Bobath Concept

THEORY AND CLINICAL PRACTICE IN NEUROLOGICAL REHABILITATION

SUE RAINE | LINZI MEADOWS | MARY LYNCH-ELLERINGTON

Written by Members of the British Bobath Tutors Association

WILEY-BLACKWELL

This page intentionally left blank

Bobath Concept

Theory and Clinical Practice in Neurological Rehabilitation

Dedication

This book is dedicated to all of our patients and students from whom we have learnt and through whom we have developed. This book is dedicated to the memory of Pam Mulholland, MCSP, Bobath Tutor, our colleague and friend.

Bobath Concept

Theory and Clinical Practice in Neurological Rehabilitation

Edited by

Sue Raine

Linzi Meadows

Mary Lynch-Ellerington

WILEY-BLACKWELL

A John Wiley & Sons, Ltd., Publication

This edition first published 2009

Blackwell Publishing was acquired by John Wiley & Sons in February 2007. Blackwell's publishing programme has been merged with Wiley's global Scientific, Technical, and Medical business to form Wiley-Blackwell.

Registered office
John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom

Editorial offices
9600 Garsington Road, Oxford, OX4 2DQ, United Kingdom
2121 State Avenue, Ames, Iowa 50014-8300, USA

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at www.wiley.com/wiley-blackwell.

Library of Congress Cataloging-in-Publication Data

The Bobath Concept: Theory and clinical practice in neurological rehabilitation / edited by Sue Raine, Linzi Meadows, Mary Lynch-Ellerington.
p. ; cm.
Includes bibliographical references and index.
ISBN 978-1-4051-7041-3 (pbk. : alk. paper) 1. Movement disorders—Patients—Rehabilitation. 2. Bobath, Berta. 3. Bobath, Karel. 4. Motor learning. I. Raine, Sue. II. Meadows, Linzi. III. Lynch-Ellerington, Mary.
[DNLM: 1. Bobath, Berta. 2. Bobath, Karel. 3. Central Nervous System Diseases—rehabilitation. 4. Physical Therapy Modalities. 5. Rehabilitation—methods. WL 300 B663 2009]
RC376.5.B63 2009
616.8′3—dc22 2008053126

A catalogue record for this book is available from the British Library.

Set in 10/12 pt Palatino by Macmillan Publishing Solutions, Chennai, India
Printed in Singapore

1 2009

Contents

Foreword

As a physician and neurorehabilitationist whose primary professional concern has been with adult patients, it may seem strange that I feel so deeply indebted to Karel and Berta Bobath, who devoted much of their lives to the rehabilitation of children with neurological problems, especially cerebral palsy. And yet, it is true. I believe that the beneficent influence of the Bobaths on our approach to neurological rehabilitation has been incomparable, and all of us who are involved in the care of people struggling to overcome the impact of neurological damage owe them a debt of gratitude. Things that we now take for granted were regarded as heretical or eccentric when the Bobaths started out on their careers so many years ago and developed an approached which combined science, and a deeply humane concern for the plight of individuals, with neurological damage with something we might call 'clinical *nous*'.

The results are plain to see for all those who have long enough memories. When I began my career as a doctor in the 1970s, stroke patients were not welcomed on medical wards and rehabilitation services were poorly developed. The nihilism of Hughlings Jackson, the father of British neurology – encapsulated in his observation that 'You can't treat a hole in the brain' – summarised the prevailing attitude. The physiotherapy these patients received was often misguided, having an orthopaedic bias, as Sue Raine notes in her contribution: massage, heat, passive and active movement techniques such as the use of pulleys, suspension and weights. The results were dreadful: stroke patients routinely ended up with severe flexion of the upper limbs (with the fingers curled over so tightly that hygiene was almost impossible), extension of the lower limbs and foot drop, so that walking was a perilous business – requiring circumduction at the hip – and not infrequently, the chronic misery of severe shoulder pain. Inappropriate splints and walking aids added to the demoralisation of the patient.

As a junior doctor, I assumed that this wretched state of affairs was an inevitable consequence of stroke. It was not until the Bobath revolution started to gain a foothold in the UK that I began to see that things might be otherwise. At the heart of the revolution was, as the title of this book indicates, a concept. And at the heart of this concept was an understanding that if you are going to promote recovery and independence, then you must (to use Geoffrey Kidd's phrase) 'talk to the nervous system in a language it understands'. At any rate, it meant an approach that was remote from the 'orthopaedic' strategy that had preceded the Bobath approach. This seems common sense now, but for many years this central notion met with incomprehension or scepticism, particularly among non-physiotherapists – including, I have to admit, myself.

Precisely, how one talks to the nervous system in a language it understands is described in practical detail in this superb book, which is a distillation of the expertise of leading neurophysiotherapists who have been central to the application and the development of the Bobath Concept in the UK. In a series of wonderfully lucid chapters, the authors combine a profound knowledge of the underlying neurophysiology of normal and abnormal movements with the insights that come from many years of practical experience. The key to the Bobath approach is understanding where the patient is 'at'. This ranges from assessing the impairment and consequent motor behaviour to determining the patient's expectations, fears, hopes and beliefs.

One of the most important aspects of the Bobath Concept is acknowledging the crucial role, in the case of upper motor lesions, of loss of inhibitory control and consequent spasticity. The possibility of influencing increased tone through afferent input led to the notion of 'reflex inhibiting postures' and less static 'reflex inhibiting patterns'. Connected with this was the suggestion that the main problem in patients was not muscle weakness but abnormal coordination of movement patterns and abnormal (usually increased) tone. This is part of a systems approach to motor control, which goes through the Bobath Concept like 'Brighton Rock' through Brighton Rock, although this has evolved radically, as will be discussed presently.

The beneficent influence of the Bobath Concept goes beyond particular techniques. If the key to neurological rehabilitation is 'talking to the nervous system in a language it understands', then it is not sufficient for the patient to receive a few bouts of physiotherapy – say, an hour a day on weekdays and nothing at the weekend – and then be treated in a way that will undo the effects of skilled hands on care. Rehabilitation should be 24 hours a day and it should therefore be a team effort: under the direction of the skilled interdisciplinary team, motor recovery is promoted continuously and consistently. The Bobath Concept, what is more, has helped to remind us that the patient requiring neurorehabilitation is not just a nervous system in a cranium and a spine but a person in, and trying to cope with, and make sense of, a complex world.

The complexity and richness of the Bobath concept is evident in the present volume. The history and theory of the concept is set out clearly by Sue Raine in the opening chapter, which makes important connections with current notions of the plasticity of the brain. Linzi Meadows and Jenny Williams focus on functional movement, teasing apart the elements that are required for efficient movement: postural control, balance strategies, patterns of movement and the determinants of muscle strength, endurance, speed and accuracy. Paul Johnson analyses a skill central to the science, art and craft of physiotherapy: assessment and clinical reasoning. The interaction between assessment and treatment ensures the continuous revision of the treatment plan in the light of the response and the evolution of the patient's condition. Evaluation is a central feature of true professionalism.

This topic is covered by Helen Lindfield and Debbie Strang in their chapter. Their thoughtful discussion of outcome measures is itself a measure of the commitment of Bobath therapists to looking critically at the effects of their treatments.

Subsequent chapters on progressing from sitting to standing and on the control of locomotion reveal the power of the Bobath approach in analysing the building blocks not only of efficient movement but, more broadly, of efficient activity and independent life. The case studies are, as one might expect, illuminating and instructive. Here, as elsewhere in the book, the real challenges of the real world are present. The chapter devoted to the recovery of upper limb function is an inspiring reminder of the reasons why we no longer see the appalling upper limb outcomes that I referred to at the beginning of this foreword. The final chapter – on the 24-hour approach of the Bobath Concept – underlines one of the distinctive contributions that the British Bobath Tutors Association (BBTA) has made to the entire rehabilitation process.

All intellectual revolutions run the danger, once they are established practice, of becoming as dogmatic as the practice and theory they revolted against, and Bobath Concept, for a while, looked like being no exception. That which was once progressive seemed like erecting a barrier to further progress, with the initial insights and hypotheses of the Bobaths being regarded as unassailable truths. A case in point relates to the veto against muscle-strengthening exercises, on the grounds that they might increase spasticity (and hence reduce function) and that muscle strength was less important than tone and higher aspects of integrated movement. Subsequent research carried out in the 1990s showed that not only did muscle-strengthening exercises not increase spasticity but also they appeared to have a beneficial effect.

It is probably because the Bobath approach attracted the most gifted practitioners, with the most critical minds and with the strongest commitment to improving neurorehabilitation, that this period of dogma was short-lived. Under the leadership of neurophysiotherapists such as Mary Lynch-Ellerington, FCSP, BBTA have encouraged a rethink of the Bobath Concept – without undermining the fundamental insight and vision – and encouraged an evidenced-based approach to the rehabilitation of neurologically damaged patients. As Karel Bobath himself pointed out, ‘the Bobath Concept is unfinished, we hope it will continue to grow and develop in years to come’. It is now recognised that postural weakness and the loss of feed-forward control in respect of anticipatory postural adjustments is the primary source of impairments, and the so-called hypertonicity that was central to the Bobaths’ thinking is now seen to be a reaction associated with trying to function against a background of a loss of postural control and voluntary movement. The role of neural and non-neural components of adverse muscle tension is also recognised and treated specifically. This is consistent with the BBTA vision of seeing the patient as someone who has individual problems and who needs ‘activating’.

The evolution of the Bobath Concept is brilliantly captured in this volume. The recognition that the best inhibition may come from engaging the patient in normal activities is an example of the way one of the notions central to the original Bobath Concept has developed. In short, the Bobath Concept lies at the heart of an approach to neurorehabilitation that is ready to take advantage of the rapidly advancing understanding – coming from neuroscience, of brain function, in particular – of the effects of and responses to damage and the factors that may drive recovery. It is no coincidence that neuroplasticity figures so prominently in the pages that follow.

While many researchers – including myself – have in the past criticised the Bobaths for seeming to establish a school, in a state of rivalry with other schools, such as those of Carr and Shepherd and of Rood, with advocacy taking the place of evidence, this is certainly no longer true. There is an open-minded willingness to document what is done with patients and to evaluate outcomes using appropriate tools. And this is not altogether surprising: the Bobath Concept itself was a key stimulus to the transition from intuition-based empirical approaches to the increasingly neuroscience-based therapies that are now emerging, and which Bobath practitioners are incorporating into their work with patients. The fact that neurological rehabilitation is now firmly located as the top table in medicine – signalled by a report from the Academy of Medical Sciences *Restoring Neurological Function. Putting the Neurosciences to Work in Neurorehabilitation* (2004) – owes much to the advocacy of the Bobath movement. Meanwhile, the fundamental ethos of Bobath – the patient as partner, rehabilitation tailored to the patient's current situation, and rehabilitation as a 24/7 activity rather than being confined to discrete sessions – remain in place. For physiotherapy, however scientifically based it becomes, will always be in addition an art, a craft and an expression of the therapist's humanity, addressed to the patient as a whole human being.

The great German philosopher Frederick Nietzsche said that 'one ill rewards a teacher if one remains always a pupil'. For this reason, the Bobaths, the teachers of a generation of therapists, will be well pleased with what their pupils and the pupils of their pupils have made of the Bobath Concept, taking it to new places, giving it a different emphasis. This book is a landmark, as important as Berta Bobath's seminal text. Contemporary therapists – from students to senior practitioners – will find it an invaluable guide and an inspiring example. The book will doubtless run into many editions as its influence on practice will lead to progressive improvement in the way physiotherapists approach the complex needs of patients who suffer the devastating blow of serious neurological injury. The editors and authors deserve our congratulations and thanks. *The Bobath Concept* should be to hand wherever neurological rehabilitation is practised.

Emeritus Professor Raymond Tallis,
BM, BCh, BA, FRCP, FMedSci, LittD, DLitt, FRSA

Preface

The British Bobath Tutors Association (BBTA) is an organisation of expert clinicians within the UK who specialise in the assessment and treatment of adults with neurological impairments utilising the Bobath Concept. All BBTA members maintain their clinical skills by working directly with patients in either the public or private sector. The primary responsibility of BBTA is to disseminate the current understanding and practice of the Bobath Concept to qualified physiotherapists and occupational therapists on postgraduate courses and to support the training process of new tutors.

