention. The left leg was less involved than the arm, but it was less active than the right leg. The left leg appeared also to have some sensory loss but less than the left arm.

Perry's anxiety, especially regarding separation from his mother and his resistance to intervention designed to increase awareness of the left arm, presented a challenge in designing interventions that he could accept. To increase his awareness of the left arm and to provide opportunities to incorporate the arm into functional activity, he needed constant practice and high-intensity intervention. These were achieved by providing twice weekly therapy (which began with Perry sitting on his mother's lap) accompanied by a home program. Because his mother has two other young children, the home program needed to be time effective. It also needed to be playful and enjoyable for all involved. Incorporating the therapy into activities of daily living accomplished the goal of providing intensive intervention and giving the family reachable goals.

Another aspect of the intervention was the prevention of secondary impairments. These included contractures in muscle groups that were constantly held in shortened postures, muscles and other soft tissue structures that did not receive biomechanical stretching during development, and an asymmetry of weight bearing on limbs.

Perry is at high risk for deterioration in his gait pattern, particularly when he runs to keep up with other children or if for any reason he walks fast. He likes to be with other children, and on no account should he be prevented from play and activities that enhance enjoyment and socialization with his peers. However, encouraging tricycle riding and other activities that all children enjoy, which at the same time promote symmetry, may help to limit secondary impairments. At this point, he did not need orthotic management to the left foot, but orthotic devices may be needed later.

Initially, Perry took most of his nutrition through breast-feeding. He received intervention from a speech therapist at the university who also addressed oral motor concerns. At this time, he was weaned from breast-feeding and had no apparent difficulty with oral feeding.

Perry's level of function has improved. However, he must continue to increase function while at the same time preventing deterioration. He has potential to progress but preventing deterioration, particularly during critical periods, such as growth spurts, and in teenage years when young adults may gain weight (thus challenging balance and mobility) or become more stressed both physically and emotionally, will help to insure optimum participation and function in later years.

Perry is on a waiting list for a research program on constraint-induced therapy[18] conducted by Children's Hospital, Seattle, and the University of Washington. Children attend this program with a play partner for several hours per day and are given interesting and entertaining activities to encourage use of the more involved arm and hand. Since Perry shows improved use of the left arm and hand when the right arm is restrained, this program may be beneficial.

Monitoring of his gait pattern continues to be a strong priority, and he will be evaluated for orthotic management in the near future. In accordance with NDT principles, deterioration in function due to progression of secondary impairments must be anticipated and prevented as far as is possible. At the same time, intervention aims toward development of the highest obtainable level of function. Perry's charm, his interest in the world and in people around him, and in learning and play, coupled with the strong support from his family, are important factors that will help toward a favorable outcome.

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Case Report B4 Achieving Sitting with Hands Free for Play in a 23-Month-Old Girl with Hypertonic Cerebral Palsy

Marjorie Prim Haynes

B4.1 Introduction

Neuro-Developmental Treatment (NDT) is a recognized therapeutic intervention for children and adults with cerebral palsy (CP) with a focus on active practice to guide the individual to his or her highest functional level.[1,2] Parents of children with special needs often seek out the services of an NDT-educated occupational therapist (OT), physical therapist (PT), and speech-language pathologist (SLP) to assist in attaining specific age-appropriate goals.

Goals/outcomes may need to be modified and updated as the child develops and as the family and child's expectations and goals change. Intervention requires frequent modifications based on the child's changes in all domains of function (participation, activity, and body structure/function). An NDT-educated therapist uses a problem-solving approach to determine where to start an intervention session based on a specific activity (function), age of the child, and the repertoire of effective and ineffective postures and movements that the child uses. Critical impairments are highlighted to allow for maximal changes in function that is performed within a single session, in the next six sessions, or in an episode of care to help the child expand participation and activities. This case highlights the process to achieve a specific age-appropriate function based on parental request and the child's present functional level while making plans for the future.

The literature addresses key areas that influence a child's overall function. Within the NDT context, posture and movement are viewed as multisystem integrities and impairments that are addressed in relationship to a specific functional task (either participation or activity) and in the contexts of both the individual and the environment.[3,4,5,6,7,8,9,10] Postural control ensures task-specific stability and efficient orientation for motor performance of functional skills.[3,11,12,13] Over time, practice of posture and movements within functional tasks influences neuronal networks and maps for functional changes.[11,14,15] In addition, time-dependent motor learning takes place with appropriate levels of feedback and practice over the course of days, weeks, months, and years, reinforcing effective and/or ineffective postures and movements to complete functions.[11,14,16,17] Theoretical constructs of motor control, motor learning, plasticity and recovery, and their applications to the practice of NDT are discussed in Chapters 12, 13, 14, and 15.

Postural control impairments and movement dyscoordination are key problems in clients with CP.[3,11,14,18,19,20] Research that focuses on addressing the postural system as a component of a specific task is limited. Two relevant randomized, controlled trials using NDT as intervention specifically focused on postural control/trunk protocol to influence overall motor skills with positive outcomes related specifically to function were identified in a PubMed database search.[21,22] Both studies highlighted the use of direct handling to facilitate postural control and movement synergies to enhance the child's ability to achieve successful motor outcomes.[21,22] Harbourne et al[23] addressed postural control specific to the motor task of sitting as a way to maximize function. Their intervention strategy included use of touch as a basis for change. Cope et al[24] combined an NDT trunk protocol that included handling with emphasis on symmetry to augment a modified constraint-induced movement therapy (mCIMT) program. The results demonstrated changes in functional use of the hemiplegic hand/arm with brain reorganization. These findings have recently been corroborated by Haynes and Phillips[25] in their study in which two children showed changes in the use of the more involved hand as well as specific gross motor functions. NDT strategies (direct intervention handling with emphases on postural symmetry, activating from a dynamic base of support, weight shifts with trunk elongation, and rotation) were incorporated by the team.

Children with bilateral spastic CP have difficulty fine tuning the degree of postural muscle contraction that is needed for a specific task.[3,11,13,26] Therefore, the child may activate muscle contractions in an improper sequence. This improper sequence influences the postural system when performing a specific task, such as sitting and reaching[4,5,26,27,28,29] or standing.[13,27,30,31,32,33] As a result, children with CP often use a top-down recruitment of muscles (cranial–caudal) to assist with sitting balance[4,5,7,31] and standing balance.[12,27,30,31,33]

Excessive antagonistic muscle coactivation emerges as a strategy to provide postural stability as an attempt to stabilize and protect balance.[4,13,26] Movement muscles (fast twitch/type II) often take over the functioning of the inefficient postural muscles (slow twitch/type I).[3,11] This change in muscle function further compromises postural control because functioning muscles are unable to maintain stability. Therefore, children with CP often use a force-control strategy in which the arms are used to generate force to transition between positions and remain upright (sitting or standing).[3,13,20] In NDT intervention, therapeutic direct handling provides specific three-dimensional directional input to facilitate postural muscles to generate a dynamic base of support.[11,21,22,23] This active base of support encourages the bottom-up (caudal–cranial) recruitment and activation of muscles supporting reactive and proactive postural control and movement coordination.[4,5,7,13,26,30]

Observation of the posture and movement systems and understanding how the systems work efficiently together is important in the NDT Practice Model for task analysis and for assisting a client to achieve skill mastery. For children with CP, targeted body system impairments that affect postural control and movement coordination are identified in the neuromuscular, musculoskeletal, and sensory systems.[3,11,14,21,22] Body systems work together to adjust posture prior to a destabilizing voluntary movement made by specific arm or specific leg movements.[3,5,30,31,33] The inability to activate postural control in anticipation of voluntary arm movement or leg movement is a clinical observation described in children with cerebral palsy.[4,28,29,31,33]

The NDT clinician analyzes the impairments that affect postural control related to a specific task, such as sitting with arms free to play. Musculoskeletal problems of shortened muscles in ankles, knees, and hip can be a limiting factor influencing atypical and ineffective postures and movements in sitting.[3,11] Neuromuscular impairments that affect sitting with arms free for play include insufficient force generation, increased tone (stiffness), and impaired muscle synergies.[3,6,14]

Ineffective muscle synergies are resistant to change or adaption and interfere with a flexible movement repertoire that is needed to meet specific task requirements that may change based on environmental demands.[3,11,14,21] Shumway-Cook et al,[3] Van der Heide et al,[5] and Westcott and Burtner[12] have concluded that patients with spastic hypertonia are unable to recruit and regulate the firing frequency of motor neurons. The sensory systems may also be compromised, affecting function.[6,10,34,35]

A therapist using the NDT Practice Model provides sufficient time to practice the posture and movement requirements of a specific task, such as sitting with hands free for play in a variety of ways and conditions. Motor learning and improving performance require practice and experimentation of specific components of the task[11,14,36] and practice of the entire task.[11,14,16,30,31,36,37] The therapist uses hands-on facilitation to guide practice.[12,13,24] As the child indicates readiness, handling is gradually removed with opportunities to practice the task independently.[11,14,25] Therefore, NDT strives to improve motor function, and judicious use of handling helps the child perform the function as energy efficiently as possible.[11,21,25]

Feedback is another important component for motor learning.[11,33] Wittenberg[15] suggests that therapies designed to restore the most normal type of motor system may prove to be the best for assisting with neuronal development (neuroplasticity). The clinician using the NDT Practice Model selects individualized feedback strategies based on the client's postural and movement responses as they relate to the specific task (functional outcome).[11,37] Physical feedback for children with CP is provided and gradually decreased as the skill is mastered.[11,37]

This case report describes problem solving using the NDT Practice Model to address the activity of sitting with Makayla, a 23-month-old girl. Makayla's mother would like her to sit safely to play with her twin sister at a child-size table. When Makayla's ability to sit safely with her hands free for play is achieved, she would like Makayla to move on her own from the floor to sitting on a chair at a small table. This is a place where the girls enjoy playing together.

This case report analyzes the postures and movements required to sit safely on a bench and free the hands for play. This skill is crucial for peer play, playing with toys, and later success in academic skills. Sitting safely with arms free is a skill used throughout life in home, work, play/leisure, and community participation. The case report then highlights Makayla's body system impairments that will be crucial to address for successful sitting. This analysis leads directly to strategies for intervention.

B4.2 Case Description

B4.2.1 Patient History—Information Gathering

Makayla was discharged home from the hospital at 4 months of age (adjusted age 23 days) with a primary diagnosis of prematurity. Birth records indicated her mother's pregnancy was complicated by maternal age and fibrotic cysts. Makayla and her twin sister were delivered by C-section. Spontaneous rupture of membranes occurred at delivery with moderate amounts of clear fluid. The delivery required no assistance. The Apgar score was 8 at 1 minute and 9 at 5 minutes. Her birth weight was 650 g (1 lb 6 oz), which is small for gestational age (SGA). During her 90-day stay in the neonatal intensive care unit, Makayla was on and off the ventilator for 30 days to support her respiratory needs. Full feeds began after the first 30 days.

A cranial ultrasound was completed for intraventricular hemorrhage (IVH) screening with no evidence of a bleed. A mild increase in periventricular white matter echogenicity was noted and could indicate ischemic changes, with the left greater than the right side of the brain. A later examination revealed no evidence for IVH or periventricular leukomalacia.

Makayla was eligible to participate in the Infant Toddler Program (ITP) by the Sandhills Children Developmental Service Agency (CDSA) due to a medical diagnosis of prematurity (gestation age of < 27 weeks) and being SGA (birth weight of less than 1000 g) at the time of discharge from the hospital. Makayla was evaluated by the ITP intake team at 4 months 14 days chronological age with an adjusted age of 37 days. Makayla was found to be developing age appropriately based on her adjusted age using the results from the Test of Infant Motor Performance (TIMP).

A 6-month follow-up evaluation was recommended due to questionable items on the TIMP and general consensus of the team. A follow-up physical therapy visit took place at age 16 months 14 days, adjusted age of 13 months 6 days. Scores on the Bayley Scales of Infant Development Motor Scale Second Edition (BSID II) placed Makayla at 10 months on fine motor skills and 7 months on gross motor skills. The PT observed an increase in extremity stiffness (tone) that was greater in the lower extremities than the upper extremities. Physical therapy services were initiated with a recommendation to seek occupational therapy services. Makayla was monitored routinely by the Special Care Clinic at Duke Medical Center.

At the age of 15 months, the medical team determined that oral baclofen administered daily would help control the lower extremity spasticity that interfered with Makayla's overall function. Makayla's mother reported that the medicine was recommended due to the "excessive stiffness" in the lower extremities. Makayla stood on her toes with mild scissoring of the feet at age 15 months with the medical team. Toe standing was a routine behavior that Makayla used at home. Her main means of locomotion was commando-crawling. On the Modified Ashworth Scale, Makayla scored a grade of 4 bilaterally.

B4.2.2 Makayla's Diagnosis

When Makayla was age 23 months, the medical team confirmed a diagnosis of spasticity (CP) affecting the lower extremities significantly greater than the upper extremities. The medical team expressed the importance of continuing with physical therapy services and occupational therapy services and initiating speech-language pathology services.

B4.2.3 Data Collection during Examination: Current Level of Function

Participation and Participation Restrictions

Makayla is a happy and energetic soon-to-be 2-year-old. She enjoys interactions with her peers and therapist. She plays routinely with her sister but is also content to play alone. Her mother states that Makayla becomes easily frustrated when she is unable to keep pace with her sister or accomplish a task. Makayla models her sister and attempts to perform the same activities. Even though Makayla strives to be independent, caregivers are needed to assist with mobility and self-care.

Makayla attends all social activities with her family, who are able to carry her or use a stroller in the community. Makayla cannot interact with playmates outside (home or community) unless she is placed where it is appropriate to creep on her hands and knees. Makayla cannot keep up with her peers during outdoor play because she is unable to walk; therefore, she spends time alone when outside.

Makayla creeps on her hands and knees to move across the floor in her environment both at home and at day care. She reverts to commando-crawling when stressed and when increase in speed is necessary to complete a task. The floor is the only place where Makayla safely plays with her sister. The W-sit position is a preferred pattern since her arms are free for play. In other sitting positions, her hands are not free for play. Instead, Makayla's arms are used for balance and support. To move safely from place to place and keep up with her peers, the family intervenes and carries Makayla when creeping on her hands and knees is not appropriate.

Activity and Activity Limitations

Makayla creeps on hands and knees to move, sits on the floor (W-sit position) independently, finger feeds, and drinks from a sippy cup when in her high chair or a chair with a safety strap. When sitting in a chair, Makayla slumps in her chair and constantly needs to reposition herself, frequently with the help of caregivers. To move to stand, she pulls up and holds with her hands. She is unable to free her hands for play in a supported standing position. Makayla enjoys standing with her sister and will remain standing on her toes supporting at furniture for ~30 seconds before collapsing to the floor. She takes one or two cruising steps leaning on the furniture and then collapses to the floor. Makayla's mother is concerned about her safety when she is upright because she frequently falls.

Standardized Testing—Outcome Measures

Results on the BSID II placed Makayla at 12 months on fine motor skills and 8 months on gross motor skills. Testing was completed by the PT from the Infant Toddler Program prior to this therapist initiating services. Occupational therapy services were not in place because her mother's primary concern was gross motor skills. On the Gross Motor Function Classification System (GMFCS), Makayla functioned at level II.

Observations of Posture and Movement

In all positions and during movement, weight is asymmetrically positioned to the right. Makayla's head is slightly flexed (capital extension with cervical flexion) with shoulder elevation. The trunk maintains a flexed pattern with the hips and knees relatively flexed. Her feet remain in plantar flexion during activities. Excessive stiffness with her lower extremities positioned into relative extension is used to maintain an upright position. See Fig. B4.1, Fig. B4.2, Fig. B4.3 and additional photos and videos of Makayla on Thieme MediaCenter.

Body Structure and Function Integrities and Impairments

Neuromuscular System

Excessive Coactivation

Lower extremity stiffness is a result of excessive coactivation of the agonist and antagonist muscles (gastrocnemius/tibialis anterior, iliopsoas/gluteus maximus).

Impaired Muscle Synergies

She primarily uses flexor and extensor muscles to carry out daily function. She therefore demonstrates a limited repertoire of synergies that contribute to her multisystem

Fig. B4.1 Makayla transitions to sit pulling with her arms and pushing with her lower extremities into relative extension using excessive stiffness. Makayla maintains plantar flexion with flexed trunk and relative hip and knee flexion.

Fig. B4.2 Makayla positions shoulders in flexion, internal rotation, and elbows flexion with hands fisted. Her trunk is slightly flexed with lower extremities positioned in relative hip and knee flexion with ankles plantar flexed.

impairments that have been introduced earlier in this report. Sagittal plane movements are consistently used to accomplish various tasks. Movements in the frontal and transverse planes are limited; therefore, lateral weight shifts with trunk extension and rotation are limited and inconsistently used in daily activities.

Insufficient Force Generation

Insufficient force generation of the postural muscles (quadriceps femoris, gluteus maximus, abdominal obliques, serratus anterior) influences her function. In addition, the lower extremity muscles have not been actively involved in the postural system (postural adjustments), resulting in insufficient force generation in the muscles of the upper and lower leg.[28,29] Makayla struggles to transition in and out of a sitting position and to maintain the upright position (sitting or standing) with hands free.

Sensory Systems

Vision

Makayla's vision (acuity) is corrected with eyeglasses according to medical records; therefore, body structure and function are intact.

Fig.B4.3 Makayla's trunk alignment is flexed with hips and knees slightly flexed and feet plantar flexed. Excessive stiffness with the lower extremities positioned in relative extension is used to maintain upright position.

Auditory

The medical team has confirmed her hearing is intact, resulting in adequate body structure and function (integrity).

Tactile

Makayla enjoys all types of touch and textures.

Vestibular

Makayla enjoys moving on the floor and likes speed. When moving up in space on the therapy ball, she does become fretful, reacting specifically to horizontal and rotational movements. Makayla reacts by pulling her body into a flexed position and verbally indicating distress. Vestibular discomfort is not dependent on speed when she is working with the therapist on the ball.

Musculoskeletal System

Range of Motion Limitations

1. Hip extension to hyperextension: 0-10° bilaterally.
2. Knee extension-flexion: 0-110° bilaterally.
3. Ankle dorsiflexion with neutral subtalar joint and knee extension: 0-8° right and 0-5° left.

Task Analysis—Sitting Posture in a Chair or on a Bench

Makayla sits in a chair or on a bench with her weight asymmetrically distributed on the sacrum (posterior) and the right hip. She frequently slides down in the chair, requiring assistance to push herself upright. Her trunk is positioned in flexion, with her shoulders elevated, knees partially extended, and feet plantar flexed and not in contact with the support surface. Hyperstiffness in the lower extremities is noted due to excessive coactivation of the agonists and antagonistic muscles around the hip, knee, and ankle joints.

Insufficient force generation of the postural muscles of the trunk and hips requires Makayla to use her arms and hands to influence alignment and upright posture and provide sitting balance. Muscles that are available and activated for Makayla to maintain this position include the rectus abdominis, iliopsoas, biceps femoris, semimembranosus, quadriceps femoris, gastrocnemius, and soleus, along with toe flexors. The activation of these muscles operating in synergy results in weight positioned on the sacrum, little contact of the posterior thighs with the chair, and little to no contact of her feet with the floor. Therefore, Makayla demonstrates an insufficient base of support (BOS) because she has minimal contact of her body to activate the muscles necessary for function. Consequently, Makayla cannot use her lower extremities efficiently as part of the BOS, and slow activation of necessary muscles interferes with lateral weight shifts and rotation to support the function of sitting. As a result, Makayla has difficulty freeing her arms for play.

B4.2.4 Evaluation Process

Physical Therapy Outcome No. 1 (For Others, See Thieme MediaCenter)

Makayla will sit independently at a child-sized table and chair with her feet planted on the floor, her weight on the ischial tuberosities, and both hands free to play with toys positioned at midline with self-readjustments for a 5-minute period by the end of 3 months.

Analysis/Synthesis of Data

Once positioned on a therapy bench (equipment used in session), Makayla did not have the balance skill to successfully sit with her hands free to play with toys in her environment. Makayla asymmetrically positioned her weight on the sacrum (right side) instead of the ischial tuberosities (Fig. B4.4). Therefore, the gluteus maximus is placed at a disadvantage to serve its major role as a dynamic postural muscle. Makayla's spine was flexed, interfering with a neutral pelvis and erect postural alignment. Therefore, an aligned trunk (head aligned over shoulders over pelvis) could not be achieved. This malalignment placed the flexor muscles (sagittal plane muscles—iliopsoas, rectus abdominis) in a position to activate and attempt to hold Makayla upright.

Makayla found it necessary to hold with her hands so that she would not fall. One strategy that Makayla used was to increase the stiffness (excessive coactivation of muscles) in her lower extremities, moving her knees to relative extension and plantar flexing her ankles. Makayla could not place her feet on the floor (surface) and use her legs effectively as part of the BOS and as part of the postural system for independent sitting. Therefore, Makayla was not able to actively weight shift with trunk elongation and rotation during sitting. She depended on arms for support rather than freeing the arms for play in space.

Physical Therapy Prognosis

Makayla's progress for independent function in sitting is excellent.

Plan of Care

The therapist and Makayla's mother discussed expectations for an episode of care based on the family's needs. Therapeutic intervention will be performed in the home or community one time a week, 1 hour per session, for 6 months. Reexamination and evaluation are planned after this episode of care.

Fig. B4.4 A pretest of Makayla's sitting on a bench. Note her flexed spine, asymmetrical weight bearing while her pelvis is posteriorly tilted, and the lack of contact of her feet with the support surface.

B4.2.5 Intervention

General Strategies

The following guidelines will be used to carry out strategies in each intervention session to meet the outcome.

- *Review (observe):* Ongoing assessment to determine the positive and negative effects of relevant single body system and multi–body system impairments on the selected outcome as each intervention session evolves. Three primary systems will be targeted for this case report, including the neuromuscular, musculoskeletal, and sensory systems (vestibular system).
- *Prepare:* Handling to address functional range of motion (ROM), sensory awareness, alignment, postural stiffness (tone), and balance. Intervention strategies are designed to activate the targeted postural and movement components necessary to carry out the functional activity.
- *Activate:* Elicit dynamic coactivation of the postural muscles and reciprocal inhibition of the movement muscles to facilitate weight shifts initiated from a dynamic base of support. Weight shifts occur in the sagittal plane (flexion–extension), frontal plane (lateral flexion–abduction–adduction) and transverse plane (rotation).
- *Practice:* Allow opportunities to practice the new changes in a variety of functional ways. Monitor handling and decrease touch input (faded feedback) to allow the child to achieve the task independently.

Session Pre- and Posttests

A session outcome will be developed and assessed as Makayla performs the task at the beginning of each session (pretest). Session outcomes revolve around sitting and play and transitioning in and out of the sitting position. The sessions will end with the same session outcome (posttest).

B4.2.6 Intervention Sessions

As intervention evolved, strategies were used in anticipation of and in response to Makayla's posture and movement as seen in **Table B4.1**.

See posttest of sitting on the bench in **Fig. B4.5**.

Selection of Equipment

The therapist selected sitting activities (practice) on a therapy bench, which offers a wider BOS to practice sitting skills. Practice on the bench included play where movement in all three planes was encouraged with a focus on lateral shifts with trunk elongation and rotation. The ball was also added as a tool to the intervention program. Ball activities provided a movement experience that targeted vestibular input that affects balance as well as a tool to address ROM (musculoskeletal impairment) and neuromuscular impairments.

The equipment was used to assist the therapist with the targeted single-system and multisystem impairments. The therapist determined that ROM limitations were noted in the hip flexors, hamstrings, and ankle dorsiflexors due to excessive coactivation in the lower extremity musculature. Dynamic trunk work in all three planes encouraged activation of the abdominal obliques, gluteals, and serratus anterior coupling for function.

Intervention Session—Handling Progression Highlights

Makayla always started her session on the floor (her choice). This position allowed the therapist to address active ROM in the hamstrings and spine during play to assist with postural alignment. Makayla was guided to move from the floor to sitting on the bench. Transition to sit was completed with rotation with the therapist's hand placement on her trunk. The therapist first prepared (addressed ROM heel cords) the feet to accept weight. Once aligned, activation of the foot/ankle muscles (gastrocnemius–soleus muscles) engaged the foot in active pushing against the surface to assist with pushoff from an active base. Once the feet were prepared and activated, the therapist's hand placement was repositioned to the upper leg and then to the trunk to emphasize postural (lower extremity and trunk) alignment and symmetry. Obtaining a neutral spine activated the postural muscles (abdominal obliques and gluteals) to take over their functional role of postural stability. This, in turn, facilitated the muscles in the upper trunk (serratus anterior, shoulder external rotators) to be activated, assisting with alignment of the head and freeing the arms.

The postural muscles continued to be activated in sitting because play included movement in all three planes, with an emphasis on the frontal (lateral weight shifts with trunk elongation) and transverse (rotation) planes. Hand placement in the sitting position varied from key points of control (KPCs) on the trunk, the upper leg, or the feet. The therapist provided input to facilitate the muscles in all three planes. Direction of input varied to guide the weight shifts during play. Input was delivered in toward midline to facilitate muscles around the trunk, down, directed to the ischial tuberosities to activate muscles in the trunk and lower extremities, and diagonally forward and backward to facilitate the movements necessary to independently sit on the bench. The therapist continually visually scanned Makayla's body to observe for changes. Her clinical changes guided hand placement. The therapist faded the input and encouraged Makayla to perform the activity (task) independently.

Input from the guiding hands provided Makayla feedback as she experienced weight on her ischial tuberosities, shoulders aligned over hips, head erect (chin tuck), and feet in contact with the surface when sitting and playing with toys in her environment. Makayla experienced (felt) how her body performed the new task in a variety of ways with guiding hands. It was then critical for her to experience the skill without touch. Scanning the body and observing Makayla's posture and movements guided the therapist to know when the hands should be removed and the skill practiced for mastery of the task.

Table B4.1 Individual Daily Intervention Plan

Physical therapy outcome no. 1: Makayla will sit independently at a child-sized table and chair with feet planted on the floor, weight on ischial tuberosities, and bilateral hands free to play with toys positioned at midline with self-readjustments for a 5-minute period by the end of 3 months.

Intervention session outcome (pre-/posttest): Makayla will sit on a bench with feet planted on the floor, weight on ischial tuberosity and bilateral hands away from body engaging in play as postural alignment is maintained for 2 minutes with therapist providing touch support as needed at end of session.

Body structures and functions	Impairments	Intervention strategies		Response
Musculoskeletal	ROM of hamstrings ROM/mobility of trunk	Play position	Long sitting with toys for play.	Independently sits with hips flexed to 90° abducted, and externally rotated. Slight knee flexion with weight on ischial tuberosities. Hands free to play in all planes.
		KPC	Placement of hands on the femurs or lower leg (ankle) or one hand on LE and trunk.	
		DOI	Down to surface, in toward trunk (allow for upward position of trunk).	Therapist occasionally needed to place KPC on trunk (DOI—down and in) to maintain upright alignment. Guided diagonal subtle weight shifts. See Thieme MediaCenter for video and photo of long sitting.
Neuromuscular	Excessive coactivation of muscles in LEs. Atypical synergistic muscle activity. Insufficient force generation.	Play position (play with large LE dissociation movement).	Transition to a creep position. Creeping on hands and knees to bench.	Independent creeping with neutral alignment of UEs and LEs. Weight on entire lower leg and wide UE and LE dissociation pattern (hands partially opened and feet plantar flexed).
		KPC	Lower leg.	
		DOI	Down and into the surface. Guiding large excursions—diagonally/forward (emphasize external rotation).	Placement of hands on trunk to achieve neutral alignment was occasionally needed.
Musculoskeletal Neuromuscular	ROM hip/knee. ROM trunk (mobility). Ankle dorsiflexion. Excessive coactivation in LEs. Atypical synergistic muscle activity. Insufficient force generation.	Play position	Transition: sit from half kneel to bilateral feet on surface and hands on bench.	Transition to sit (without head).
		KPC	Hands on LE to guide half kneel and bilateral feet in contact with surface. Hands placed on trunk to guide weight to bilateral feet (entire foot) on surface and focus on trunk alignment.	Accomplished transition up to hands and feet on bench. Unable to rotate to sit—therapist needed to reposition hands to trunk to achieve control, then removed as therapist felt active muscle work under the hands. Therapist reevaluated trunk ROM (mobility) as well as scanned the body to determine postural alignment.
		DOI	Down/into the surface. Directing diagonally forward (allowing upward positioning of the body as she moved upright).	See photos of transition to table at home on Thieme MediaCenter.
Musculoskeletal Neuromuscular	ROM in LEs (ankle dorsiflexion 0–5°). Trunk ROM. Alignment. Atypical synergistic muscle activity in the trunk. Excessive coactivation in LEs (ankle, knee, hip joints).	Play position	Sitting and play (bench).	Sit independently and play using arms.
		KPC	Feet for neutral alignment. Reposition to upper leg (femur). Lateral aspect of trunk during play.	Therapist had to move from the feet to the trunk with KPC. Hands engaged in bilateral play.
		DOI	Down and into activate muscles around the ischial tuberosities. Directional (diagonal) movement to accommodate the play. Play to encourage extension/rotation and flexion/rotation of trunk.	Therapist had to place hands (KPC) on trunk providing DOI down and in to activate postural muscles (gluteals, external rotators, abdominal obliques, serratus anterior). Removed hands when postural muscles were activated. See video of playing in sitting and photos of therapist's hand placement on Thieme MediaCenter.

(continued)

Body structures and functions	Impairments	Intervention strategies		Response
Musculoskeletal Neuromuscular Sensory	ROM in LEs (hips, knees and ankles). Atypical synergistic muscle activity in the trunk.	Play position	Transition to stand (play with ball), then guide up to sit on ball.	Stand with upright posture with hands on the femurs. Upright posture allowed a steady neutral head with erect trunk.
		KPC	Hands on upper leg (femur)/ trunk.	Guided body on the ball and allowed Makayla to rotate and sit. Therapist always positioned the ball so that Makayla remained on top to push up into a seated position.
	Excessive coactivation in the LEs (ankle, knee, hip joint). Insufficient force generation. Vestibular	DOI	DOI: Down and into lateral aspects of the foot allowing for lengthening and alignment upright. Guide movement (diagonally forward/backward maintaining DOI in and down onto the ball, assisting with rotation.	Small movement was provided to give her opportunities to play with vestibular information.
Musculoskeletal Neuromuscular Sensory	ROM in LEs (hips, knees and ankles).	Play position	Sit and play on ball; transition off ball.	Once Makayla adjusted to the sensory input, she enjoyed both slow and rapid movements on the ball.
	Trunk ROM.		Guided movement and play to encourage extension and flexion with rotation and upright extension.	
	Atypical synergistic muscle activity in the trunk.			
	Excessive coactivation in the LEs (ankle, knee, hip joints).			Guided play that included independent movement—extension/rotation, flexion/rotation.
		KPC	Upper leg (femur).	Makayla enjoyed supine over ball to lengthen trunk flexors as well as hip flexors. Makayla transitioned in and out of sit on ball using rotation.
	Insufficient force generation.	DOI	Down and in to activate muscles around the ischial tuberosities.	
	Vestibular		Diagonally directed input for weight shifts and rotational movements.	Transition off ball—straight down and forward while emphasizing extension of the trunk, hip, knees, and total foot contact.
Closure			Intervention moved back to sit for posttest with free play.	

Abbreviations: KPC, key points of control; DOI, direction of input; LE, lower extremity; ROM, range of motion; UE, upper extremity.

Fig. B4.5 Posttest: Makayla sitting on bench with weight on ischial tuberosities, erect trunk, and posterior thighs and feet in contact with surface. Bilateral hands move out in space during play.