BBTA is a member organisation of the International Bobath Instructors Training Association (IBITA) and has strong links worldwide. Members of BBTA provide education and training to therapists both within the UK and abroad.

The theoretical basis and application of the Bobath Concept has continued to develop with considerable growth in knowledge areas such as neuroscience, neuromuscular plasticity, motor control and motor learning. Although fundamentally the concept has the same core principles, its application has evolved in line with current evidence. For many years, the developments within the Bobath Concept have been disseminated through introductory, basic and advanced Bobath courses. These courses facilitate clinical reasoning and its application, based upon an understanding of efficient functional movement, the systems control of movement and the principles of motor learning. Individuals with neurological pathology take part in the courses and contribute to the educational experience.

The popularity of the courses has continued to grow and therapists often ask whether there is a textbook they can refer to in order to support their learning. It is with this in mind that this book has been written, so that it can be a reference for therapists to develop a deeper insight into the clinical application of the Bobath Concept.

This book is intended to provide both undergraduate and postgraduate health professionals with many of the elements felt to be important in understanding the clinical reasoning process used in the application of the Bobath Concept. The book is structured in such a way that the first four chapters guide the reader in gaining an understanding of the current theory before moving to the application of the Bobath Concept into clinical practice. From this foundation, Chapters 5–7 consider the application in depth, with clinical examples in the areas of moving between sitting and standing, control of locomotion and the recovery of function of the upper limb. Chapter 8 considers the 24-hour approach of the Bobath Concept to neurorehabilitation and the need for exploring partnerships in the rehabilitation setting.

The aim of this book is to provide the therapist with an understanding and ability to apply the principles of the contemporary Bobath Concept and to promote and enable greater clinical effectiveness and to optimise the functional outcome for all patients in the area of neurorehabilitation. The primary objective is to improve the quality of life of all the patients we treat.

Contributors

Sue Raine is the Clinical Lead Physiotherapist at Walkergate Park for Neurorehabilitation and Neuropsychiatry and a Bobath Tutor.

Linzi Meadows is a Clinical Director of the Manchester Neurotherapy Centre and Neurological Teaching Centre and an Advanced Bobath Tutor.

Jenny Williams is a Senior Physiotherapist at the Stroke and Head Injury Clinic in Warrington and a Bobath Tutor.

Paul Johnson is a Clinical Lead Physiotherapist in Neurology at Gateshead Health NHS Foundation Trust and a Bobath Tutor.

Helen Lindfield is Principal Physiotherapist at the Wolfson Rehabilitation Centre, Wimbledon and a Bobath Tutor.

Debbie Strang is a Team Lead Physiotherapist at Hairmyers Hospital, Glasgow and a Bobath Tutor.

Lynne Fletcher is a Clinical Director of the Manchester Neurotherapy Centre and Neurological Teaching Centre and an Advanced Bobath Tutor.

Catherine Cornall is a Physiotherapy Clinical Specialist at the National Rehabilitation Hospital, Dun Laoghaire, Ireland and a Bobath Tutor.

Sue Armstrong is a Clinical Specialist for Gwent NHS Trust and a Bobath Tutor.

Ann Holland is a Clinical Specialist (Physiotherapy) at the National Hospital for Neurology and Neurosurgery at Queens Square, London and a Bobath Tutor.

Mary Lynch-Ellerington is a Fellow of the Chartered Society of Physiotherapy and a Senior Bobath Instructor.

Janice Champion is a Specialist Clinician at Medway Maritime Hospital, Gillingham, Kent and a Bobath Tutor.

Christine Barber is the Director of Therapy Services at the Bobath Centre for Children with Cerebral Palsy and Adults with Neurological Disability and a Bobath Tutor.

Clare Fraser is a Team Leader in Neurological Physiotherapy at the Wirral University Teaching Hospital NHS Foundation Trust and a Bobath Tutor.

Acknowledgements

Our very deep gratitude goes to our colleagues in BBTA, Alan Bass, Anna Hamer and Pam Mulholland, who so willingly gave their time, to proofread all of the chapters and offer professional advice and support.

For their contribution to Chapter 3 we thank Ann Holland and Liz Mackay, and for Chapter 7 we thank Lynne Fletcher. For data collection and analysis with Chapter 6 we thank Professor Jon Marsden and Dr Gita Ramdharry. For the generous use of his diagrams we thank Dr Nigel Lawes. For reading and reviewing so constructively we thank Professor Michael Barnes. We feel privileged to have had Professor Raymond Tallis write the foreword of this book.

For her support throughout we thank Carol Morrison our secretary at BBTA. Our very special thanks are owed to the patients and their families who have kindly allowed their case histories and aspects of their clinical treatment to form such a major part of this book.

1. *The Bobath Concept: Developments and Current Theoretical Underpinning*

Sue Raine

Introduction

There are a number of neurological approaches used in the management of the patient following a neurological deficit. The Bobath Concept is one of the most commonly used of these approaches (Davidson & Walters 2000; Lennon 2003), and it offers therapists working in the field of neurological rehabilitation a framework for their clinical interventions (Raine 2006). This chapter will provide the reader with an overview of the Bobath Concept including the founders of the approach and its inception, the theoretical underpinning and its application into clinical practice.

The founders and development of the Bobath Concept

Karel Bobath was born in Berlin, Germany in 1906, and trained there as a medical doctor, graduating in 1936. Berta Ottilie Busse was also born in Berlin, in 1907. Her early training was as a remedial gymnast, where she developed her understanding of normal movement, exercise and relaxation (Schleichkorn 1992). They both fled Berlin in 1938 just before the Second World War. In London Mrs Bobath trained as a physiotherapist, graduating from the Chartered Society of Physiotherapy in 1950 (Schleichkorn 1992). Dr Bobath started his career working in paediatrics and later more specifically with children with cerebral palsy (Schleichkorn 1992).

Prior to the 1950s, conventional neurological rehabilitation had a strong orthopaedic bias, and promoted the use of massage, heat, passive and active movement techniques such as the use of pulleys, suspension and weights (Partridge et al. 1997). Splints and walking aids such as calipers and tripods were provided to enable the patient to function. Stroke sufferers at that time presented with the same stereotypical spastic patterning, with flexion of the upper limb and extension of the lower limb (Bobath 1970). The hemiparetic upper limb, a non-functional appendage, and the lower limb acting as a prop during ambulation.

In 1943 Mrs Bobath was asked to treat a famous portrait painter, who had suffered a stroke and was unhappy with conventional treatment (Schleichkorn 1992). Mrs Bobath focused her treatment on the affected side, basing her interventions on her knowledge of human movement and relaxation. She observed that with specific handling, tone was changeable and that there was potential for the recovery of movement and functional use of the affected side. Mrs Bobath continued to explore and further develop these early observations and techniques into principles of treatment. Mrs Bobath developed an assessment procedure that was unique and of great significance to the advancement of the physiotherapy profession, as it moved away from the medical prescription. Working in partnership with Mrs Bobath, Dr Bobath studied and applied the available neurophysiology at that time, to provide a rational explanation for the clinical success.

Together they created the Bobath Concept, a revolutionary approach which has continued to develop and help change the direction of neurorehabilitation. They described the Concept as hypothetical in nature, based on clinical observations, confirmed and strengthened by the available research (Schleichkorn 1992).

The neurophysiology available to Dr Bobath during the early years was based on animal experimentation (Bobath 1970). The evidence supported a hierarchical model with the emphasis on descending control from the cortex to the primitively organised spinal cord. The complexity of the nervous system was defined in terms of size and number of connections and was seen as being a number of hard-wired tracts with electrical activity running through them. Movement was thought to be elicited through the stimulation of reflexes in the spinal cord, with the primitive reflex patterning seen at birth refined during maturation, through inhibition from higher centres. Lesions to the pyramidal tract were found to produce a loss of inhibitory control and therefore contralateral spastic hemiplegia. Inhibition was therefore seen by Mrs Bobath as important in adapting motor behaviour, and her early clinical interventions demonstrated that it was possible to influence tone through afferent input (Bobath 1970, 1978). This led to the development of 'reflex inhibiting postures' and later the less static 'reflex inhibiting patterns', which used rotational movement components to fractionate the stereotypical patterns (Bobath 1990). Although the nervous system was thought to be irreparable, Mrs Bobath found changes in clinical presentation that demonstrated modification of the nervous system.

Mrs Bobath described, in 1990, that the main problem seen in patients was abnormal coordination of movement patterns combined with abnormal tonus, and that strength and activity of individual muscles were of secondary importance (Bobath 1990). Assessment and treatment of motor patterns was seen as key to functional use. Reflex inhibiting postures were discarded for greater emphasis on movement and function, with the patient taking an active role in their treatment. The best inhibition was seen as the patient's own activity (Mayston 1992). The emphasis in treatment was on normalising tone and facilitating automatic and volitional movement through specific handling. Mrs Bobath felt it was important that treatment was not a structured set of exercises to be prescribed to all patients, but a wide variety of techniques that could be adapted and flexible to meet the individual's changing needs (Schleichkorn 1992). Mrs Bobath advocated a 24-hour, holistic approach which involved the whole patient, their sensory, perceptual and adaptive behaviour as well as their motor problems (Bobath 1990). Although preparation was seen to be important, Mrs Bobath stressed that it had to directly translate into function.

The Bobath Concept was not exclusive but could be applied to all patients with a disorder of motor control, regardless of how severe their cognitive or physical deficits might be.

The Bobath Concept continued to develop throughout Dr and Mrs Bobath's lifetime. In 1984 the Bobaths founded the International Bobath Instructors Training Association (IBITA 2007), an organisation that maintains the standards of teaching and developments of the Bobath Concept worldwide. Mrs Bobath stated that each therapist works differently according to their experiences and personality, but all can build treatment upon the same Concept (Schleichkorn 1992). Dr Bobath stated 'the Bobath Concept is unfinished, we hope it will continue to grow and develop in years to come' (Scheichkorn 1992; Raine 2006).

In conjunction with the growth of knowledge in areas of neuroscience and the evaluation of clinical practice, there have been ongoing developments in both the theoretical underpinning of the Bobath Concept and its clinical application (Raine 2007; Gjelsvik 2008).

Current theory underpinning the Bobath Concept

Advances in clinical techniques and technical resources over the last decade have provided therapists with increased evidence in the fields of neuroscience, biomechanics and motor learning (Royal College of Physicians 2004). These developments deepen the understanding of human movement and the impact of pathology, helping to guide therapists in their clinical interventions to maximise the patient's functional outcome. There is strong evidence to support the effect of rehabilitation in terms of improved functional independence and reduced mortality (Royal College of Physicians 2004); however, there has been insufficient evidence to identify if any one therapy approach is better than another. Research that has been designed to evaluate effectiveness of individual neurorehabilitation approaches has been fraught with methodological difficulties (Paci 2003; Luke et al. 2004).

The contemporary Bobath Concept is a problem-solving approach to the assessment and treatment of individuals with disturbances of function, movement and postural control due to a lesion of the central nervous system (CNS), and can be applied to individuals of all ages and all degrees of physical and functional disability (Raine 2006; IBITA 2007). The theory underpinning the Bobath Concept considers an approach to motor control that encompasses not only important key features about the individual but also how they interact in the world around them. The ability of the individual to plastically adapt and learn from new challenges enabling them to refine their motor behaviour is the basis by which patients have the potential to recover following injury. Motor learning theories provide the principles that guide and enhance the physiological modifications which support refinements in movement to change functional performance over time. In order to optimise motor learning and recovery in patients with neurological dysfunction, it is essential to have an understanding of how a lesion of the upper motor neuron (UMN) will impact on the individual and their motor control.

Systems approach to motor control

The systems approach to motor control provides the foundation of the current theoretical underpinning of the Bobath Concept (Raine 2006). The systems theory is based on the work of Bernstein (1967). Bernstein recognised that it was important to have an understanding of the characteristics of the movement system, and the external and internal forces acting on the body, in order to develop an understanding of the neural control of movement. From a biomechanical viewpoint, he considered the many degrees of freedom provided by the numerous joints within the body and the control needed to enable them to work together as a functional unit.