Toy Presentation

Presenting toys low to the ground from the bench or from the floor reinforced excessive flexion in the trunk. Therefore, toys were typically positioned at chest height both at midline and away from midline. This positioning for play encouraged a postural alignment that supported weight on the ischial tuberosities with trunk symmetry, activating the postural muscles (gluteals, abdominal obliques, and serratus anterior).

Play

Selecting age-appropriate play or activities that are interesting and engaging is important to the NDT clinician. Makayla enjoyed activities where she could use her hands successfully. Engaging activities for Makayla included play with bubbles, beads, and dress-up clothing. Makayla was encouraged to take the lead in the play (child directed) and the therapist followed.[14] Engagement in an activity made working on the components of a task easier to practice. Throughout the session, Makayla was provided with opportunities to practice components of the task as well as the complete task in a variety of ways in her home environment.

B4.2.7 Preparing for the Future

Standing and transitioning to stand were also included in intervention sessions but were not the focus in the early sessions. Standing became more important as her skills improved. Mother and family spent an additional 10 to 20 minutes at home encouraging Makayla to play with her new skills with her twin sister during their daily routines. Therefore, carryover, which included practice of the skill, took place in Makayla's daily family routines. See Thieme MediaCenter for videos and photos of standing play in later intervention sessions.

B4.2.8 Results

Pre- and postintervention session outcomes tests showed consistent changes in function. A posttest was used during each session to guide the therapeutic intervention. The therapist determined that, by addressing the neuromuscular and musculoskeletal impairments, changes were noted in the postural system and movement system affecting function. Makayla demonstrated changes in trunk alignment with decreased weight on the sacrum and with feet in contact with decreased touch from the therapist. Weight on the feet increased the BOS making the lower extremities a dynamic part of the postural system.[12,31,33] This weight bearing allowed bilateral hands free to play.

Sitting independently in a chair in day care was successfully accomplished by 3 months. Makayla's mother reported that Makayla sits with her peers to eat and participates in circle activities in a regular chair.

The first feature that changed was transitioning into a sit position without the use of her head from the floor to the bench. Completing the sit process on the bench (rotation required) was accomplished early in the intervention process. Independent transitioning into the chair with rotation was successfully performed by the end of the 4-month period. See additional video of sitting transitions on Thieme MediaCenter.

Makayla's mother reported that Makayla stood alone for 10 seconds and took two steps to move between furniture and is now actively cruising along furniture. This skill was accomplished by 6 months. Photos on Thieme MediaCenter highlight positive changes in Makayla's standing posture.

As Makayla's mother saw the improvement in her standing and beginning walking skills, she began to put the splints on daily for several hours (Fig. B4.6). Splints had been ordered for Makayla when she began to initiate standing. A posture control walker was introduced to Makayla after 4 months of intervention by this therapist. Makayla uses the walker for short-distance walking between classrooms and on the playground.

Fig. B4.6 Makayla is wearing splints. Alignment depicts an erect trunk with minimal hip and knee flexion and arms in guard position as she stands with feet flat and without therapist support.

B4.2.9 Discussion

Selecting age-appropriate single-session outcomes that support the short-term and long-term outcomes was essential to monitor and evaluate for changes. A pretest and posttest were set for each session. These tests were guided by observations of Makayla's posture and movements and her function after each session. Strategies predicted for the next session were based on the changes that occurred during the current session.

Makayla practiced activities using a variety of tools (floor, bench, ball, and chair). Through practice with variety in the therapy session plus carryover at home, the motor performance of transitioning on and off a bench and sitting independently on the bench transferred to independent sitting and transitioning in and out of a toddler chair in her home, day care, and community environment (motor learning). The practice with variety may have increased the success rate for motor learning.[14,16]

The therapist used the outlined guidelines for establishing intervention based on the task or tasks outlined for each session. The NDT Practice Model includes ongoing assessments by observing the body systems and prioritizing the impairments that are most critical to address to influence the established task. The neuromuscular, musculoskeletal, and vestibular system remained the targeted systems noted to affect Makayla's function. Handling included preparation to address the postural and movement systems, including functional ROM, sensory awareness through vestibular input, alignment with symmetry, postural tone, and balance. Specific hand placement and direction of input (in and down and diagonally forward/backward) activated Makayla's postural control from the BOS, eliciting postural muscles to work in all three planes. Makayla was challenged to work in the frontal (lateral weight shifts with trunk elongation) and transverse (rotation) planes. The development of dynamic postural stability allowed the muscles of the movement system to work together for function. Practice of the task in a variety of ways with KPC facilitated the development of the specific activity. Mastery of the specific activity (motor performance) occurred as the handling (touch) was decreased and finally terminated (faded feedback). Practicing of the skill in the community with the assistance from the family allowed transference and motor learning.

The selection of appropriate handling to encourage alignment and the activation of muscle groups were important factors for functional changes. The therapist's hands were positioned (KPC) on the child's body providing a specific direction of input (feedback), which enabled Makayla to experience (ability to activate from a dynamic BOS) how her body reacted and moved as the new skills were practiced. This practice provided an avenue for the development of new neural pathways (neuroplasticity). The child's body was visually scanned as the therapist felt and determined what was happening under the hands as well as above and below the hands. As Makayla took over the control (muscle activity), the therapist's hands were softened and then removed. For mastery of the new function, Makayla initiated the task independently and completed all the components of the task successfully without therapeutic intervention. Mastery of the new motor function (motor performance) had occurred. Practice, in a variety of settings and conditions, was critical for motor learning to occur. Makayla was given opportunities to practice the new skills in a variety of ways. Her mother had a small chair and table at home where the girls ate their snack daily. The day care provided a small chair and table so that she could interact with her sister and peers during the day. Makayla was now able to sit safely with her arms free in her home and community and practice fine motor skills.

This case report suggests that using the NDT Practice Model has proven to be a successful avenue to evaluate Makayla's progress and has served to provide guidelines for an individual treatment session. Girolami and Campbell,[22] Arndt et al,[21] and Haynes and Phillips[25] have also followed a similar process with infants and young children as a means to progress their young clients and make changes in age-appropriate functional outcomes. Grading the handling in the context of the child's activities and environment has proven a valuable addition to practice and functional changes.

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Case Report B5 Enhancing Functional Independence in a 10-Year-Old Boy with Cerebral Palsy, Spastic Quadriparesis

Colleen Carey

Neuro-Developmental Treatment (NDT) is a problem-solving approach that focuses on the identification and intervention of sensorimotor impairments.[1] Studies by Slusarski[2] and Arndt et al[3] support the efficacy of NDT intervention for the improvement of gait in children with cerebral palsy and for the improvement of dynamic trunk control in infants with posture and movement dysfunction. However, other literature regarding the efficacy of NDT interventions often does not reflect the essence of NDT. For example, Mahoney et al[4] discuss the effects of early motor intervention on children with Down syndrome and cerebral palsy. In their work, the authors state, "NDT involves handling a child with the goal of inhibiting abnormal tone to facilitate automatic reactions to promote normal development." This is a limited and outdated definition of the NDT approach and does not capture the critical aspects of NDT. Essential to NDT is analysis of system impairments as they relate to functional activities and participation.[5] Emphasis on the components of alignment, base of support and weight shift, as well as posture and movement strategies drive the intervention strategies.[5] Finally, outcome development with the focus on functional skills that are meaningful to the family and child is fundamental to successful outcomes.[5]

B5.1 Introduction

This case report present to clinical specialists the decision-making framework and clinical reasoning that are used in NDT. This report describes the changes in motor abilities, motivation, and individual empowerment that developed following the application of NDT principles, twice weekly for 45 minutes, within a 10-week period of physical therapy, for a 10-year-old child with cerebral palsy, with motor and topography classifications of spastic quadriparesis.

B5.2 Data Collection and Examination

Jamie is a 10-year-old boy with spastic quadriparesis. Jamie is a precocious boy who is charming to the many adults that he encounters on a daily basis. He is bright and engaging while easily holding conversations about pop culture, local sports teams, and the gossip of his community. Recently, he has been on a quest to meet one of his favorite celebrities. However, he has a difficult time connecting with peers his age that may not share his interests or preferred activities.

Jamie was the product of a 28-week gestation and was diagnosed with periventricular leukomalacia (PVL) during his neonatal course. His medical history is otherwise unremarkable. He received physical therapy services from the age of 7 months to the present time in a variety of settings, including early intervention, school-based therapy services, and outpatient physical therapy services. He also received occupational therapy services from age 12 months to the present. He has had intermittent periods of speech-language therapy, primarily focused around oral motor control and articulation concerns. He has no history of soft tissue surgery. He received Botox (Allergan) injections to both hamstrings in June 2005 and March 2009.

B5.3 Examination of Functional Movement Skills

Jamie's motor disability is classified as level IV according to the Gross Motor Function Classification System.[6] Children with a Gross Motor Function Level IV show self-mobility with limitations, such as power mobility in the community. He currently attends a public school in mainstream classes and completes grade-level academics without any learning disabilities. He shows anxiety and does not employ coping strategies well within personal relationships. For example, he is uncomfortable with play with same-aged peers and friends who may not be willing to play the video game of his choice. He may not tolerate going to a friend's party that is loud and chaotic. Ultimately, his anxiety may be driven by difficulties in motor performance.

B5.4 Neuromuscular Control

Jamie demonstrates decreased neuromuscular control of both upper and lower extremities and trunk. Control, strength, and coordination of the right arm and leg are better than the left. Jamie shows disruption of sequential muscle activation, making it difficult maintain stability in response to changing environmental demands. Additionally, he shows difficulty with scaling movement control of both upper and lower extremities. Likewise, he shows impaired ability to selectively activate his legs. As a result, he cannot modify movements quickly in response to functional demands, and therefore patterns of movement are more stereotypic in nature. He also has disrupted coordination of functional muscle synergies for effective antigravity control. Consequently, his stability response to balance perturbation is impaired. Jamie shows ability to initiate movements but has reduced ability to sustain activation of antigravity postures of the shoulder girdle stabilizers, elbow extensors, hip abductors, hip extensors, and knee extensors. He also has a tendency to fix or stabilize the pelvis with muscle activation of hip flexors and hamstrings. Therefore, he shows instability during functional demands, such as lifting or reaching. Additionally, he shows decreased movement of his center of mass over his legs to activate against his support surface with his feet. Jamie shows significant instability of the trunk, and his sustained postural activation of the trunk and pelvis for core stability is poor as evidenced by his performance more than 2 standard deviations below the mean on the Sitting Reach Test.

B5.4.1 Strength/Range of Motion

Overall strength of the trunk is in the poor range (2/5 grade of strength). Overall lower extremity strength is in the fair range (3/5 grade of strength) in the right leg and poor range (2/5 grade of strength) in the left leg, except for right hip abduction, extension, and plantar flexion, which are in the poor range (2/5 grade of strength). Range of motion of the lower extremities is decreased in the hip extensors with −20° of hip extension on both legs. He has 30° popliteal angle on the right leg with 40° popliteal angle on the left leg. Hip abduction is 45° on the right and 30° on the left. Ankle dorsiflexion is 0 to 30° with the knee extended on the right and 0 to 15° on the left. Plantar flexion is within normal limits on both sides. Knee extension is within normal limits.

B5.4.2 Sensory Awareness and Processing

Jamie demonstrates limited kinesthetic awareness of his lower extremities; he has poor awareness of his body in space. His functional vision is influenced by decreased control of visual tracking, diminished sustained visual attention, and reduced depth perception. He is hyperalert to auditory input and enjoys opportunities for vestibular input, but he has a difficult time focusing on tasks when his environment is too stimulating. As a result, he has difficulty modulating emotions, attention, and movements. Additionally, Jamie shows good problem solving in cases of novel motor challenges. With excitement, his postural tone increases, and with fatigue, his tone decreases. His overall endurance for activity is low. However, with frequent changes in tasks, he can sustain movement activity for long periods.

B5.4.3 Activities of Daily Living

He is dependent (assists in < 25% of task) for dressing and hygiene. He is able to complete a stand pivot transfer to the toilet involving turning/changing direction with moderate assistance (completes 50% of the transfer). Jamie requires moderate pelvic assistance as well as verbal/visual cues to complete transitions that involve turning his body in space about its axis. He also feeds himself independently.

B5.4.4 Movement Skills

In terms of gross motor capabilities, Jaime demonstrates significant activity limitations. The Gross Motor Function Measure (GMFM) was chosen to document Jamie's gross motor function performance as compared with other children with cerebral palsy. The GMFM-88 is a standardized observation instrument validated to measure gross motor function changes over time in children with cerebral palsy.[7] His scores are provided in Table B5.1.

Specific activities reveal a performance level consistent with that of an exercise ambulator. He is able to sit on a typical chair with back support and standby supervision for a period of 5 minutes. He can use his hands for nonrefined functional skills when seated in a typical chair. When seated in an adapted chair with a pelvic belt positioned, foot plates, and trunk lateral support, he is able to use his hands for fine manipulation of simple objects, such as picking up checkers or keyboarding. He is able to sustain upright sitting in an adapted seat with fair to good symmetry. However, he has a tendency to posture the head/neck in mild hyperextension with upward visual gaze. With environmental setup or positioning of the speaker at an appropriate level, he is able to orient his head upright in midline and sustain the posture for 15 minutes or more.

Also noted is the posture of arms flexed with high guard with a tendency to posture with the hips adducted or the hips and knees bent in standing. Consequently, he uses a walker to sustain standing independently. He is able to walk with a reverse walker for ~ 200 yards before needing a rest. Jamie ambulates within his home with control necessary to negotiate turns around furniture and through doorways with close adult supervision for safety due to occasional loss of balance. He has demonstrated the ability to walk a quarter of a mile on a track with significantly reduced speed, during his school's walk-a-thon. He is also able to control the walker to turn 45 to 90° while walking with a significant decrease in walking speed when turns are involved. He is able to walk a distance of 45 feet in 45.4 seconds.

He is independently mobile in a power wheelchair with supervision for safety in congested environments. Jamie uses a power wheelchair for mobility within the school environment. He is able to scoot himself to the edge of the wheelchair to initiate a sit to stand transfer. He transfers

Table B5.1 Jamie's scores on the GMFM-88

Lying and rolling	69%
Sitting	58%
Crawling and kneeling	12%
Standing	5%
Walking/running	6%
Total Score	30%
Mean GMFCS IV	36%
Median GMFCS IV	32.9% Standard deviation: 14

Abbreviations: GMFCS, Gross Motor Function Classification System; GMFM, Gross Motor Function Measure.

from wheelchair to stand with minimal assistance (completes 75% of the transfer). He is able to lift himself back into the wheelchair once seated on the edge of the wheelchair. Additionally, he is able to turn on and turn off the power to the wheelchair, and he shows safety awareness in the wheelchair.

Jamie is able to navigate within his classroom with 75% accuracy when the wheelchair speed is low, the environment is consistent and unchanged, visual cues are provided in open areas, and the end goal is presented before he begins to move. Difficulties in depth perception result in the need for cues to avoid children and obstacles that are between him and a desired destination in the distance.

B5.4.5 Participation

The International Classification of Functioning, Disability and Health (ICF) model stresses the importance of participation as a measure of disability. In the process of evaluating the influence of motor limitations on overall participation, measures such as the Children's Assessment of Participation and Enjoyment (CAPE)[8] are useful. The CAPE measure is a self-reported assessment that examines participation in activities outside of the school day, and it provides information regarding context and enjoyment. The scale has a rating for the areas of diversity (types of activities in which he participates), intensity (the frequency of participation), with whom (the people in his family or community with whom he participates), where (activities in the home vs. the community), and enjoyment (enjoyment received from participation). A higher score for each rating area indicates a higher level of participation for that area. Testing with the CAPE was completed and demonstrated results for Jamie as seen in Table B5.2.

Test results show that Jaime participates in a wide variety of activities with his diversity value (types of activities in which he participates) greater than the values observed in both the Canadian and the Australian studies[9,10] (two studies using the CAPE that defined representative performance ranges for children with cerebral palsy). His overall intensity (the frequency of participation) is low, similar to the values seen in the Canadian study. Also similar to the study values, Jamie shows decreased value of with whom (the people in his family or community with whom he participates) because his activities are primarily completed with family members. His *where* value reflects emerging participation in activities in school and the community as opposed to in the home only. His overall enjoyment is slightly above average but lower than reported values in the Australian study.

Summary of Function Based on the ICF Model Assessment

Participation

- Jamie participates in family life, including meals and play with his siblings.
- He participates with his extended family in community activities.
- Jamie attends public school in mainstream classes and completes grade-level academics.
- He shows anxiety and does not employ coping strategies well within personal relationships.

Participation Restrictions

- He has limited play or interaction with same-aged peers without the presence of someone from his family.
- He may not be willing to play the video game of his choice with friends who do not always comply with his wishes.
- He may not tolerate going to a friend's party that is loud and chaotic.

Activities

- Jamie ambulates with a walker and standby supervision.
- Jamie transfers from wheelchair to walker with minimal assistance.
- Jamie transfers from wheelchair to bed or an alternative chair with moderate assistance.
- Limitation: Jamie is unable to move out of his wheelchair into alternative household positions, such as lying in bed, sitting on a sofa, moving to a table and chair for meals, moving to the toilet.

Body Function and Structure (Key Impairments)

- Increased hip and knee flexion in standing.
  - Excessive muscle activity/increased muscle stiffness of hip adductors and hamstring muscle, upper extremity flexors.

Table B5.2 Jamie's CAPE scores

	Scale	Raw score	Canadian values	Australian values
Diversity	0–55	32	28.43	26.5
Intensity	0–7	2.53	2.76	2.02
With whom	0–5	2.84		2.63
Where	0–6	3		2.5
Enjoyment	0–5	3.09		4.03

Abbreviation: CAPE, Children's Assessment of Participation and Enjoyment.

    - Decreased selected isolated control of right–left leg coordination.
    - Weakness of hip abductors and extensors, knee extensors left greater than right.
- Left lower extremity activation and control is decreased compared with the right.
- Inability to maintain stable pelvic position while achieving length/elongation of the hamstrings.
- Decreased ability to sustain postural muscle activity needed to stabilize lower extremity joints for movement control.
- Difficulty adjusting trunk posture to move the center of mass over the base of support/inability to control dynamic pelvic control for weight shift.
- Poor sensory feedback of lower extremity position.
- Motor planning difficulties with reference to coordination of the right and left leg as well as upper extremity use.

Contextual Factors

- Contextual factors are critical to the understanding of a child's function and participation.[11] For this child, a large extended family that is actively involved helps to bring Jamie for therapy and encourages Jamie's full participation within the family. They readily identify his passions and work to enable his participation in activities that support those passions. For example, an extended family member brought Jamie to the local pro football preseason camp to enable Jamie to watch the players and participate in the autograph signing session. Also, the family supports Jamie's therapeutic interventions and offers financial support when insurance denies equipment or services for Jamie.
- In contrast, there are barriers to progress. Jamie has three younger siblings that compete for attention and often increase the complexity of the home environment. This makes it more difficult for Jamie to successfully complete movement skills in the home. In addition, Jamie's issues with anxiety influence his performance and motivation in therapy.

B5.5 Evaluation

The following discussion is a reflection of the decision making that went into a plan of care using the NDT framework. Based on the evaluation information, parent and child goals were discussed. As a clinician using the NDT Practice Model, the therapist embraces the idea that sensorimotor impairments will affect the whole person. Thus the sensorimotor impairments inherent in a child with cerebral palsy will influence their participation on a motor level, a social level, and an emotional level. Therefore, in choosing outcomes, the clinician needs to identify outcomes that reflect the child's participation in school and family life.

The overall goal of NDT is to improve function.[5] Jamie has a long-term goal of attending college. In the more immediate future, his parents would like to see him have more opportunities to interact with friends in environments other than his home with parental support for physical transitions. The results of the CAPE supported these goals. In assessment of Jamie's participation, the CAPE identified that he is involved in a wide and diverse set of activities. However, the majority of the activities occur with immediate and extended family members. This information led to a clinical assessment of the many motor skills that Jamie needs to develop to be more independent in terms of mobility in environments other than his home.

Within the context of Jamie's current participation and his personal goal to participate more in age-appropriate activities, the therapist identified the participation limitation that Jamie is unable to move out of his wheelchair into alternative household positions, such as lying in bed, sitting on a sofa, moving to a table and chair for meals, or standing with his walker. The ability to move out of his wheelchair to the toilet is also critical. As the therapist, the family, and Jamie discussed these findings, the ability to transfer in and out of his wheelchair to alternative household positions was identified as one skill that could improve his independence in a variety of environments as he moves into his teenage years.[12,13] The wheelchair to bed transfer was chosen to be addressed first within the therapy session as a wheelchair to mat transfer. Once Jamie established this function in a stable environment, the therapist would work to integrate it in the changeable environment of the home and with a variety of surfaces, such as the bed or couch. Within that context, the ICF construct was used to identify goals and intervention planning.[14]

The rationale for selection of intervention strategies and sequences, outcomes, and goals is based in several assumptions of the NDT approach. The first assumption is that the primary problem in cerebral palsy, and in this child, is an impaired pattern of postural control and motor coordination. The clinician assumes that these impairments are changeable and that the child's function improves with intervention in a task-specific context.[15,16,17]

Functional Outcomes/Goals

- Independent sit to stand transfer.
- Independent transfer wheelchair to chair, wheelchair to bed.

B5.6 Plan of Care

The NDT-based clinician's plan of care emphasizes Jamie's active role in the development of outcomes and related goals. It reflects the identified functional movement impairments and system impairments as well as the hands-on facilitation techniques to change movement strategies, thereby providing the best energy-efficient performance of functional skills. Although the therapist's hands are primarily on Jamie during the intervention session, he is an active participant at all times within the session. In addition, the force and direction of the handling vary as the therapist controls alignment, facilitates graded movement control and activation, and modifies the motor demands of the task.

Design and implementation of intervention strategies are also rooted in the principles of NDT. NDT intervention involves identification of components of movement in the sagittal plane, the frontal plane, and the transverse plane. It also involves attention to alignment, base of support, and movement of the center of mass.[18] The assumption that these movement impairments are changeable and the child's function changes to meet the postural demands of the environment drives the intervention.[17,19]

The clinician determines which functional or structural impairments will potentially change Jamie's ability to transfer out of or into his wheelchair. If his leg mobility and dissociation improves, will he be better able to side step during his transfer? If intervention achieves a change in significant missing components of the movement, will his motor system be able to reorganize his movement strategies? For example, Jamie moves primarily in a sagittal plane. During the pretest of his transfer ability, he approached the task with a sagittal plane movement set, as seen in his pretest in Fig. B5.1. He moved forward reaching for the mat with his arms in front of him, which resulted in lying prone across the mat with his legs dangling off of the mat.

The therapist must then question, "What movement components can one change that will result in Jamie spontaneously choosing a strategy that involves lateral weight shift through the pelvis?" The NDT clinician's intervention reflects the identified functional movement impairments and system impairments. This identification is coupled with the hands-on facilitation techniques to change movement strategies that provide the opportunity for the best energy-efficient performance of a functional skill.

Specific intervention strategies as well as the chosen sequence of movement strategies are developed to address the identified system impairments as they relate to functional activities and participation.[14] Key points of control provide a link to the critical handling necessary to achieve the desired outcome.[20] Within each session, movement control was developed within the context of a task.[8,17] In a young child, the play activity shapes the motor task. In an adult, the movement skill of walking or transfers forms the task. In the sessions with Jamie, a combination play involving sports games or board games and functional movement activities were used as a basis of the sessions.

Fig. B5.1 Pretest: transfer was completed in sagittal plane and resulted in incomplete transfer.

In all of the intervention sequences, alignment is of utmost importance. Alignment enables efficient muscle activation. A framework of a sample session is included in Table B5.3. Included is a movement sequence followed by a rationale for why those specific movement activities were completed. Key components of movement that the therapist was trying to develop within the session are also detailed. Furthermore, ongoing evaluation during the session was essential to guide the intervention planning and occurred throughout every intervention session. A session outcome is presented within the chart to identify the immediate focus of the individual session as well as how achievement of the goal or the lack of achievement of the goal was used to drive the next session.

Throughout the consecutive intervention sessions, the therapist provided the opportunity for practice presented in random sequences.[19] The sessions were planned, including challenging tasks without overwhelming the neuromotor system. Ultimately, the goal of motor learning is essential for integration of the new motor skill within Jamie's daily activities. Intrinsic feedback, Jamie's active involvement in problem solving, and therapist-guided intrinsic feedback all led to his empowerment and a reduction in motor performance-driven anxiety.

In addition to twice-weekly PT sessions, Jamie completed a home program. Home program activities included dynamic mobility activities for improved range of motion of the hip flexors, hip adductors, and hamstrings; activities to increase sensory awareness of both legs with facilitation of active movement of the leg against resistance; ambulation activities; bicycling with an adapted tricycle; and modified swimming. These home activities were targeted to address lower extremity (LE) muscle activation, active assisted LE mobility, and LE sensory awareness.

B5.7 Outcomes

Jamie was highly motivated throughout the intervention sessions. Although frustration with execution and completion of motor tasks occurred frequently, Jamie was able to be easily supported and redirected to the task at hand. Involvement in the outcome development was one piece that was critical to his motivation to work through his frustration to achieve his personal goals. Additionally, the focus on participation was meaningful and motivating for Jamie. He was able to relate the connection of a particular exercise to the improved participation and enjoyment that he would experience if he achieved his goal. Finally, Jamie's active engagement in the activities helped

Table B5.3 A sample intervention session for Jamie

Goal of the session	Intervention strategies and sequence	Tasks	Rationale	Results
Jamie will independently shift his weight 6 inches on a therapy bench with upper extremity weight bearing on the bench surface.	• On large therapy ball, supine to side lying with leg dissociation, top leg flexed across body leading change in center of mass to one side.[16] • On large therapy ball and leg dissociation, facilitate frontal plane weight shift for mobility of hip joint, key point pelvis, lateral direction of force.[16] • Prone back off the ball into symmetrical extension. • Stand symmetrical with distal upper extremity support maintaining hip extension. • Facilitate frontal plane weight shift with upper extremity weight bearing into large therapy ball.[16] • Facilitate partial stand weight shift and transfer side to side in frontal plane on bench.	• Vestibular play on therapy ball. • Facilitated upper extremity weight bearing while playing with a manipulative board game. • Standing and engagement in story telling. • Transfer simulation.	Using identified key impairments to body structure and function, the session focused on increased lower extremity dissociation and stressed improved activation of lower extremities as well as improved postural control in the frontal plane.	Jamie required contact guard at the pelvis to complete the lateral weight shift on the bench to move 6 inches.

him to feel empowerment over and mastery of his body and the successful movement in space. Jamie successfully achieved the outcomes of independently transferring from wheelchair to the mat table and from the mat table back into the wheelchair. Jamie initially approached the transfer in the sagittal plane, and it resulted in an incomplete transfer. Following intervention, he approached the transfer with a functional frontal plane movement. Fig. B5.1 demonstrates the incomplete transfer in pretest, and Fig. B5.2 demonstrates the later successful wheelchair transfer. The next short-term goal would be to integrate this activity into the home environment. Please see Thieme MediaCenter for further photographs of Jamie during intervention.

B5.8 Discussion

Several factors were successful in the change in functional transfers for Jamie and his achievement of the goal of independently transferring from wheelchair to mat table. First, it was important to use outcome measures that help to identify the participation limitations for the child. Focus on a top to bottom approach helped Jamie to prioritize and to take ownership of the achievement of functional outcomes.

By using the ICF model in conjunction with the NDT problem-solving process, the therapist was able to identify which system impairments were critical to Jamie's limitations in participation. Using the NDT Practice Model, the therapist identified the system impairments, and attention was given to posture and alignment, base of support, active engagement of posture control, selective isolated movement control, and movement of the center of mass in the various planes of movement.

The components of movement addressed within the session and sequencing of movements within functional tasks was effective in achieving the desired outcome. In reflecting upon the sequence of sessions and Jamie's acquisition of independence in this transfer, and applying these to future sessions, the therapist should include additional visual targeting within his motor tasks. In hindsight, it was evident how significant the role of vision was in terms of his postural control.

In addition, the variety of activities completed as part of Jamie's home program was critical to increasing sensory awareness in his trunk and legs and to improving sensory processing of his movement experiences. They

Fig. B5.2 Posttest: transfer was completed in frontal plane and resulted in independent transfer.

resulted in Jamie being better able to integrate the motor skills that he learned and practiced within his therapy sessions. As Jamie concluded the unit of sessions working toward independence in transfers, he said, "Now what? I have some other things that I want to work on like stairs." Jamie's sense of accomplishment and motivation to continue to expand his skills for meaningful participation sums up the essence of NDT. The aim of NDT intervention is to optimize function. As NDT therapists, we are charged with ongoing research to support the effectiveness of NDT in changing functional outcomes.

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Case Report B6 Clinical Management of a Feeding Disorder in a Child with a Complex Medical Diagnosis

Gay Lloyd Pinder

B6.1 Introduction

For many children, the ability to eat and drink by mouth develops naturally during the first year of life, a seemingly innate skill. A speech-language pathologist (SLP), an occupational therapist (OT), or a physical therapist (PT) who specializes in working with children with feeding problems understands that the oral feeding and drinking process is a highly skilled, complex process that involves the interaction of multiple body structures and functions.[1] Eating and drinking by mouth are multisystem processes with contributions from the sensory, motor, respiratory, and upper gastrointestinal (GI) and lower GI systems.[2] A therapist with an understanding of the Neuro-Developmental Treatment (NDT) Practice Model will be cognizant of the contributions of each system but will also see the importance of postural control and postural stability as being the foundation with all areas of development, including gross motor, fine motor, and oral motor playing a role in the process of development of oral feeding skills.

B6.2 Early Feeding Skill Development in the Presence of Medical Interventions

The foundation of basic feeding skills is grounded in postural stability and in the development of head control, shoulder girdle stability, and trunk control.[3] When an infant is born with major dysfunction of one body structure, the impairments may influence the development of other body functions, and feeding skills can be severely affected, with impairment of function lasting for many years.[4] Often, these medically fragile infants must receive their early nutritional sustenance through supplementary feeding tubes, such as a nasogastric tube or a gastrostomy or jejunoscopy tube.[5] Table B6.1 describes the different types of feeding tubes. Although infants can then grow and thrive, they lack the experience of food in their mouth, which heightens their sensitivity issues and limits their development of the oral motor skills needed for learning to eat and drink by mouth.[5,6]

Learned oral aversion and lack of oral sensory experience and practice at a critical age often develop when infants are born with medical conditions that necessitate invasive diagnostic procedures and medical interventions, including surgeries that require long-term hospital-based recovery periods. These types of events during infancy may have a significant influence on early development in many areas, including gross motor, fine motor, social and emotional, oral motor, and early play and communication.[7] Although an infant can often "catch up" in many areas of development once the original medical issue is resolved, some areas continue to feel the influence and require long-term intervention to resolve the effects of that early medical experience. One key area of development that can continue to reflect the effects of the negative experiences of the medical treatment is the area of oral feeding skills.[8]

In the past 15 years, the medical community, including doctors, nurses, and therapists, have become far more aware of the potential long-term negative influence of early necessary but invasive medical procedures on the development of feeding skills in infants and young children.[5] This awareness has resulted in early intervention, often even while the infant is still in the special care nursery of the neonatal intensive care unit (NICU). The medical team works to involve parents and to support the infant through positioning and early positive oral experiences to minimize the negative influence of the necessary medical procedures.[1]

Intervention at an early stage of recovery can begin to build the foundation for later development of oral feeding skills, even while the infant is receiving nutrition through supplementary feeding tubes.[7,9] Even with this early recognition of the need for support and the efforts to provide that support, the journey toward oral feeding may be a long one, even lasting for years, for many children. This case report is one such journey for Jagraj, a boy who, at the age of 4 years, is still on his journey toward eating and drinking by mouth.

B6.3 Jagraj's Birth and Medical Needs

Jagraj was born full term (birth weight 7 lb 7 oz) on October 24, 2008. He was the firstborn son in a Punjabi home. At 2 days of age, he was transferred to the Special Care Nursery at the local children's hospital. His medical issues at birth included coarctation of the aorta and ventricular septal defect (VSD), for which he had corrective open heart surgery at 2 weeks of age. Jagraj was also diagnosed with pulmonary hypertension and acute respiratory failure and was on a ventilator during his hospital stay. That initial cardiac surgery was followed at 3 weeks of age by a second surgery to repair his diaphragm to improve his respiratory status. At that time, a gastrostomy–jejunostomy tube (G-J tube) was placed for feeding because Jagraj was unable to maintain his nutritional needs through oral feeding and had been diagnosed with failure to thrive.

After the second surgery, Jagraj remained in the hospital for another 6 weeks, positioned in supine to promote recovery. This static positioning was necessary for Jagraj to facilitate postoperative healing, but it limited his early exploration of movement and sensorimotor experiences during

Table B6.1 Types of feeding tubes

Type of feeding tube		Insertion–destination	Strengths (+) and limitations (−)
Nasogastric	NG-tube	Nose to stomach	+ No surgery required
			+ Can do bolus or continuous-drip feedings − Possible adverse oral facial stimuli
			− Presence in nose is uncomfortable
Gastrostomy	G-tube	In stomach	+ No aversive oral–facial stimuli
			+ Can be removed easily when no longer needed
			+ Bolus feedings are possible
			− Requires surgical placement
			− Site requires daily care
			− Potential risk for increased gastroesophageal reflux (GER)
Jejunostomy	J-tube	In jejunum, often in association with gastrostomy tube (G-J tube)	+ Same as gastrostomy
			+ Bypasses stomach so less risk of GER
			− Requires surgical placement
			− Site requires daily care
			− Requires trip to hospital if tube falls out
			− Requires continuous-drip feeding

a critical period of development. During the first 3 months of life, the infant begins to develop head and trunk control against gravity, stability of the shoulder girdle complex, and segmental mobility of the rib cage. Experiences of being held and moved through space and being positioned in prone, side lying, and supported sitting collectively contribute to the infant's ability to act and interact with his world.[10] These were experiences Jagraj missed as he lay on his back on his wedge, first in the hospital and later at home.

In addition to his cardiac disorder, Jagraj was also diagnosed with gastroesophageal reflux (GER). He vomited with every feeding, and even without feeding, multiple times a day. A G-J tube was placed at 3 weeks of age with a continuous drip established directly into his small intestine, bypassing his stomach, except for medication. Thus, at a time when a newborn infant should be developing early feeding skills through breast feeding with his mother, experiencing the pleasant sensation of being full after being hungry, and then being cozy and comfortable in her arms, Jagraj was throwing up every time he felt food in his digestive system and had to remain on the wedge on his back, even when he felt sick. His mother was equally traumatized, wanting to protect her new baby and to feed him. Instead, she had to watch him in the crib, with tubes connected to every orifice, strapped flat with his huge chest wound healing. She had to watch him throw up repeatedly, even with the feeding tube. This picture is far too familiar to therapists who specialize in feeding, working with mothers and their children at 2 and 3 years of age with this medical history who continue to struggle with feeding issues.

Ten weeks after he was born, Jagraj had healed from the heart surgery and was discharged home on oxygen on December 23, 2008. He weighed 9 lb at the time of discharge. However, the necessary medical intervention had influenced all areas of his early development, including his development of motor skills, his development of early play and communication skills, and most significantly, his development of oral feeding and drinking skills.

B6.4 Jagraj's Development

In typical development at 5 months, infants are active in prone, beginning to roll in both directions, and beginning to sit with minimal support, head upright and arms free to reach and grasp, with hands and objects coming to their mouth for exploration.[10] At 5 months of age, when Jagraj arrived at the therapy center for his initial evaluation, he had only been in supine, held in arms, or seated slightly reclined on a wedge, in a car seat, or in an infant recliner. In prone, Jagraj could not lift his head off the surface and was unable to push himself up onto his forearms. When placed on his stomach, as the family had been instructed, to build his strength and stamina, Jagraj quickly began to fuss and then cry in protest. His mother or grandmother would then immediately pick him up to comfort him and stop his crying. With no encouragement to remain in prone, Jagraj's overall stamina remained poor, and marked weakness was noted, particularly in his shoulder girdle and abdominal musculature. He continued to be unable to take weight on his arms to push up into head and trunk extension to look around. He was unable to roll from back to front or front to back and, as a result, did not activate his rectus abdominis or obliques, which he needed to move himself upright into sitting.

With the combination of weak abdominals and poor shoulder girdle strength and stability, Jagraj was unable to transition up against gravity from prone/supine to sit and later from sit onto all fours for crawling. Jagraj did not sit independently until he was almost 9 months old, and then he needed to be placed in sitting because he was unable to transition up independently. He resisted attempts to assist him onto his hands and knees. The result of this chain of effects, beginning with the original medical problem that necessitated early immobility, was an ongoing influence on the whole child in all developmental domains, including mobility, social, self-care (including feeding), and communication.[11]

In addition to wanting to comfort and protect this baby, the firstborn son who had suffered so much, Jagraj's family was driven by another factor. When Jagraj cried, he vomited and lost whatever calories he had been fed. Caloric intake and weight gain were already a significant issue, as indicated in the diagnosis of failure to thrive. Thus, in addition to wanting to provide comfort, his mother and grandmother also wanted to prevent his vomiting so he could grow. Note that the other factor that triggered vomiting was any stimulation to his mouth. As a result, Jagraj consistently resisted any attempts to help him bring hands or objects, including a nipple, to his mouth with the consequence being increasing hypersensitivity and gagging that consistently cycled to vomiting. The result of this situation was threefold: first, Jagraj was making no changes in his development of gross motor skills, including strengthening of his shoulder girdle and trunk, which would strengthen the abdominals to help decrease the reflux activity[12]; second, Jagraj's negative connection to his mouth with subsequent oral aversion was progressing with the lack of successful oral play[5]; and third, the family's response to Jagraj's crying was reinforcing his experience that crying worked as a successful communication tool.[7] Over time, the last aspect of the situation would slow Jagraj's progress in areas of social interaction and early communication.

B6.5 A Summary of Jagraj's Health and Disability According to the International Classification of Functioning, Disability and Health Model

The following International Classification of Functioning, Disability and Health (ICF) model summary describes Jagraj's capabilities at the time of his initial examination at the Children's Therapy Center at 5 months of age.

- Contextual factors.
  - Involved and motivated family who cherish and love Jagraj and want to do exactly what he needs to thrive and grow.
  - Firstborn son in Punjabi home.
  - Family includes parents and paternal grandparents in same house with no other children.
  - Grandmother's full attention focused on her only grandson.
  - New baby with severe medical needs with instruction given to family to avoid activities that cause vomiting (i.e., crying causes vomiting, therefore avoid activities that cause baby to cry).
  - Medically stable enough to come home from hospital at 3 months of age.
- Participation.
  - Lives at home with parents and grandparents.
- Participation restriction.
  - Unable to eat with family at mealtimes.
  - Unable to actively explore his world.
- Activity.
  - Fed through jejunoscopy tube (j-tube) on continuous feed on a pump.
  - Gastrostomy tube used for medications.
  - Nicely engages adults with eye contact when held in front, or as he lays reclined in car seat, infant bouncy seat, or infant recliner.
  - In full supported sit, beginning to hold head more upright to look around and to look at adult in front of him.
  - Open to very short movement facilitation to provide him with movement experience in prone and supine.
  - Enjoys being held in upright to look around his environment.
  - Will bring hands together and hold.
  - Will grasp a toy or spoon and hold it for 10 to 15 seconds.
  - Will sometimes touch toy to his own lips momentarily.
- Activity limitation.
  - No experiences with moving; subsequent lack of interest in moving as well as being placed on his tummy.
  - Unable to push himself up on forearms and hold head up to look around.
  - Unable to tolerate tummy time for more than 5 seconds without crying and soon vomiting.
  - No oral eating or drinking—no experience with full/empty tummy cycle, with consequence of no experience of hunger cues therefore no sense of appetite to drive interest in oral feeding.
  - No objects or hands to mouth due to learned oral aversion.
  - Will not bring toy or spoon to mouth to explore for longer than 5 to 8 seconds.
  - Responds to sight of bottle by fussing and turning away, clear signs of oral aversion.
  - Will not touch toy to his own lips if someone else is holding.
  - Gags on tastes of formula or baby food touched to lips.

Table B6.2 presents Jagraj's body structure and function integrities and impairments.

Table B6.2 Jagraj's body structure and function integrities and impairments

Body structures	Body functions	Integrity	Impairment
Brain	Cognition		Inability to understand that hunger and eating have a connection
Stomach and intestines			Gastroesophageal reflux
			Slow gastrointestinal motility
			Extremely low tolerance for feeding volume increase, even at the 1–2 mL level; therefore on continuous pump for 21 h/d
			Decreased ability to gain weight and grow
Muscle and skeletal	Muscle strength		Decreased strength of trunk, left-side weakness, lack of arm strength to bring objects to mouth, quick to become fatigued
	Postural alignment		Open mouth Jaw extended held open when in challenging positions, primarily when moving up against gravity With jaw open, decreased opportunity to swallow with result of profuse drooling
	Skeletal stability		Two thoracic surgeries–median sternotomy
Heart	Oxygen transport		Cyanotic defects–surgically corrected at 2 weeks of age and 3 weeks of age Coarctation of the aorta and ventricular septal defect Pulmonary hypertension
Eyes	Vision	Intact	
Ears	Auditory	Intact	
Sensory			Oral hypersensitivity Excessive gag reflex, which leads to vomiting
Mouth	Swallow	Intact	
Motor system		Intact	

B6.6 Intervention

The discussion that follows is closely linked with the video on Thieme MediaCenter, which the reader is encourage to view in conjunction with the summaries provided in the text.

B6.6.1 Initial Examination at Age 5 Months

Jagraj was referred to the Children's Therapy Center for early intervention services when he was discharged from the hospital. The initial evaluation was on April 13, 2009, when Jagraj was 5 months old. Jagraj qualified for services based on his performance on the Bayley Scales of Infant and Toddler Development, Third Edition (Bayley-III) and the Developmental Assessment of Young Children (DAYC). His scores are shown in Table B6.3.

B6.6.2 Home- and Center-Based Intervention: Age 5 to 19 Months

Jagraj's final goal is to enjoy food and drink by mouth and to no longer be dependent on his feeding tube. Through the series of videos shown on Thieme MediaCenter, he will be seen to make gains in all areas of development, including gross motor skills, social and emotional development, development of communication skills, and development of play skills, including the concepts involved in play and the exploration of objects. Also evident is his jaw extension relaxing with the emergence of overall postural stability. With the decrease in the jaw extension, Jagraj's jaw will begin to close, and his saliva swallows will increase proportionately. With the food play and experience increasing, made possible and paralleling his development of postural stability, his gag will decrease to the point that, by the end of the series, he is putting food in his mouth and actively exploring with obvious pleasure. With the subsequent decrease in his early strong oral aversion, Jagraj is truly *making friends with food* and enjoying positive experiences that encourage the continued practice he needs to move forward toward his goal of eating and drinking by mouth. He has demonstrated success here, but he can and will improve on these skills.

Jagraj was 5 months old when a combination of home-based and center-based therapy began. The therapy program included weekly cotreatments with the OT and SLP working together with his mother and grandmother. The family goals, in order of priority, were as follows:

- Growth (weight gain).
- Learning to eat by mouth.
- Learning to walk.

Table B6.3 Standardized test results

Assessment tool	Score	Standard deviation (SD)
Bayley Scales of Infant and Toddler Development, Third Edition (Bayley-III)		
Fine motor	80	−1.34 SD
Gross Motor	70	−2.0 SD
Developmental Assessment of Young Children (DAYC)		
Self-Help	6	−0.33 SD
Communication	8	−0.46 SD
Social-Emotional	6	−0.64 SD
Cognitive	7	0 SD

The program-based goals and outcomes were developed with the family and began as follows.

Gross Motor Goals

- Jagraj will tolerate time on his stomach, beginning with 1 minute, with the goal being to lengthen the prone time, and practice holding himself up first on forearms and later on extended arms. Rationale for outcome: In this position, he will be able to look around the room and will not always have to be held. This activity will also help to activate his core and strengthen his abdominals, which are needed to help decrease the GER.
- Jagraj will practice sitting independently and learn to catch himself when he tips over. Rationale for outcome: In sitting, Jagraj can begin to reach for objects, bringing them to his mouth for exploration. This play experience will both decrease his oral sensitivity and build his understanding of his world and how he relates to it. Learning to balance and catch himself when he tips over will build not only his shoulder girdle but also his confidence in his own body as he learns to move.
- Jagraj will learn to move from sitting onto his hands and knees in preparation for crawling. Rationale for outcome: This is the beginning of his independent mobility and prepares him for walking.

Oral Motor

- Jagraj's vomiting will decrease, and he will begin to gain weight. His weight will be monitored each week, the goal being that his weight will be higher than the previous week. Rationale for outcome: Until the vomiting can be controlled, Jagraj will continue to lose calories and his weight gain will be slow. Furthermore, until the vomiting can be controlled, Jagraj will not be interested in eating and drinking by mouth.
- Jagraj will bring his hands and objects to his mouth with less gagging and no vomiting. Rationale for outcome: The more Jagraj controls what comes to his mouth, the more he will be able to tolerate without gagging. The more sensory input he experiences in his mouth, the less gagging will occur. Since the gagging triggers the vomiting, if the gag can be decreased, the vomiting will subsequently also decrease.
- Jagraj will actively suck on a pacifier. Note that one suck would be celebrated! Rationale for outcome: Jagraj needs to be able to suck to bottle-feed. Also, sucking on a pacifier stimulates swallowing and can help to decrease reflux activity.
- Jagraj will accept tastes of baby food on his lips without gagging. Rationale for outcome: Being able to accept tastes without gagging is the beginning of experiencing the pleasures of eating by mouth. On a sensory level, accepting tastes is the beginning of eating.

B6.6.3 Current Status

The reader is now directed to Thieme MediaCenter that accompanies this text to view extensive video coverage of Jagraj's intervention, including his status in 2014 at almost 6 years of age. As of September 2014, Jagraj had entered kindergarten and learned English. He was learning to read and write at that time. He was eating many foods and was drinking from a cup, even at school, and he was very proud of himself. He made a list of foods he likes.

- Chicken McNuggets
- French fries
- Crackers and cheese
- Cheese and meat sandwiches
- Corn dogs
- Apple Jacks cereal
- Bananas
- Apples
- Gummy bears

He says he may eat vegetables when he grows up, but the topic is under consideration now. He would appreciate it if veggies were not so green.

From a medical perspective Jagraj is now off all medicines except for a daily dose of MiraLAX (Bayer) because constipation continues to be an issue for him and has an impact on his appetite. He is still using his G-tube but is eating an increasing volume orally. He has a morning 8 oz bolus before school and an evening 8 oz bolus before bed. He is on blended tube feedings every other day with 350 calories from PediaSure (Abbott) in between. The goal is for him to regain the weight (2 lb) he lost over the summer when his mother temporarily stopped the tube feedings to encourage him to eat orally. Jagraj is now eating during the day but he needs to regain the lost weight. Once Jagraj is back up to 40 lb, the plan is to gradually decrease the tube-fed calories as he increases his oral intake.

Jagraj is no longer in regular therapy of any kind. He attends a regular school with his peers and will leave his mother at the door of his classroom. This separation was a huge step for Jagraj and marks his graduation into his big boy status. As he settles into the classroom routine and begins to eat more at school, the plan is to gradually decrease the morning tube feeding to encourage his appetite. Because the night feeding enables Jagraj to sleep through the night, it will be the last supplement to fade out.

B6.7 Results and Discussion

As introduced in Chapter 1, a key premise of NDT's philosophy of patient/client management is to consider the whole child and to build on strengths to enhance functional capabilities. For most people, the ability to eat is not only a physiological necessity for nutrition but is also very much a social and emotional experience that is positive and life giving. For a parent or grandparent, the instinct to nurture and protect is epitomized in feeding a child. At a very basic level, the maternal–child bond is developed and strengthened through the feeding/nursing process. With Jagraj, the maternal–child bond was not forged through feeding. Nutritional sustenance was mechanically delivered, and the experience was not particularly positive for either mother or child.

As a young infant, Jagraj endured multiple and lengthy medical procedures that led to much discomfort and pain. Within the context of his serious medical complications, considering Jagraj as an infant with abilities and possibilities was the foundation from which his NDT-based therapy program began. For Jagraj, the development of gross motor skills had a positive influence on his development in other areas, including oral motor, feeding, communication, and social-emotional development. His therapists recognized the interrelatedness of the different domains of functioning as they observed the whole child growing and changing simultaneously in the different domains, including mobility, social, self-care, and communication.

The domino effect was easily apparent in Jagraj's development. As his overall physical stamina improved, his core muscle stamina improved, which led to increased strengthening and stability in his shoulder girdle and abdominal musculature. This change led to an increased ability to tolerate movement and to sit more securely and be more comfortable in the high chair for food play and interaction. With the developing trunk stability and postural control, Jagraj no longer felt the need to "hold on" with his jaw in extension and was able to begin to close his jaw, even while standing. Having his jaw closed enabled Jagraj to swallow spontaneously more often, with the result of decreased drooling. With the developing trunk stability and postural control, Jagraj was also able to be more in control of the food with his improved fine motor skills, and as a result, he became more tolerant of food experiences.

The fine motor skills also enabled Jagraj to begin to use sign language for communication as he was practicing sound production. His signs were effective because they were easy to read and they gave him success with his early communication efforts. He could control the food through his signing by shaking his head to say "no," to ask for "more please," or to say "I'm all done." With this control through communication, Jagraj was willing to take more risks with food—touching, smelling, and exploring. With the increase in experience and familiarity with the food, his gagging and overall oral aversion decreased proportionately, though slowly.

On the other hand, while his vomiting decreased somewhat and slowly, Jagraj's family continued to be concerned about his weight gain and health. In his first months of life, his cardiac and pulmonary conditions restricted Jagraj's activity to barely more than breathing. The focus of his medical team then was basic growth to stabilize Jagraj's overall health. This was communicated to the family, and they were concerned and focused on calories and weight gain. Their concern did not allow them to accept the fact that Jagraj was going to vomit occasionally while he practiced with food. Each time he vomited they reacted with anxiety. This continued even after Jagraj's health had stabilized and he had begun to gain weight. There continued to be an undercurrent of anxiety around the food issues and the vomiting. The weekly weigh-ins were anticipated with both excitement and angst.

As Jagraj progressed and the early goals were achieved, his feeding goals were upgraded, and by September 21, 2009, at 11 months of age, they were recorded as follows:

- Jagraj's gag will decrease in frequency and move back so food can be on his tongue.
- When Jagraj gags, he will not vomit every time.
- At rest, Jagraj will maintain jaw and lip closure.
- Jagraj will swallow his saliva as measured by the decreasing number of bibs used per day.
- Jagraj will swallow water, purees, and meltables.

Table B6.4 provides specific information relative to Jagraj's growth, medication, amount of vomiting, formula intake, and G-tube feeding schedule, as well as improvements in oral motor and gross motor skills.

Jagraj's therapists operated on principles founded in NDT and, with that foundation, an understanding of normal development with the interconnections between domains of the motor, oral motor, and sensory systems. The SLP understood that postural strength, control, and stability were critical for Jagraj to move forward in his development of oral feeding skills. Where a traditional SLP working in the area of feeding would focus primarily on oral motor skills and perhaps sensory work,[13] the NDT-trained SLP evaluated not only Jagraj's oral skills and sensory issues but also his early motor status, including

Table B6.4 Summary of changes from 5 to 19 months of age

Date Age	Medications	Formula	Weight	G-tube schedule and rate	Vomiting	Oral skills	Motor skills
March 2009 5 months	Zantac (Boehringer Ingelheim)	Similac	13 lb 12 oz	Daytime: 75 mL bolus every 3 h Night: continuous at 33 mL/h	4–5/d large volume sometimes at night	Toys to mouth Tastes from finger	Not rolling; not sitting independently; reaching for toys
May 2009 7 months	Prilosec (Procter & Gamble)	Similac	15 lb 14 oz	Same	Same	Same	Rolling in both directions
June 2009 8months	Prilosec	Similac	16 lb 4.6 oz	Same	Same	Same	Sitting independently by end of June
July 2009 9 months	Prilosec	Similac	16 lb 11 oz	Daytime: 80 mL bolus every 3 h Night: continuous at 37 mL/h	Same	Same	Learning to transition out of sitting to all fours
Sept 2009 11 months	MiraLAX (Bayer) added Polycose (Abbott) for calories		17 lb 3.2 oz 17 lb 11.2 oz	Daytime: 85 mL bolus 4/d Night: continuous at 44 mL/h	3–4/d and often after bolus	Tastes from therapist 9–11 bibs/d	On hands and knees trying to crawl
Oct 2009 12 months	Same	Same	18 lb 5 oz	Daytime: 90 mL bolus Increased to 93 mL bolus Increased to 94 mL bolus Night: continuous at 44 mL/h	3–4/d and every week in therapy	Sips from cup; less gagging but still vomiting 8–10 bibs/d	Beginning to crawl with wide base; if placed in stand, cruising but leaning on surface
Nov 2009 13 months	Same	Same	18 lb 7 oz 18 lb 10.1 oz	Daytime: 95 mL bolus Increase to 100 mL bolus Increase to 105 mL bolus Night: continuous at 44 mL/h	Same	Mum-Mums; sips from cup; creamed corn 8–10 bibs/d	Crawling with wide base of support; jaw locked in upright but more mobile in high chair
Dec 2009 14 months	Same	Same	19 lb 3 oz 20 lb 8 oz	Daytime: 115 mL bolus Increase to 130 mL bolus Increase to 140 mL bolus Night: continuous at 44 mL/h	3–4/d but not every week in therapy	Playing actively with finger foods; tastes on fingers and spoon 8+ bibs/d	Crawling with knees more under hips; pushing wagon in standing but unable to sit back down
Jan 2010 15 months	Same	Same	21 lb 11.7 oz 22 lb 6.2 oz	Daytime: 150 mL bolus Night: continuous at 44 mL/h	Mostly 3/d but sometimes 1/d	Same	Close to walking independently
Feb 2010 16 months	MiraLAX after first feeding instead of before	Same	22 lb 8 oz	Daytime: 155 mL bolus Night: continuous at 44 mL/h	2–3/d but less volume	Playing with mashed potatoes at home	Walking but not steady; arms in high guard
March 2010 17 months	Same	Same	22 lb 15.8 oz 24 lb 2 oz	Daytime: 65 mL bolus Night: continuous at 44 mL/h	2/d and often 1/d	Leans forward for sips of water and tastes on spoon 5 bibs/d	Walking more steady; sitting at small table
April 2010 18 months	PediaSure (Abbott)	Same	Tube leak No weight check	Daytime: 170 mL bolus 5/d Night: 11 p.m.–2 a.m., 5 oz total	Tube broken so bolus leaked; no vomiting	Biting finger foods and spitting out; swallowing sips of water	Unable to step up onto mat consistently; afraid to crawl through tube
May 2010 19 months	Back to Similac (Abbott)	Same	23 lb 11 oz	Same	1–2/d but much less volume	Same 4 bibs/d	Stepping onto mat; crawling through tube

his head control and shoulder girdle stability as well as his abdominal strength and overall postural control. She started sessions with motor activities to prepare Jagraj for work in the high chair. She recognized that he was using his jaw for stability and that, if his overall stability could improve, he would no longer feel the need for jaw extension. With that change, Jagraj could actively "let go" of his jaw as a point of stability so it could be free to close for an efficient swallow.

The video series on Thieme MediaCenter shows Jagraj's progression, documenting not only his working with food in the high chair but also his changes in his gross motor activities. Beginning at 12 months of age, when Jagraj returned from his trip to India, the therapist began counting the number of bibs per day as a way to monitor changes in his profuse drooling, paralleling the increase in his spontaneous swallowing, resulting in part in his improved jaw closure. The number of bibs decreased from 9 to 11 down to 3 per day. This change, documented in **Table B6.4**, clearly demonstrates the changes in his posture alignment, relaxed positioning of his jaw, improved jaw closure, and decrease in drooling that paralleled Jagraj's overall improvement in motor control, postural stability, and gross motor function.

B6.8 Conclusion

Jagraj represents a growing group of young children who, in our world of ever-improving medical knowledge and treatment possibilities, have survived severe medical issues thanks to intense medical intervention. On the other hand, that intervention has also interrupted important developmental processes and thereby influenced key skill areas, such as early feeding. We are learning about the importance of early intervention and what that intervention should look like. We are also learning that, for many children, the shift from supplementary tube feeding to oral feeding is a complex process involving many body and contextual systems.

The transition to oral feeding can be a lengthy process involving work in many areas, and all are based on that basic foundation of postural stability and control. It is a journey for both child and family and reaches into all aspects of the family life. It is a journey that requires a full support team, from a variety of disciplines and specialties, including the primary care provider, gastroenterologists, pulmonologists, ear-nose-throat specialists, dieticians, nurses, therapists, psychologists, social workers, and others. SLPs, OTs and PTs armed with knowledge and skills in NDT bring a unique perspective to the therapy table, an in-depth understanding of development, as well as an awareness of the foundational importance of postural control and stability.

The NDT practitioners' ability to see the child as a whole person in the world that she or he lives in and to understand the family's needs, wants, goals, and dreams can help to make the journey more understandable and manageable for both the child and the family.

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Case Report B7 Developing Independent Downhill Skiing for a Child with Ataxic Cerebral Palsy

Karen Goldberg and Ruth DeMuth

B7.1 Introduction

As Neuro-Developmental Treatment (NDT) therapists, we have used the International Classification of Functioning, Disability and Health (ICF) model over the last 2 decades in our clinical approach to enhancing the skills in functional and meaningful tasks for our patients.[1,2] We have also attended to overall quality of life issues, including the social participation domain of the ICF model.

Our literature demonstrates the social cost of disability for children.[3,4,5] Parents and youths report isolation, loneliness, and lack of self-efficacy (a person's belief in his or her ability to succeed in a particular situation).[5] Differences in social participation (outside of home) between children with cerebral palsy (CP) and children without disability demonstrate a marked difference between the groups, with less participation and interaction in the population with CP.[6] A study published by Palisano et al[6] showed that social and community participation of children and youths with CP is associated with older age (13–21) and with children whose Gross Motor Function Measure (GMFM) scores were at level I as well as at levels IV and V. What does this mean for the group of children with CP at levels II and III?

Being able to function socially in society and to have recreational activities have been delineated as core values in our public school systems. We, as physical, occupational, and speech therapists, have roles as consultants for accessibility, activity modifications, and assistive technology, and as advocates for inclusive environments.[3]

As an experienced physical therapist prior to becoming an adaptive ski instructor, I (KG) never would have considered putting a nonambulatory child with ataxic CP on skis. This personal adventure for me demonstrated that, as Neuro-Developmental Treatment (NDT)-educated therapists, we have a full understanding of our patient's movement problems resulting from interaction of multiple systems leading to participation restrictions.[2] Also, in sports, we can easily understand what the functional limitation is and problem-solve with persons in the sport of the child's choice to help evaluate adaptations to facilitate sport participation.

Skiing offers an element of moving through open space outdoors with speed, affecting the visual, vestibular, and postural systems in a beneficial and organizing manner. With the increasingly serious problem of childhood obesity and our knowledge that daily exercise has a posit-ive impact on our quality of life, we have an important role both to help our children participate in sports and to encourage participation in a sport as a direction toward a long-term healthy lifestyle.

B7.2 Literature Pertaining to Sports with Children with Cerebral Palsy

In reviewing the literature for information on adaptive skiing and CP, an article published in 2006 demonstrated improvement in the GMFM score for ambulatory children with CP who had 10 weeks (one session per week) of adaptive downhill skiing (ADS).[7] Other literature pertaining to CP, recreation, participation, or physical fitness was extremely limited.[8] Sports commonly described were swimming and hippotherapy.[9,10]

B7.3 Professional Ski Instructors of America

Adaptive skiing became recognized by the Professional Ski Instructors of America (PSIA) in 1996 as a specialized area of ski instruction and certification for those individuals who were interested in teaching skiing to individual students with a vast range of physical and developmental challenges. When choosing adaptive skiing as a discipline in professional ski instruction, a person is required to take a series of courses in biomechanics, skiing, teaching, disability awareness, and knowledge of specialized ski equipment. There are three levels of certification; once completed, an individual can then become accredited as a trainer in adaptive skiing.

The purpose of developing this body of knowledge for adaptive ski instructors is to provide education to the already accredited ski instructor on the specialized methods of teaching people with disabilities, including information on common medical diagnoses, visual impairment, cognitive impairment, biomechanics, and adaptive specific equipment, such as a mono ski for individuals who have limited mobility from the waist down (e.g., a spinal cord injury, multiple sclerosis, or amputations); a bi-ski for individuals that are considered more involved, such as a those with quadriplegia; or even a ski bra to help with abduction and ski tip stabilization.

B7.4 The Adaptive Skiing Experience

As an adaptive ski instructor (ASI), I (KG) functioned as an employee of a resort company under the direct supervision of RD. I served clients for the entire day and attended to all their daily needs (lunch, bathroom, emotional needs). A variety of tools, such as signing, flash cards, and gesturing, were used for children who were nonverbal. A phone or personal interview with the parents occurred prior to meeting the child. Initially, the children would often display insecurity and fear at either the novelty of the ski environment or the instructor, and the fitting of boots and skis that would occur together with the parents provided us all with the opportunity to engage in a playful manner with the child, similarly to what occurs in a therapy setting to ease a transition.

Because the ski environment is typically high energy, fun filled, and happy, it is often the case that the separation of the parent and child goes smoothly. Once the thrill of moving through space freely occurs (through the use of adaptive equipment), the child is engrossed in the new experience, and parental separation typically is no longer an issue. We learn early on to get going with skiing!

The principles of assessment, equipment selection, and ski instruction that I was taught match my NDT practice. Evaluation of the family and child's needs as an individual, as well as the child's function, body structure, strength, and cognitive function with respect to her medical restrictions, are analyzed to put the client into the safest, least restrictive adaptive equipment for a maximum ski experience.

As part of my training, I was required to role-play different disabilities and use various pieces of adaptive equipment while trusting other trainees to lead me down the slope. This reminded me of all the handling laboratories and adaptive equipment laboratories we had as NDT students.

B7.5 Patty Grace's Therapy Assessment

The child, Patty Grace, featured in this case report did not receive physical therapy services from this therapist outside of the adaptive skiing program. This case report is a retrospective study. The author, KG (ASI instructor), was an instructor under the supervision of the author RD (director of an adaptive ski school). RD instructed Patty Grace in her beginning ski experience and knew the student and family from both ski school and the community. Patty Grace was selected as a person to demonstrate how, in spite of her significant locomotion restrictions, she was able from the beginning of adaptive skiing to participate as a skier on Vail Mountain and to progress quickly in participating with less physical support. Further, the remarkable point of this case study is to highlight the similarities of our NDT philosophies, assessments, and viewpoints on inclusion of function and participation with the sport of adaptive skiing.