Bernstein considered the control of integrated movement to be distributed throughout many interacting systems working cooperatively. He stated that 'coordination of movement is the process of mastering the redundant degrees of freedom of the moving organism', recognising the importance of stability and control in movement. He described how muscles could work in synergies to help solve this movement problem, such as in postural control and locomotion.

Shumway-Cook and Woollacott (2007) expand Bernstein's theory to describe the systems approach, emphasising like Mrs Bobath, that human motor behaviour is based upon a continuous interaction between the individual, the task and the environment. They describe movement as resulting from a dynamic interplay between perception, cognition and action systems, and highlight the CNS's ability to receive, integrate and respond to the environment to achieve a motor goal (Brooks 1986). Many systems and subsystems work cooperatively for the integration of movement into function. They work both hierarchically by means of ascending pathways and through parallel distributed processing where many brain structures are processing the same information simultaneously (Kandel et al. 2000). The nervous system uses a shifting focus of control depending on many biomechanical, neuroanatomical and environmental influences.

It is the systems approach theory to motor control which forms the foundation for the underlying principles of assessment and treatment encompassed within the contemporary Bobath Concept (Raine 2007). The Concept considers that motor control is based on a nervous system working with both hierarchical and parallel distributive, multi-level processing amongst many systems and subsystems involving multiple inputs, and with modulation on a number of levels within this processing. It sees the potential for plasticity as the basis of development, learning and recovery within the nervous and muscular systems.

Plasticity

Neuroplasticity

The plasticity of a structure is its ability to show modification or change. Motor learning is the permanent change in an individual's motor performance brought about as a result of practice (Wishart et al. 2000; Lehto et al. 2001). The structures undergoing modification which need to be considered during motor learning are neural plasticity and muscular plasticity. The capacity of the nervous system to change is demonstrated in children during the development of neural circuits, and in the adult brain, during the learning of new skills, establishment of new memories, and by responding to injury throughout life (Purves et al. 2004).

Modification in neural function in maturity appears to rely primarily on carefully regulated changes in the strength of existing synapses (Kandel et al. 2000). Learning an activity is synapse and circuit specific, and can be modified with synaptic transmission being either facilitated (strengthened) or depressed (weakened). These short-term changes in the efficacy of synapse transmission are due to modification of existing synaptic proteins which may last up to a minute (Purves et al. 2001; Calford 2002). For motor learning to occur these short-term changes need to be reinforced to promote more significant cellular and molecular modifications (Calford 2002).

Changes lasting days, weeks, months and even years, demonstrating carry-over in a motor performance and learning, require the synthesis of new proteins and changes in gene expression, which directs change in synaptic circuitry and localised formation of new axon terminals and dendritic processes. These structural modifications can strengthen the synapse by long-term potentiation or can weaken the synapse by long-term depression (Calford 2002). It is the strengthening of some synapses, and circuits, over others which enables refinement of a motor skill or performance to allow carry-over from one day to the next.

The nervous system and neuromuscular system can adapt and change their structural organisation in response to both intrinsic and extrinsic information. The manipulation of this information can directly effect a change in the structural organisation of the nervous system through spatial and temporal summation and the facilitation of pre- and post-synaptic inhibition. If two or more stimuli are presented and then reinforced together, associative learning can occur. This enables relationships in stimuli to be predicted and can link two aspects of motor behaviour occurring at the same time, such as hip and knee extension through stance phase in gait. Neuronal cortical connections are strengthened and remodelled by our experiences; this means that 'neurons that fire together, wire together' and promote motor learning (Hebb 1949; Johansson 2003). There is a direct relationship between the neural molecular form and functional performance (Kidd et al. 1992). The nervous system is continually undergoing modification based upon its experiences, and it is these modifications which then support its role in achieving efficient and effective functional goals in a variety of environments.

Neuroplastic changes following injury

Any acquired brain injury will result in subsequent neuronal cell death, interruption of their axonal projections and potential cascade of degeneration to communicating neurons (diaschesis) (Cohen 1999; Enager 2004). The impact the lesion has on motor control and function will depend upon the location and the size of the lesion. The model of neuroplasticity provides evidence that the brain will respond to injury by reorganisation and adaptation aimed at restoring function (Stephenson 1993; Nudo 2007). There are three neuroplastic phenomena that occur in the nervous system following a lesion which facilitate structural and functional reorganisation (Bishop 1982; Kidd et al. 1992). These include denervation supersensitivity, collateral sprouting and unmasking of silent (latent) synapses.

Denervation supersensitivity occurs when there is a loss of input from other brain regions. An increased release of transmitter substance causes a heightened response to stimulation (Wainberg 1988; Schwartzkroin 2001). Post-synaptic target neurons become hypersensitive to the transmitter substance, increasing the number of receptor sites. Collateral sprouting appears in cells around the lesion, where collateral dendrites make connections with those synapses lost by cell necrosis (Darian-Smith & Gilbert 1994). Unmasking of silent synapses occurs when previous non-functioning neurons are accessed to form new connections (Nudo 1998; Johansson 2000). There has been increasing work demonstrating regeneration within the nervous system (Nudo 1998; Johansson 2000). Changes within the structure of the nervous system can be organised or disorganised producing adaptive or maladaptive sensorimotor behaviour, which can promote or be detrimental to recovery (Nudo & Friel 1999; Nudo 2007).

Cortical plasticity

Cortical representation areas have been found to be modified by sensory input, experience and learning, as well as in response to brain injury (Bruehlmeier et al. 1998; Nudo 2007).

Cortical changes following injury include the loss of specific sensorimotor functional representation with direct physical and functional consequences. Although not totally reversible, there have been numerous findings demonstrating cortical plasticity and remapping following a cortical lesion. Where representation of an area has not totally been lost, the representation of the peri-infarct tissue and areas in axonal communication with the lesioned area, through axonal sprouting, have been found to take on representation and therefore function of the lesioned area (Rapisarda et al. 1996; Cramer et al. 1997). Reorganisation has been seen in areas of the visual cortex which becomes associated with tactile tasks in blind subjects who read Braille (Sadato et al. 2004).

Changes seen following peripheral lesions are based on the cortical response to changing input which can either be upgraded or downgraded, such as remapping in subjects following amputation or selective anaesthesia, where there is a reduced representation of the affected area and an increase of representation of adjacent areas within the cortex (Merzenich & Jenkins 1993; Yang et al. 1994). The Bobath Concept explores this potential for cortical reorganisation through selective afferent input to optimise internal representation and influence movement control. Selective motor training or manipulation of the task, environment, or aspects of the individual as part of movement re-education also aims to promote plastic changes. This has been seen in the cortical representation of the left hand, in a left handed string instrument player which when scanned shows greater cortical representation compared with the left hand of a non-string player (Elbert et al. 1995). Enriched environments giving subjects greater than normal stimulation have been shown, at the right time, to promote significant neuroplastic changes and improvement in functional outcomes (Ohlsson & Johansson 1995; Johansson 1996).

Emergent properties of each cortical area are constantly shaped by behavioural demands, driven largely by repetition and temporal coincidence (Nudo 2007). Bernstein (1967) describes the importance of not just repetition, but 'varied' repetition. Such repetition drives motor cortical areas to form discrete modules in which the conjoint activity is represented as a unit, rather than fractionated and individual muscle contractions (Nudo 1998). Skilled motor activities requiring precise temporal coordination of muscles and joints must be practised many times over and applied into everyday meaningful activities for optimal carry-over. Bayona et al. (2005) describe the consequence of the motor system as 'use it or lose it'. In the somatosensory system of the brain it is 'stimulate it or lose it'. Both are essential considerations in the Bobath Concept.

Muscle plasticity

Like neuroplasticity, the adaptability of muscle has been investigated extensively. Skeletal muscle is one of the most plastic tissues in the human body (Kidd et al. 1992; Lieber 2002). Virtually every structural aspect of muscle, such as its architecture, gene expression, fibre type distribution, number and distribution of alpha motor units and motor end plates, number of sarcomeres, myosin heavy chain profile, fibre length, mitochondrial distribution, tendon length, capillary density and muscle mass, has the potential for change with the appropriate stimulus (Dietz 1992; Pette 1998; Mercier et al. 1999; Lieber 2002). Skeletal muscle can be either conditioned or deconditioned depending upon the demands put on the muscle, and these can influence properties such as strength, speed and endurance of the muscle. The range of muscle fibre types allows for the diverse role and function of muscle needed to support human movement (Scott et al. 2001). It is the adaptability of the proteins and the design of sarcomeres and myofibrils which provides the basis for the modelling and remodelling of a large spectrum of fibre types to match the specific requirements and altered functional demands (Pette 1998). Muscle fibre phenotype is driven by neural activity and mechanical factors, a combination of stretch and activity (Goldspink 1999).

Studies have shown that with an increased demand there is a shift from fast to slow fibre types, an increase in size and number of mitochondria and an increase of the capillary density with an overall hypertrophy of the muscle (Mercier et al. 1999; Lieber 2002). With reduced demands or disuse there is muscle wasting due to decreased protein synthesis. This atrophy is more rapid in slow oxidative, postural and biaxial muscles with a slow to fast shift in fibre type and a reduction in the capillary density (Mercier et al. 1999; Lieber 2002). Inactivity in a shortened position results in an increase in connective tissue, an increase in stiffness and resistance to passive stretch (Williams & Goldspink 1973). Muscles immobilised in a shortened position have been found to lose sarcomeres, with the remaining sarcomeres increasing in length to maximise tension in this shortened position (Grossman et al. 1982).

Neurological lesions and the resultant neuroplastic changes have a significant impact on the demands placed upon muscle. Early stages show an inability to achieve the execution of a voluntary command and leave the muscle in a position of inactivity and immobility (Gracies 2001). Muscles may receive an increase or loss of drive to the alpha motor neuron and its motor end plate, which will lead to a complex combination of conditioning and deconditioning. Where hypertonic muscles are immobilised in a shortened position the potential for a contracture develops with muscle atrophy, loss of sarcomeres, failure of actin and myosin cross-bridges to disengage, and accumulation of connective tissue (Watkins 1999; Gracies 2001). It has been found that even in the case of increased drive, however, muscles have been found to weaken due to insufficient motor unit synchronisation and decreased torque generated by the muscle (Gracies, 2001). Muscle imbalance in compliance, length and strength will all influence coordination for selective movement control. The main length associated changes interfering with function have been identified as a decrease in muscle length and an increase in muscle stiffness, and it is these secondary musculoskeletal complications that are associated with poor functional outcome (Ada et al. 2000).

Andrews and Bohannon (2000) identified that it is not only the hemiparetic side that presents with muscle changes but that the non-hemiparetic side also presents with muscle weakness compared to normal subjects. This highlights the significance of learned non-use in both hemiparetic and non-hemiparetic sides and highlights further the need for an individualised, holistic approach to the treatment of patients with neurological dysfunction (Hachisuka et al. 1997).

Kandel et al. (2000) describe plasticity as the potential that endows each of us with our individuality. It is the ability of the CNS to be manipulated and restructured, which is the key to successful therapy (Stephenson 1993; Schaechter 2004), and it is this neuroplasticity that is the primary rationale for treatment intervention in the Bobath Concept (Raine 2007).

Motor learning

Motor learning refers to the permanent change in an individual's motor performance brought about as a result of practice or intervention (Wishart et al. 2000; Lehto et al. 2001). Motor learning principles help identify how we can best manipulate the individual, the task and the environment to influence long-term neuroplastic changes to promote an individual's motor performance.

There are a number of stages that are necessary in learning a new skill. The stages describe a progression through cognitive to automatic levels whereby the performance is refined and shows carry-over of learning (Wishart et al. 2000; Halsband & Lange 2006). This process demonstrates the developments in cortical representation for the learning of the new skill. Motor learning theories suggest that active participation, practice and meaningful goals are all essential for learning (Schmidt 1991; Winstein et al. 1997). Taub (1993) and Winstein et al. (1997)

agree that practice is fundamental for motor learning and improving skill in both healthy and movement-impaired individuals.

There are numerous variables that are considered to be important determinants in motor learning which have been investigated using healthy individuals learning novel motor skills (Winstein 1991; Marley et al. 2001; Ezekiel et al. 2001; Lehto et al. 2001). These include:

- practice (amount, variability, contextual interference [order of repetitions such as blocked or random]);
- part or whole task;
- augmented feedback (frequency, timing, bandwidth [level of performance to be reached before feedback provided]);
- mental practice;
- modelling;
- guidance;
- attentional focus (goal attainment) and contextual variety.