Patty Grace is a 9-year-old girl who has a diagnosis of ataxic CP as a result of glucose transporter type 1 (Glut1) deficiency.[11] This deficiency is associated with intellectual impairment, visual impairment, gross and fine motor delay, speech and language delay, and seizures. She is on seizure medication.

An evaluation of Patty Grace's posture and movement, body systems, and functional activities took place in a community playground setting 4 years after she began skiing. The selection of a playground setting was determined based on Patty Grace's ability to ambulate independently in her school with the supervision of her aide for safety. The playground provided an age-appropriate setting to observe her gait, spontaneous function, postures, and movements as well as age-appropriate sensory perceptual skills, communication, and behavior.

Using the NDT Practice Model with the ICF model guiding organization of domains of functioning, Patty Grace's functional activities in the playground setting were found to be as follows.

B7.5.1 Gross Motor Functional Activities, Participation—Social Functional Domain

Patty Grace can control her body posture and movement in sitting, in standing, and when walking on an uneven surface. She can climb up a slide and ascend and descend stairs, leading with her right leg, descending with her left leg, while holding a railing. Patty Grace uses her arms to assist her in all movement transitions, and places her hands appropriately on playground equipment to adjust her balance or position.

B7.5.2 Communication Skills

Patty Grace's receptive communication is good, and it far exceeds her verbal abilities to communicate. She often responds with "yes" or "no," or points. Cognitively, she is functioning at the first-grade level. She now uses an iPad with audio application.

B7.5.3 Social/Emotional Skills

Patty Grace attends but does not always direct her face toward the speaker. Socially, she is appropriate for her age.

B7.5.4 Postures, Movements, and Functional Limitations—Gross Motor

Patty Grace demonstrated very little rotation in her trunk for all movement transitions and moved in the sagittal plane. Her gait was wide-based, feet pronated, trunk aligned posteriorly to her hips, and her head often tilted to the right side. This posture contributed to her slow movement and poor coordination. An example of her functional limitation was her inability to sit on the teeter-totter with her feet flat because she needed to keep her legs widely abducted, which hampered her ability to initiate moving the teeter-totter into the air.

B7.5.5 Body Function and Structure

Patty Grace demonstrated a loss of anticipatory control in activation of postural musculature. There was a delay in her ability to direct her body to a new piece of equipment on the playground and walk toward it. Toward the end of the playtime, her gait became slower, possibly due to postural control weakness and fatigue, which her mother reported as a contributing factor.

Musculoskeletal Control

Examination of her feet on the playground bench was conclusive for bilateral ankle pronation and heel cord tightness, with the right ankle at just less than 0° dorsiflexion and the left at 0° dorsiflexion.

Sensory Systems Tested—Vision

For her gross visual assessment, having Patty Grace track a small red ball from side to side across midline and in a circle demonstrated saccades of her right eye. She moved her eyes and head simultaneously. Thus, each time she directed her eyes, her head moved toward the target, which challenged her to sustain her postural control.

B7.5.6 Assessment

From this cursory evaluation, it became apparent that Patty Grace's movement patterns showed the following:

- Limitations in movement planes—she moved in the sagittal plane only.
- Force production difficulty of her postural muscles, especially her right hip flexor, and bilateral hip extensors.
- Spatiotemporal impairments with a lack of adaptability, quickness, and reliability.
- Visual function delays.

Patty Grace also required monitoring for safety on the playground on unfamiliar equipment and for sudden seizure activity.

B7.5.7 Historical Information

Patty Grace was placed in an early intervention program at 4 years of age when the family moved to the Vail Valley in Colorado. She was nonverbal, could nod for yes or no, and was dependent on her caregivers. Patty Grace's parents were avid skiers and worked as part-time ski instructors for Beaver Creek Resort. It was there that her parents learned of adaptive skiing and the Small Champions program for children with disabilities taught by adaptive ski instructors at the Vail Snow Sport School. Her parents were very apprehensive given that Patty Grace used a wheelchair and was nonambulatory, but they shared Patty Grace's need to participate in what everyone was doing in the mountains and her love of movement and speed.

B7.6 Skiing Assessment and Instruction

Student assessment is the most important part of getting someone with a disability set up for skiing. It is very similar to what a physical therapist does before sessions, assessing and evaluating what will be worked on for that day. For the ski instructor to teach a successful lesson, the instructor must have a complete picture of the student's abilities, movements, and goals. Gathering this information from the parents ahead of time at the initial phone reservation assists the instructor and program director to create a lesson plan and determine what type of adaptive equipment may be needed.

Once the student arrives on site, the physical assessment and equipment fitting will be completed. The instructor must take into consideration the cognitive, affective, and physical aspects of the student. The instructor must look at the student's stance and gait; balance fore, aft, and laterally; strength; and mobility to determine if a student will stand and ski or sit and ski. Then the medications that the student is taking and any associated side effects are assessed. Each adaptive program has a personalized assessment sheet or student information form and follow-up notes for future lessons, similar to a physical therapist's evaluation and intervention plan.

The assessment is guided by specific questions and discussion, and then moves into the physical aspects, such as muscular function and strength, to determine which muscle groups a student can use or cannot use or if there is a weakness from side to side, and how long they can remain active.

Skills needed to ski must be assessed, and each person is assessed on how he or she is able to use the body for these skills.

- Edging movements—movements that increase or decrease the edge angle of a ski are achieved through tipping parts of the body on a central axis—tipping the ankles, knees, spine and/or head (lateral weight shift). Any kind of tipping of a body part relative to the slope angle is inclination. A skier can incline the entire body into the slope or tip different parts to different degrees.
- The next skill is turning movements or rotary skill—movements that increase, limit, or decrease rotation of the ski. These skills determine if a student can move the femurs in the acetabulum through closed chain lower extremity movements to create a circular motion about an axis—similar to bilateral integration. An atypical muscle synergy pattern, which will interfere with the sequencing of movements required in skiing,

may be detected. This is common in the beginning lessons with a person with mild CP or hemiplegia or a student who is unable to maintain equilibrium.

- The next skill is pressure control in movements—the pressure applied on the skis. This control or manipulation is achieved through leverage, flexion and extension, redistribution of weight from foot to foot, increasing and decreasing edge angle, and muscle tension, to allow changing a turn's shape and size. To maintain the desired pressure, several movements are required from the body or accomplished through the aid of adaptive equipment.
- The last skill to assess is dynamic balance—it is important for the body to be skeletally aligned. In skiing, *alignment* refers to the positioning of the body so that the forces derived from the interaction of the skis on the snow pass through the core or center of mass to produce the intended movement action or reaction. The slippery surface of the snow can cause issues for an individual, or it can enhance a more fluid motion. This motion is optimized when the skis, boots, or adaptive equipment is selected or modified to complement and/or to correct body movements to enhance strength and predictability of body movements. For example, if a student has severe alignment issues, these will need to be addressed before the student goes on the snow to create a flat ski from the start.

The final assessment is a cognitive assessment. Can the student hear, understand, and answer questions? Is the student's level of cognition age appropriate?

Once a full student assessment is completed, the instructor can start to formulate a plan for adaptive equipment that may be needed to assist this person in skiing. Adaptive instructors are constantly assessing and reassessing throughout the day. Once on the slope, we use a process called movement analysis to assess a student's ability, the movement patterns and skill blending to identify the cause-and-effect relationships of ski–snow contact. The instructor analyzes the separate components of the student's movements to determine the skill and movements and identifies the steps and changes needed to produce the desired result, such as symmetrical turns or varying turn shape from medium to small.

B7.7 Patty Grace Learns to Ski

Patty Grace was ~6 years old, with very low postural tone, when she arrived for ski instruction. She had spent most of her time being transported in a wheelchair, and she was using ankle-foot orthoses (AFOs) for ankle stability to stand for short periods of time. She was unable to walk without the assistance of a walker. She had been told she would never walk independently. Cognitively she was delayed due to seizures.

For Patty Grace, the bi-ski was the most suitable piece of equipment, with fixed outriggers on the side.[12] The bi-ski is an adaptive ski device that allows a skier to be seated and ski (Fig. B7.1). This device has articulating swing bow skis that allow for easy edge-to-edge movements. The fixed outriggers are placed on the side of the ski to facilitate the side-to-side movements but inhibit it from falling over. The design of the bi-ski and the abilities of the student and partnership with the instructor allow a person with a high level of disability to ski almost everywhere on the mountain. The bi-ski allows a student to participate in the ski lesson by leaning from side-to-side to engage the edges of the bi-ski. The more Patty Grace participated in skiing and following stand-up skiers, the more she understood the concept of skiing. This was the ski experience that was a catalyst for Patty Grace to want to stand and be more independent. Her goal was to stand and ski just like her brother and sister and everyone else (Fig. B7.2).

As Patty Grace developed in muscle strength and in coordination, she was able to start to stand and ski with a piece of equipment called the Slider (Fig. B7.3).[12] This piece of equipment is designed by Freedom Factory and is similar to a walker, but it has arm troughs and can be manipulated into 16 different positions to accommodate multiple disabilities. The concept for this piece of equipment was adapted from a hospital walker drilled onto a set of skis and has evolved to allow the student with a disability a wider range of movement and support, accommodating a larger population of individuals with disabilities.

When a person transitions from adaptive equipment, it is important to redo an assessment. For her stand-up skiing assessment, Patty Grace used regular ski boots without her AFOs, so it was important to check the canting—was she standing on a flat foot or pronating or supinating? Could she plantar-flex or dorsiflex? Again, the assessment took into consideration the cognitive, affective, and physical aspects of her disability.

Fig. B7.1 Patty Grace learning to ski with her ski instructor.

Fig. B7.2 Patty Grace and her ski instructor, Ruth, demonstrating training for use of a bi-ski.

Fig. B7.3 Patty Grace demonstrating use of a Slider.

For Patty Grace, we had to add a slight wedge on the inside of her boot because she has a tendency to pronate, which would make it hard for her to keep her skis flat and would hinder her ability to initiate a turn when the ski was not flat. Developmentally, Patty Grace also had trouble with hip abduction and adduction—it is very common in young skiers to want to abduct and very difficult to adduct. Therefore, a ski bra and spreader bar were used. A ski bra is a metal device that clamps onto the tips of the ski to keep the tips together while allowing the tails to push away/adduct. The spreader bar is placed by the heels and forces the student to maintain a slight wedge position, and if the student tries to abduct, the movement is halted, allowing the legs to only adduct.

In adaptive skiing, proprioceptive and kinesthetic learning, receiving feelings and sensations through the body to help a student learn the correct skiing movements, are used constantly. Hence the instructor is constantly adding or eliminating equipment once a desired movement pattern is achieved. Once the muscles have learned this move through constant repetition and the student is able to perform, equipment such as the spreader bar and ski bra are eliminated. This motor learning and conditioning of muscle memory are the ski movements learned by practice or experience that lead to a relatively permanent gain in performance of muscle control.[13]

The next thing we assessed was Patty Grace's endurance and ability to stand for longer periods of time. Within a month of skiing, only on weekends, Patty Grace was standing and skiing and had mastered the Slider on the beginner hill. It was time to go up the mountain; however, her fatigue factor was a big issue. Her quadriceps had not developed sufficiently, so the Constant–force Articulated Dynamic Struts (CADS) system (CADS USA, Inc.) was used.[14] The CADS system is used by students who have a deficit in their quadriceps strength or who are not able to flex and extend for extended periods of time. The CADS system was designed by Walter Dandy in 1988 to re-create the leg muscles with a simple rubber band and pulley system. The mechanism transfers loads from the legs to fiberglass rods, thereby reducing the muscular energy required. Patty Grace used the CADS for probably 2 to 3 months of skiing on the weekends and then decided she did not need them anymore. Again, this was a piece of equipment that was used to stimulate motor learning and strength of her muscles to support her body while maintaining balance in motion. As she progressed, we could see she would be able to walk greater distances unaided. So it was time to eliminate another piece of equipment and see if she could do it on her own.

Patty Grace now skies almost all blue runs (moderately difficult) to some groomed black diamond runs on the mountain; she now has the ability to ski with family and friends with the aid of only the Slider.

B7.8 Conclusion

With appropriately selected adaptive ski equipment based on her functional abilities and body structures and functions, Patty Grace was able to participate in Alpine skiing, which her family enjoys. She demonstrated improvement in her cardiovascular endurance, muscle strength, and self-esteem by participating in this sport. This accomplishment affected her motivation to learn to ambulate independently in physical therapy, and it impacted her success in achieving physical therapy goals. Her mother shared that currently she would like to learn how to rock climb.

Therapists and adaptive ski instructors both need to focus on what their clients *can* do, not on what they *cannot* do. In adaptive skiing, a person with a disability is referred to as differently abled—still able to ski and participate with family and friends like everyone else. Adaptive instructors find ways to provide the recreational experience of a lifetime. My experience as a therapist and applying my knowledge of therapy, blending it with skiing and movement in a different environment, has given new meaning to my work as a therapist.

Please see additional photographs of Patty Grace skiing and her ski equipment on the Thieme MediaCenter.

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Case Report B8 Providing Ongoing Neuro-Developmental Treatment–Based Physical Therapy Intervention for a Medically Fragile Child with Severe Disabilities

Judith C. Bierman

B8.1 Introduction

Physical therapists (PTs) who work with children see a wide spectrum of clients or students. Even if one considers the management of only those children with developmental disabilities or with cerebral palsy (CP), the scope of practice remains wide. The focus narrows substantially when considering the examination of and intervention for children with CP who are severely involved. These children represent a small number and are especially challenging for clinicians to manage.

In trying to best prepare future therapists for the entire breadth of potential practice, professional educators tend to emphasize the most prevalent issues or those the clinician would be most likely to encounter. Because children with developmental disabilities who are severely involved represent such a small percentage of the total population, therapists may be less prepared to manage the special needs of this population. In addition, there is a general perception that therapy is less effective for individuals who are more severely involved because these children may be perceived as being unlikely to make marked progress. Therapists managing a busy case schedule may elect to and be directed to provide more intensive therapy for children who are more likely to make faster functional gains.

Brandon is one child who is included in this group of children who are more severely involved. Brandon and his twin, Blake, were born at 25 weeks' gestation (Fig. B8.1a, b). Initially, Brandon was the healthier of the twins and was discharged from the neonatal intensive care unit (NICU) after 4 months. However, after a short stay at home, he demonstrated increasing difficulties and was admitted to the pediatric intensive care unit (PICU) for a month and a half. Both he and his brother were diagnosed as having CP, although Brandon had more significant impairments and activity limitations than did Blake. During this second hospital stay, the family was advised to consider halting intensive medical intervention because the predicted outcome for Brandon was bleak. The family decided this was not an option for Brandon. They took Brandon home with his brother and started the journey as a family.

This case report describes Brandon as a child with severe involvement within the framework of the International Classification of Functioning, Disability and Health—Version for Children and Youth (ICF-CY).[1] The case report thus offers therapists an example of how a Neuro-Developmental Treatment (NDT) framework was used specifically to improve the participation domain for a child functioning within level V of the Gross Motor Function Classification System (GMFCS).[2,3,4] Intervention focused on improving Brandon's participation in his home and community and included both the careful selection of adaptive equipment and assistive technology and direct hands-on intervention within the NDT Practice Model.

B8.2 Review of the Literature

In the definitions of CP,[5,6,7,8] the effects of the posture and movement disorder are anticipated to be present throughout life, but the impairments and their influences on functional activity and participation are changeable across that lifetime. Although CP is viewed as a chronic condition, currently, it is usually not viewed as one that will significantly alter the length of life. The life span of individuals with CP is now approaching a typical length unless one includes those that are severely involved.[9,10,11] Hutton[12,13] reported that a

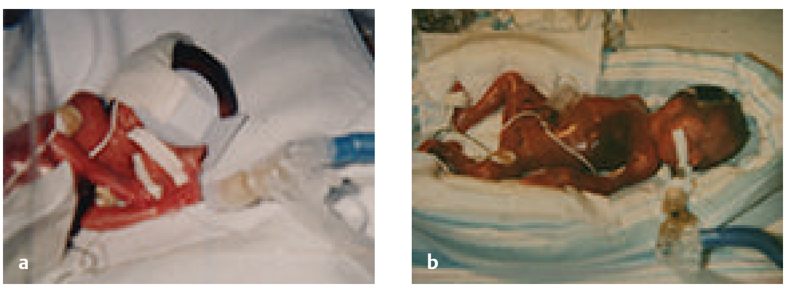

Fig. B8.1 **(a)** Brandon on his birthday. **(b)** Brandon's twin, Blake, on his birthday.

2-year-old with severe CP has an ~40% chance of living to age 20 as compared with a child with mild CP, who would have a 99% chance. The most frequently reported causes of death include respiratory diseases, epilepsy, and congenital malformations.[13] Additionally, there are several factors associated with a shorter life span, including the number of impairments, the overall severity level, mobility restrictions, feeding difficulties, seizures, lower cognitive function, decreased visual acuity, quadriplegia, and impaired respiratory function.[14]

B8.2.1 Who Is the Child with CP Who Is Severely Involved?

Social Function: Participation and Participation Restrictions

In a review paper by Imms et al[15] in 2008, it was reported that all children with CP were found to have more restricted participation diversity and intensity as compared with children without disabilities. These findings were confirmed in more current reports.[16,17,18] Children who are severely involved GMFCS[2,3,4] level V are found to have the most restricted participation, with activities being performed either individually or with the extended family, rather than being community based.[15,16] The level and intensity of participation are determined by a combination of multiple contextual factors, including the specific child's characteristics, family characteristics, education, and health care and community services.[16,17,18,19,20,21,22] Overall, the child's gross motor function and adaptive behavior are important factors in determining participation.[21] Knowledge of the child's preferences also has a role in the selection of appropriate opportunities for participation.[17] Finally, environmental modifications and assistive technology are important considerations in enabling participation of children with CP.[22]

Therapists who work with individuals who are more severely involved must take these factors into account because a prime role of intervention is to improve participation. The therapist should include a careful review of individual and environmental contextual factors, gross motor skills, and development of adaptive skills that would support participation in the data collection, examination, evaluation, and plan of care. Environmental factors should include a review of the availability and use of adaptive equipment and assistive technology. This process is well imbedded in the NDT Practice Model.

Individual Function Activity and Activity Limitation

Children who are severely involved are identified by the significant activity limitations in many areas of daily life function. Activity is currently classified as related specifically to the GMFCS,[2,3,4] the Manual Ability Classification System (MACS),[23,24] and the Communication Function Classification System (CFCS)[25] skills. In all three systems, level V would include the description of children with severe activity limitations. The skills are summarized in Table B8.1.

B8.3 The Family with a Child with Severe Developmental Disabilities

After the birth of a child with special needs, the parents are faced with raising a child without specialized training. Typically, parents anticipate sharing in the development of motor milestones, such as rolling over, sitting, walking, running, bicycling, or maybe even the Olympics. Instead, parents of children who are severely involved observe their child struggling to achieve even basic skills. Strategies to teach motor skills employed with siblings are not effective in improving the desired skills. If referred for physical therapy and asked what their goals are for their child in therapy, those parents usually answer, "I want my child to walk." The parent may not have any idea of what is actually possible.

Often parents at the time of diagnosis report that physicians stress what is not likely or possible to occur for their child. The parent may be clinging to the hopes

Table B8.1 Classifications of function: level V descriptors

Functional classification system	Classification description
Gross Motor Function Classification System (GMFCS) level V	Physical impairments restrict voluntary control of movement and the ability to maintain antigravity head and trunk postures. All areas of motor function are limited. Functional limitations in sitting and standing are not fully compensated for through the use of adaptive equipment and assistive technology. At level V, children have no means of independent mobility and are transported. Some children achieve self-mobility using a power wheelchair with extensive adaptations.[2,3,4]
Manual Ability Classification System (MACS) level V	Does not handle objects and has severely limited ability to perform even simple actions. Requires total assistance.[24]
Communication Function Classification System (CFCS) level V	Seldom effective sender and receiver, even with familiar partners. The person is limited as both a sender and a receiver. The person's communication is difficult for most people to understand. The person appears to have limited understanding of messages from most people. Communication is seldom effective, even with familiar partners.[25]

and dreams of all parents for their children. However, the more realistically achievable gross motor skills may be that these children will sit safely in a car seat, that they will do a standing transfer from the wheelchair to the bed, or that they will take a few supported steps with the assist of a caregiver. These are not activities that parents routinely include in goal statements nor are they routinely included in standardized lists of developmental milestones. They are, however, activities that can dramatically alter participation for both a child with severe involvement and that child's entire family.

It may also be necessary for the clinician to take a slightly different view of functional activity when providing intervention for individuals with more severe involvement. These individuals may not perform some of the basic activities that are typically achieved in infancy. Most functional lists are more often skewed toward higher-level skills. The clinician working with a more severely involved child may need to search with the family to discover specific functional activities that would be most meaningful and helpful for the family and for the child. For example, it might be important for a child to be able to lie comfortably in supine and sleep in a bed other than his own so that the family could visit the homes of the extended family.

B8.4 Case Description

Brandon spent the initial months of his life in an NICU. Initially, he was the healthier of the twins and was discharged from the NICU after 4 months. However, after a short stay at home, he demonstrated increasing difficulties and was readmitted to the PICU for a month and a half. (See photos in photo gallery in the NICU file on Thieme MediaCenter.) This case report will be presented from age 2, when Brandon and his family moved to the therapist's geographic area, and will follow him to the end of his life at age 10. The ICF-CY[1] model will be used to organize the clinical description for Brandon. The description begins with the domain of social function, transition to individual function domain, and finish with the body structure and function domain. Finally, the influences from the environmental and personal contextual factors are discussed, with the overarching influences on all of the domains.

The domains and contextual factors are explored in three different time frames. The first frame includes the early years for Brandon and Blake, when the care was more like baby care. Although the two boys were different, both boys needed to be carried, positioned, fed, diapered, and so forth. The second frame is the early school years. Brandon was attending school, but the differences in abilities and participation were more evident, not only between same-age peers but also with his twin. The final frame explores when Brandon became more medically fragile such that what separated him from his brother as well as his peers was more medically based rather than activity or participation based.

B8.4.1 Medical Diagnoses

Brandon's diagnoses (listed in approximately chronological order) include intraventricular hemorrhage (IVH, bilateral grade IV), bronchopulmonary dysplasia (BPD), retinopathy of prematurity (ROP, stage III+; resolved), hydrocephalus, CP, cortical visual impairment, severe mental retardation, seizure disorder, oral motor dysfunction, gastroesophageal reflux disease (GERD), chronic sinusitis, chronic pneumonia, hypothyroidism/hypoadrenalism, scoliosis, gastrostomy tube (G-tube) for all nutrition, osteopenia, and bilateral hip dysplasia.

B8.4.2 Examination

Social Function—Participation and Participation Restrictions

Brandon was always a full participant in family life. Once living at home, he shared a bedroom with his twin and slept at the same hours. As he became more medically fragile, he was moved into his own bedroom because his sleep and wake cycles were less consistent. His room was centrally located so that he could be a part of family life, and it was spacious enough to accommodate all of his equipment. His bedroom looked like a boy's bedroom rather than a hospital room. Brandon's family moved twice to better accommodate his needs in the home and to support his inclusion in family life. The family had meals together throughout Brandon's life, even though Brandon was fed by a G-tube. They enjoyed music and had regular video nights at home. Brandon participated in all of these activities, whether in his wheelchair, his special activity chair in the family room, his stander, or in one of his parents' arms.

Brandon and his brothers liked to play together, especially when he was upright in his chairs or stander. Brandon liked to shake bells secured to his wrist and did it best in supported standing. He and his brother would dance together in this fashion. His family life did change significantly when he was 5 years old with the addition of a younger brother. He had to learn to share his parents' attention even more, to play with someone younger than himself, to wait for short periods, and to take turns. His home environment was now more active and complex.

Brandon's participation with the family expanded to include his extended family. He loved visits of his grandparents and liked to be held and pampered by them. He could sleep, eat, and play in his home with the assistance of his grandparents while the parents had some respite from the constant care of Brandon and Blake. He also learned to be cared for by in-home nurses and adjusted to having a series of less familiar adults assist him with all activities of daily living (ADLs). He had preferences of who could assist him, but he did participate with this wider group of caregivers. In his final days and hours of life, he returned to being held in the arms of his parents, where he had always experienced the least discomfort and the best possible breathing, and where he did what he did best, which was to love and to be loved. See photos in the galleries

"I am a Twin," "I am a Unique Person," and "I am a Family Member" on Thieme MediaCenter.

Brandon initially attended a public preschool for children with special needs and then an elementary school in a self-contained class for children with severe and profound physical and cognitive impairments. He attended the same school as his brother for the initial years. It was not the neighborhood school, making it more difficult to build a convenient group of friends nearby. As the differences between Brandon and Blake's educational needs widened, the boys attended different schools. Neither Brandon nor Blake could ride the regular school bus. Their mother chose to drive Brandon to school because it was difficult to position him safely in his chair for the long rides without her watchful eye. By 8 years of age, his health eventually prevented him from attending school, even in a small self-contained class, so educational services were provided on a homebound basis with a teacher coming in on a weekly basis.

Brandon initially participated in early intervention with home-based occupational therapy, physical therapy, and speech-language pathology services. His parents selected to have clinic-based outpatient therapy services where therapists were more familiar with a medical model required for his care and directed toward meeting his specific needs. At age 2, he began outpatient therapy services when his health permitted. He also attended frequent medical visits with a wide range of specialists, in both Augusta and Atlanta, Georgia. He lived at home whenever care could be provided there, even when it required multiple hours of home health nursing care. He required multiple trips to the hospital, however, for stays varying from several days to a month at a time. Hospitalizations were based on respiratory infections, one cardiac arrest, severe gastrointestinal (GI) problems, and several episodes of infections that were difficult to diagnose and treat. Most visits entailed PICU stays, with an occasional stay on the regular pediatric floor. As time progressed, the home environment was adapted to provide most of the needed medical equipment and supplies of a hospital room, and Brandon's mother and regular in-home nurses were able to provide closer supervision. Brandon's mother was also better able to detect and respond to his signs of distress or recovery compared with unfamiliar hospital staff. The entire family dynamics changed when Brandon was in the hospital. Blake especially missed his brother and would at times report that he had some unnoticed medical problem that required a trip to the hospital.

Individual Function—Activity and Activity Limitations

Brandon's functional activities varied based on his health. He could usually reposition himself by rolling when uncomfortable if positioned in prone, supine, or side lying. He could, at different points in his life span, sit independently, either in a modified long sit position or in supported bench sitting with upper extremity (UE) support, and he enjoyed sitting in a wide variety of chairs outside his wheelchair. He also, at times, could assist with standing transfers between these chairs or when preparing to be picked up and carried if supported by a caregiver and when wearing his ankle-foot orthoses (AFOs). He could usually stand with support of his stander, a partial body-weight-bearing device (PBWB), or an adult to watch videos or play with his brother. He could take some assisted steps during his healthier periods. These skills would improve as his health did and then disappear for periods after each hospitalization or when his oxygen saturations remained very low. His desire to accomplish daily tasks never decreased, and he worked hard each time after a medical crisis to regain those skills.

Body Structure and Function: Integrities and Impairments

Multisystem Issues Related to Posture and Movement

Brandon required support in all antigravity postures. He could lie independently in prone, supine, or side lying but required support for sitting and standing. As a preschooler, he could roll quickly from prone to supine and developed head control for sitting and standing for short periods of time. In all postures, Brandon always assumed a large base of support and was asymmetrical. His head was usually rotated and laterally flexed to the right and hyperextended. He had a significant scoliosis. Surgical spinal stabilization corrected this spinal asymmetry and made sitting far easier for him. His extremities also demonstrated the asymmetry, the lower extremities (LEs) more so than the UEs.

He had a paucity of movement, especially when his O_2 saturation levels (SaO_2) were low. He tended to move in full flexion or extension, but the range of movement was altered by his surgeries. When feeling well, he could demonstrate reciprocal flexion and extension in the LEs and could reach with either arm. He could move his extremities but had difficulty after each surgery developing the control necessary to manage the new situation (e.g., the hip control in both sitting and standing after an osteotomy). He had the freest movement when supported in the PBWB.

Single-System Integrities and Impairments

Brandon had many system impairments that varied across time. For each system, a general status will be given along with trends across time for that system. The constant changes in different systems' status, the interaction between the body systems and posture and movement impairments, and the influence of all of this on his functional activity were challenging for the PT to analyze and to make the necessary shifts in his plan of care and intervention.

Regulatory System

At age 2, Brandon had difficulty with temperature control and could not go outside on very hot days. He had increased redness across the extremities and would also suddenly flush. His heart rate and SaO_2 levels demonstrated sporadic changes not based on activity or observable environmental stresses, reflecting poor central regulation of basic physiological systems. He always required more sleep than his brother and always had difficulty with constipation. He was initially more irritable than his brother, and if something went wrong in the day, the entire day could be a bad day.

By age 9, Brandon could demonstrate a wider variety of states. He could be happy, quiet, fussy, or angry. Changes in status were often related to SaO_2 levels. He wore a monitor at all times that sounded when his O_2 levels were below 85%. His heart rate fluctuated. He took melatonin as needed to aid in sleep.

Respiratory System

Brandon demonstrated greater impairments in the respiratory system with chronic pneumonia. He first required supplemental O_2 at night for sleep apnea and eventually the use of O_2 throughout most of the day. The spinal stabilization also immediately improved his SaO_2 levels. He eventually required a tracheostomy and required ventilation on several hospital stays. His baseline SaO_2 gradually dropped and was monitored constantly. After the tracheostomy, the shifts in SaO_2 were not significantly altered by changes in postures, allowing him to be positioned safely in prone, supine, sitting, or standing. He had ongoing difficulties with congestion and upper airway infections. He developed severe sinusitis. He frequently stopped breathing altogether during seizures, yet the physicians had difficulty with balancing sufficient seizure medication to control his seizures and maintain adequate O_2 levels because the medication also tended to decrease his respiratory drive.

His breathing pattern was primarily diaphragmatic without full expansion of the rib cage. Medications for the respiratory system included Singulair (Merck Sharp and Dohme Corp.), Nasonex (Merck Sharp & Dohme Corp.), Pulmicort (AstraZeneca), albuterol, Atrovent (Boehringer Ingelheim), and Clarinex (Merck Sharp & Dohme Corp.) daily. In addition, he took tobramycin and Septra (Pfizer, Inc.) to address the chronic respiratory infections.

Cardiovascular System

During the later stages of Brandon's life, his heart rate was also monitored constantly by the oxygen monitors. His heart rate varied from the 40 bpm range when he was asleep to between 60 and 80 bpm when he was awake and alert, but it did occasionally jump to the mid to upper 90s. He did have one cardiac arrest during a long seizure when he was 8 years old.

Neuromuscular System

Brandon could initiate, sustain, and terminate motor unit activity but had difficulty with the control/gradation of muscle activation and the coordination or timing and sequencing of muscle activation for functional activities. He initially had the greatest difficulty in terminating motor unit activity and would depend on a caregiver or changes in the environment to inhibit muscle activation. Most often, the muscle activation was isometric or concentric in nature with almost no eccentric control demonstrated. He also demonstrated a restricted number of synergies for function, with limitations in isolated control. He moved in full patterns of flexion and extension or if his head was positioned more asymmetrically—one side of his body in full flexion and the contralateral side in extension.

His overall dynamic stiffness varied from being low to very high. The changes were based on intrinsic changes in physiological status as well as from changes in the environment. He demonstrated very low levels of stiffness and was more flail when his oxygen levels were the lowest. He demonstrated clonus more so in the left LE than in the UEs. At times, however, he could demonstrate clonus throughout both LEs, both UEs, and even at the jaw.

Brandon had multiple medical interventions that addressed his neuromuscular system with eight sets of Botox (Allergan) or phenol injections to the hamstrings, adductors, and gastrocnemius, as well as to the pectorals, sternocleidomastoid, and latissimus dorsi. He had a baclofen pump trial but did not have a pump inserted, so he took oral baclofen daily. His seizure medications included phenobarbital, Trileptal (Novartis), Keppra (UCB), and Diastat (Valeant Pharmaceuticals North America) as needed for uncontrolled seizures. These medications also influenced his neuromuscular status.

Musculoskeletal System

Skeletal deformities include leg length discrepancy with the left ~1 in shorter than the right. The legs also demonstrated asymmetry in circumferences, with the left calf being a quarter inch bigger than the right and the left thigh being 2 in smaller than the right. As mentioned previously, he developed a scoliosis that was surgically stabilized. He had right hip dysplasia with surgical correction. He had severe forefoot varus on the left. He had severe osteopoenia with a fracture of his left distal femur with titanium rod implantation and later removal. He had marked limitations in range of motion (ROM) in both the UEs and the LEs and had significant weakness in all four limbs.

Integumentary System

His skin overall was fine and fragile. This fragility was true particularly in his hands and feet and was perhaps related to impaired distal circulation. His compromised skin integrity made it more difficult to wear orthoses successfully and required ongoing modifications of fit and careful monitoring within the day and across time.

Brandon developed fascial restrictions after surgical procedures that influenced his ROM. The most notable restrictions were near his left knee after the femoral fracture repair and at his right hip after the osteotomy. He also had allergic reactions to medications that resulted in severe rashes. He used a ketoconazole shampoo, an antifungal medication used twice per week for chronic irritations in his scalp.

Gastrointestinal System

Brandon had severe GERD with subsequent G-tube placement and a Nissan procedure within the first months of life. Even after the Nissan procedure, vomiting of meals was common. Brandon had difficulties with drooling and with constipation that were related to intrinsic impairments as well as being associated with his medications for other body system issues. His medications for his GI system included Reglan (Baxter Pharmaceutical), Robinul (Caspar Pharmaceuticals), MiraLAX (Bayer), Prevacid (Takeda Pharmaceuticals USA, Inc.), and vitamin B complex drops.

Sensory Systems

Although Brandon was reported to have cortical visual impairments, he did see many things in his environment. His ability to focus or track items changed based on his health status. Brandon had good hearing. He loved vestibular input, and his swing was his favorite way to get that input. Brandon loved tactile input, including deep pressure, particularly with cuddling, and he enjoyed moving tactile input.

Contextual Factors—the Family, Health Care System, Schools, Equipment, and Brandon's Health as an Individual

The family preferred country living and being outdoors. Brandon had excellent support of his family. When Brandon was 3 years old, the family moved to another state for better employment for the father, but the family found that they could not find adequate therapy services for Brandon and Blake, so they returned to the previous state to obtain those services.

It was stressful for the family to have two boys with very different special needs. Blake was ambulatory by age 2 but had a diplegia with a marked asymmetry. He had sensory impairments with difficulty attending to tasks and had been identified as being on the autism spectrum. The younger brother also had some health concerns with a cardiac defect that resolved spontaneously.

The parents were the foundation of the family. The stresses on a marriage of having a single child born prematurely and then raising that child with special needs are well documented.[25,26] In this family's case, the stress was multiplied with twins, both with disabilities. In addition, one child had multiple medical crises and the need for ongoing intensive medical care in the home. Brandon's dad managed the roles of being the bread winner, a father, a spouse, and the caregiver for any one of the children at times.

Brandon's mother was the day to day, minute to minute manager for the family. She did all the jobs of every mother, with cooking, cleaning, feeding, dressing, bathing, playing, teaching, as well as driving to two different schools, to therapies, to medical appointments; coordinating the array of professionals who provided care for the boys; loading and unloading equipment; using adaptive equipment; monitoring that equipment; and then making suggestions as to how it could work better for her child. She even stayed in the hospital during Brandon's stays. Brandon's mother responded to the challenges and stresses by educating herself and completing nursing school.

Brandon's extended family is also strong, with the grandparents supporting the parents during difficult hospitalizations as well as in good or healthy times to allow some respite. The family lived in a town with a major children's medical center with the availability of most of the medical specialists required for Brandon's care. Brandon's family had good insurance through the father's work. Brandon's case manager through the insurance company worked well with the health care providers and streamlined the process for prior authorizations for his care as outlined in the family's policy. In addition, Brandon qualified for Medicaid in the state as a secondary form of insurance.

Brandon's family and health care team obtained necessary medical and adaptive equipment. The following is a list of equipment Brandon used in October 2009:

- Adjustable protective bed.
- Adapted car seat.
- Adapted toilet seat.
- Adapted vestibular swing.
- Bath bench.
- Bilateral solid AFOs.
- Continuous positive airway pressure (CPAP) machine.
- Chest physical therapy.
- Feeding pump.
- Knee immobilizers.
- Monitor for SaO_2 and heart rate.
- Nebulizer.
- Oxygen concentrator.
- Positioning activity chair.
- Standing, Walking, and Sitting Hip Orthosis (SWASH).
- Supine stander.
- Thoracic-lumbar-sacral orthosis (TLSO)
- Wheelchair.

Brandon's medications are summarized in Table B8.2.

Table B8.2 Summary of medications from October 2009

Medication	Dose	Schedule
Phenobarbital	20 mg/5mL	5 mL twice a day
Baclofen	10 mg tablet	One tablet 3 times/d
Reglan (Baxter Pharmaceutical)	5 mg/5 mL	4 mL 4 times/d
Trileptal (Novartis)	300 mg/5mL	7.5 mL every morning and 8 mL every evening
Keppra (UCB)	100 mg/1mL	6 mL twice a day
Singulair (Merck Sharp & Dohme Corp.)	5 mg tablet	1 tablet daily
MiraLAX (Bayer)		1 capful every other day (MWF)
Robinul (Caspar Pharmaceuticals)	1 mg tablet	1 tablet 3 times/d
Nasonex (Merck Sharp & Dohme Corp.)		2 puffs each nare twice a day
Melatonin	1 mg tablet	1–2 tablets hours of sleep as needed
Prevacid (Takeda Pharmaceuticals USA, Inc.)	30 mg solutab	Once daily
Pulmicort (AstraZeneca)	0.5 mg/2 mL	2.5 mL 3 times/d via jet nebulizer
Albuterol	2.5 mg/3 mL	3 mL 4 times/d via jet nebulizer
Atrovent (Boehringer Ingelheim)	5 mg/2.5 mL	5 mL 3 times/d via jet nebulizer
Clarinex (Merck Sharp & Dohme Corp.)	5 mg/2 mL	5 mL daily
Diastat (Valeant Pharmaceutials North America)	5 mg	As needed
Ciprodex (Alcon)		4 drops in affected ear twice a day as needed
Cortef (Pfizer)	5 mg tablet	1 tablet every morning and ½ tablet every evening and stress dose 3 tablets every 8 h as needed for fever/vomiting
Synthroid (AbbVie)	125 µg tablet	½ tablet daily
Ketoconazole shampoo	2%	Use 2 times/wk
Vitamin B complex drops		1 mL daily
Tobramycin	40 mg/mL vial	Give 80 mg by inhalation twice a day for 30 days, then 30 days off
Septra (Pfizer, Inc.)		15 mL every day
Nutrition	6 oz PediaSure (Abbott) with fiber flushed with 15 mL of water	Give 4 times/d in 4 h intervals during daytime only

B8.4.3 Evaluation Summary

The analysis of the data gathered from annual examinations varied. As Brandon grew, the desired participation and activity outcomes changed. Brandon's parents were critical in selecting outcomes around which intervention focused. Across the years during his annual evaluations, the parents consistently stated that they wanted one focus to be on sitting for a variety of functions as well as wanting him to stand and take assisted steps. There were, however, also time frames in which the family said that they had no idea as to what was possible due to the multitude of medical complications. The therapist educated the family as to what might be important skills to develop for the future and what were potential future complications that could occur based on Brandon's overall status.

As Brandon's health changed, the relative importance of each impairment changed. Initially, the family focused on outcomes that were more developmentally age appropriate. He learned to roll and to inch forward on the floor in a commando-style crawl.

The following is a summary of outcomes from his annual evaluations and the associated intervention objectives related to the highest-priority impairments.

- By age 2 to 3 years, the family wanted him to be able to sit and hoped for some form of ambulation, even if it was with assistance.

  Therefore, the outcomes for the years when Brandon was 2 and 3 years old were that he would be able to do the following:

  - Sit on the floor in either long or tailor sitting consistently for 20 seconds for play at home.
  - Bench sit with elbows propping on a tabletop surface for 45 seconds at a time for educational activities and to watch videos or his brother at play.

    - Be able to perform stand pivot transfers between surfaces of equal heights; that he could hold supported standing for 30 seconds to aid in transfers and in ADLs, such as dressing.
    - Transfer from his wheelchair to other chairs with assistance of an adult to UEs and trunk but not LEs while wearing AFOs.
- By age 4, the outcomes were expanded to include the following abilities:
    - Sit for longer episodes (up to a minute at a time).
    - Transfer with assist of an adult to only the pelvis.
    - Stand with support of a surface while engaging in UE play.
    - Take 50 steps with assistance of an anterior support walker with support of the therapist at the pelvis.
- By age 5, the outcomes were that Brandon would be able to do the following:
    - Sit without support for 3-plus minutes at a time to watch a video or listen to a song.
    - Walk 10 feet in a PBWB system, advancing the limbs independently but with the adult controlling the speed and directionality of the movement of the device.
    - Transfer between chairs of uneven heights.
    - Roll independently to cross a room for play.
- For the first time, when Brandon was 8 years old, the functional outcomes began to include qualifiers concerning SaO_2. However, they kept a focus on skills in transferring, sitting, rolling, and assisted walking. They included Brandon being able to do the following:
    - Transfer through stand pivot with assist of adult.
    - Take five assisted steps in suspension-style walker.
    - Reposition himself in prone, side lying, or supine to improve respiratory pattern, SaO_2, or comfort level.
    - Participate at home or at school in at least six different positions.
- By age 9, the outcomes included being able to do the following:
    - Sit on a bench with support of a small table to his arms for 10 minutes with supervision for play with a family member.
    - Stand in stander for 30-minute episodes to complete a single educational activity.
    - Take 10 assisted steps in a PBWB device with SaO_2 remaining above 90%.

In order for Brandon to reach these outcomes, impairment related objectives were identified during each evaluation. Initially (age 2–3), the highest-priority objectives included that Brandon would need increased ROM in the LEs, increased dissociation between the trunk/pelvis/LEs, and increased dissociation between and within the LEs. It was also noted that Brandon would need more active rotation in the trunk and neck and would need increased strength and control in the LEs to meet the established outcomes.

When Brandon was 4 years old, the list of objectives expanded to include more consistent recruitment of the postural muscles of the trunk and neck with the continued emphasis on increasing isolated control in the trunk and extremities and on increasing soft tissue length and strength of the muscles.

By age 5 years, the impairment-related objectives included increasing postural holding through the head and trunk, increasing isolated control between trunk and extremities, increasing ability to perform lateral weight shifts through the lower body, increasing strength through all extremities and the trunk, increasing soft tissue mobility, and increasing symmetry.

At age 8 and 9 years, the plan of care also included mention of increased chest expansion during respiration, an increase in body symmetry, and increased respiratory support for gross motor function.

It is possible to track the therapist's problem-solving process relating impairments to activity limitations and subsequently to the individual's participation restrictions. The evaluation of Brandon not only outlines the relationships between the different domains but also lays the foundation of the individualized intervention plan.

B8.4.4 Intervention

The intervention process with Brandon across the years was modified to meet his ongoing changes in medical status. The therapist used the NDT problem-solving process and Practice Model at every step of the intervention course. As reported in the literature, the participation of a child with severe involvement is heavily influenced by the child's gross motor functional abilities as well as the child's preferences.[15,16,17,18,19,20,21] For this report, two specific aspects of intervention across the years will be presented. The first is related to sitting with support for functional activities and participation, and the second focuses on working in supported standing again for increased activity and participation. Both examples include a review of problem solving related to the selection of adaptive equipment for use in the home and community as well as the specific intervention strategies that were used to address impairments within functional contexts.

Supported Sitting

The ability to sit independently or with support has been identified as a critical component for success in a wide variety of functional activities as well as increasing the participation of the individuals.[16,17,18,19,20,21,22] For Brandon, sitting was important for many activities and participation. Brandon had episodes when he could sit independently for minutes at a time for play or interaction with others. However, he more often sat with support for activities and participation at home for family activities, such as for meals, birthday parties, play, and recreation, and for many of his medical treatments, as well as for loving and cuddling (see photos on Thieme MediaCenter). As expected, Brandon's respiratory status was better in upright positioning, such as sitting, than in supine.[27,28,29,30] Thus he frequently slept in supported sitting. He also needed to be in a more upright posture during meals and for at least an hour after his meals due to his reflux.

As he grew, gained weight, and was too big to be carried places, he was transported in sitting in a wheelchair. He had to be able to sit to ride in the family vehicle for trips to school (when he was able to attend), to his medical appointments, to therapy sessions, to participate in family errands such as taking his brothers to and from school, and for long rides for vacations or to visit his grandparents. He sat to participate in family activities, such as video night, to play with his dad on vacation in the surf, and to swing outside in an adaptive swing. He sat in his parents' laps to be cuddled and hugged and for play.

His adapted activity chair was such a part of family life that 2 years after his death, it still remains in the family room and is used by his siblings for the same activities for which Brandon used it. He sat at school for learning. Initially for school, he needed to be able to sit safely on a school bus as well as in chairs within the school setting.

From this long list, it is clear that supported sitting was important for Brandon. One of the challenges for the therapist was then to determine what made it so difficult for Brandon to achieve this skill. What were the impairments that contributed to the difficulties? What recommendations could be made concerning the selection and use of adaptive seating to improve function and participation? What could the therapist do to address the impairments in terms of hands-on intervention and suggestions for home management or carryover?

Brandon's adaptive equipment related specifically to sitting for participation or activity and included a wheelchair, car seat, bath seat, swing, and activity chair. His wheelchairs were custom designed to increase participation and activity and to both address current impairments and minimize chances for future secondary impairments. As Brandon grew and new chairs were required, the decision-making process changed. Decisions were based on what had worked well in the previous chair, what progress had been achieved, what had not worked well, and what new challenges were being encountered. The team involved in the problem solving included the parents and grandparents, the seating specialist from the durable medical equipment supplier, the physical and occupational therapist, the physician, and the case manager. Each chair ordered required a careful assessment and teamwork to make the best choice. The wheelchair selected had a bright orange frame—Brandon's favorite color and one of the parents' school colors. The family had lots of Auburn accessories, including blankets, jackets, and pillows, matching the chair and encouraging interactions with a variety of people in the community. This strategy served to increase Brandon's inclusion in conversations in many settings. Brandon was naturally handsome, but these additions made him more approachable for people who did not know how to approach or talk with a child who is severely involved and in a wheelchair.

Table B8.3 contains the list and rationale for the customized components in Brandon's chair.

Table B8.3 Brandon's wheelchair with rationale for each component

Chair component	Rationale
Tilt-in-space	A tilt-in-space chair was selected to aid in positioning throughout the day.
	Impairment-related decisions:
	• The tilt mechanism was necessary due to the respiratory and digestive impairments and his seizure disorder. Brandon's SaO_2 dropped during and after seizure activity. He demonstrated postictal lethargy for several hours and needed to be reclined for sleep.
	• He frequently had better SaO_2 when upright and also avoided problems secondary to severe reflux when more upright.
	• When positioned well in the chair, Brandon did not have the ability to relieve pressure, and the tilt provided options to avoid skin breakdown.
	• The tilt also reduced the postural demands of sitting.
	Participation-related decisions:
	• Brandon could sit upright for short times, but his appointments and trips into the community often exceeded his endurance. The tilt option allowed longer outings.
	• The tilt range was also shifted such that the chair could tilt forward by 10–15° to assist in transferring in and out of the chair. The option allowed a wider variety of caregivers strategies to better position his body in the chair and to assist Brandon in standing transfers.
	• This modification allowed him to tilt forward or backward sufficiently to relieve pressure and to assist in ADLs, such as dressing while in the chair.

(continued)

Chair component	Rationale
Seat cushion and back	• The seat cushion included special foam to allow padding and yet be firm enough for positioning of his LEs.
	• Brandon's legs were asymmetrical in length and in positioning. The seat cushion was shorter on the left than the right.
	• The cushion had troughs to help keep the limbs in more neutral abduction/adduction and toward neutral rotation.
	• The cushion prevented asymmetrical abnormal pressure over the ischial seats and across the area of the greater trochanters that were more prominent after the osteotomies.
	• Due to the severe osteopenia, the legs needed to be padded to prevent bumps during transport.
	• The seat back was a slightly rounded back to help position the trunk in midline over the pelvis. Once the spine had been stabilized, he did not require a molded cushion back as he did not demonstrate marked rotational deformity related to the scoliosis.
Lateral pads	• Even after his spinal stabilization, Brandon required bilateral trunk pads to position the upper body over the pelvis.
	• The pelvis could be positioned almost in midline, but there was a tendency for Brandon to lean to the side and to laterally flex the neck to his right with the head flexed forward toward the chest.
	• The lateral pads helped to keep the thoracic spine near midline and therefore to keep the head more in midline.
Pelvic stabilizer	• The pelvic stabilizer (seat belt) was modified to meet his specific needs. A wide neoprene strap that was the width of his femurs was selected. This style belt instead of a narrower car seat style belt spread any pressure exerted on the femurs out across more area.
	• It also increased the sensory input to the femurs against the seat cushion as being the base of support rather than having Brandon pull into greater thoracic flexion to provide a sense of stability.
	• All the stabilizing straps had to be quick release as Brandon had seizures that interfered with respirations, and it was important that he be able to be lifted from the chair quickly.
Dynamic harness	Brandon typically pulled his upper body into full flexion when positioned in sitting. Part of this tendency was due to the difficulty the Brandon had in isolating motion from one body part to another. When Brandon flexed at the hips and knees and ankles, as happens in sitting, his trunk also pulled into flexion with the rectus abdominis and pectorals pulling him forward. With the positioning in the chair, Brandon required increased input to hold the upper body into greater extension. A wider harness that crossed the shoulders to assist in positioning the scapulae in slight adduction and to gain some depression of the shoulder girdle was used. A wide variety of harnesses were tried as is seen by watching his chairs across the years.
Collar	The positioning of the trunk via the seat cushion and back, scoliosis pads, pelvic stabilizer, harness, and the head support were not sufficient to keep Brandon's head from pulling forward, down, and laterally such that it could be trapped to the side of the support. A collar assisted more directly to depress the shoulders and keep the top of the spine against the seat back. The neck could also be held more in midline and decrease the increasing impact of the spinal asymmetry and the pelvic girdle.
Head support	Brandon had tried more head supports than any other component of the chair. None of them worked entirely well. Brandon moved his head forward into flexion and then laterally flexed it to the side and would also extend the neck asymmetrically from this posture.
Chin roll	A chin roll was added for a period of ~18 months. This roll was used to block the pull of the head into forward flexion and subsequent lateral flexion and asymmetrical extension or chin jutting. The asymmetrical posture was particularly problematic when he was riding in the car because the extreme positioning prevented easy breathing. His mother had to stop the car to reposition Brandon at times. He would stay in the corrected position only for moments. We began using the roll only as a training device with a caregiver sitting and watching to be sure it did not block his breathing. His pulmonologist approved the modification. However, it became possible for him to sit for long times without ever pulling his head forward, down, and to the side. Finally, the last chair did not require the chin roll because Brandon sat erect with his head in midline. It was thought that this worked by gradually changing the set point for the muscle spindles of the neck extensors and increasing activation of the postural extensors (refer to Chapter 4 on a posture and movement model), and that it changed the perception of the visual horizon.

Abbreviations: ADLs, activities of daily living; SaO_2, oxygen saturation.

Brandon's wheelchair was an important contextual factor in his life. However, selecting it and monitoring it for fit and function were only small parts of the intervention plan. The therapist had to intervene to prepare and assist Brandon to learn how to sit in the chair, to develop the functional skills that could occur while he was in the chair, and to instruct the family in how to capitalize on possibilities the chair afforded to address Brandon's impairments and to maximize his participation. After establishing the session outcomes, the therapist needed to be mindful of the impairments identified in his evaluation that interfered with functional sitting in the chair. Once these were known, the therapist could select intervention strategies that would best address each impairment.

Summary of Impairments Preventing Activity or Participation Related to Supported Sitting

Multisystem Impairments

- Decreased postural control of head, neck and trunk.
- asymmetry LEs > UEs; atypical alignment of the hips.
- Poor sitting balance.
- Slow and limited limb movement—predominantly to midrange movement.

The options for specific standardized testing of the multisystem impairments are still somewhat limited. However, clinical measures for postural control are being developed.[31,32,33] In addition, the literature is beginning to explore the effectiveness of adaptive seating on posture and control in children with CP.[34]

Single-System Impairments

Skeletal

These bony deformities contributed to asymmetrical weight bearing through the pelvis and therefore poor alignment.

- Scoliosis with surgical stabilization.
- Hip dysplasia; status post–derotation osteotomy.
- Osteopenia with fracture of left distal femur repaired with titanium rod.
- Leg length discrepancy with left leg ~1 in shorter than right.

Muscular/Soft Tissue

- Shortened cervical muscles, right more than left, and extensors more than flexors.
- Shortened hip musculature—flexors, extensors, and hamstrings and shortened gastrocnemius–soleus groups.
- Decreased strength of all muscles with all muscles below the Fair grade.

Integumentary

These range limitations make it more difficult to move the pelvis over the femurs for dynamic control in sitting and contribute to poor trunk and head control. He did not have significant issues surrounding the spinal stabilization.

- Fascial restrictions that limited movement following each surgery with restrictions
  - Near incision sites from the osteotomy.
  - Near left knee near fracture site.
  - Throughout the abdomen related to GI surgeries and his shunt placement and revisions.

Neuromuscular

- Decreased recruitment of postural motor units.
- Muscle activation with isometric or concentric work most often and with extremely limited eccentric control.
- Limited repertoire of movement synergies with limited movement in frontal plane and extremely limited movements in transverse plane.
- Decreased isolated recruitment within limbs.
- Hyperstiffness of all four limbs.

Sensory

- Diagnosed with cortical visual impairments.
- Decreased somatosensory awareness of the lower body.

Specific Physical Therapy Intervention to Meet Outcomes Related to Participation in Supported Sitting

A pretest was performed in each session that focused on a sitting activity. In addition to having an activity pretest, Brandon required a medical status pretest to establish boundaries for the day. Brandon's mother and, with time, his home health nurses, were excellent at providing information on his status that could set the stage for a good day or a not-so-good day. As is common in children with severe involvement, many of Brandon's activities were borderline skills. Even a slight decrease in his medical status could result in major changes in his functional abilities. For Brandon, monitoring his respiratory status and his regulatory status had to be an ongoing process. However, in many ways, it was made easier by the constant use of a pulse oximeter with an alarm that triggered at an established basement level. Brandon's overall affect was also a clear expression of his O_2 level. When he was not getting adequate oxygenation, Brandon became lethargic, even if his monitor had not registered the critically low oxygenation level. However, Brandon usually came to therapy ready to move, to work, and to try new tasks. If he did not have that attitude, he did not feel well.

The first step in each session was to transition out of the wheelchair. Even when the activity outcome involved sitting in his wheelchair, the first therapeutic activity done after the pretest was to transition him out of the chair. The only way to facilitate Brandon to sit more functionally in the chair was to transfer him out of the chair and begin to address the impairments that were interfering with the outcome achievement.

The preparation aspects of intervention usually began with a focus on the respiratory and regulatory systems. The role of the therapist usually was not to treat the respiratory system because he was on numerous medications to address those needs (see medications listed in Table B8.2). There were, however, occasions when a session did include chest physical therapy. The strategies addressed the changes in the proportions of the chest[29] as well as providing direct chest physical therapy.[27,28] These were most often performed with Brandon positioned on a large therapy ball (the surface was forgiving for any of his trunk or limb malalignments) and could be rolled to assist in drainage. Brandon enjoyed the rhythmic clapping on his chest, and at times, this strategy was also used to modify his neuromuscular status by decreasing his overall hyperstiffness. The PT could then gradually reposition the limbs to elongate the overactive or tight muscles of the hips, shoulders, and trunk through weight shifting, tractioning, and adding manual vibration through the length of the limbs. This work also provided an opportunity to introduce elongation of the hamstrings through weight shifting of the pelvis across the LEs. He had greater limitations on the left because it was the leg that had fractured. He had fascial scarring both distally and medially near the knee at the point at which the titanium rod had been inserted and proximally from the varus derotation osteotomy that had been performed. At times, the therapist added myofascial elongation to lengthen those specific regions.

There were many other days when it was not necessary to start with this respiratory intervention and ball strategies. On those days, we were more likely to start the session by jointly addressing the musculoskeletal and neuromuscular impairments with Brandon moving into, out of, and around a variety of sitting postures. When he was in physical therapy, he was moving and transitioning between functional postures. Initial movements or transitions stressed weight shifting in the frontal and transverse planes through and over the pelvis (Fig. B8.2). With assistance, Brandon could transition from a modified prone or supine position through side lying and move up and down toward sitting. A larger ball allowed more support to greater parts of his body. After Brandon's spinal stabilization, most of this motion occurred at the pelvic–femoral (hip) joints and within the shoulder girdle, but there were associated movements of the ribs and soft tissue of the trunk.

For function, Brandon needed to be able to move his pelvis over stabilized femurs. His legs needed slightly more

Fig. B8.2 Brandon working with casts on following orthopaedic surgery. The therapist focuses on facilitating increased head and trunk control and pelvic–femoral (hip) mobility while Brandon plays with his younger brother and mom.

than 90° of hip flexion to be placed in the wheelchair, when he was lifted from the chair, and to make small weight shifts forward to vocalize, to reach for items, toys, caregivers, or his brothers. He needed to be able to relieve pressure from the ischial tuberosities. These weight shifts were important both in and out of the chair. The mobility was facilitated during activities of play, reach, or transitions primarily out of the chair.

When Brandon was positioned in the chair, there were many constraints, such as the seat belt, the harness, and the shape of the cushion that made it difficult for Brandon to achieve active range or control. Brandon's therapist had to support part of the upper body weight and assist in the gradation of the movement, but the therapist was able to gradually move with Brandon into greater hip flexion and into abduction/adduction and into external/internal rotation on each side.

At times, the therapist used myofascial elongation strategies across the hamstrings, especially medially, and more often on the left than the right to increase Brandon's range. His mother was instructed on how to perform this type of soft tissue lengthening and could sit and hold him at home and provide this gentle type of elongation. She could report to the therapist times when his connective tissue was tighter or more elastic. She also could apply similar strategies to assist in opening his hands and to increasing shoulder girdle mobility.

Another of the musculoskeletal issues that influenced his ability to sit was one of hypermobility at the cervical–thoracic junction. Brandon did not have adequate control or strength to hold his head erect—his head would drop or, at times, pull forward toward his chest. With the lack of mobility in his thoracic spine and also a lack of motion in the middle of the cervical spine, all of the motion occurred at the base of the neck in the lower cervical vertebrae. The soft tissue was overstretched on the posterior aspect of this region. Therefore, the caregivers frequently needed to help position Brandon's head appropriately.

Brandon's head position initially was very difficult to manage. When he was seated in chairs with support, he could pull his head forward, down, out, and around any support that was provided on his right. A chin roll placed under his chin to control this pull was eventually used. Direct therapy always addressed this problem. Brandon did not have adequate recruitment of the postural muscles of the neck, particularly for extension. He compensated for this by relying on the asymmetrical use of the more superficial muscles, such as the upper trapezius and scalene muscles.

Isometric contractions of the deep cervical extensors in the shortened range were facilitated during therapy activities so that Brandon could hold his own head erect. The therapist initially had to support the head because he could not hold his head alone. Brandon took over control initially for brief moments and then for gradually longer periods. As reported by Stockmeyer in Chapter 4, postural muscles are recruited bilaterally, thus resulting in a reduction in Brandon's asymmetry. Therefore, activities chosen for Brandon were reaching toward items or, as pictured in Fig. B8.2 with his mom and brother, allowing active movement through the pelvic girdle and UEs while stressing the postural work of the trunk. Using these and similar strategies on a regular basis, Brandon no longer required the chin roll to protect head alignment in his wheelchair or at any time when he was sitting within 18 months. Brandon demonstrated that slow, steady, and persistent pace is a hallmark of intervention for children with more severe impairments and can be effective. Once again, refer to the photos on Thieme MediaCenter of Brandon while wearing his LE casts, but think about the head control issues and then refer to the photo of Brandon and his dad at the beach using a very similar set of key points in very different settings.

Brandon's sensory impairments were also addressed throughout the session. Despite Brandon's diagnosis of cortical visual impairments, he could definitely see some things and enjoyed people and brightly colored items, especially if they were also noisy. As his postural control improved, so did the consistency of his use of vision. He focused on items and tracked slowly moving items. His visual system was used to improve his postural orientation, and at the same time, his improved postural control improved his functional use of vision. He sat better when focusing on something, most often on a face.

Brandon enjoyed vestibular input, such as swinging in a swing or being pushed rapidly through space while in the PBWB device. He seemed to enjoy changes in speed of movement and sat better when moving. (See pictures on Thieme MediaCenter of Brandon on swings at home as well as at therapy and even on horseback prior to his spinal stabilization.)

Brandon was a great cuddler and enjoyed touch, preferring gentle but deep touch. He rested best while snuggled into his mother's arms. All of Brandon's lower extremity surgeries had decreased somatosensory awareness of the lower body, so he relied on other body segments for awareness. It was as if his sense of postural security came from his shoulder girdle and from his visual and auditory system. Intervention strategies that incorporated weight shift over his lower extremities to increase awareness of the base of support through the ischial tuberosities and thighs freed his arms for play, for reach, and as an assist for communication. As a child who had experienced so many invasive and uncomfortable procedures throughout his life, Brandon seemed able to distinguish noxious versus supportive, nurturing, and encouraging touches. Through the touch and handling of his parents and therapists, he could mold his body into the seat cushions of his wheelchair more successfully. He could also adapt to sitting in his swing, or his car seat, his activity chair, or the easy chair with one of his parents. He could, at times, sit on the floor with support of a small table in front of him for play.

Home Programs to Promote Carryover for Functional Sitting

During each session, Brandon's parents were provided recommendations on how to include therapeutic activities throughout his daily routine. Brandon's mother was also able to generate her own ideas of how to incorporate the handling in home life. Brandon's dad could rarely attend sessions, but the picture of them in the surf on Thieme MediaCenter demonstrates his dad using the same strategies to facilitate alignment of the head and neck as the therapist used during PT sessions.

Brandon's mother could best read his signs as to when they should not come to therapy versus when it would be helpful to come for a session. She monitored soft tissue limitations well and communicated concerns to the therapist at the start of a session. She also could see needs for modifications to the wheelchair, activity chair, or swing. Brandon's home program was truly jointly created, an ever-changing entity, and inherently a part of each session.

Supported Standing

It is important to people to be able to be upright and on their own two feet. Brandon's family also had many goals for him that centered on being upright, even if this required support. There were multiple purposes for Brandon being upright in supported standing. First, Brandon liked standing up, and he liked taking steps with assistance. He was motivated by those activities. It was also important to the parents. In preparation for this case report, Brandon's mother was asked to identify the most important pieces of standing equipment that should be reviewed for Brandon. She said that, on a daily basis, the stander was used the most in the home (Fig. B8.3) and that he played more in it, but that without the PBWB device she would never have had the chance to see her son walk.