One of the key features that needs consideration in all aspects of practice is to ensure a situation is created that allows the individual to engage in a problem-solving process to enable them to achieve the task (Marley et al. 2001). It has been found that the more practise the better (Sterr & Freivogel 2003).

Varied conditions and random practice are more effective for motor learning (carry-over in performance), whereas static conditions and blocked practice are more effective for improvements in the immediate motor performance (Wishart et al. 2000; Marley et al. 2001). Part and whole task practice benefits are dependent upon the task to be learned. Whole task practice is suggested when tasks are continuous (reach and grasp) or reciprocal (walking) in nature (Dean & Shepherd 1997). Part tasks are useful when an activity can be broken down into a number of separate discrete tasks. Augmented feedback shares information about the characteristics (knowledge of the performance) or the outcome (knowledge of the results) of the movement. Although performance may be improved with continuous feedback, motor learning has been shown to be better with infrequent feedback and/or summary of results (Saladin et al. 1994). Feedback provided once a set level of failure has been passed (bandwidth) has also been found to be beneficial for learning (Ezekiel et al. 2001). Feedback is also important in motivating the individual which is seen as essential in the rehabilitation process.

Mental practice, defined as the rehearsal of a task without overt physical activity, has shown a positive learning effect, especially when used in conjunction with physical practice. It can be useful when there are limitations in the amount of time or energy for engagement in activity, or when physical practice outside the therapy session would be hazardous or detrimental to the rehabilitation process (Lehto et al. 2001).

Physical demonstration of the task (modelling) and activities designed around meaningful goal-directed tasks have been found to be beneficial (Wulf et al. 1999). Without context of a task, movement patterns may exist but they will be devoid of strategies (Majsak 1996). The task is essential in providing context and meaning.

It is the task and the movement strategy that will determine and organise the movement patterns the individual selects. It has been found that excessive guidance or physical devices offering continuous restraint, directing movement reduces the need for problem-solving and does not improve learning (Ezekiel et al. 2001). Guidance must be selective, graded and must challenge the individual to problem-solve their movement difficulties.

Motor learning principles need to be taken into consideration with all patients. They need to be chosen and facilitated appropriately to enable the individual to be actively involved in finding solutions for their motor problems. Motor learning is often demonstrated not just by increased precision in the acquisition of the motor performance but the variability with which the individual is able to achieve the activity (Majsak 1996). The importance of giving the individual movement choices or diversity in movement strategies will also enable them to transfer their skills to numerous tasks and environments. Opportunities need to be made where the individual is problem-solving and error correcting their own movement in preparation for the transfer of skills and application of skills for achievement of meaningful motor activities.

Following stroke, the individual will present with a number of musculoskeletal (biomechanical), neuromuscular, sensory-perceptual and cognitive constraints which may limit or challenge the potential for the achievement of motor learning in certain motor skills. Preparing the individual's musculoskeletal and sensory systems may be necessary for the optimal integration of cognitive processing to enable efficient and effective goal attainment. There needs to be a balance between the amount of time in preparation and the amount of time used in selective part or whole task practice. Interactions between the constraints of the individual, the environment and the task are complex and continuous (Majsak 1996).

Upper motor neuron syndrome

Following a brain injury an individual will often have a complex presentation impacting not only on the neuromuscular system but also on the musculoskeletal, sensory-perceptual and cognitive systems (Cohen 1999). The upper motor neurone (UMN) syndrome encompasses all the dyscontrol characteristics associated with a lesion affecting some or all of the descending motor pathways (Barnes 2001). The features of an UMN syndrome have been divided into two broad groups. The negative phenomena of the syndrome are characterised by a reduction in motor activity (weakness, loss of dexterity, fatigueability), whereas the positive phenomena are associated with symptoms that demonstrate an increase in motor activity (spasticity, clonus, associated reactions) (Barnes 2001; Sheean 2001). The negative features are often more disabling than the positive features. Adaptive or mechanical features must also be acknowledged, and take into consideration the resultant changes on the neural system, muscle and soft tissue (Carr & Shepherd 1998).

Hypertonicity is a combination of disinhibition (neural changes), plastic reorganisation and mechanical changes (Raine 2007). Spasticity is the neural component of hypertonia and is velocity dependent, which means that the faster the muscle is stretched the greater the resistance that is felt (Lance 1980). The resistance associated with spasticity not only makes movements more difficult, but causes the muscle to remain in a shortened position leading to further hypertonicity and adaptive shortening (Grossman et al. 1982; O'Dwyer et al. 1996). The significance of hypertonia varies considerably from individual to individual and so does its impact. Spasticity is difficult to quantify and is not universally understood to be the same by everyone (Raine 2007). The most current definition, however, relates well to the clinical setting; spasticity is 'disordered sensory-motor control, resulting from an UMN lesion, presenting as intermittent or sustained involuntary activation of muscles' (Pandyan et al. 2005). Associated reactions are another positive feature which can lead to adaptive muscle shortening. Walshe (1923) described associated reactions as postural reactions in muscle deprived of voluntary control that is tonic in nature. They are abnormal, involuntary, stereotyped movement patterns of the affected side and are triggered in many ways (Lennon 1996). They are phasic contractions lacking a background of postural control (Dvir et al. 1996) and interfere with the recovery of function and the ability to perform efficient and effective movement.

There needs to be consideration of the combination of all the features of the UMN syndrome and the resultant impact that these have on the patient. Altered muscle tone, weakness and incoordination, along with adaptive changes in muscle, soft tissue and their alignment, will all impact on the ability to recover efficient movement and will limit function in a patient following stroke. It is often the inability to generate sufficient tone (negative feature) against gravity however, which creates the greatest difficulty for the patient following an UMN lesion. It has been identified that abnormal coordination of movement patterns, poor balance, sensory deficits and abnormal tone are the main physical problems of people with hemiplegia (Raine 2007). It is important to consider weakness not only as a muscular problem following stroke, but as reduced specificity of neuromuscular innervation, with weakness seen both in the trophic and synaptic components of neural activity (Kandel et al. 2000). Although strength of individual muscle groups is less important than their coordination in patterns of activity, strength may still be an issue for efficient movement in some patients, as muscles need sufficient activity to generate force for action and function (Mayston 2001). It is recognised that if the CNS is damaged, it has to compensate. It is the therapist's job to guide the individual's recovery so that they can achieve their maximal functional potential within the constraints of the damaged CNS (Raine 2007). Figure 1.1 shows the integration of the key theoretical areas underpinning the Bobath Concept.

Clinical application of the theory underpinning the Bobath Concept

Motor control

The Bobath Concept involves the whole patient, their sensory, perceptual and adaptive behaviours as well as their motor problems, with treatment tailored to the patient's individual needs (Lennon 1996; Raine 2007). In the Bobath Concept the potential of both patient and therapist is explored as an interactive process. It is

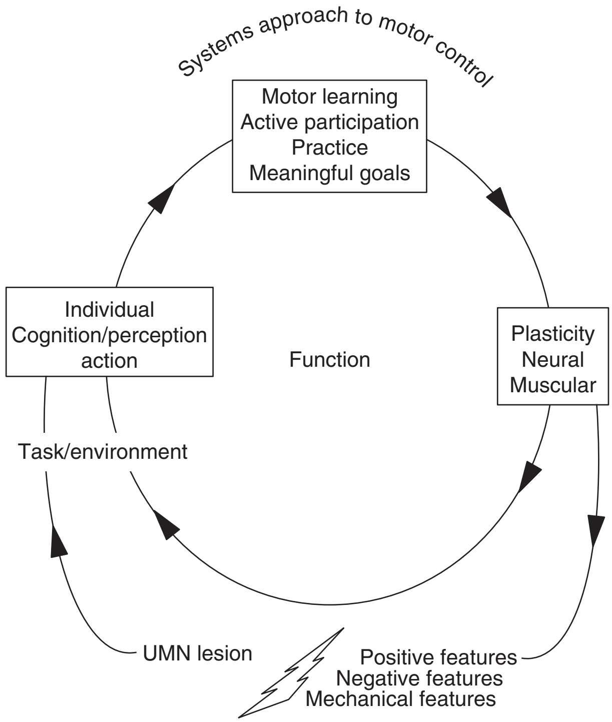


Fig. 1.1 Integration of the key theoretical areas underpinning the Bobath Concept.

essential for therapists to be skilled in movement analysis and have an understanding of the components of human movement. It is the application of knowledge of motor control and human movement, neurophysiology and motor learning which promotes specificity and individuality in assessment and treatment of an individual to optimise function. Each patient is assessed in terms of their lesion, individual movement expression and potential to maximise their movement efficiency. Treatment cannot be predicted, stereotyped or repetitive, as it must continuously adapt to the individual's changing responses (Partridge et al. 1997).

The Bobath Concept is goal orientated and task specific, and seeks to alter and construct both the internal (proprioceptive) and external (exteroceptive) environment in which the nervous system and therefore the individual can function efficiently and effectively (Raine 2007). Treatment is an interaction between therapist and patient where facilitation leads to improved function. The role of the therapist is to both teach movements and make movement possible by utilising the environment and the task appropriately. Treatment is aimed at improving the efficiency of the movement compensation following an UMN lesion. Rehabilitation is a process of learning to regain motor control and should not be the promotion of compensation that can occur naturally as a result of a lesion (Raine 2007). Therapy aims to promote efficiency of movement to the individual's maximum potential rather than normal movement (Raine 2007).

Therapy is an interactive process between individual, task and the environment (Shumway-Cook & Woollacott 2007). The individual is evaluated in terms of total function within changing environments, and the intervention process is individualised to their bio-psycho-social needs (Panturin 2001). Therapy addresses the neuro-muscular system, spinal cord and higher centres to change motor performance, taking into account neuroplasticity, an interactive nervous system, and individual expression of movement (Raine 2007). The Bobath Concept directs treatment to overcome weakness of neural drive after an UMN lesion through selective activation of cutaneous and muscle receptors. Early therapy will reduce secondary loss of cortical tissue and thus enable greater possibilities for recovery (Nudo et al. 1998).

Therapists need to be aware of the principles of motor learning: active participation, opportunities for practice and meaningful goals (Raine 2007). The emphasis in treatment is on active participation of the patient on either an automatic or a volitional basis, or a combination of both. Movements must be 'owned' by the patient and be experienced both with and ultimately without the handling of the therapist (Raine 2007). For learning or relearning to occur there needs to be the opportunity to practise (Mayston 2001). As soon as patients are able to practise aspects of movement with appropriate activity, this is encouraged as part of their rehabilitation programme. The decision to use part or whole task practice is selective and dependent upon both the task and the individual. If efficiency in the motor skill is inadequate, the therapist may look at movement components to improve skill. Repetition is important in the consolidation of motor control, but it does not mean moving in exactly the same way every time; 'repetition without repetition' (Bernstein 1967; Lennon & Ashburn 2000). As part of the rehabilitation process the therapist must consider the 24-hour management of the patient and their way of life (Raine 2007). Patients should be provided with advice and guidance on movement and function, for the periods between therapy sessions, in order to achieve carry-over. Preventative and promotive aspects of therapy need to be addressed on a continual basis, and should take into consideration issues of physical and cardiovascular fitness.

Therapy addresses abnormal, inefficient stereotypical movement patterns that interfere with function (IBITA 2007). Treatment is aimed at preventing the establishment of spasticity and maximising residual function (Cornall 1991). Therapists do not normalise tone but they can influence hypertonia at a non-neural level by influencing muscle length and range (Lennon 2003). Therapists can achieve tone reduction in a number of ways such as mobilisation of muscles and stiff joints, muscle stretch, practice of more normal movement patterns, and through more efficient, less effortful performance of functional tasks (Mayston 2002). Weight bearing can help influence abnormal tone only if the patient is able to adapt and change muscular alignment actively (Raine 2007). Therapists work on tone to improve movement, not to normalise tone for its own sake (Lennon et al. 2001).