Fig. B8.3 Brandon standing in his stander at home.

Brandon's therapist also had opinions that influenced the plan of care. The therapist had worked in a residential care facility for adults with developmental disabilities and believed that standing was important to develop the skill of performing standing transfers, allowing his parents or other caregivers to better care for him. Most agencies have requirements for a two-person lift for transfers when a client weighs more than 50 lb. This requirement means that, when extra staff members are not readily available, the individual is more likely to remain in bed, in the wheelchair, or within the facility rather than participating in the community-based activities. Individuals who are more severely involved are often small for their age for many years. It may be easier to lift and carry these individuals than to try to transfer them through standing. However, it may also take a long time to develop the skill to perform a standing transfer. If the therapist waits until the child is heavy enough to require standing transfers for safety or efficiency, it may be too late to teach the skill because it frequently takes a long time to develop the ability to transfer. In addition, there may be too many secondary impairments that emerge and prevent the skill from developing. Therefore, the next segment of the case report describes the long-term outcome of Brandon transferring through supported standing with assist of one caregiver. Two elements of this outcome for the transferring skill will be presented even though there are more prerequisites. The first is the use of supported standing, and the second is taking steps in supported standing as is needed for transfers in more complex environments.

Another purpose for providing supported standing and walking opportunities for Brandon was to intervene with many of his impairments and medical conditions. Brandon had severe osteopenia, or low bone mineral density (BMD). He also had a fragility fracture, which is identified as an increased risk in children with decreased BMD.[35] Factors known to contribute to this disorder are decreased weight bearing, the use of anticonvulsants, poor nutrition (related to G-tubes), and decreased exposure to sunlight.[35,36] Because bones respond to the stresses and strains placed on them with changes in growth,[37] it was important that Brandon have a standing program.[38,39,40] The standing was also observed clinically to improve his GI status with less burping and less severe constipation and to improve his SaO_2. There is increasing evidence of the benefit of PBWB for supported treadmill training on impairments and function for children with CP.[41,42,43]

Adaptive Equipment for Standing and Supported Walking

The adaptive equipment that was tried or recommended at different times for Brandon for supported standing included a vertical stander, a prone stander, a supine stander, a PBWB device, an anterior support walker, and a gait trainer. This case report focuses on the regular use of a stander to address the physiological impairments and also reviews the use of a PBWB device for assisted ambulation and for assistance in transferring.

Brandon regularly stood in a stander at home. He enjoyed standing, and his upper extremities were free for play when he stood. Initially, his standing was performed in a prone stander, but as he developed increasing difficulties with head control, the use of a supine stander became more appropriate. He used standers as a strategy to increase bone mineral density and to increase range of motion into hip extension, knee extension, and dorsiflexion to offset the time he spent in supported sitting with hip and knee flexion. The family noted that his SaO_2 was better and that he had fewer problems with his ongoing constipation when he was positioned in supported standing on a regular basis. As described earlier, the therapist chose to work on the functional skill of standing transfers with a long-term outcome of being able to transfer without being lifted by caregivers. The PBWB system allowed Brandon to sit and stand safely with his hands free and with gradually increasing weight bearing through his feet. The therapist could assist the weight shift by positioning him on a slanted bench in sitting. She could facilitate the transition from sit to stand, and Brandon could then stand with hands free. The PBWB device provided the environmental context that allowed standing with the therapist managing alignment of the trunk and LEs. The PBWB device also provided extra hands to allow the therapist to work on developing the skill of standing transfers. Without the PBWB, the therapist always had to sit behind him to help support his head and trunk. The therapist felt that there was more lift involved when she was behind Brandon compared with if she could be in front, supporting the knees and bringing him forward and upward.

With Brandon in the PBWB device, the therapist could assist with step-taking over the treadmill or across ground. Brandon enjoyed taking steps and worked hard while in the upright posture. On good days he could take many assisted steps in this fashion. His brothers appreciated his abilities with comments such as, "Mom look! Brandon is walking!" The typical protocol for PBWB was not followed. The device was used as an intervention environment, or, if you will, another set of hands for the therapist. Its use provided more possibilities for both Brandon and the therapist.

Specific Physical Therapy Intervention to Meet Outcomes Related to Participation in Supported Standing and Assisted Ambulation

The equipment that assisted Brandon to stand was an important adjunct to his intervention, but it was an adjunct and was not his intervention. Brandon's physical therapy was scheduled for roughly once a week. Brandon's plan of care included outcomes based on supported standing and ambulation throughout his life. Rather than describing his intervention system by system as was done in the section of the text related to sitting, the intervention process related to supported standing will be presented starting at the base of support and progressing upward. The impairments that interfered with standing and ambulation in each body area will be outlined. Then the intervention provided will be reviewed, first describing the direct hands-on strategies included in therapy sessions and summarizing key aspects of the individualized home program recommendations that were given to the family.

Brandon's feet were small for his age and height. In his early years, he clearly demonstrated limitation in range of motion with difficulty achieving neutral dorsiflexion. He initially also had overly sensitive feet. His mother and therapist believed that some of the sensitivity was based on his medical history with a long-term hospitalization as a newborn with frequent sticks to his heels for blood work. The therapist included deep firm pressure to the soles of his feet and introduced weight bearing through bare feet on carpet with the therapist controlling the ankle into neutral dorsiflexion and holding the talus in close to neutral alignment. During therapy, when supported in the PBWB device, he stood with bare feet to allow more input to the feet without having to hold full body weight on his ankles that were weak and often malaligned without the support of his AFOs. In addition, when Brandon was supported in a single-leg-stance posture, the therapist could drag the foot of the swing leg across the surface and facilitate an active step forward. The mother was instructed in rubbing the feet after baths.

Brandon had solid ankle AFOs that he wore when he was wearing shoes. This positioning held his feet in alignment that made standing on his feet possible. By age 8, Brandon's ankles demonstrated decreased range, but his range was around neutral dorsiflexion. His feet, therefore, provided a good base on which to stand when wearing his AFOs. In addition, Brandon had limited range at his knees. He consistently had limitations moving toward knee extension more on the left than the right because that was the leg that had fractured. Brandon developed deep scarring just proximal to the knee. The therapist used myofascial elongation strategies to gain soft tissue length. The mother also learned how to perform this elongation on a regular basis at home. Brandon kept adequate range to move from 90° of knee flexion in sitting to full extension for standing. He had the greatest difficulty with the strength of the quadriceps to move him toward standing and to hold the knee extension for standing. When in the support of the PBWB device, Brandon could stand and isometrically hold his quadriceps bilaterally in the shortened range as is necessary for strengthening the postural muscles. He could also, when barefooted in the device, recruit the gastrocnemius–soleus group as well as the hip extensors.

The therapist could assist him in a stance position with the lower extremities working in phase, in stride with disassociation of the two legs, and in step-stand positions requiring maximal disassociation. In addition to the work on postural control, the therapist also worked on the transfer from bench sitting with support of the PBWB device to standing and from sitting to standing with the anterior support of either the therapist or a large therapy ball. During this time, the emphasis was on moving through the range with more concentric work following the principles for strengthening the movement muscles. In the early years, this was very easy to facilitate, but it became more difficult as he gained weight related to his medications. The therapist assisted with the forward/upward weight shift with support to the pelvis as well as to the upper body. However, it still did not require a lift of his body weight, and with the use of a transfer disk, he could transfer between chairs of similar heights. These therapeutic activities were important in laying the foundation for functional standing transfers at home, at school, or in the community.

Brandon's parents were instructed in activities to do at home, and therefore they also played a role in the long-term management of the soft tissue mobility in the trunk and LEs that influenced transfers. Brandon stood daily in a stander that positioned the knees well into maximal knee extension. He also had knee immobilizers that he wore at night to help manage his tendency to develop tightness in the medial hamstrings. Both his mother and father could perform myofascial strategies and would rub his knees and the scarred area as they held him in their laps for TV and snuggle time. The family also learned how to transfer Brandon from sitting in his wheelchair to supported standing on the foot plates of the chair in preparation for carrying him. This transfer strategy allowed Brandon to practice parts of the transfer daily and did not require a total lift of his body weight by scooping under his somewhat fragile femurs.

Brandon's hips were the focus of many of his impairments. He had bilateral hip dysplasia with a history of an osteotomy. He also had a scoliosis that had led to a pelvic obliquity that complicated the LE positioning in standing. Brandon preferred to keep both hips flexed and demonstrated a slight windswept posture. He also had significant osteopenia, which required that input to the LEs be gentle even when firmly moving toward abduction, external rotation, and hip extension. For standing and transfers, the therapist stressed the movement of the pelvis over more stable femurs. When working in sitting, Brandon was encouraged to reach for items away from his base of support that required movement of the hips into greater flexion and relative abduction/adduction as well as external rotation. In supported standing in the PBWB device, Brandon could take steps with the assistance of the therapist, who could facilitate the movement of the pelvis over a stable LE. This movement could happen across the ground, but even more repetitions were possible when the PBWB was positioned over the treadmill. The therapist used the treadmill to assist the support leg to move into greater extension while she could assist from the weight-bearing knee for alignment and the swing leg to prepare the foot for heel strike.

Brandon's trunk and head control was better in supported standing. In this position, he did not have to work as hard to hold his head up against gravity compared with sitting. While he still had a tendency to be asymmetrical with his head position, he tended to be more alert in upright and demonstrated better head control. He did well when the therapist could engage his vision and performed best when a family member was the moving target that he tracked.

Brandon could also demonstrate better control of lateral weight shifting and could free his arms for play in supported standing. The supported work also provided opportunities for respiratory exercise, with the therapist having the ability to increase mobility of the ribs for either bucket handle or pump handle movement during respirations. He tended to be more vocal, which also increased the depth of his breaths.

B8.5 Results and Discussion

If the value of physical therapy intervention is based on the number of checkmarks on a standardized test or how quickly impairments on the list are remediated, then it could be argued that Brandon's intervention was not valuable. Brandon died on August 4, 2010 (Fig. B8.4). He experienced all of the sequelae associated with individuals with his long list of diseases, disorders, and impairments.

If, however, one determines the value of intervention by evaluating the quality of life or by determining how well the person met individualized goals and the self-determined purpose of his life no matter what those goals may be, then a very different assessment can be reached. Brandon's parents made a choice when he was a young baby to support his life within their family. The family learned across time what that decision would mean. Brandon's parents believed that his purpose in life and his gifts were to love and be loved. The literature now clearly supports that therapists are to address the individual's and family's goals with a focus on participation and activity. Brandon was a full participant in his nuclear and extended family's life. He participated in the community in a group of educators and rehabilitation workers and had friendships with those adults. He was a happy, hardworking individual. He shared his gift of love abundantly with those in his life.

In terms of functional activity gains, he was able to sit in his chair, in a swing, on a sofa, in his bed, and in an adult's lap. He could transfer from his wheelchair to another chair with his feet on a transfer disk on a small bench. He moved to supported standing from his chair to be picked up by an adult. He could share his opinions on daily activities. He could let you know many of his basic wants and needs through facial expressions and vocalizations.

Brandon's case report is also an avenue to review all of the philosophical tenets of NDT that were presented in the first chapter of this text. The therapist clearly approached Brandon as a whole. The outcomes were focused on improving his participation and activity. Brandon's therapist built on his individual strengths while addressing his restrictions, limitations, and impairments. She was always simultaneously mindful of Brandon's past, present, and future. Teamwork was critical throughout Brandon's life. The therapist acknowledged the influences of typical development in designing his intervention. The therapist and parents worked together to insure active carryover through home programming. There was clearly a hands-on approach to his intervention. Therefore, Brandon's case report demonstrates how NDT was put into action with one individual who was severely involved and medically fragile.

B8.6 Conclusions

Children who are severely involved often have many complex and interactive diseases, disorders, and impairments. Problem solving of a skilled clinician is required to organize intervention to provide the best possible care. Therapists can be better prepared to anticipate and address the needs of this growing population of individuals. The ICF-CY model is an extremely valuable tool to assist the therapist to organize the examination, evaluation, plan of care, and intervention process. The application of this model is demonstrated throughout Brandon's case.

Another related observation is that, during Brandon's life, there were no standardized tests that could adequately measure and document changes in each domain of the ICF for children with severe disabilities. Of particular note is a paucity of tests focusing on participation or the activity domains. Certainly, better tests that are more sensitive to changes in the participation and activities in individuals who are more severely involved are needed.

The health field is now being faced with a growing population of children who are surviving extreme prematurity and who overcome multiple medical crises. At this time, the service delivery is usually segmented by age, with intervention offered by a series of therapists. Brandon could have had physical therapy, occupational therapy, and speech-language pathology services provided through early intervention, by separate teams during his preschool versus elementary years at school, at an outpatient clinic, and perhaps at the hospital during those periods. Brandon did need therapists in his different settings; however, in his case, it is suggested that the age-based intervention be reconsidered. Brandon had a complex list

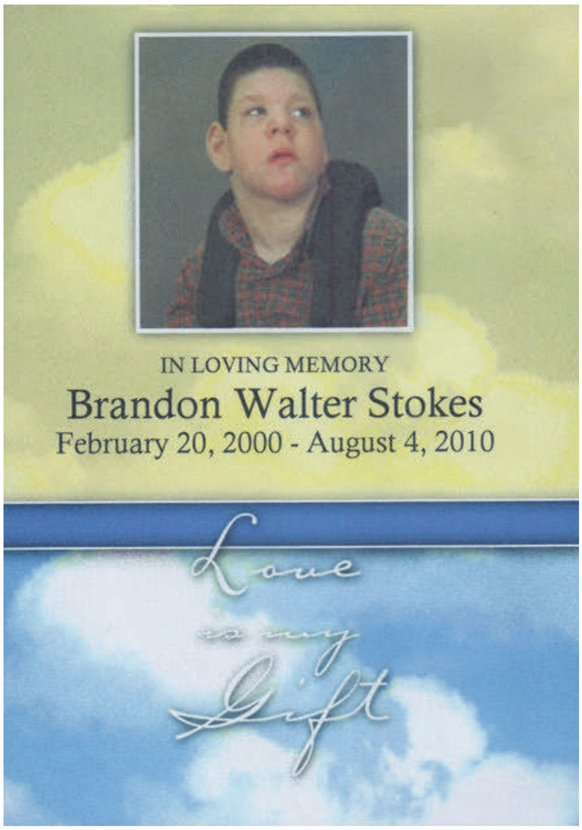

Fig. B8.4 A celebration of Brandon's life.

of strengths and impairments with a very specific list of desired parental goals. PTs may need to consider the option of developing a specialist for serving individuals who are severely involved. Brandon did have many medical specialists outside of his primary health care physician (pediatric neurologist, pulmonologist, orthopedist, gastroenterologist, etc.). These specialists offered specialized and focused care, but had Brandon lived past 21 years of age, he would have had to change those specialists as well as frequently change therapy teams. It seems advantageous for families to have the option of working with a specialist across the life span to serve the individual and family and to consult with other therapists who may be less familiar with the specific needs of individuals with severe involvement. Families would not then be repetitively faced with trying to find a therapist who has the skills and desire to serve their child.

Therapists interested in individuals with severe involvement who practice from an NDT framework have the knowledge base, the ongoing evaluation and problem-solving skills, and the handling skills to serve as such a specialist and therefore can offer these clients a greater opportunity for participation and meaningful activity.

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Case Report B9 Examining Neuro-Developmental Treatment with Increased Intensity for a Child with Spastic Quadriplegic Cerebral Palsy and Dystonia

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B9.1 Introduction

Therapists are often plagued with the following questions, How much intensity best meets a particular patient's and family's needs? Does a different intensity from the traditional once weekly intervention make a difference in a client's everyday functioning? This case report examines a young boy whose significant medical history and multiple medical needs require daily nursing intervention. In addition, this case report explores how daily intensive Neuro-Developmental Treatment (NDT) provided by a team consisting of occupational, physical, and speech therapists positively influenced a child and his family. Documented changes in the child's functional outcomes in family-identified areas of greatest priority are outlined as well.

Exploring different interventions of varying intensities and their effectiveness continues to be a focus and need of pediatric therapy research. Pediatric therapists—occupational therapists (OTs), physical therapists (PTs), and speech-language pathologists (SLPs)—in North America are often educated in NDT and use the NDT Practice Model with children having neuromotor difficulties.[1,2] The theoretical framework surrounding NDT aligns with the World Health Organization's (WHO's) International Classification of Functioning, Disability and Health.[3] The dynamic systems theory (DST), neuronal group selection theory (NGST), and principles of motor learning and control all contribute to NDT Practice Theory.[4]

Intervention using NDT can be provided at varying intensities. In many settings, therapy in the United States is often provided at a weekly frequency for up to 1 hour in duration, often limited by insurance and other health care benefits.[5] In the research on intervention, ***intensive treatment*** may refer to many different delivery methods of intervention.[6] ***Intensive treatment*** can relate to specific interventions (direct, consultative, or adjunctive therapy), frequency of intervention sessions (ranging from one time a month to more frequently), or specific length of time of a session or length of time of therapy. In the information specifically on cerebral palsy, the optimal intervention frequency has not been definitively documented in the research.[7]

The importance of evidence-based research guiding clinicians' decisions in physical therapy is known.[8,9,10] Integrating the best published research evidence, using clinical expertise and patient values, is the essence of evidenced-based practice.[11] Optimal intervention intensity for the best functional results with quality research is what caregivers, clinicians, health care providers, including third party payers, and even clients themselves are interested in reviewing. A review of research examining the use of NDT is provided here, with specific analysis of NDT research with increased intensity in recent years.

B9.2 Research on Neuro-Developmental Treatment with Increased Intensity

In the past 20 years, many studies have included some aspect of NDT intervention. A few studies have examined using NDT with an increased intervention intensity surrounding NDT certificate courses (Arndt et al[12] during a baby course, and Slusarski,[13] Knox and Evans,[14] and Herndon et al[15] during pediatric NDT/Bobath certificate courses). Three of these four studies had positive findings.[12,13,14] Since 1991, five studies by researchers—Mayo,[16] Tsorlakis et al,[17] 2 studies by Trahan and Malouin[18,19] and Bierman[20]—used NDT as the type of handling intervention while specifically researching intervention intensity. These five studies are reviewed in Table B9.1.

Increased interest by therapists and caregivers about optimal therapy frequency continues. Due to the limited but supportive findings for NDT at an intensive level, more research is required on intervention with increased intensity. This case report explores the effects of NDT using a collaborative team of OTs, PTs, and SLPs with an increased intervention intensity of 4 hours per day for a duration of 2 weeks with a 6-year-old boy with spastic quadriplegia with dystonia cerebral palsy (CP). The unique nature of this intensive program involving extensive team collaboration had added benefits to the client. The team collaboration provided the opportunity for outcomes to be reinforced in different contexts and more easily incorporated into his daily routine.

B9.3 Case Description

Sam is a 6-year-old boy with the diagnoses of spastic quadriplegia CP with greater involvement on the left side, dystonia, periventricular leukomalacia (PVL), seizure disorder, gastroesophageal reflux (GER), and hypothyroidism. He is the youngest of three children (with an older brother and sister) and has a loving and active family. He enjoys music and singing. Books are one of his favorite hobbies. He is a happy child who is quick to smile, and he squeals with delight and happiness, which can be felt and seen throughout his entire body. Sam also enjoys playing with peers and likes outside play, including swinging, riding a bike, and going down playground slides. He has attended

Table B9.1 Significant research examining Neuro-Developmental Treatment with increased intervention intensity

Researcher	Mayo[16]	Tsorlakis[17]	Trahan and Malouin[19]	Trahan and Malouin[18]	Bierman[20]
No. of subjects	29	34	50	5 (more severe involvement)	1
Ages	4–18 months	3–14 years	12–79 months	10–37 months	5 ½ years
Frequency	Weekly NDT vs. basic program with monthly revisions	2×/wk vs. 5×/wk NDT	2×/wk NDT	4×/wk NDT for 4 wk then off 8 wk	PT 3–4 h/wk OT and SLP 1 h, 3–4×/wk Aquatics 4–6 h/wk
Duration	6 months	16 weeks	8 months	6 months	5 months
Results	Weekly NDT made statistically significant changes	5×/wk made > changes, but both NDT groups had statistically significant changes	Statistically significant changes	4×/wk NDT with a break showed increased motor skills and retention	Improved motor level from V to III on the GMFCS

Abbreviations: GMFCS, Gross Motor Function Classification System; NDT, Neuro-Developmental Treatment;

NDT intensive programs held in the past and was treated by all three disciplines during this program. He attended the intensive program for the first time for a 2-week period last year, and he previously attended the weekly intensive sessions to address client and family needs.

The NDT intensive program offers daily intervention with OT/PT/SLP, depending on the client's needs identified by the family. The client participates in 2 hours of intervention in the morning, an hour break for lunch, and then more intervention for 2 hours in the afternoon. In this case report, Sam participated in both the morning and the afternoon sessions. In addition, the intervention is offered for 1- or 2-week sessions based on the client's needs, and our client participated in the 2-week program. The intensive program Sam attended this year continued to have collaboration among physical, occupational, and speech therapies. He participated in two daily, 2-hour sessions with a total of 4 hours of therapy for 2 consecutive weeks (with weekends off). He was out of town for 1 day the first week due to a family function.

Family concerns and goals for the 2 weeks of the intensive included "using a cane or other device less restrictive than a walker" for his walking, working on using his augmentative communication device, especially focusing on how it can be used in the classroom, using name stamping in the classroom, and increasing left-hand use. Please see Fig. B9.1, Fig. B9.2, Fig. B9.3 for the pretest of these goals.

B9.3.1 Relevant Medical History

Sam was born prematurely at 27 weeks' gestation. He weighed 1 lb 10 oz and was 13 in long. He was initially placed on a ventilator and was weaned after 6 days. On day 13, Sam had an air embolus resulting in cardiac arrest and a coding episode 10 minutes in duration. He required ventilation for an additional 14 days. He came home from the hospital after 80 days. He had a hernia surgery before he was released from the hospital.

Sam was bottle fed until 1 year of age when a gastrostomy tube (G-tube) was placed. The G-tube was changed to a gastrostomy–jejunostomy (G-J) tube in March 2007 and is required to be changed every 3 months. Eye surgery was performed at 1 year of age. Reflux medication was initiated at birth in the hospital and continues to be needed at this time.

Sam began to have seizures in October 2006 (almost 3 years old). He continues to have seizures, but they are managed with his current seizure medications. Ear tubes were placed in March 2007. The left pressure equalizer tube has fallen out, but the right tube remains. Hypothyroidism was resolved in January 2010.

Present medications include oral baclofen (tone management), Felbatol (Meda Pharmaceuticals, Inc.), Dilantin (Pfizer, Inc.) (seizures), milk of magnesia (constipation), and Prevacid (Takeda Pharmaceuticals USA, Inc.) (acid reflux). Seizures have significantly decreased over the last year. Break-through seizures have occurred since the first seizure in October 2006 with sickness (croup) and change of routines. Sam had phenol and Botox (Allergan) injections in February 2010 and Botox again in May 2010 to further manage his tone and prevent loss of range and skills. Botox injection sites include left biceps, hip adductors, bilateral hamstrings, and right gastrocnemius–soleus muscles. He currently receives physical therapy,

Fig. B9.1 On Sam's occupational therapy pretest, he needed hand over hand assistance to successfully grasp the name stamp, align the stamp on the line, and push with adequate pressure to leave his name imprinted clearly on the line.

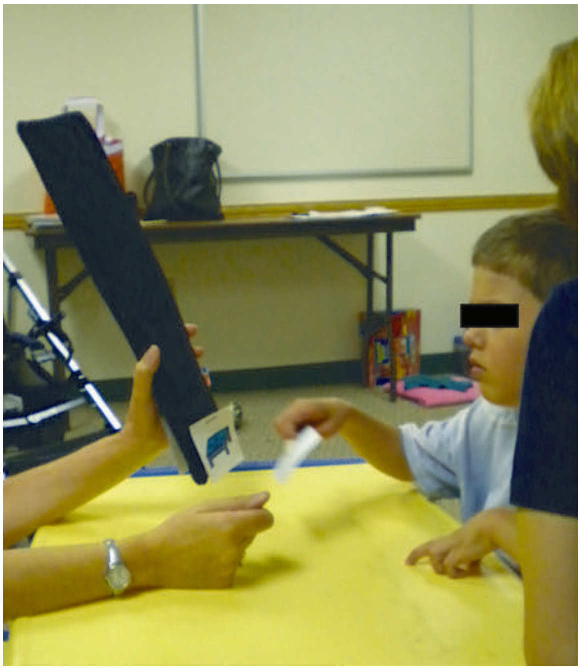

Fig. B9.2 In the speech therapy pretest Sam needed multiple visual and verbal prompts to attend and make the selection. It was difficult to capture in a photo how much visual and verbal prompting Sam needed to attend and make his selection.

Fig. B9.3 The physical therapy pretest picture demonstrates Sam using his quad cane walking with assistance from his mom at his right shoulder and left trunk.

occupational therapy, and speech-language therapy each two times per week for 30 minutes through school to address educational needs and one time per week privately to address more medical-based needs.

Sam functions at the Gross Motor Function Classification System (GMFCS) level IV (able to walk short distances with assistance but needs wheeled mobility in community, and he sits with support of his trunk to maximize hand function).[21] In the last year he has grown over 2 in. He currently has a nurse with him throughout the day and will be getting a specially trained dog for his seizures. When asked why the family continues to participate in an intensive program, the family reported that the program has provided a more thorough understanding of Sam's skill level using collaboration from a multidisciplinary team with good suggestions for future intervention. The basic foundation of NDT encourages therapists to examine the client's needs from a holistic team approach, which may contribute to the family's satisfaction in this intensive program.[4]

B9.3.2 Participation

Sam attends regular kindergarten (started half days and then transitioned to full days Tuesday–Friday and a half day on Monday in January; typically a child his age attends full days Monday–Friday) and enjoys social interactions with three close friends at school. Although Sam did not enjoy assemblies at school initially due to the noise, he now tolerates and participates in these without difficulty. He is now able to go outside in the winter to play on the playground with his classmates and tolerates hats and mittens. He participates in regular physical education (PE) with assistance from his school PT. Sam is playing regular tee-ball while wearing his ankle-foot orthoses (AFOs) and using his walker. He is eating lunch (self-feeding with utensils and finger-feeding a variety of consistencies) in the lunchroom with his peers, and socializing using an augmentative communication device (has 45 cells), which is used throughout the day. He drinks from a hard, insulated cup with a straw spout. He enjoys participating in all family activities, including recently attending a family wedding out of state requiring Sam and his family to travel by airplane. He attends Sunday school at his church regularly.

B9.3.3 Participation Restrictions

Sam started kindergarten in 2010 with a one-on-one aide provided by the school, and full inclusion has been a challenge. His home nurses follow him to school to address his medical needs, which include medications given on a regimented schedule, and they are designated as first responders for medical care. In addition, his nurses provide nutrition and medication throughout his day as prescribed. Despite his complex medical needs, Sam is still able to attend school and be included. He needs assistance for pudding-consistency foods during his lunch time, which limits his ability to engage socially with his peers. He is restricted in participation at recess at school due to decreased independent mobility. He is unable to speak and requires his alternative augmentative communication (AAC) device, except for a few signs (i.e., yes, all done, talker, hi/goodbye, thank-you, blows kisses, shakes head no [inconsistently]). He continues to need diapers for bladder and bowel control, but he is working on independent toilet training and is successful two to four times per day. He attends Sunday school at church with the help of a physical therapy student from a local university. Sam enjoys social interactions with peers, and outings, such as going to the water park. It is difficult for him to communicate in all situations (e.g., at the water park because his AAC device cannot be used there).

B9.3.4 Activity and Activity Limitations

Sam walks with a walker under close supervision. He is able to walk with his mom or the nurse's assistance holding his two hands. He is able to sit on the floor (W-sitting) and bench-sit independently. He is unable to move from the floor to standing without support, and other transitions require assistance. He uses his right hand for functional use with the left hand as a support. He uses his right index finger to access his AAC device. He easily engages his right hand in play and manipulation, such as turning pages in books, grasping and throwing balls, and playing with water toys. He uses his left hand to engage in batting tasks. He needs assistance for bilateral activities that need more precision, such as assistance to open his left hand and maintain left-hand grasp with resistance.

B9.3.5 Body Structure and Function

Sam is most often positioned sitting in his wheelchair or on a bench, or he is supported in standing. Postures requiring postural stability, control, and graded movement are difficult for Sam. Functional rotational components use is limited with rotation seen often with lateral flexion of the trunk on the right side (immature weight shift). Asymmetry is noted with the left upper extremity held close to the body with elbow and wrist flexion. The lower extremities (LEs) are often in a crouched posture with hip and knee flexion, and ankle dorsiflexion (in AFOs). External support is often required with transitions and activities requiring stability.

See Table B9.2 for a summary of single-system body structure and function.

Relationship of Center of Mass and Base of Support

Sam tends to keep a wide base of support (BOS) in sitting on the floor (W-sitting) and a narrower BOS often crossing his LEs in stance with support. When Sam is relaxed, his center of mass (COM) is forward over his BOS (and pelvis posterior). He is unable to actively maintain his COM evenly, with weight bearing often noted asymmetrically shifted to the right side. His COM is maintained at a lower level in stance (crouch gait) over his BOS.

Table B9.2 Body structure and function: single-system evaluation

System	Variable	Distribution	Body Area
Neuromuscular	Timing	Difficulty sustaining postural activation	Gluteal/abdominal and gastrocnemius–soleus
	Timing	Difficulty terminating	Pectoralis, latissimus dorsi, left biceps brachii, left thumb adductors, ulnar deviators, iliopsoas, hamstrings
	Dynamic stiffness	Left > right	BLE and LUE
	Force generation	Insufficient	B gastroc-soleus, B quadriceps, R scapular depressors
	CA/RI relationships	Decreased CA core postural muscles, poor synergistic activity	Serratus anterior, external and internal obliques, gluteals
	Intra-/interlimb dynamics	Limited within and between limbs	Graded midrange of LEs and UEs
	Modulation/scaling	Poor modulating of grip and load forces sequentially	

(continued)

Table B9.2 Body structure and function: single-system evaluation *(continued)*

System	Variable	Distribution	Body Area
	Coordination of postural stability of movement	Difficulty coordinating for dynamic activity and movement	
	Synergies	Restricted variability with limited movement repertoires, effort further decreased variability and speed	Initiated movements with R
	Spasticity	Increased	B hamstrings, B adductors, R gastrocnemius–soleus, L bicep
	Extraneous movement	Overflow movements in hands during UE activities	
	Fractionated/dissociated movement	Decreased	LEs and UEs, especially hands
	Hypokinesia	None	
Musculoskeletal	Range of motion, joint and soft tissue	Limited	Shoulder flexion (100°), B upper trapezius, L > R pectoralis and latissimus, L bicep (elbow extension—45°), brachioradialis, pronator teres, wrist flexors, ulnar deviators, long finger flexors, thumb abductors, LEs: B iliopsoas, adductors, proximal and distal hamstrings (medial > lateral), gastrocnemius–soleus
	Range of motion, joint and soft tissue	Over lengthening	B rhomboids, lower trapezius, quadriceps femoris, midfoot intrinsic muscles, triceps
	Muscle extensibility and functional range	Muscle extensibility decreased	Increased tendinous insertion of hamstrings and gastrocnemius–soleus
	Muscle strength	Weak	Postural muscles throughout, especially deep extensors and core abdominals
	Endurance	Poor	Maintaining sustained postural strength and alignment—overlengthened quadriceps used to sustain erect posture against gravity
	Skeletal abnormalities		Decreased thoracic extension and rib cage mobility, increased lordosis
Somatosensory	Proprioception	Decreased	Trunk, LEs > UEs (especially LEs with ankle-foot orthoses), L > R
	Tactile	Defensiveness	Head, hands, feet—is improving (i.e., able to go outside in winter wearing hat and mittens)
	Vestibular	Enjoys predictable	Swinging, bouncing on ball with varied intensity, jumping
	Sensory processing and modulation	Delayed processing time, stressed with auditory	i.e., multiple verbal commands and noise, seen by his hitting his head with his hand or crying, not able to attend assemblies at school initially, now tolerates/participates in these without difficulty
	Regulatory (arousal, state regulation, emotional regulation and control)	Improved over last year, but continues to be a concern	i.e., more at ease with novel people and environments, ability to play outside with multiple kids and noises
	Vision	20/20 R 20/40 L	Was patched on R eye to strengthen L for 3 years, difficulty sustaining B visual focus and separating eyes from head
	Auditory	B hearing WNL Difficulty modulating	Variable auditory responses—hypersensitive to sudden noises, such as toy dropping on hard surface or other loud noises; hyporesponsive to voices
	Gustatory	Decreased tolerance	Cold (e.g., ice cream)

Abbreviations: B, bilateral; BUE, bilateral lower extremity; CA, coactivation; LEs, lower extremities; LUE, left upper extremity; RI, reciprocal; UEs, upper extremities; WNL, within normal limits.

Alignment

Sam does not distribute his weight evenly when sitting or standing. He tends to keep his head laterally flexed to the right and rotated to the left. Bilateral shoulders are elevated, and his scapulae are anteriorly tipped and abducted. The left upper extremity (UE) is held in humeral extension, internal rotation, abduction, elbow flexion, forearm pronation, ulnar deviation, and wrist flexion. His fingers are often flexed and his thumb is collapsed at the carpometacarpal (CMC) joint. Right UE alignment dynamically changes based on the activity. His trunk is laterally flexed to the right, and pelvic obliquity is noted with the pelvis rotated posteriorly on the right side. The LEs are maintained with bilateral hip flexion, adduction, and internal rotation, knee flexion, and ankle dorsiflexion (although the gastrocnemius–soleus is tight; atypical midfoot mobility is noted). Sam moves asymmetrically using the right side for mobility and the left side for stability (poor static and dynamic postural control and stability). Sam maintains posturing of the left UE with minimal active engagement.

Anticipatory Postural Adjustments and Weight Shift

Sam often does not demonstrate the anticipatory control needed for postural adjustments based on demands external to his body.

Movement Components

He demonstrates movement components biased toward flexion with the influence of gravity, but he initiates movement with trunk extension and limited rotational components. Sagittal plane movements are preferred over frontal plane lateral weight shifts and limited transverse plane rotation.

Muscle Stiffness/Tone

He demonstrates increased stiffness both proximally and distally in the left UE and bilateral LEs with stiffness greater in the UE versus the lower and the left greater than the right in the LEs.

Gait

Limited step and stride length is noted as left greater than right. A crouched gait is often noted while wearing his hinged AFOs. Difficulty is observed maintaining erect posture for independent stance and gait using the gluteal and abdominal muscles simultaneously for postural support. The quadriceps femoris is maintained in an overlengthened position, and terminal knee extension in stance (vastus medialis) is difficult to maintain. Weight bearing is noted with the feet collapsed medially (midfoot) with the heel maintained in a valgus position.

Gastrointestinal

Sam receives milk of magnesia daily to assist with regular bowel movements, and this has significantly reduced his constipation. In addition, he receives high-calorie Ensure (Abbott), which softens stools. Gastroesophageal reflux is controlled with Prevacid taken nightly while sleeping (administered through G-tube). Sam has had retching difficulties in the past, but this has decreased with Prevacid. A G-J tube is used for nutritional and medication needs. The G-tube is used during the day and the J-tube is used only for night medication.

Respiratory

After attending kindergarten with 24 classmates this past winter, he was sick from February to May, which included croup, enlarged tonsils and adenoids (scheduled to be removed in August), and strep throat three times. Deep inhalation is limited.

B9.3.6 Equipment

Supportive positioning stroller, commercial dynamic stander, posterior walker with bilateral forearm troughs (with TheraBand, The Hygenic Corporation, on the left) and lateral trunk support, a quad cane, bilateral hinged AFOs with free dorsiflexion (these are worn all day except when playing on the floor), bilateral resting night splints to increase dorsiflexion, a left bicep elongation cast, a left wrist and thumb splint, knee immobilizers, and an alternative augmentative communication device (AAC) with 45 space cells wrist talker.

B9.3.7 Contextual Factors: Environmental and Personal (Facilitators/Barriers)

Sam is hypersensitive to loud, unexpected noises. Sam is part of an active family, and he has consistently received therapy throughout his life. The family is moving to a new home in a few months with increased wheelchair accessibility.

B9.3.8 Instrumentation/Outcome Measures

Due to the complex medical needs, extensive motor involvement, and the need for collaboration among team members and family, two outcome measures were used. The Goal Attainment Scale (GAS)[22] and the Canadian Occupational Therapy Measure (COPM)[23] were used by all disciplines (physical therapy, occupational therapy, and speech therapy) during the 2-week NDT intensive program (see Instrumentation Using the GAS and COPM later in the chapter). These measures were used to capture the functional changes he would make during this time frame. Most standardized measures on the market at this time are not normed on children with complex medical and motor involvement, do not show minimal or qualitative changes, and do not allow collaborative goal setting. The PTs, OTs and SLPs wrote individualized goals using the GAS after discussing priorities with the family. For this case report, Sam's mom was interested in Sam working on using a less cumbersome walking device, improving his use of his augmentative communication device, and working on stamping his name on papers for school.

B9.3.9 Intervention

The intervention described in this case report used the NDT Practice Model. Intervention was provided by two NDT instructors and two NDT-educated therapists. The protocol for the intervention consisted of a thorough assessment; individualized direct handling with problem solving throughout the session; preparatory activities; core postural muscle activation with attention to alignment, BOS (primary weight-bearing surface), and center of mass; elongation (if needed) followed by activation of muscles; practice; repetition of skills; and team collaboration. An example of a typical therapy session is included in Table B9.3. Guidance (facilitation or inhibition) was provided by direct handling for improving body alignment, weight bearing, weight shifting, midrange control, proximal holding, and variety of movement.

Refer to Thieme MediaCenter to view a photo sequence that accompanies this table. There are additional photos and videos of other intervention sessions with Sam as well.

B9.3.10 Results

Sam completed 9 out of the 10 sessions consisting of 4 hours per day of NDT intervention during the 2-week period. One session was missed due to the family having an out-of-town obligation. The pre- and postintervention GAS goals are charted later in the chapter (see Fig. B9.7).

B9.3.11 Preintervention Goals for Physical, Occupational, and Speech Therapy

Please refer to Summary of GAS Goals for Sam at the end of the chapter.

Table B9.3 Neuro-Developmental Treatment intervention details: one example of a typical intervention session[a]

	Child's starting position	Activities initiated by child	Activities imposed by therapist	Key points of control	Handling inhibition (−) or facilitation (+)	Environmental adaptation or equipment used
Preparation activities	Standing-pushing bilateral hands into large ball	Body weight shift forward and UE pushing	L wrist alignment and elongation	L ulnar border and L thumb web space	−	Large orange therapy ball, AFOs on with external rotator straps
ABCs: alignment, base of support, center of mass	Prone and sitting	Reaching for Gertie ball (Therapro)	"Superman"—thoracic extension Unyoke UEs Elongation L biceps	B elbows and gluteals	+	Large orange ball, Gertie ball
Core muscle activation	Sitting—pelvis in alignment: extension with rotation	Throwing ball and reaching to ball	UE weight bearing and trunk rotation	L hand thenar and web space, lower thoracic spine	+	Large orange ball, Gertie ball, hula hoop target
Elongation/activation	Sitting	R hand grasping	L hand grasp, sustained grasp and release	L hand ulnar border and web	−	Bench, Play-Doh
Practice time (including repetition and simulation of goal)	Sitting	R hand grasp/release	L hand grasp and toy placement	L hand ulnar stabilization	+	Bench, stretchy lizard, snake and worms, plastic eggs, pull string on bumble ball

Abbreviation: AFO, ankle-foot orthosis; B, bilateral; UE, upper extremity.
Source: Chart used by Ustad et al,[24] 2009 and adapted by Debbie Evans-Rogers, March 2010 for dissertation research.
[a]Functional Activity/Goal: Sam will release items using his left hand on second attempt 3/5 trials while in sitting with assist to stabilize his wrist, forearm, and the object.

Goals: Expected level of outcome—level 0 on GAS established for 2-week goals during intensive program.
Physical therapy goal:
1. Sam will stand independently with quad cane in right hand pushing down into floor to balance independently 20 seconds (standby supervision only).
Occupational therapy goals:
1. Sam will release items using left hand with assist to stabilize wrist, forearm, and object on second attempt 3/5 trials.
2. Sam will cleanly stamp his name on a line using his right hand (without smudges, smears, and entire name) by third attempt with verbal cues only.
Speech goals:
1. Sam will use AAC device to initiate interaction with peers on three occasions, requiring minimal prompting to initiate the interactions during the session.
2. Sam will use AAC device for six turn-taking interactions with peers during game when provided cues during session.
3. Sam will follow visual schedule participating in each activity up to six pictures, 15 inches, each activity until picture is removed and next pictured activity is presented.

At the conclusion of the 2-week period of NDT intervention, Sam demonstrated improvements in GAS scores across all disciplines (see Summary of GAS Goals for Sam). His performance is pictured in Fig. B9.4, Fig. B9.5, and Fig. B9.6.

The greatest improvements were noted in the physical therapy and occupational therapy scores. The physical therapy GAS score improved from a −2 to a +2 level with the patient exceeding the “0” predicted score of standing balance using a quad cane to being able to take four to six steps independently.

Fig. B9.4 By the end of his occupational therapy session, this posttest picture was taken, which demonstrates Sam’s ability to independently grasp the name stamp and push it with adequate pressure to imprint his name on the paper without smudges or smears and with his entire name on the first attempt. Quality of imprinted name decreased with multiple trials.

Fig. B9.5 In the speech therapy posttest, Sam needed only one verbal prompt.

Fig. B9.6 The physical therapy posttest picture demonstrates Sam’s improved balance using the quad canes and his ability to take four to six independent steps with the quad cane after the intensive program.

The occupational therapy GAS scores improved from a −2 to a +2 level with the patient exceeding the "0" predicted score with being able to stamp his name independently on a "name line" for his paper for school work and with being able to release a toy with wrist support.

Scores also increased on the discipline-specific speech scores from a −2 level to a +1 level for AAC use when initiating an interaction with a peer, and from a −1 level to a +2 level for following a visual schedule while participating in six activities.

On the COPM, scores also improved pre- to postintervention () across all disciplines, with the greatest improvements noted on the following: the *satisfaction level* increasing from a 3 to an 8 score for the physical therapy goal; the *performance level* increasing from a 3 to a 7 for the physical therapy goal; both the *performance* and the *satisfaction levels* increasing from a 4 to an 8 on the second (name stamping) occupational therapy goal, and both the *performance* and the *satisfaction levels* increasing from a 5 to an 8 on the first occupational therapy goal. *Performance* and *satisfaction levels* improved from a 7 to a 9 on the third SLP goal (visual schedule) and from a 3 to a 4 on the first speech therapy goal (initiating interaction using AAC). *Performance* and *satisfaction levels* did not change on the second speech therapy goal (AAC with peer turn taking).

Other subjective and functional changes noted in the patient included system impairment improvements in the following systems.

Sensory Systems

Improved proprioception of LEs and UEs with weight bearing, improved proprioception of hands bilaterally, increased modulation and self-regulation as seen by ability to handle novel, frequent loud noises and changes in expected routine, and improved anticipatory response.

Musculoskeletal System

Endurance and strength of core postural muscles improved, elongation of iliopsoas and hamstring muscles, and alignment of hips with greater hip extension and external rotation on the right, elongation of pectoralis muscles bilaterally, range of motion and soft tissue changes in the left bicep, pronator teres, wrist flexors, ulnar deviators, long finger flexors, and thumb adductors.

Neuromuscular System

Decreased dynamic stiffness in the left UE during activities, increased force generation in the right scapular depression, quadriceps and gastrocnemius–soleus muscles (when standing on a wedge) in mid to end range up to stance, increased initiation and sustaining coactivation of core postural muscles, increased fractionated movements in the right hand, improved scaling of the left hand, and decreased overflow of movements in hands.

Respiratory System

Slower, deeper breathing during exertion.

B9.3.12 Other Changes

Sam's ease with new people was noticeably improved. He used new icons with his AAC, and he enjoyed turn taking and games with his peers. He anticipated changes of activities using the visual schedule. His alignment improved in his stander.

B9.4 Discussion

Similar to a recent case report on increased intensity of therapy for a child with gross motor delay by Schreiber,[25] the results of this case report indicated that the 6-year-old participant with spastic quadriplegia CP and dystonia had positive effects from an intensive NDT program consisting of a 4 h/d intensity for a 2-week duration.

Objective improvements were noted using GAS and the COPM. Further objective and subjective improvements were noted by the therapists and caregivers. Specifically, the participant in the study demonstrated functional improvements in standing balance and walking using a quad cane, stamping his name for school papers, grasp/release using his left hand, and interactions using a visual schedule and AAC device.

Specifically with this case report, although gains were made with all the goals, the greatest gain was made in the PT discipline goal for balance using a quad cane. This change may be due to the collaborative effort of the PT and OT working toward a similar activity for Sam—helping him with his proprioception and muscular strength for pushing with his right UE. The occupational therapy name-stamping goal provided direct carryover to the physical therapy weight-bearing goal with the quad cane for improved balance in stance. This finding strengthens an important aspect of NDT intervention—the collaborative effort of all disciplines working with children. If goals can be made collaboratively (e.g., during this intensive intervention period the PT had a goal for using his right hand to push down into the quad cane and the OT had a goal for using his right hand for pushing down his name stamp), more practice ensues with each discipline, working toward improving functional performance.

During this case, because each discipline met daily, discussing daily interventions, and further collaboration existed with the family, the in-home nursing attendants (with the family and nurse present at all sessions), and other therapists. During this case study, collaboration seemed to play a significant role in the patient's increased performance on his functional outcomes. Other aspects to be considered regarding the largest gain in the physical therapy goal of walking may be due to the PT focusing on only one goal versus multiple goals, and the balance/walking goal with the quad cane might have had increased practice due to its priority by the family.

In published research, therapeutic interventions, such as treadmill training, constraint-induced movement therapy, and strength training with increased intensity have had positive results.[26,27,28,29] In this case report, significant gains were noted using intensive therapy sessions daily for a 2-week period using an NDT approach. The research by Ottenbacher et al[30] corroborates positive findings with subjects receiving NDT as compared with control-comparison subjects not receiving the intervention, and more recent research supports using NDT with an increased intensity[12,17,20,31] Intensive programs may be successful given that a layering effect of therapy ensues with carryover from one day to the next. The aspect of quality therapy with an increased intensity using functional, objective goals continues to require exploration.

Many considerations need contemplation when considering more intensive therapy. Families and therapists may use more intense therapy programs to assist with specific skill acquisition. In this program, the family was required to provide the transportation for the therapy, and they were actively involved with goal writing and were present throughout each therapy session. Similar to Trahan and Malouin's[18] findings, parental involvement was high over this 2-week intensive program. Many families could not commit to this type of intensive program, possibly due to other scheduled commitments, such as work, sibling and other family requirements, limitations with financial resources, and other difficulties.[25] Intensive therapy over long periods may be stressful for families.[32] The child must also be willing to participate and able to endure longer sessions.

It would be of interest to further explore the benefits of intensive therapy interventions provided in this format of daily multidiscipline intensive therapy sessions for periods varying from the 2 weeks and over a longer duration of time (e.g., with a longitudinal study over a 1- or 2-year period). The intensive program might be provided for a 2-week period quarterly, with rest periods and follow-up testing on goals to determine if improvements have been maintained and generalized to different settings during the time off. If goals were maintained after improvements noted during an intensive program, different therapy options could be made available for parents. Tracking the patient's improvements/gains for carryover over time would be important to monitor to grasp a better understanding of the optimal intensity of therapy that could be offered to parents for their children. Qualitative research exploring parent, therapist, and client perspective surrounding intensive therapy is also needed.

Numerous interventions and adjunct therapy tools are available to therapists to assist with functional improvements when managing their patients. Although using the Gross Motor Function Measure (GMFM) in conjunction with the Pediatric Evaluation of Disability Inventory (PEDI) have been found to be beneficial outcome measures for gross motor changes in children with CP,[14] the challenge continues for pediatric therapists to explore other appropriate outcome measures with therapy. Similar to research by Mailloux et al,[33] using GAS for children with sensory integration dysfunction, this report used GAS for children receiving NDT intervention.[34] In this case report, the GAS and COPM served as the functional outcome measures with positive outcomes found by the researchers pre- to postintervention. GAS and COPM were used across all disciplines with ease.

Worthy of contemplation is the level of expertise and knowledge of the therapists providing services in this specific intensive program. Two of the therapists providing services for this child were NDT instructors, and the other two therapists had considerable pediatric experience and training in NDT. Most individuals with NDT education have had a considerable amount of teaching and practice with specific quantitative goal writing, which may have facilitated the ease of goal writing using the GAS. Even with the consideration of these aspects in this case study, the GAS and COPM were found to be useful as quantitative outcome measures examining changes in function pre- and postintervention.

B9.5 Clinical Implications and Conclusions

The importance of evidence-based research in clinical practice to optimize patient care is evident in pediatric rehabilitation.[35] Performing pediatric research and publishing case reports by clinicians in peer-reviewed journals continue to be needed. Documenting changes pre- and postintervention in pediatric clients using quantitative and qualitative data by objective and subjective reporting is invaluable.[36,37]

Clinician reporting can expand therapists' knowledge and ultimately benefit clients. We found in our case that using functional outcome measures helped keep therapists focused on goals that had meaning and value to the family and child. In addition, the measures provided a way to quantify functional changes and document the family's perception and benefit of the changes. Exploring appropriate functional outcome measures, such as the COPM and the GAS, which are economical and available for the clinician and can be easily used to monitor client progress, is needed.[36] Not only is this documentation essential for clinicians, clients, and their families, but it might also provide data and information beneficial for third party coverage and research funding.

Additionally, the importance of further exploration of optimal therapy intensity should not be overlooked. This single subject case study found favorable results using a comprehensive team intensive program with a child having multiple, complex medical needs. The client demonstrated functional changes in a short time frame, and the family reported favorable benefits to the changes. As experienced pediatric therapists, the wear on caregivers of numerous therapy visits over many years has been observed and has influenced this research. Since optimal therapy frequencies are not conclusive in the research for each of our clients, alternative therapy options available to caregivers that work best for their life routines or that show significant improvements in little time for their children should continue to be a priority in further research. Coinciding with the American Physical Therapy Association's Vision 2020, therapists need to strive for optimizing movement for all individuals improving participation in society, and this vision needs to be the focus even when the client is of a young age.[38]

Caution is required with case reporting results, and generalization should not be made for all children. Many limitations exist with single-case reporting methodology.

Further research with appropriate rigor, including increased subject number with varying diagnoses and ages, randomization, blinding, greater control of variables including specific skill retention with longitudinal data, and further statistical analysis are needed before conclusive results showing positive effects using an intensive NDT program can be generalized.

B9.6 Acknowledgment

This case report was completed as part of a mixed method design of a PhD dissertation research project in Pediatric Science at Rocky Mountain University of Health Professions, Provo, Utah, for the first author.

We would like to thank Sam and his family, the intensive program therapists, and Partners in Progress, specifically Linda Kliebhan and Rona Alexander, for their support of this case report.

B9.7 Instrumentation Using the GAS and COPM

Goal attainment scaling is a 5-point Likert scale initially used as a method to evaluate mental health treatment and expanded to include applications in a variety of settings, including rehabilitation. Scaled levels of GAS range from a − 2 score to a + 2 score. The level descriptions are as follows:

- −2 (much less than expected outcome).
- −1 (somewhat less than expected outcome).
- 0 (predicted level of outcome).
- +1 (somewhat more than expected outcome).
- +2 (much more than expected outcome).

After discussing with caretakers their goal priorities, therapists write the discipline- specific, objective goals using GAS. Goal attainment scaling was used with this case report because of its ability to assess change brought about by intervention.

The COPM is a 10-point Likert scale that has been used to identify and prioritize everyday issues affecting occupational performance. The COPM has been used often as a self-perception instrument once specific problems have been targeted. The COPM is scored on the current ability to perform a task (with this case report using the discipline-specific GAS goals), rating the importance, performance, and satisfaction of the activity. The level descriptors scale consists of the following:

- Importance: 1—not important at all to 10—extremely important.
- Performance: 1—not able to do it at all to 10—able to do it extremely well.
- Satisfaction: 1—not satisfied at all to 10—extremely satisfied.

The COPM was included in this research because of the participatory scoring process of the caretakers assisting to produce quantitative data. Parents scored the COPM pre- and postintervention using the goals written by each discipline using GAS. The first researcher provided in-servicing for each therapist on writing goals using GAS and COPM scoring.

B9.8 Preintervention GAS Goals for Physical Therapy, Occupational Therapy, and Speech Therapy (with full scaling)

B9.8.1 Physical Therapy Goal with Specified Level of Attainment on GAS: −2, −1, 0, +1, +2

Physical Therapy Goal 1: Balance with Quad Cane
−2: Sam will stand independently with quad cane in right hand pushing down into floor to balance independently 1–2 seconds (close supervision).
−1: Sam will stand independently with quad cane in right hand pushing down into floor to balance independently 10 seconds (standby supervision only).
0: Sam will stand independently with quad cane in right hand pushing down into floor to balance independently 20 seconds (standby supervision only).
+1: Sam will stand independently with quad cane in right hand pushing down into floor to balance independently to take two independent steps (standby supervision only).
+2: Sam will stand independently with quad cane in right hand pushing down into floor to balance independently to take four independent steps (standby supervision only).

B9.8.2 Occupational Therapy Goals with Specified Level of Attainment on GAS: −2, −1, 0, +1, +2

Occupational Therapy Goal 1: Left Hand Release
−2: Sam will release items using left hand with assistance to move thumb and fingers and stabilization to wrist, forearm, and object.
−1: Sam will release items using left hand with assist to stabilize wrist, forearm, and object on fifth attempt.
0: Sam will release items using left hand with assist to stabilize wrist, forearm, and object on second attempt 3/5 trials.
+1: Sam will release items using left hand with assist to stabilize wrist, forearm, and object on first attempt 3/5 trials.
+2: Sam will release items using left hand with assist to stabilize object only on first attempt 3/5 trials.

Occupational Therapy Goal 2: Name Stamping

−2: Sam will use hand over hand assist to sustain pushing to cleanly stamp his name on a line using his right hand (without smudges, smears, and entire name).

−1: Sam will cleanly stamp his name on a line using his right hand (without smudges, smears, and entire name) by fifth attempt with verbal cues and physical guidance.

0: Sam will cleanly stamp his name on a line using his right hand (without smudges, smears, and entire name) by third attempt with verbal cues only.

+1: Sam will cleanly stamp his name on a line using his right hand (without smudges, smears, and entire name) by second attempt with verbal cues only.

+2: Sam will cleanly stamp his name on a line using his right hand (without smudges, smears, and entire name) on first attempt with verbal cues only.

B9.8.3 Speech Therapy Goals with Specified Level of Attainment on GAS: −2, −1, 0, +1, +2

Speech Therapy Goal 1: General Interaction

−2: Sam will use AAC device to initiate interaction with peers on one occasion by initiating response to "hi" requiring minimal prompting to initiate the interactions during the session.

−1: Sam will use AAC device to initiate interaction with peers on two occasions, requiring minimal prompting to initiate the interactions during the session.

0: Sam will use AAC device to initiate interaction with peers on three occasions, requiring minimal prompting to initiate the interactions during the session.

+1: Sam will use AAC device to initiate interaction with peers on four occasions, requiring minimal prompting to initiate the interactions during the session.

+2: Sam will use AAC device to initiate interaction with peers on five occasions, requiring minimal prompting to initiate the interactions during the session.

Speech Therapy Goal 2: Turn-Taking with Peer

−2: Sam will use AAC device for 2 turn-taking interactions with peer during game when provided cues during session.

−1: Sam will use AAC device for 4 turn-taking interactions with peer during game when provided cues during session.

0: Sam will use AAC device for 6 turn-taking interactions with peer during game when provided cues during session.

+1: Sam will use AAC device for 8 turn-taking interactions with peer during game when provided cues during session.

+2: Sam will use AAC device for 10 turn-taking interactions with peer during game when provided cues during session.

Speech Therapy Goal 3: Visual Schedule

−2: Sam will follow visual schedule participating in each activity up to two pictures.

−1: Sam will follow visual schedule participating in each activity up to four pictures.

0: Sam will follow visual schedule participating in each activity up to six pictures until picture is removed and next pictured activity is presented, attending for 15 minutes.

+1: Sam will follow visual schedule participating in each activity up to six pictures until picture is removed and next pictured activity is presented, attending for 30 minutes.

+2: Sam will follow visual schedule participating in each activity up to six pictures, pointing to remove picture and for next pictured activity, attending for 30 minutes.

B9.8.4 Summary of GAS Goals for Sam

Goals: Expected level of outcome-level 0 on GAS established for 2-week goals during intensive program.

Physical therapy goal:

1. Sam will stand independently with quad cane in right hand pushing down into floor to balance independently 20 seconds (standby supervision only).

Occupational therapy goals:

1. Sam will release items using left hand with assist to stabilize wrist, forearm, and object on second attempt 3/5 trials.
2. Sam will cleanly stamp his name on a line using his right hand (without smudges, smears, and entire name) by third attempt with verbal cues only.

Speech therapy goals:

1. Sam will use AAC device to initiate interaction with peers on three occasions, requiring minimal prompting to initiate the interactions during the session.
2. Sam will use AAC device for six turn-taking interactions with peer during game when provided cues during session.
3. Sam will follow visual schedule participating in each activity up to six pictures, 15 minutes each activity until picture is removed and next pictured activity is presented.

B9.9 Colored Charts

See Fig. B9.7 and Fig. B9.8.

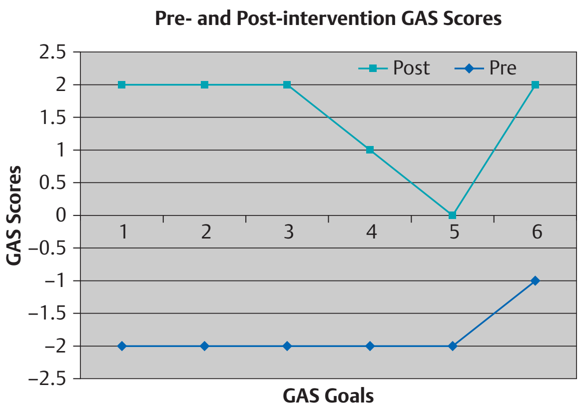

Fig. B9.7 Pre- and postintervention scores using the Goal Attainment Scale.

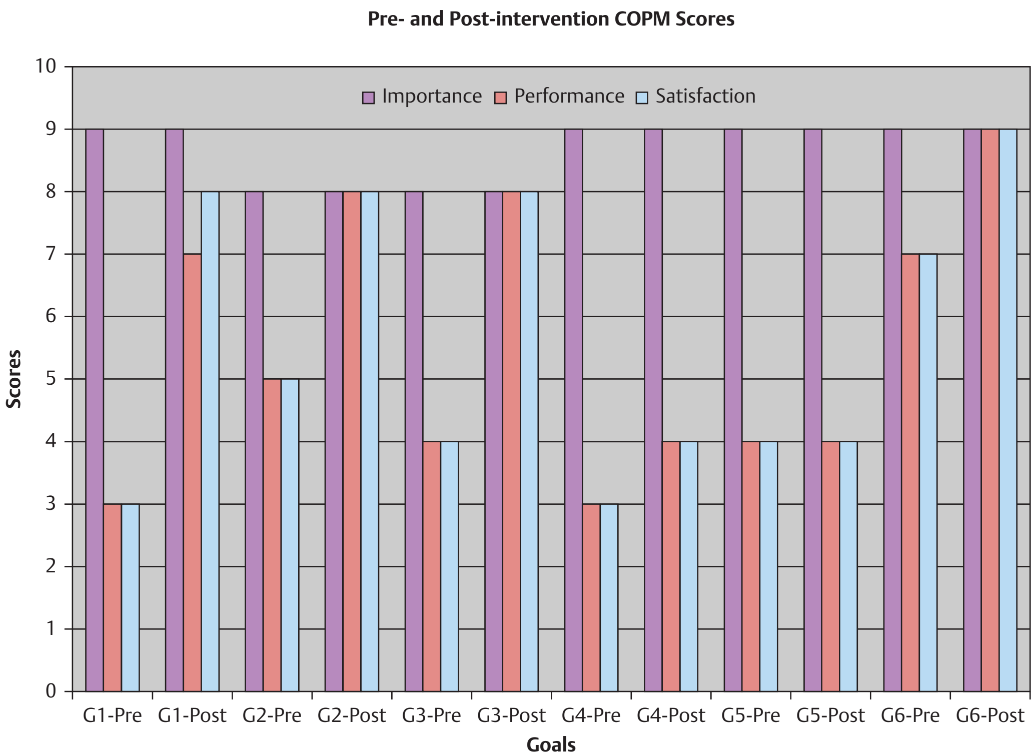

Fig. B9.8 Pre- and postintervention Canadian Occupational Therapy Measure scores.

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Glossary

Activity/Activity limitation: Execution (or lack) of a task or action by an individual.

Adaptive plasticity: The ability of the body systems to adapt over time or compensations for lost function.

Adult onset/childhood onset/congenital: Classifications used to indicate the timing of the pathophysiology.

AFO: Ankle-foot orthosis designed to align the foot and ankle, provide stability when walking or standing, support weakness around the ankle and foot, and help prevent deformities.

Agnosia: The inability to recognize familiar objects via a sensory modality, such as vision, while retaining the ability to recognize the same object with other sensory systems.

Altitudinal defects (visual): A field defect with loss of all or part of the superior half or the inferior half of the visual field of one or both eyes, and which respects the horizontal meridian.

Amblyopia: Reduced visual acuity that cannot be improved by optical means.

Anticipatory postural control: The production of forces prior to the intended movement that is critical to setting the posture to maintain the body in appropriate alignment against the force of gravity while allowing tasks to be accomplished.

Apraxia: A group of disorders of conceptualization, planning, and execution of learned, skilled movements, gestures (especially sequences of gestures), and/or tool use despite intact motor and sensory systems, comprehension, and cooperation.

Apraxia of speech: Difficulty coordinating muscles to plan, sequence, or execute syllables or words.

Assessment: Includes examination and evaluation of a client.

Assistive technology: Any useful device that assists an individual to actively perform tasks that would otherwise be difficult or impossible due to underlying system impairments (e.g., mobility aids, computer-generated communication devices, personal care items, positioning equipment).

Assumption: A fact or hypothetical statement taken for granted that underlies best practice standards. A statement that guides or frames the thought process underlying the evaluation, intervention planning, and implementation process.

Asymmetry: A common impairment of posture describing the posture or movement in either children with cerebral palsy or adults with stroke in which the two sides of the body show differences in motor functions. Usually related to multisystem impairments.