Weakness is always underlying the presentation of associated reactions. Patients may use associated reactions as a pathological form of postural fixation when stability cannot be accessed (Lynch-Ellerington 2000). Bobath therapists seek to find the causal effect of associated reactions rather than merely changing the pattern produced by the associated reaction. Associated reactions are changeable and can be used as an indicator of the patient's efficiency of motor control, effort or complexity of movement or anxiety, and can guide the therapist in their clinical decision-making. The aim is to control rather than inhibit associated reactions (Lynch-Ellerington 2000).

A primary concern of the Bobath Concept is the activation of the patient to overcome postural hypotonia. In therapy there is a need to address the problem of an individual's specific ability to create tone against gravity for the necessary postural stability on which selective movement is based (Lynch-Ellerington 1998). If the cause of a movement compensation is the lack of posture and balance, then it is only giving the patient more appropriate control over their posture and balance that will ultimately reduce the presentation of the compensation. There may be many reasons other than just motor problems which can influence posture and balance, such as sensory and perceptual problems. Selective movements of the trunk and limbs, both concentric and eccentric, are interdependent and interactive with a postural control mechanism. Therefore, the recovery of selective movement is a prerequisite for efficient postural control, alignment and function (Raine 2007). Balance in an individual is achieved through improving their orientation and stability in relation to postural control (Mayston 2002). There may be an element of conscious control over muscle tone; however, the aim is for the patient to develop control of their balance and movement on an automatic basis in order to initiate and control functional movements. It is recognised that some movements may have to be cognitive, such as some manipulative activities of the hand or during learning of goal-directed movements. However, an individual who has to think about their balance will be unable to carry out any other activity simultaneously (Leonard 1998). A key aim of treatment intervention is to optimise postural and movement strategies in order to improve efficiency and maximise the patient's ability to interact automatically within their environment.

Sensory systems

Sensory systems provide essential information about both the internal and external environments upon which skilled movement is based and refined. Ultimately, in therapy, the aim is to re-educate the patient's own internal referencing system to provide accurate afferent input, giving the patient the best opportunity to be efficient, specific and have movement choices (Raine 2007). At some stages of skill acquisition, somatosensory referencing may be emphasised over verbal or visual feedback. This change of sensory priority is essential to reduce compensation strategies, such as visual fixation, and challenges the patient to use more appropriate sensory strategies for the task (postural control, balance, stereognosis). Specific stimulation may be necessary to promote localisation of movement, for example fingers, but sensory stimulation on its own is not the whole picture. It has to be combined with active movement (Raine 2007). Voluntary movement is one of the most powerful forms of sensory stimulation on which more refined movement can be built (Leonard 1998).

Musculoskeletal system

Muscles need sufficient activity to generate force for action (Mayston 2001). As part of treatment it is important to create the appropriate length and compliance of both muscle and soft tissues to have sufficient joint range to achieve the required functional movement components. It is also essential to achieve appropriate length for efficient muscle activation (Mayston 2001). Optimising muscle length must incorporate the complex relationship of stability and mobility components for the task (Mayston 2001). To achieve the appropriate muscle balance for function, treatment may require selective and specific strength training (Raine 2007). Body weight and gravity can be used to strengthen muscles as well as appropriate resisted exercises (Raine 2007).

Therapists' handling techniques aim to provide the patient with control over aspects of their stability and alignment, and guide them to achieve more efficient movement patterns (Raine 2007). Within therapy there is an emphasis on the patient learning to generate movements as efficiently as possible. However, movements must be owned by the patient and be experienced both with and ultimately without the handling of the therapist (Raine 2007).

Adjuncts to therapy

The Bobath Concept can be complemented with other modalities and adjuncts such as structured practice, use of orthotics and muscle strengthening (Mayston 2007). Splinting and orthoses may be indicated to gain alignment or a good weight-bearing base for improved proximal and truncal activity (Mayston 2001). Restraint of the less affected body parts manually during a therapy session may be used to assist activation of the affected parts (Raine 2007). The therapist utilises selective constraint through posturing a limb or through an environmental support. Constraint-induced movement therapy and motor mental imagery may be used as part of a patient's home programme. Mental imagery would be considered where there is insufficient active movement, where the effort of movement leads to an associated reaction or only generates inefficient detrimental movement strategies or where fatigue prevents sufficient physical practice. To improve postural control or aid reciprocal activity of the lower limbs as part of the walking pattern, the therapist may choose to use a treadmill with or without body-weight support and this could include facilitation to enable the most efficient pattern. The therapist through a variety of techniques of handling and activating the patient can make movement necessary and possible, and incorporate these more efficient ways of moving into everyday life (Mayston 2001). Using other techniques in parallel, such as Maitland mobilisations, is compatible with the Bobath Concept (Lennon & Ashburn 2000). The decision to use such adjuncts is made on the basis of the therapists' detailed observation, analysis and interpretation of the individual's functional task performance and a shared process of setting goals with the client (Mayston 2002).

Function

Therapy is based on the assessment of the patient's potential. A role of the therapist is to facilitate balance and selective movement as a basis for functional activity and successful goal acquisition. Successful goal acquisition in a given task must then be practised to improve efficiency and promote generalisation (Raine 2007). The therapist must address both the specific movement components of the task and the functional activity in order to achieve goals (IBITA 2007). In therapy, movement is facilitated and the therapist's handling is modified as the individual achieves independence, with the aim of giving the patient movement choices, which can be incorporated into functional activity. It is important that patients should not be stopped from moving in a certain way unless they have been provided with an alternative strategy, which achieves the same goal (Mayston 2002). For example, the therapist should not stop a patient from walking; however, where walking may be detrimental to their recovery the patient may be advised to walk only with the appropriate facilitation or walking aid (Raine 2007). Preparation is of no value in itself, but must be incorporated into functional activity, which is meaningful to the patient in order to promote carry-over (Raine 2007). Goals need to be realistic according to the patient's potential and appropriate to the environment encountered during daily life (Mayston 2001). The therapist must consider not only the application of therapy to explore the individual's potential for functional activity but also for participation within social, recreational and leisure activities. In the Bobath Concept treatment has 'change of functional outcome' at its centre (Raine 2007).

Summary

The Bobath Concept was developed by the Bobaths as a living concept, understanding that as therapists' knowledge base grows their view of treatment broadens (Raine 2006). These developments have been in response to, and supported by, advances in the fields of neuroscience, biomechanics and motor learning. As described by Mayston (2007), there have been many changes in the Bobath Concept and many aspects that remain the same.

Aspects that stay the same:

- It is a problem-solving and analytical approach.
- An understanding of tone, patterns of movement and postural control that underlie the performance of functional tasks.
- The idea that it is possible to modify the way a task is performed through handling and activation to make it more efficient, effective and successful for the individual.
- It encourages the active participation of the individual.
- The importance of application of movement, with practice, into function.

Aspects that have changed:

- Changes in the understanding of tone to encompass both neural and non-neural elements.
- The realisation that spasticity as understood by Lance's definition (1980) is rarely a major source of the patient's movement disorder.

- Greater openness to the use of other modalities and adjuncts which will complement the Bobath Concept such as treadmill training, structured practice, the use of orthotics and muscle strengthening.

It is necessary to continually apply and evaluate new knowledge and evidence as it becomes available as part of the ongoing development of the Bobath Concept. As Dr Bobath stated, 'the Bobath Concept is unfinished, we hope it will continue to grow and develop in years to come' (Schleichkorn 1992).

Key Learning Points

- The systems approach to motor control provides the foundation of the current theory underpinning of the Bobath Concept.
- Therapy is an interactive process between individual, task and environment.
- Preparation is of no value in itself, but must be incorporated into functional activity which is meaningful to the patient, in order to promote carry-over.
- Plasticity underlies all skill learning and is a part of the nervous systems function.
- Therapists need to be aware of the principles of motor learning: active participation, opportunities for practice and meaningful goals.
- The Bobath Concept can be complemented with other modalities and adjuncts such as structured practice, use of orthotics and muscle strengthening.

References

Ada, L., Canning, C. & Dwyer, T. (2000) Effect of muscle length on strength and dexterity after stroke. *Clinical Rehabilitation*, **14**, 55–61.

Andrews, A.W. & Bohannon, R.W. (2000) Distribution of muscle strength impairments following stroke. *Clinical Rehabilitation*, **14** (1), 79–87.

Barnes, M.P. (2001) An overview of the clinical management of spasticity. In: *Upper Motor Neurone Syndrome and Spasticity: Clinical Management and Neurophysiology* (eds M.P. Barnes & G.R. Johnson), pp. 1–11, Cambridge University Press, Cambridge.

Bayona, N.A., Bitensky, J. & Teasell, R. (2005) Plasticity and reorganisation of the uninjured brain. *Topics in Stroke Rehabilitation*, **12** (3), 1–10.

Bernstein, N. (1967) *The Coordination and Regulation of Movement*. Pergamon Press, Oxford.

Bishop, B. (1982) Part 4. Lesion-induced reorganisation of the CNS. Recovery Phenomena. *Physical Therapy*, **62** (10), 1443–1451.

Bobath, B. (1970) *Adult Hemiplegia: Evaluation and Treatment*. Heinemann, Oxford.

Bobath, B. (1978) *Adult Hemiplegia: Evaluation and Treatment*, 2nd edn. Butterworth-Heinemann, Oxford.

Bobath, B. (1990) *Adult Hemiplegia: Evaluation and Treatment*, 3rd edn. Butterworth-Heinemann, Oxford.

Brooks, V. (1986) *The Neural Basis of Motor Control*. Oxford University Press, Oxford.

Bruehlmeier, M., Dietz, K., Leenders, K.L., et al. (1998) How does the human brain deal with a spinal cord injury? *European Journal of Neuroscience*, **10** (12), 3918–3922.

Calford, M.B. (2002) Dynamic representational plasticity in sensory cortex. *Neurosciences*, **111** (4), 709–738.

Carr, J. & Shepherd, R. (1998) *Neurological Rehabilitation: Optimizing Motor Performance*, Butterworth-Heinemann, Oxford.

Cohen, H. (1999) *Neuroscience for Rehabilitation*, 2nd edn. Lippincott Williams & Wilkins, Philadelphia.

Cornall, C. (1991) Self-propelling wheelchairs: The effects on spasticity in hemiplegic patients. *Physiotherapy Theory and Practice*, **7**, 13–21.

Cramer, S.C., Nelles, G., Benson, R.R., et al. (1997) A functional MRI study of subjects recovered from hemiparetic stroke. *Stroke*, **28**, 2518–2527.

Darian-Smith, C. & Gilbert, C. (1994) Axonal sprouting accompanies functional reorganisation in adult cat striate cortex. *Nature*, **368**, 737–740.

Davidson, I. & Walters, K. (2000) Physiotherapy working with stroke patients: A national survey. *Physiotherapy*, **86**, 69–80.

Dean, C.M. & Shepherd, R.B. (1997) Task related training improves performance of seated reaching tasks after stroke. *Stroke*, **28**, 1–7.

Dietz, V. (1992) Human neuronal control of automatic functional movements: Interaction between central programs and afferent input. *Physiological Reviews*, **72** (1), 33–69.

Dvir, Z., Panturin, E. & Prop, I. (1996) The effect of graded effort on the severity of associated reactions in hemiplegia patients. *Clinical Rehabilitation*, **10**, 155–158.

Elbert, T., Pantev, C., Weinruch, C., Rockstroh, B. & Taub, E. (1995) Increased cortical representation of the fingers of the left hand in string players. *Science*, **270**, 305–307.

Enager, P., Gold, L. & Lauritzen, M. (2004) Impaired neurovascular coupling by transhemispheric diaschesis in rat cerebral cortex. *Journal of Cerebral Blood Flow and Metabolism*, **24** (7), 713–719.

Ezekiel, H.J., Lehto, N.K., Marley, T.L., Wishart, L.R. & Lee, T.D. (2001) Application of motor learning principles: The physiotherapy client as a problem-solver. III. Augmented feedback. *Physiotherapy Canada*, **Winter**, 33–39.

Gjelsvik, B.E. (2008) *The Bobath Concept in Adult Neurology*. Thieme, Stuttgart.

Goldspink, G. (1999) Changes in muscle mass and phenotype and the expression of autocrine and systemic growth factors by muscle in response to stretch and overload. *Journal of Anatomy*, **194**, 323–334.