Ataxia: The inability to coordinate a normal or expected muscle activity during voluntary movement so that smooth movements occur. Most often due to disorders of the cerebellum or the posterior columns of the spinal cord; may involve the limbs, head, or trunk.

Athetosis: One of the group of disorders classified as dyskinesia. Characterized by a succession of slow, involuntary movements that are abnormal in timing, direction, and spatial characteristics and impairments in postural stability.

Balance: Ability to maintain the center of mass (COM) within the base of support (BOS) during functional activities.

a. **Anticipatory balance:** Anticipatory balance occurs in anticipation of internally generated destabilizing forces as a result of the body's own movement. Postural adjustments occur prior to the initiation of a movement action to counteract expected perturbations to ensure stability.

b. **Reactive balance:** Reactive balance occurs in response to external forces acting on the body, changing the base of support or disturbing the position of the center of mass. Sensory feedback is required to initiate the process of response.

c. **Adaptive balance:** Adaptive balance allows changes in postural control as the task and environment change while posture and movement unfold.

Baroreceptors: Receptors that sense changes in blood pressure and send information to the central nervous system to alter vasoconstriction and vasodilation to alter blood pressure.

Base of support (BOS): All points of the body in contact with surfaces, and the area of the surfaces between the points.

Benign paroxysmal positional vertigo (BPPV): A condition in which a person develops a sudden sensation of spinning, usually when moving the head. It is the most common cause of vertigo.

Bilateral: Pertaining to, involving, or affecting two (i.e., both) sides.

Bimanual: Using or requiring the use of both hands in complementary or simultaneous actions.

Biomechanical components of movement: Quantitative characteristics of movement based on the interaction of internal and external forces acting on the body (e.g., range of motion, strength, skeletal and articular structures).

Body structure/function: One domain on the health and disability continuum of the ICF model that describes the integrity and impairments of the anatomical parts of the body, including the organs, limbs, and trunk and their components, and the physiological and psychological functions of body systems.

Bronchopulmonary dysplasia: Abnormal development of lung tissue. It is characterized by inflammation and scarring in the lungs. It develops most often in babies born prematurely, who are born with underdeveloped lungs.

Center of mass (COM): Hypothetical point of a body at which the total mass is considered concentrated.

Central nervous system (CNS): The portion of the nervous system that includes the brain and spinal cord.

Cerebral palsy (CP): A group of disorders of the development of movement and posture causing activity and participation limitations. Attributed to nonprogressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, cognition, communication, perception, and/or behavior, and/or by a seizure disorder.

Chemoreceptors: Receptors in the body that detect chemical changes; found in the carotid body, brainstem respiratory centers, and sensors for taste and smell, and in the skin, muscles, and viscera.

Chorea: A type of dyskinesia characterized by dancelike movements that appear jerky and random and are not voluntarily suppressible.

Closed (kinetic) chain: Movement that occurs when the distal portion of the body segment is anchored or fixed (as in weight bearing).

Coactivation/cocontraction: The simultaneous activation of agonist and antagonist muscle groups around a joint in which both agonist and antagonist increase activity, resulting in increased active joint stiffness. Can be normal or abnormal depending on whether the degree of stiffness meets the task requirements.

Compensation: New or alternative motor strategies or movement substitutions used to accomplish a functional goal or task, albeit less efficiently and effectively.

Concentric contraction: A type of muscle activation that increases tension as the muscle shortens.

Contextual facilitators and barriers: According to the ICF model, personal or environmental factors that can be identified as either facilitators or barriers based on the impact on the individual. Personal factors include lifestyle, coping mechanisms, and self-worth. Environmental factors include immediate personal environment, school, home, workplace, and available social structures.

Coordination: The process by which posture and movement components are sequenced and organized in order to produce a functional movement for a specific action or goal.

Cortical visual impairment: Lesions in the posterior visual pathways from the lateral geniculate to the visual cortex resulting in difficulty processing and interpreting visual information in the visual cortex.

Deductive reasoning: Deriving a conclusion by inference from general premises.

Degrees of freedom: The number of separate independent elements of movement in a system that must be controlled to complete a task.

Descriptive knowledge: Declarative knowledge; knowledge of facts, attributes, and relationships stored in memory.

Diaschisis: A period of rapid neural recovery that immediately follows a brain insult and allows for stabilization of undamaged areas and recovery of functions that have not been destroyed.

Diffusion tensor imaging (DTI): A refinement of magnetic resonance imaging that allows the physician to measure the flow of water and track the pathways of white matter in the brain. DTI is able to detect abnormalities in the brain that do not show up on standard MRI scans.

Diplegia: A topographical classification of cerebral palsy described as damage of the upper motor neurons causing more damage to control and coordination of the lower body and visual system compared to the upper body.

Distributive model of neural organization: Input for movement is distributed among many sites of the nervous system, which cooperate and contribute to the production of motor behavior.

Domains of ICF model: The three domains are social functions (participation or participation restriction), activities (functional activities or activity limitation), and body structure and function (integrities or impairments). The domains are interactive and dynamic.

Dynamic systems theory (DST): A systems theory which proposes that meaningful tasks, in specific environmental conditions, spontaneously self-organize the various body systems, which then adopt a specific organization to create or change the movement patterns.

Dysarthria: Motor speech disorder resulting from weakness, paralysis, incoordination, or stiffness of the muscles used in speech.

Dysautonomia: Dysfunction of the autonomic nervous system in its control of heart rate and blood pressure; a group of complex conditions that are caused by a malfunction of the autonomic nervous system (ANS).

Dyskinesia: Distortion or impairment in performing voluntary movement characterized by spasmodic or repetitive involuntary movements.

Dysmetria: Inability to accurately move an intended distance.

Dysphagia: Referring to swallowing and swallowing disorders.

Dyspraxia: A term used to describe children with similar impairments to adults with apraxia who have difficulty using tools, sequencing gestures, and sequencing motor tasks without muscle weakness, sensory loss, incoordination, aphasia, or cognitive impairment.

Dystonia: A type of dyskinesia characterized by sustained muscle contractions that result in twisting and abnormal postures.

Eccentric contraction: A type of muscle activation that increases tension as the muscle lengthens.

Effective posture or movement: Postures, movements, and postural control that result in functional skills or activities or prepare for higher-level skills.

Environmental factors: The physical, social, and attitudinal environments in which people live and conduct their lives and the community services available to the individual.

Episode of care: Health care services provided for a specific illness during a set time period.

Evaluation: The portion of the client assessment that includes synthesizing the findings from the data collection and examination based on clinical judgment and problem solving. Identifies and describes the relationships among the relevant factors from each domain in the ICF model. Includes an analysis of these relationships as they relate to the client's impairments and potential for change, and forms hypotheses linking intervention planning to anticipated outcomes.

Evidence-based practice: The use of current research evidence, clinical expertise, and patient values to guide clinical decision making.

Examination: The portion of the client assessment that includes comprehensive screening and specific testing by the clinician. It includes observations of posture and movement, standardized testing, or observation of functional activities and limitations and review of the individual systems.

Executive functions: Goal-oriented behavior; the capacity to plan, manipulate information, initiate and terminate activities, recognize errors, problem-solve, and think abstractly.

Exteroception: Sensory receptors that provide information from the external environment.

Facilitation: The strategy of therapeutic handling that makes a posture or movement easier or more likely to occur.

Fascia: Connective tissue composed primarily of collagen that surrounds other tissue; it is a fibrous sheet that separates muscle cells, fascicles, and their layers.

Fascicle: An organized bundle of muscle fibers.

Feedback (closed-loop system): Motor control processing in which sensory feedback is used for the ongoing production of skilled movement.

Feed-forward (open-loop system): Motor control processing that does not rely on sensory feedback during execution of the movement.

Force production (of muscles): The tension produced by muscles to maintain posture or movement.

Forward reasoning or **pattern recognition:** A type of clinical reasoning in which the clinician associates impairments, limitations, and restrictions of a current patient with previously seen patients and adopts a previously successful management strategy.

Frontal plane: Any plane that divides the body or body segment longitudinally into anterior and posterior portions. The motions of abduction and adduction occur in the frontal plane.

Generalized motor programs (GMPs): A theory which proposes that the nervous system stores abstract representations of movement and retrieves and produces movement plans with considerable flexibility based on prior experience and learning without the need for sensory feedback.

Goal: Statements by the client and family describing what they want to achieve as a result of intervention.

Gravitational insecurity: Uncertainty or fear of movement, especially when the head is tilted away from the upright position.

Handling: See *therapeutic handling*.

Hemiparesis: Motor impairments of partial paralysis or weakness on one side of the body; less severe than those seen in hemiplegia.

Hemiplegia: Motor impairments of paralysis on one side of the body in persons with cerebral palsy or stroke.

Hemorrhagic stroke: A stroke resulting from rupture of a blood vessel in the brain.

Homonymous hemianopia or hemianopsia: Loss of visual information form one hemifield in both eyes produced by damage to fibers posterior to the optic chiasm.

Hyperacusis: Increased sensitivity to sound.

Hyperbilirubinemia: Excess of bilirubin in the blood.

Hyperkinesis/hypokinesis: Abnormally excessive/depressed movements caused by lesions to central nervous system pathways that influence movement characteristics, such as force, timing, and selection of synergies.

Hyperreflexia: Excessive phasic and/or tonic stretch reflex responses.

Hyperstiffness: Excessive resistance to muscle stretch, regardless of whether the stretch is passive or active. Can be produced by active muscle contraction or by myoplastic changes following damage to the central nervous system.

Hypertonia: A group of conditions characterized by excessive stiffness, tension, or activity of the skeletal muscles and abnormally increased resistance to externally imposed movement about a joint.

Hypokinesia: See *hyperkinesis/hypokinesis*.

Hypotonia: A group of conditions including diminished tone, tension, or activity of the skeletal muscles.

Hypothesis: A reasonable explanation for an observation, phenomenon, or scientific problem that can be tested by further investigation; serves to guide both NDT assessment and intervention.

Hypothesis-guided inquiry or **Hypothetico-deductive reasoning:** A type of clinical reasoning in which the clinician generates a hypothesis based on data from the patient, which is then tested to generate or refine the hypotheses. This is done until a management strategy is clearly defined.

Hypothetical deductive approach: An approach of cue identification, hypothesis generation, and evaluation.

ICF model: The International Classification of Functioning, Disability and Health. The World Health Organization's framework that provides a universal classification, definition, measurement, and policy formation for disability and health. Includes descriptions of body system integrity/impairments, individual activities/activity limitations, and participation/participation restrictions.

Impairments: Problems in single or multiple body systems that impede the individual from accomplishing functional activities or participating fully in life.

Individual function: One domain in the continuum of health and disability of the ICF model that describes activity and activity limitations.

Integrity of body systems: Functions of various single or multiple body systems that serve the individual in changing contexts.

Ineffective posture or movement: Postures, movements, and postural control performed in a manner that does not allow function to result, results in loss of function over time, damages body systems and structures, and/or prevents the attainment of new and more skilled function.

Inhibition: The strategy that an NDT therapist uses, which involves specific handling of a client to restrict, redirect, or constrain atypical or inefficient postures and movements that interfere with the development of more selective motor patterns and efficient function. Usually combined with facilitation.

Intralimb coordination: Timing and sequencing of motor activity within a limb.

Interlimb coordination: Timing and sequencing of motor activity between limbs.

Interoception: Sensory receptors that provide information about the body's internal environment.

Instruction (in motor learning): Physical, verbal, and visual clues that help a client and aid a client's performance and learning.

Intervention: Specific therapeutic decisions and methods designed to produce changes in the health condition of a client requiring purposeful interactions between a therapist and client, and, when appropriate, with others involved in the client's care.

Intervention strategy: Specific procedural application of intervention guided by problem solving and decision making designed to accomplish a change in body system function, posture, movement, activity, or participation.

Ischemic stroke: A stroke caused by insufficient supply of blood and oxygen to a part of the brain.

Isolated control: Ability to isolate movement of a single joint(s) necessary for precise movement and dexterity for refined function. Also called fractionated movements.

Isometric contraction: A type of muscle activation that increases tension as it holds a fixed length.

Key points of control: Intervention strategy that requires the therapist to contact the client's body purposefully and specifically to produce changes in alignment before a movement sequence, or to control the speed, direction, or effort the client uses during movement.

Kinesthesia: An awareness of dynamic joint motion.

Knowledge of performance: Augmented feedback related to the nature of the movement produced to complete a task.

Knowledge of results: Augmented feedback related to the nature of the result produced in terms of the environmental context.

Kuypers's organization of the motor system: Organization of descending tracts in the nervous system based on position in the spinal cord; the medial system innervates muscles of the neck and trunk, and the lateral system innervates muscles of the limbs.

Kyphosis: A posterior convex curvature of the spine: may be typical, reduced, or excessive.

Language disorder: Impairments in comprehension, use of spoken or written symbols; many involve form, content, or function of language.

Life span or life cycle framework: A framework that assumes that goals and intervention strategies must change over the life cycle to continue to meet the client's changing needs.

Long-term outcomes: Measurable, functional long-term results of intervention that are client focused. Outcomes should include an action verb, the functional performance, the conditions under which the performance will be met, and the criteria the performance must meet. "Long-term" is variable, based on the setting and population being served.

Macular defects: Defects of the small spot where vision is keenest in the retina.

Management: The whole system of care. Includes direct and indirect intervention, periodic assessment, home and community carry-through programming, and patient/client and family education.

Model: A schematic description of a system, theory, or phenomenon that accounts for its known or inferred properties and may be used for further study of its characteristics. See *NDT Practice Model*.

More involved side/less involved side: Previously referred to as involved side/uninvolved side in clients with hemiplegia.

Motor control: A theoretical explanation of how the central nervous system, environment, and body systems interact and organize individual joints and muscles to produce coordinated functional movement.

Motor development: The body system processes underlying emergence and changes in motor skills that occur across the life span based on experience, maturation, and aging.

Motor learning: A set of processes directly related to practice or experience leading to relatively permanent changes in motor skills.

Motor performance: Observable attempt of an individual to produce a voluntary action, reflecting a change that occurs based on the quality of the posture and movement during an activity or task.

Motor planning: An internal process that involves the ability to predict the future state of the motor system or the consequences of its action.

Motor skill: The consistent attainment of a motor task with economy of effort. It reflects producing a performance with maximum certainty, minimum energy, and/or time.

Motor unit: The alpha motor neuron and skeletal fibers it innervates; motor units are classified as fast glycolytic, or fast fatigue (FF), fast oxidative glycolytic or fast fatigue resistant (FR), and slow oxidative (S).

Movement: A multisystem body structure and function. Movement selection is shaped by the neuromuscular system, musculoskeletal system, sensory systems that provide feedforward and feedback, the context (personal and environmental), and behavioral intentions.

Movement analysis: Understanding and describing the postural components, muscle and joint alignment, and movement components needed for efficient movement to occur.

Movement system: The primary controller when wide range and fast speed of movement are required for transitions, mobility, and precision. The primary goal is mobility. Controlled through the lateral descending system.

Movement synergies: Groups of muscles crossing many joints that work together as a unit to complete a functional task or action in a specific context.

Muscle recruitment: The activation of motor units; recruitment increases as more motor units activate simultaneously or in sequence.

Muscle tone: The force, stiffness, or tension with which a muscle resists being passively lengthened by externally imposed forces.

Narrative reasoning: A type of clinical reasoning in which the clinician listens to the patient's perspective and the context of the patient's problems. It is a type of reflective management that demands collaboration to create a management strategy.

Negative sign or impairment: Motor behavior that is absent or diminished because of the pathophysiology. Describes insufficient muscle activity or insufficient control of muscle activity; for example, weakness, impaired selected motor control, ataxia, and apraxia.

Neuro-Developmental Treatment (NDT): Originally called the Bobath Approach, NDT is a therapeutic framework used by clinicians who work with people with stroke, traumatic brain injury, cerebral palsy, or similar neuropathologies, linking examination and intervention through a well-defined practice model, which considers both strengths and limitations of individuals and their needs to participate in life's activities.

a. **NDT assumptions:** Hypothetical statements that underlie best practice standards of NDT. Ideas that originated with the Bobaths and changes derived from the motor sciences compose the current therapeutic model of NDT.

b. **NDT Practice Model:** A description of clinical practice that explains and relates the therapist's descriptive and procedural knowledge, both specific to NDT and to the profession to which the therapist belongs, to interaction with a client and family in the therapy process for the purpose of promoting life skill outcomes.

Neuromuscular control: The scaling, grading, or modulation of muscular forces and tension around a joint to accurately execute specific tasks.

Neuroplasticity: The ability of the brain to change throughout the life span, exhibiting growth and reorganization depending on experience, use, or disease.

Neuronal groups: Collections of strongly connected neurons.

Neuronal Group Selection Theory (NGST): A theory developed by Edelman, which proposes that neural structures and the other body systems are organized for diversity and are capable of selecting from a multitude of task-specific responses, species-specific, yet variable, adaptive motor behaviors.

Neuronal maps: Connections of neuronal groups distributed among vast areas of the nervous system and organized so that distinct areas of perception, cognition, emotion, posture, and movement are spontaneously activated in response to the task conditions, forming global maps for efficiency.

Neural shock: The temporary injury to intact areas of the nervous system as a result of insult to the central nervous system.

Nystagmus: Involuntary movement of the eyes in any direction: a normal response to rotational or temperature stimulation of the semicircular canals or when moving the eyes to the end of horizontal positions; abnormal stimulation nystagmus occurs without external stimulation.

Objective: Desired changes in impairments of the body systems.

Open (kinetic) chain: Non-weight-bearing movement with the distal segment free in space.

Ophthalmologist: A specialist in medical and surgical eye problems. Because ophthalmologists perform operations on eyes, they are considered to be both surgical and medical specialists.

Optokinetic reflex: Normal reflex that allows the eye to follow objects in motion when the head remains stationary (e.g., observing individual telephone poles on the side of the road as one travels past them in a car).

Optometrist: A health care professional concerned with the health of the eyes and related structures, as well as vision, visual systems, and vision information processing in humans. Optometrists are trained to prescribe and fit lenses to improve vision, and to diagnose and treat various eye diseases.

Otolith organs: The utricle and saccule of the inner ear, which contain receptors that respond to head position relative to gravity and to linear acceleration/deceleration of the head.

Outcome: Statements of objective, measurable, observable changes in activities and participation as a result of intervention. It includes time and contextual reference and the client's satisfaction with care. It is the end result of therapeutic management and describes what intervention can achieve with clients.

Participation/restrictions: Involvement (or lack thereof) of an individual in life situations.

Patent ductus arteriosus: A condition in which the ductus arteriosus does not close; the ductus arteriosus is a blood vessel that allows blood to go around the baby's lungs before birth. Soon after the infant is born and the lungs fill with air, the ductus arteriosus is no longer needed. It usually closes in a couple of days after birth.

Pathophysiology: The underlying medical or injury process, at the cellular or tissue level, of either neural or body structures, that interferes with or interrupts the normal physiological and developmental processes in any domain of the individual, such as cerebral palsy, stroke, or traumatic brain injury.

Pattern recognition: See *forward reasoning*.

Perception: The conscious recognition and interpretation of sensation into meaningful forms.

Plan of care: The organization, analysis, and prioritization of information that the therapist includes when determining the overall therapeutic management of a particular client. Statements that follow each discipline's best standard of care specify the expected outcomes, predicted level of optimal improvement, specific interventions used and proposed, and duration and frequency of treatment.

Plasticity: The ability of the nervous system to reorganize its structure, function, and connections in response to intrinsic or extrinsic stimuli or after neural insult.

Positive sign or impairment: Motor behavior that leads to an involuntarily increased frequency or magnitude of muscle activity, movement, or movement patterns, such as hypertonia, chorea, tics, and tremor.

Postural alignment: Postural alignment is a part of orientation and balance and refers to the relationship of one body segment with another or of the position of the entire body to the base of support.

Postural control: The relationship between posture and movement. Control of the body's position in space for the purposes of stability against the force of gravity and orientation of the body segments to each other in task-specific relationships.

Postural orientation: One of two functions of postural control. This multisystem function includes alignment of the trunk and head with respect to gravity and support surfaces, visual environment, vestibular structure and function, proprioception (especially from the head and neck), and internal body referencing (interoception).

Postural system: The primary system that assures the upright position against gravity to maintain or regain balance and orientation during transitions.

Postural tone: Distribution of muscle activity in antigravity muscles such that they are able to simultaneously maintain posture against gravity and adapt their stiffness to allow flexibility for movement.

Posture: A position that the body can actively assume and the alignment of body segments with each other that provides the basis of function.

Practice: Experimentation and repetition of postural and movement possibilities to promote motor learning and proficiency.

Practice model: A written description of the complexity of clinical practice for the purpose of analyzing, problem solving, and predicting functional outcomes of intervention.

Praxis: Praxis, meaning *action* in a general sense, refers to the ability to do something, whether it is the practice of art, science, or movement skill. When used in the field of habilitation and rehabilitation, *praxis* refers to movement skills. Praxis is doing.

Primary impairment: Results directly from the original pathology.

Principle: General, comprehensive, and fundamental rules for conduct and action. The link between the abstract theory and philosophy and the concrete practice.

Procedural knowledge: Knowledge of how to do a skill; the knowledge of how to perform, or how to operate; how a therapist performs intervention.

Proprioception: A sensory awareness of position and posture.

Pusher syndrome, contraversive pushing or ipsilateral pushing: Most often associated with hemorrhagic stroke. The individual pushes away from the less involved side leading to loss of postural balance and falling toward the more involved side.

Reticular activating system (RAS): The system of cells of the reticular formation of the medulla oblongata that receive collaterals from the ascending sensory pathways and project to higher centers that control the overall degree of central nervous system activity, including wakefulness, attentiveness, and sleep.

Quadrantanopia: Visual field loss in a quarter of the visual field of the eye. The defect is usually bilateral because it is caused by a lesion past the optic chiasm.

Quadriplegia: A topographical classification of cerebral palsy that is due to extensive damage of the upper motor neurons, which causes damage to the control and coordination of most body segments.

Qualitative research methods: A narrative description that includes asking open-ended questions, interviews, and observations to explore how individuals experience various phenomena.

Reactive balance: The ability to respond to perturbation from the environment, or self-initiated movements that displace the center of mass outside the base of support; also called equilibrium reactions.

Reciprocal activation: A relationship of muscle activity around a joint in which increased activity of the agonist is accompanied by decreased activity of the antagonist.

Recovery: The reorganization and plasticity changes in the central nervous system after an injury which implies that an individual can perform the function in the same manner and with the same efficiency and effectiveness.

Reflux: The flow of food or gastric juices from the stomach into the esophagus, and referred to as gastric esophageal reflux disease (GERD).

Rigidity: Increased resistance of a limb to movement in both flexion and extension throughout the entire range that is not velocity dependent.

Saccades: The series of involuntary, abrupt, rapid, small movements or jerks of both eyes simultaneously in changing the point of fixation.

Sackett's levels of evidence: A commonly cited method of assessing research based on the five levels of scientific support.

Sagittal plane: A plane that divides the body longitudinally into left and right sides and includes the motions of flexion and extension of the limbs and trunk.

Sarcomere: The contractile unit of a muscle fiber made of actin and myosin myofilaments.

Sarcopenia: Reduction in muscle mass that occurs as a result of aging or neuropathology such as stroke. Affects the lower extremity muscles more than the upper extremity muscles.

Scoliosis: A postural deviation of lateral curvature of the spine.

Scotoma: A dark spot in the visual field.

Secondary impairment: An impairment that does not result directly from the original pathophysiology and generally develops across time.

Selection (in NGST): The process by which competing neuronal groups provide structural diversity in the formation of the anatomy of the brain and guarantee that the brain and body maintain the conditions for adapting in a changing environment.

Self-organization: A concept within the dynamic systems model which hypothesizes that interacting systems can organize themselves and create motor patterns.

Semicircular canals: Three tiny circular tubes at right angles to each other in the inner ear that contain fluid and can sense when that fluid is moving in each of the three dimensions that make up our three-dimensional space.

Sensory processing: The ability of the nervous system to perceive, interpret, modulate, and organize sensory input for use in generating or adapting motor responses.

Sensory systems: Body systems responsible for receiving information from the environment through specialized cells and transmitting it to the central nervous system. This information is used for perception, control of movement, regulation of the functions of internal organs, and maintenance of arousal.

Single-system impairments: Specific system structure and function-specific system impairments that can be attributed to a single body system.

Sensory systems: Body systems responsible for receiving information from the environment and the body through specialized cells and transmitting it to the central nervous system. This information is used for perception, control of movement, regulation of the functions of internal organs, and maintenance of arousal.

Short-term outcomes: Measurable, functional short-term results of intervention that are client focused. An outcome should include an action verb, the functional performance, the conditions under which the performance will be met, and the criteria the performance must meet. Varies based on the setting and population being served.

Skill: The consistent attainment of a motor task with economy of effort, reflecting a performance with maximum certainty, minimum energy, and/or time.

Smooth visual pursuit: The tracking by the eyes of a slowly moving object at a steady, coordinated velocity.

Social function: One domain of the ICF model. On the continuum of health and disability describes participation and participation restrictions.

Somatosensory systems: Provide information about body awareness through touch, proprioception, pain, and temperature.

Spasticity: A motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes (muscle tone) with exaggerated tendon jerks resulting from hyperexcitability of the stretch reflex as one component of the upper motor neuron syndrome. A common motor disorder in stroke, cerebral palsy, and traumatic brain injury.

Spatiotemporal: Having to do with space and time.

Spondylolysis: A defect in a specific region of the spinal column. This region of the spinal column, called the pars interarticularis, connects adjacent vertebrae in the spine.

Standardized tests: Objective tests used to gauge changes over time using a standard format.

a. **Norm-referenced tests:** compare an individual's performance with peers.
b. **Criterion-referenced tests:** compare a client's performance to a predetermined criterion.
c. **Self-referenced tests:** compare an individual's performance to his or her own performance at another point in time.

Stiffness: Changes in mechanical-elastic characteristics of muscular and connective tissues. Stiffness is a normal phenomenon, though excessive stiffness may interfere with efficient posture and movement; it is not always caused by central nervous system damage.

Strabismus: An imbalance or weakness of the muscles that control eye position and movement.

a. **Esotropia:** one eye turns in.
b. **Exotropia:** one eye turns out.
c. **Hypertropia:** one eye turns up relative to the other.

Strategy: A course of action that gives direction to a collection of ideas and guides choices.

Striatum: The caudate nucleus and putamen of the basal ganglia.

Stroke: A sudden, focal neurological deficit resulting from the disruption to the blood supply in the brain.

a. **Ischemic stroke:** related to thrombotic, embolic, or hemodynamic factors.
b. **Hemorrhagic stroke:** results from rupture of the vessels of the brain and subsequent release of blood into the extravascular space.

Symmetry: Symmetry in posture and movement refers to the distribution of a person's mass and pressure on a support surface and is considered to be one aspect of postural control.

Synergy: A group of muscles that works together to produce motor behavior.

Systems theory: A model of motor control developed by Bernstein which contends that biological organisms, like other physical systems, are multidimensional in which no one system has priority of organizing or determining the behavior of the system.

Task: An activity.

Task analysis: Understanding and describing the components of a functional activity; ability to breakdown a composite task into its subcomponents.

Tenets: A set of ideas or guidelines assumed as true.

Theory: A formal statement concerning a set of interrelated concepts or observable phenomena with the intent of describing a systematic view of events or patterns to explain observations or predict the occurrence of future events. Generalizes beyond the specific incidences included as evidence and provides a link between experience and intellectual reflection in a particular context.

Therapeutic handling: A primary intervention that NDT therapists use to assist a client in achieving independent function. Includes interventions of facilitation and inhibition, which target the client's posture and movement and multisystem impairments.

Tinnitus: A sensation of ringing in the ear.

Traumatic brain injury (TBI): An insult to the brain, not of degenerative or congenital nature, caused by an external physical force that may produce a diminished or altered state of consciousness and results in an impairment of cognitive and/or physical functioning.

Transverse plane (horizontal plane): A plane that is at right angles to both the sagittal and frontal planes and divides the body into superior and inferior portions. Motions of rotation occur around the longitudinal axis.

Tremor: Alternating activity of the agonist and antagonist controlling a joint, leading to alternating joint movement that is small in amplitude and high in frequency.

Typical/atypical posture and movement: Previously referred to as normal/abnormal posture and movement.

Vertigo: An illusion of movement.

Visual accommodation: A process by which the eye adjusts and is able to focus, producing a sharp image at various changing distances from the object seen. The convexity of the anterior surface of the lens may be increased or decreased by contraction or relaxation of the ciliary muscle.

Vestibular ocular reflex: A normal reflex in which eye position compensates for movement of the head. It is induced by excitation of the vestibular apparatus.

Vision therapist: A professional who delivers an individualized, supervised, intervention program designed to correct visual-motor and/or perceptual-cognitive deficiencies.

Weakness: The inability to generate sufficient levels of force in a muscle or group of muscles for the purposes of posture and movement. Weakness can result from a primary neuromuscular impairment or secondary changes in the musculoskeletal system.

Weight bearing: The distribution of the body weight at rest in relation to the support surface and in anticipation of movement.

Weight shift: A change in the distribution of the body weight relative to the base of support in anticipation of or during movement.

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Practice Model—Person

Person Seeking Therapy
A person and family who have contextual factors and a unique relationship with health care

- Openness to share information about self and family beliefs, customs, values, traditions, and other cultural issues
- An understanding of and a willingness to share what she/he and family want from therapy
- Openness to share personal and therapy history; past experiences; body shape and size
- Openness to share information about his/her home environment, goals, and challenges

Explains why she/he seeks therapy
States knowledge of condition(s) seeking therapy for
Provides current health status
Describes daily routine of work/personal life/recreational interests
Describes self: functional abilities/losses or lack of development, personal needs, or desires
States expectations of management, including intervention
Provides relevant medical and social history

- Willingness to provide information about the knowledge of her/his health condition(s) and how she/he continues to learn about the condition(s) presented for management
- Knowledge gained through formal and informal life experiences, including school and higher education, career/profession/employment and social peer groups
- Willingness to allow the therapist to observe him/her during tasks, activities, participation that are challenging or difficult to perform
- Beliefs about people with health conditions and disabilities/illnesses and about the value of therapy

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- Openness to share current functional capabilities and explore how these influence future functioning
- Openness to share effective/ineffective postures and movements and the influences on life
- Openness to understand the role/importance of therapeutic touch/handling in the therapy process

Shows spontaneous function and postures/movements
Demonstrates function, postures/movements that therapist requests
Teaches and learns more about own postures/movements, functions, diagnosis, prognosis
Gives feedback through many systems in response to therapist

- Willingness to share information about learning preferences and preferred mode of learning
- Knowledge of his/her body and an openness to share likes and dislikes about posture and movement, including those for talking and eating
- Willingness to actively participate in the examination process

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- Ability to share hopes and fears as related to health condition(s)
- Willingness to respect opinions and value thoughts of others and self

Defines desired goals and outcomes
Identifies, defines, edits information about self
Further defines and refines desired outcomes

- Willingness to communicate with the therapist and openness to form a therapeutic relationship
- Willingness to communicate likes and dislikes about what occurs in therapy and with home program

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- Willingness to actively engage in the therapy process, follow directions, respect boundaries, and understand why limits are set
- Collaboration skills in teamwork
- Communication skills, including verbal, non-verbal, and written

Consents to management, including intervention
Actively participates (sensorimotor, psychological, cognitive/language, behavioral)
Carries out home programming
Provides feedback of successes/challenges
Shares information with team members

- Willingness to actively participate in intervention, sharing her/his goals and expectations
- Willingness to ask and answer questions about self and family
- Willingness to actively/physically work in therapy

Practice Model—Therapist