Gracies, J.-M. (2001) Pathophysiology of impairment in patients with spasticity and use of stretch as a treatment of spastic hypertonia. *Physical Medicine and Rehabilitation Clinics of North America*, **12** (4), 747–769.

Grossman, M.R., Sahrman, S.A. & Rose, S.J. (1982) Review of length-associated changes in muscle. Experimental evidence and clinical implications. *Physical Therapy*, **62** (12), 1799–1809.

Hachisuka, K., Umezu, Y. & Ogata, H. (1997) Disuse muscle atrophy in lower limbs in hemiplegic patients. *Archives of Physical Medicine and Rehabilitation*, **78**, 13–18.

Halsband, U. & Lange, R.K. (2006) Motor learning in man: A review of functional and clinical studies. *Journal of Physiology, Paris*, **99** (4–6), 414–424.

Hebb, D.O. (1949) *The Organisation of Behaviour. A Neuropsychological Theory*. John Wiley & Sons Inc, New York. In: Guest Editorial. Neurorehabilitation and brain plasticity. *Journal of Rehabilitation Medicine* (B.B. Johansson, 2003), **35**, p. 1.

IBITA (2007) Theoretical assumptions and clinical practice. http://www.ibita.org/

Johansson, B.B. (1996) Functional outcome in rats transferred to an enriched environment 15 days after focal brain ischaemia. *Stroke*, **27** (2), 324–326.

Johansson, B.B. (2000) Brain plasticity and stroke rehabilitation. The Willis Lecture. *Stroke*, **31**, 223–230.

Johansson, B.B. (2003) Guest editorial: Neurorehabilitation and brain plasticity. *Journal of Rehabilitation Medicine*, **35**, 1.

Kandel, E.R., Schwartz, J.H. & Jessel, T.M. (2000) *Principles of Neural Science*, 4th edn. McGraw-Hill, USA.

Kidd, G., Lawes, N. & Musa, I. (1992) *Understanding Neuromuscular Plasticity*. Edward Arnold, London.

Lance, J.W. (1980) Symposium synopsis. In: *Spasticity: Disordered Motor Control* (eds R.G. Feldman, R.R. Young & W.P. Koella), pp. 485–495, Year Book Medical Publishers, Chicago.

Lehto, N.K., Marley, T.L., Ezekiel, H.J., et al. (2001) Application of motor learning principles: The physiotherapy client as a problem-solver. IV. Future directions. *Physiotherapy Canada*, **Spring**, 109–114.

Lennon, S. (1996) The Bobath Concept: A critical review of the theoretical assumptions that guide physiotherapy practice in stroke rehabilitation. *Physical Therapy Reviews*, **1**, 35–45.

Lennon, S. (2003) Physiotherapy practice on stroke rehabilitation: A survey. *Disability and Rehabilitation*, **25** (9), 455–461.

Lennon, S. & Ashburn, A. (2000) The Bobath Concept in stroke rehabilitation: A focus group study of the experienced physiotherapists' perspective. *Disability and Rehabilitation*, **22** (15), 665–674.

Lennon, S., Baxter, D. & Ashburn, A. (2001) Physiotherapy based on the Bobath Concept in stroke rehabilitation: A survey within the UK. *Disability and Rehabilitation*, **23** (6), 254–262.

Leonard, C.T. (1998) *The Neuroscience of Human Movement*, Mosby, St. Louis.

Lieber, R.L. (2002) *Skeletal Muscle Structure, Function and Plasticity. The Physiological Basis of Rehabilitation*, 2nd edn. Lippincott Williams & Wilkins, London.

Luke, C., Dodd, K.J. & Brock, K. (2004) Outcomes of the Bobath Concept on upper limb recovery following stroke. *Clinical Rehabilitation*, **18**, 888–898.

Lynch-Ellerington, M. (1998) Letter to the editor: Associated reactions. *Physiotherapy Research International*, **3** (1), 76–81.

Lynch-Ellerington, M. (2000) What are associated reactions? *Synapse*, **Spring**, 28–30.

Majsak, M.J. (1996) Application of motor learning principles to the stroke population. *Topics in Stroke Rehabilitation*, **3** (2), 27–59.

Marley, T.L., Ezekiel, H.J., Lehto, N.K., Wishart, L.R. & Lee, T.D. (2001) Application of motor learning principles: The physiotherapy client as a problem-solver. II. Scheduling practice. *Physiotherapy Canada*, **Fall**, 315–320.

Mayston, M.J. (1992) Therapeutic concepts. The Bobath Concept – evolution and application. In: *Movement Disorders in Children. Medicine Sports Science*, Vol. 36 (eds H. Forssberg & H. Hirschfield), pp. 1–6, Karger, Basel.
Mayston, M.J. (2001) The Bobath Concept today. *Synapse*, **Spring**, 32–35.
Mayston, M.J. (2002) Problem solving in neurological physiotherapy – setting the scene. In: *Neurological Physiotherapy* (ed S. Edwards), 2nd edn, pp. 3–19, Churchill-Livingstone, Edinburgh.
Mayston, M.J. (2007) What has changed and what stays the same in the Bobath Concept? http://www.fysio.dk/sw15980.asp
Mercier, J., Perz-Martin, A., Bigard, X. & Ventura, R. (1999) Muscle plasticity and metabolism: Effects of exercise and chronic diseases. *Molecular Aspects of Medicine*, **20**, 319–373.
Merzenich, M.M. & Jenkins, W.M. (1993) Reorganisation of cortical representations of the hand following alterations of skin inputs induced by nerve injury, skin island transfers, and experience. *Journal of Hand Therapy*, **6** (2), 89–104.
Nudo, R. (1998) The role of cortical plasticity in motor recovery after stroke. *Neurology Report*, **22** (2), 61–67.
Nudo, R.J. (2007) Post-infarct cortical plasticity and behavioral recovery. *Stroke*, **38** (part 2), 840–845.
Nudo, R.J. & Friel, K.M. (1999) Cortical plasticity after stroke: Implications for rehabilitation. *Reviews in Neurology (Paris)*, **155** (9), 713–717.
O'Dwyer, N., Ada, L. & Neilson, P. (1996) Spasticity and muscle contracture following stroke. *Brain*, **119**, 1737–1749.
Ohlsson, A.L. & Johansson, B.B. (1995) Environmental influences on functional outcome of cerebral infarction in rats. *Stroke*, **26** (4), 644–649.
Paci, M. (2003) Physiotherapy based on the Bobath Concept for adults with post-stroke hemiplegia: A review of effectiveness studies. *Journal of Rehabilitation Medicine*, **35**, 2–7.
Pandyan, A.D., Gregoric, M., Barnes, M.P., et al. (2005) Spasticity: Clinical perceptions, neurological realities and meaningful measurement. *Disability and Rehabilitation*, **27** (1/2), 2–6.
Panturin, E. (2001) The Bobath Concept. Letter to the editor. *Clinical Rehabilitation*, **15**, 111.
Partridge, C., Cornall, C., Lynch, M. & Greenwood, R. (1997) Physical therapies. In: *Neurological Rehabilitation* (eds R. Greenwood, M.P. Barnes, T.M. McMillan & C.D. Ward), pp. 189–198, Taylor & Francis Group, London.
Pette, D. (1998) Training effects on the contractile apparatus. *Acta physiologica Scandinavica*, **162**, 367–376.
Purves, D., Augustine, G.J., Fitzpatrick, D., Hall, W.C., LaMantia, A-S., McNamara, J.O. & Williams, S.M. (eds) (2001) *Neuroscience*, 3rd edn. Sinauer Associates, Massachusetts, pp. 582.
Raine, S. (2006) Defining the Bobath Concept using the Delphi technique. *Physiotherapy Research International*, **11** (1), 4–13.
Raine, S. (2007) Current theoretical assumptions of the Bobath Concept as determined by the members of BBTA. *Physiotherapy Theory and Practice*, **23** (3), 137–152.
Rapisarda, G., Bastings, E., de-Noordhout, A.M., Pennisi, G. & Delwaide, P.G. (1996) Can motor recovery in stroke patients be predicted by early transcranial magnetic stimulation? *Stroke*, **27**, 2191–2196.

Royal College of Physicians (2004) *National Clinical Guidelines for Stroke*, 2nd edn. Royal College of Physicians, London.

Sadato, N., Okada, T., Kubota, K. & Yonekura, Y. (2004) Tactile discrimination activates the visual cortex of the recently blind naïve to Braille: A functional magnetic resonance imaging study in humans. *Neuroscience Letter*, **359** (1–2), 49–52.

Saladin, L.S., Baghdady, M., Nichols, L. & Logan, S. (1994) The effect of reduced relative frequency of feedback on motor learning in stroke patients. *Physical Therapy*, **5** (suppl), S122.

Schaechter, J.D. (2004) Motor rehabilitation and brain plasticity after hemiparetic stroke. *Progress in Neurobiology*, **73**, 61–72.

Schleichkorn, J. (1992) *The Bobaths: A Biography of Berta and Karel Bobath*. NDTA and Therapy Skill Builders, Tuscon.

Schmidt, R.A. (1991) *Motor Learning and Performance: From Principles to Practice*. Human Kinetics Publishers, Leeds.

Schwartzkroin, P. (2001) Mechanisms of brain plasticity: From normal brain function to pathology. *International Review of Neurobiology*, **85**, 1–15.

Scott, W., Stevens, J. & Binder-MacLeod, S.A. (2001) Human skeletal muscle fiber type classifications. *Physical Therapy*, **81**, 1810–1816.

Sheean, G. (2001) Neurophysiology of spasticity. In: *Upper Motor Neurone Syndrome and Spasticity: Clinical Management and Neurophysiology* (eds M.P. Barnes & G.R. Johnson), pp. 12–78, Cambridge University Press, Cambridge.

Shumway-Cook, A. & Woollacott, M.H. (2007) *Motor Control: Theory and Practical Applications*, 3rd edn. Lippincott Williams & Wilkins, Baltimore.

Stephenson, R. (1993) A review of neuroplasticity: Some implications for physiotherapy in the treatment of lesions of the brain. *Physiotherapy*, **79** (10), 699–704.

Sterr, A. & Freivogel, S. (2003) Motor-improvement following intensive training in low functioning chronic hemiparesis. *Neurology*, **61**, 842–844.

Taub, E. (1993) Techniques to improve chronic motor deficit after stroke. *Archives of Physical Medicine and Rehabilitation*, **74**, 347–354.

Wainberg, M. (1988) Plasticity of the central nervous system: Functional implications for rehabilitation. *Physiotherapy Canada*, **40** (4), 224–232.

Walshe, F. (1923) On certain tonic or postural reflexes in hemiplegia with reference to the so called 'associated movements'. *Brain*, **46**, 1–37.

Watkins, C.A. (1999) Mechanical and neurological changes in spastic muscles. *Physiotherapy*, **85** (11), 603–609.

Williams, P.E. & Goldspink, G. (1973) Connective tissue changes in immobilized muscle. *Journal of Anatomy*, **138** (2), 343–350.

Winstein, C.J. (1991) Designing practice for motor learning: Clinical implications. In: *Contemporary Management of Motor Control Problems*: *II Step Conference* (ed. M. Lister), pp. 65–76, Foundation for Physical Therapy Inc, Alexandria.

Winstein, C.J., Merians, A. & Sullivan, K. (1997) Motor learning after unilateral brain damage. *Neuropsychologia*, **37**, 975–987.

Wishart, L.R., Lee, T.D., Ezekiel, H.J., Marley, T.L. & Lehto, N.K. (2000) Application of motor learning principles: The physiotherapy client as a problem-solver. I. Concepts. *Physiotherapy Canada*, **Summer**, 229–232.

Wulf, G., McNevin, N., Shea, S.H. & Wright, D.L. (1999) Learning phenomena: Future challenges for the dynamical systems approach to understanding the learning of complex skills. *International Journal of Sports Psychology*, **30**, 531–537.

Yang, T.T., Gallen, C.C., Ramachandrav, V.S., et al. (1994) Non-invasive detection of cerebral plasticity in adult human somatosensory cortex. *Neurology Report*, **5** (6), 701–704.

2. *An Understanding of Functional Movement as a Basis for Clinical Reasoning*

Linzi Meadows and Jenny Williams

Introduction

The contemporary Bobath Concept is based on a systems model of motor control, the concept of plasticity, principles of motor learning, and an understanding and application of functional human movement. An in-depth understanding of human movement is crucial to the clinical reasoning process. Mrs Bobath made a distinction between 'rehabilitation concepts', which were concerned with quantitatively assessing whether or not a patient can perform a function, and the Bobath Concept, which is concerned with quality of function (Bobath 1990). Quality of movement is identified as motor performance at a behavioural level and is important in developing more effective neuro-rehabilitation strategies (Cirstea & Levin 2007).

The current opinion concerning rehabilitation concepts is that therapists design treatments which are aimed at improving the quality and quantity of postures and movements essential to function (Shumway-Cook & Woollacott 2001). This, however, is complex and does not merely involve an understanding of movement within a vacuum. It is vital that treatment is designed around goals which are specific to each patient in their particular life setting. A model of interacting constraints developed by Newell (1986) identifies the link between the individual, the task and the environment in the development of motor performance. Movement is both task specific and constrained by the environment, which means that an individual generates movement to meet the demands of the task being performed within a specific environment. An individual's ability to meet interacting task and environmental demands determines that person's functional capability.

This chapter looks at the essential requirements for efficient functional movement as a basis for clinical reasoning in the Bobath Concept. It outlines the importance of linking motor control and motor learning principles in order to maximise the potential of the patient with neurological dysfunction. The chapter includes an overview of how the nervous system is involved in this process.

Normal movement versus efficient movement

An understanding of normal movement has always been seen as fundamental to the Bobath Concept, but this has often been misinterpreted as being the ultimate aim of the Bobath therapist. Normal movement, or activity, may be considered to be a skill acquired through learning, for the purpose of achieving the most efficient and economical movement, or performance of a given task, and is specific to the individual (Edwards 2002). However, some authors suggest that normal movement is not relevant to neurological rehabilitation (Konczak & Dichgans 1996; Latash & Anson 1996).

The Bobath Concept acknowledges that normal movement and qualitative movement do not always equate because of the wide range of efficiencies and compensations within the 'normal' population of individuals without a neurological deficit. Latash and Anson (1996) consider movement patterns in the normal population to represent a spectrum from clumsy and impaired movement, at one end, to perfection and uniquely specified movement, at the other. A recent study identified that the Bobath Concept aims to promote efficiency of movement to the individual's maximum potential rather than normal movement (Raine 2007).

Bernstein (1967) identified that the fundamental problem of the motor systems was coordination and control of the vast numbers of degrees of freedom. He describes how conclusions about the development of optimal motor performance can be observed by comparing changes in parameters such as speed, accuracy and variation under a variety of conditions to gain insight into the workings of the biological systems (Bongaardt 2001). Qualities that are associated with high levels of efficient performance include maximum certainty of goal achievement, minimum energy expenditure and minimum movement time (Schmidt & Wrisberg 2000).

Key knowledge underpinning the Bobath Concept uses the 'normal' subject, as well as the patient with a neurological dysfunction, to help us understand how our patients can achieve optimal ways of moving in order to function with less effort and in a more efficient manner. Movement patterns are flexible and variable in intact subjects and less so in the neurological patient. A key aspect of achieving variability of functional movement relates to postural control (van Emmerik & van Wegen 2000), and this is a crucial consideration in the Bobath Concept.

Movement develops from the interaction of perceptual (integration of sensory information such as body schema), action (motor output to muscles) and cognitive systems (including attention, motivation and emotional aspects of motor control). Each of these has to be taken into consideration in the clinical reasoning process. This is supported by Mayston (1999) who identifies five aspects relating to the production of efficient functional movement in the neurological patient:

1. Motor – postural and task-related activity
2. Sensory – selective attention by the nervous system to relevant stimuli
3. Cognitive – motivation, judgement, planning and problem-solving
4. Perceptual – spatial and visual including figure-ground
5. Biomechanical – complementary neural and biomechanical aspects of control

Disruption to this complex integrative process leads to the patient using compensatory strategies in order to function in any manner possible. The patient with neurological dysfunction has far fewer options and the compensatory strategies that they develop are stereotyped and less adaptable. These stereotypical movements become more established over time and result in the patient having limited movement choices.

The Bobath Concept is described as working on both a component and task level, whereby missing components are identified in order to promote a more qualitative performance of movement. If specific components of movement are addressed and improved during treatment, they need to be integrated into a functional context to ensure their carry-over into everyday life. The primary goal of the Bobath Concept is to maximise the potential of the patient, based upon an in-depth assessment of how the performance of the identified functional task can be improved.

Compensatory strategies

The Bobath Concept recognises that changes in the nervous system can be organised or disorganised producing adaptive or maladaptive sensorimotor behaviour (Raine 2007). If compensatory strategies become established, they may block potential recovery (Cirstea & Levin 2007). Ultimately, behavioural experience is one of the most potent modulators of cortical structure and function (Nudo 2007). Limited or no movement is the worst experience for the patient as the nervous system is deprived of information. The idea that all movements have to be perfect is not a workable solution. Compensatory strategies, however, can be minimised to allow the patient to realise their potential for efficient long-term motor recovery. This requires a careful assessment of the individual within their own environment, based on their particular neurological deficit. The ultimate aim of the Bobath therapist is to explore the potential of the individual through the inherent plasticity within the system (Liepert et al. 2000; Nudo 2003). Neuroplasticity refers to the capacity of the nervous and muscular system to adapt and re-organise itself in response to changes in the task, individual or the environment.

Mrs Bobath (1990) studied movement analysis in-depth, and much of her written work emphasises the analysis of normal sequences of movement in order to promote more efficient and less effortful movements. The emphasis is on the quality of goal-directed movement and the minimising of compensatory strategies that may lead to stereotypical, effortful and non-adaptive movement strategies (Lynch & Grisogono 1991). A recent study investigated how the damaged nervous system compensates for deficits in reaching (Cirstea et al. 2003). The researchers analysed the following parameters in order to explore strategies employed in recovery from stroke:

- Movement speed
- Movement variability
- Movement segmentation
- Spatial and temporal coordination

When compared with healthy subjects, there was greater deviation in these parameters in the more severely impaired group than in the mild and moderate groups. From the results, it was suggested that a critical level of recovery may exist where patients switch from a strategy that produces new movement patterns, to one where motor recovery is characteristic of healthy performance. This may be important clinically in understanding how some compensatory patterns of movement may improve skill acquisition, and others may disrupt it. Although this study has limitations in its methodology, relating to the small sample size and lack of randomisation, it does raise some interesting questions for consideration.

The study also found that there was a positive correlation between trunk movement and limitation of range in the arm, which highlights the compensatory strategies employed in the trunk with an increase in motor deficit in the arm (Cirstea et al. 2003). There was a significant correlation between abnormal movement patterns in stroke patients and the level of upper limb motor impairment. The importance of severity of stroke and also specificity of training have been found to be key factors in arm recovery in the acute phase of rehabilitation (Winstein et al. 2004).

Motor control and motor learning

The Bobath Concept utilises an understanding of motor control and motor learning in order to promote the best possible outcome for each patient. Motor control is defined as the ability to regulate or direct the mechanisms essential to movement, whereas motor learning is described as a set of processes associated with practice or experience which leads to relatively permanent changes in the capability of producing skilled action (Shumway-Cook & Woollacott 2007). Clinical reasoning must therefore involve an understanding of how movement is produced (motor performance) and also how it is learned (motor learning).

Principles of motor learning include active participation, meaningful goals and opportunities for practice. These principles must therefore be incorporated into programmes for the best outcome within rehabilitation. Introducing goal-oriented activities that are particularly interesting and motivating to the patient directly affects the limbic connections and has a potent affect on the acquisition of movement. Mrs Bobath emphasised that where possible, treatment should be functionally relevant and carried out in real-life settings for effective carry-over.

Mulder and Hostenbach (2001) identified four basic rules for motor learning.

1. Input (information) is essential.
2. Input must be variable.
3. Input must be meaningful.
4. The site of training must be related to the site of application.

Motor learning can be divided into two areas, namely explicit and implicit learning. Explicit learning relates to the learning of factual information and involves conscious high-level cognitive functions. Implicit learning is particularly involved in the learning of a motor skill which is less under conscious control. The learning of a motor skill may require more attention in the initial stages until the learning has progressed and it becomes more automatic.

Motor learning can be divided into three distinct phases (Halsband & Lange 2006):

1. Initial stage: slow performance under close sensory guidance, irregular shape of movements, variable time of performance
2. Intermediate stage: gradual learning of the sensorimotor map, increase in speed
3. Advanced stage: rapid, automised, skilful performance, isochronous movements and whole field sensory control.

A key aspect of implicit learning relates to the use of, or integration of, sensorimotor information in the production of skilled movements. This involves many different areas of the brain, including the basal ganglia, cerebellum, brainstem and the sensorimotor cortex. The systems control of skilled movement is complex and involves parallel processing at many different levels, which means that the nervous system has options available in the production of movement. It is therefore unlikely that patients will entirely lose the ability to improve their efficiency of motor control. This is in contrast to explicit learning involving higher-level cognitive functioning related to specific areas of the brain.

In treatment it is particularly important to have an understanding of the systems deficit relating to the neurological damage in order to guide appropriate treatment interventions.

Neural mechanisms that integrate posture and movement are widespread throughout the nervous system and are recruited in patterns that are both task and context specific (Stuart 2005). The learning of skilled motor activities, producing smooth, coordinated patterns of movement, requires precise temporal coordination of muscles and joints which are practised many times over (Nudo 2007). Internal models, involving sensorimotor maps, are used by the nervous system for anticipatory adjustments in the development of skilled movement (Takahashi & Reinkensmeyer 2003). Therefore specificity of practice enables the patient to access more appropriate patterns of activity, which is essential in therapy to promote the recovery of skilled functional movements. This is supported by a recent study in which motor improvements were seen when the patient was attentive to the patterns of activity rather than the motor outcome (Cirstea & Levin 2007). However, too much explicit instruction relating to performance may interfere with implicit motor sequence learning after stroke (Boyd & Winstein 2003). Auditory information is processed cognitively and therefore can interfere with the automatic processing of other senses involved in implicit learning. Therefore care must be taken in order to allow the patient an opportunity to experience and be attentive to movement that is performed under their own control. Concurrent augmented verbal feedback is identified as boosting performance, but degrading learning (Jensen et al. 2000).

Explicit information is often used in the education of a task. For example, explicit information may be used to identify what is interfering with or limiting the implicit learning of a task. Information may be given explicitly to the patient, carer or interdisciplinary team members and may involve aspects of:

- organising the environmental constraints such as the height of bed or work top;
- constraint of one body part to allow another to move;
- alteration of the whole task in terms of initiation, sequencing, speed and timing of the task;
- strengthening of specific components of the task in functionally relevant situations;
- appropriate postural orientation for the task;
- advice to carers or interdisciplinary team members on handling.

Facilitation, through specific handling, is also part of the practice of the Bobath Concept and is used in a variety of ways; for example:

- to augment sensorimotor information and heighten the awareness of a body part;
- to promote a more efficient sequence of activity in the development of, for example, anticipatory postural adjustments (APAs).

There is preliminary evidence that neurofacilitation techniques improve motor function in stroke patients by normalising activity in the sensorimotor network (Miyai et al. 2002). Significant short-term effects on gait parameters have also been demonstrated using neurofacilitation techniques (Hesse et al. 1998).

The importance of afferent information in the control of movement

The link between cognition, perception and action has already been identified in this chapter as being crucial to the achievement of independent and adaptable functional behaviour. Perception is based on information received by the nervous system through specific modalities of afferent information including cutaneous and joint receptors, muscle spindle, golgi tendon organs, vestibular information, vision, auditory information, olfactory information and taste. Through this information we perceive the external world, remain alert, form a body image and regulate our movements (Kandel et al. 2000).

The control of efficient movement requires the individual to be tuned into visual, vestibular and somatosensory information (cutaneous, joint and muscle receptors) (Fig. 2.1). All of these contribute to the development of an internal representation of body posture which is referred to as the postural body schema. This provides a basis for all interactions involving perception and action towards the external world and is likely to be partly genetically determined and partly acquired through ongoing experiential learning. It is therefore adaptable and vulnerable, and is dependent on the ongoing information that it receives.

The internal representations of body posture can be considered as a general neural mechanism for resolving sensory problems. They bring together information from many sensory sources, combining incoming and outgoing information (Massion 1994; Perennou et al. 2000). It is thought that a central nervous system model of body dynamics is essential to anticipatory control of posture during movement (Frank & Earl 1990).

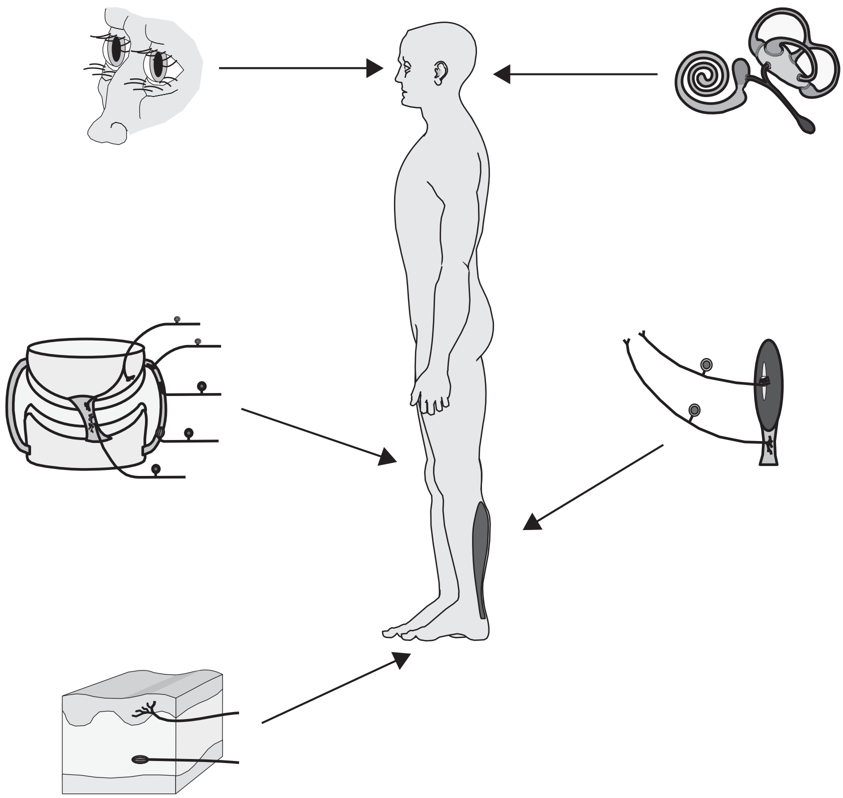


Fig. 2.1 Body schema receiving information from (top right, going clockwise) the vestibular apparatus, muscle afferents, cutaneous afferents, joint afferents and vision. Reproduced with permission from Nigel Lawes 2009.

The postural body schema consists of:

- alignment of body segments to each other and in relation to the environment;
- movement of the body segments in relation to the base of support;
- orientation of the body in relation to gravity (verticality).

The integration of visual, vestibular and somatosensory information is complex and dependent on intact sensory motor networks. It has been suggested that there is a sensory re-weighting of afferent information dependent on different sensory conditions (Oie et al. 2002). This allows for a bias towards the most appropriate senses dependent on the task and the environment.

The neurological patient will use available senses which will directly affect their postural body schema. This is particularly evident in patients who have diminished somatosensation and may then place a greater reliance on visual and vestibular information. A common problem that may develop is acquired sensory loss due to lack of appropriate use of somatosensory information.

Under normal conditions, the nervous system may weigh the importance of somatosensory information more heavily than visual or vestibular inputs, although during the learning of new motor skills, visual information for postural control may temporarily become more important, until the skill becomes more automatic and the somatosensory information resumes a primary role (Lee & Lishman 1975). Patients with neurological dysfunction often continue to rely heavily on visual information, limiting the integration of somatosensory information.

Systems control of posture and movement

The complex picture which is exhibited in patients with neurological conditions almost always involves damage to the systems which control posture and voluntary movement. When the descending drive to the spinal cord is disrupted, this leads to problems organising appropriate goal-orientated patterns of activity on a background of postural control. The human body is fundamentally unstable due to the evolvement of bipedal stance to free the upper limbs for function. Maintaining stability requires a finely tuned complex processing of information in order to maintain appropriate postural stability within the many varied postures that are necessary for us to function on a daily basis.

Postural responses occur in anticipation of and alongside movement, and during unexpected perturbations, and are commonly known as feed-forward and feedback control, respectively (Fig. 2.2). Feed-forward postural responses are also known as APAs. These can be divided into preparatory and accompanying APAs

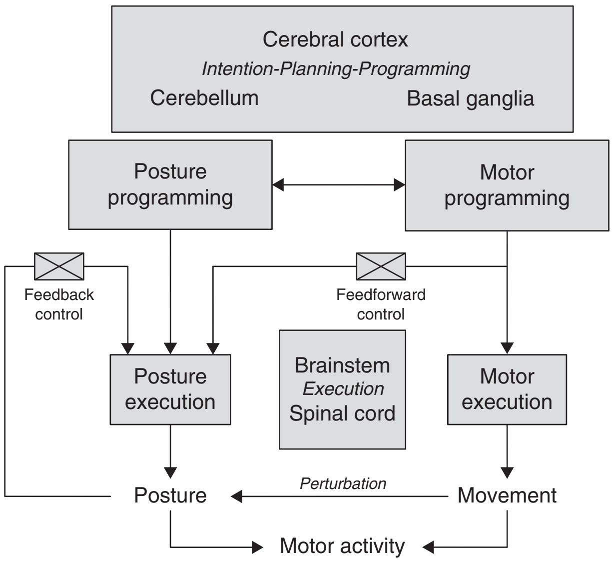


Fig. 2.2 Central organisation of postural control. Reprinted from Lalonde, R. & Strazielle, C., Brain regions and genes affecting postural control in *Progress in Neurobiology*, **81**, 45–60, copyright 2007 with permission from Elsevier.

which occur prior to and during movement (Schepens & Drew 2004). Preparatory APAs (pAPAs), occurring prior to voluntary limb movement, maintain postural stability by adapting to any destabilising forces (Horak 2006). The complex control of APAs in trunk muscles which occur during upper limb movements (Lee et al. 2007) highlights the need to understand this process for effective treatment of the neurological patient.

Intended actions involve motor planning at a higher level, including the cerebellum, basal ganglia and cerebral cortex, and form feed-forward mechanisms to adapt motor and sensory systems on the basis of previous experience. Although postural control and balance activities can be influenced by the cortex, they are regulated by systems in the brainstem (Fig. 2.2). Automatic responses to unexpected perturbations occur on the basis of ongoing visual, vestibular and somatosensory information. Recruitment of appropriate musculature to produce rapid postural control strategies involves medial descending systems, including the vestibulospinal and pontine reticulospinal systems. They act on axial and proximal muscles, and are involved in maintaining an upright posture and integrating movements of the limbs with the trunk. Lateral descending systems, including corticospinal and rubrospinal systems, are responsible for the recruitment of distal muscles and therefore support postural control through the production of selective movement (Ruhland & Le van Kan 2003; Schepens & Drew 2004; Lalonde & Strazielle 2007). In patients with neurological dysfunction, there is usually a bias of systems damage which results in different presentations.

A primary problem in many patients is the weakness of neural drive to postural muscles which leads to difficulty producing appropriate antigravity activity for smooth coordinated movement. Muscle weakness and reintegrating afferent information contribute to postural instability in stroke (Marigold et al. 2004). This leads to fixation strategies that prevent the patient from developing adaptable movement and limits their movement choices. Interestingly, reduced APAs have been identified with asymmetric postures of the lower limb during upper limb abduction in healthy adults (Aruin 2006).

Requirements of efficient movement

Identifying the requirements of efficient movement with respect to function is fundamental to clinical reasoning in the Bobath Concept. Postural control is an essential foundation for movement with the following being key requirements incorporated into postural control for functional movement:

- Balance strategies
- Patterns of movement
- Speed and accuracy
- Strength and endurance

Understanding how these interlink and influence each other is especially important in understanding the complexity of the control of movement for clinical reasoning.

Postural control

Variability of human movement is related to postural control and allows for adaptable functional behaviour (van Emmerik & van Wegen 2000). There is little argument in the literature regarding the importance of postural control for efficient movement (Pollock et al. 2000; Massion et al. 2004; Kibler et al. 2006). It involves the ability to orientate and stabilise the body within the force of gravity using appropriate balance mechanisms.

The recovery of balance is a critical component for achieving independence in the activities of daily living (Lundy-Ekman 2002). The ability to maintain the body's centre of mass within a specific boundary is dictated by the efficiency of the individual's balance mechanisms. Therefore, the stability limits which refer to the boundaries in which an individual can maintain their balance without changing the body's orientation to the base of support is also individual.

Analysis of postural alignment is an important feature of the assessment process (Lennon & Ashburn 2000). Bobath therapists analyse posture and movement through the alignment of key points in relation to each other and in relation to a given base of support. Key points are described as areas of the body from which movement may most effectively be controlled (Edwards 1996). They are divided into proximal, distal and central key points. The distal refers to the hands and feet; the proximal to the shoulder girdles, head and pelvis; and the central to the mid-thoracic region. These areas have a dynamic interrelationship with each other through active control of body musculature in a three-dimensional orientation. It is important to recognise that these key points relate to functional units (Gjelsvik 2008): for example, the pelvis relates to the interaction between the hips and lumbar spine and includes all the joints and muscles involved.

The alignments of key points, within a posture, are described as postural sets. This is a means of identifying the active connections between body segments in different postures and enables the therapist to develop hypotheses as to how the patient has been moving and how they might attempt to move. A postural set reflects arrested movement. Posture can be assessed in stable and dynamic situations in order to analyse functional activity. There are core postural sets that are part of functional movements, which include standing, supine, sitting, sidelying, stepstanding and prone.

The control of the appropriate level of neuromuscular activity in relation to a given posture and functional goal requires the nervous system to adjust postural tone appropriately. This is related to the effect of gravity and the base of support, and continuously adapts with respect to changing environmental demands in order to counteract the force of gravity. Descending spinal activity normally adapts the postural muscle tone through its influences on the spinal cord circuitry. This allows the muscles to be more or less appropriately stiff or compliant to enable both appropriate alignment for stability and movement.

Knowledge of the support conditions is only possible if the relationship with the base of support is not simply a biomechanical one but a proprioceptive interaction between the body and the interfacing environment. The base of support acts as a reference point for movement within a posture and for movement from one position to another. The quality of interaction with the base of support is not only affected by the body segments directly interfacing with the environment but by the dynamic alignment of all body segments.

Balance strategies

Balance strategies allow for the organisation of movement in a framework of postural control. They are patterns of movement or adaptations in muscles, resulting from feed-forward and feedback mechanisms that are influenced by learning, experience and sensory inputs. Preparatory postural adjustments (pAPAs) are anticipatory balance strategies which prepare the body for movement whilst accompanying APAs occur during the movement. Reactive balance strategies allow the body to respond to unexpected displacements.

APAs prepare the body for expected movement displacements and therefore are important in maintaining postural orientation during functional activity. They occur in muscles, just before or alongside focal movements, in order to stabilise the body or its segments during the execution of the movement (Schepens & Drew 2004). They are experience dependent and are therefore learned responses modified by feedback (Mouchnino et al. 1992; Massion et al. 2004).

Pre-programmed muscle activation patterns, in synergies, allow for APAs that enable efficient postural alignment and central stability to be achieved against the potentially destabilising forces of an expected movement. APAs enable stability of one body segment for the mobility of another during functional movement. For example, it has been shown that appropriate core muscle recruitment can increase the capacity of muscle activation in the extremities (Kebatse et al. 1999; Kibler et al. 2006).

Disruption of postural control can cause delays in APAs, disturbed temporal sequencing and decrease in amplitude of postural responses (Slijper & Latash 2000; Dickstein et al. 2004). Following nervous system damage and the subsequent disruption of postural activity, balance responses commonly become more response based rather than anticipatory, due to lack of appropriate feed-forward mechanisms. A key element of rehabilitation intervention is to ensure that muscle activation patterns producing APAs resulting in, for example, improved core stability are being appropriately recruited during re-education of efficient functional activity. Postural strategies include the ankle and hip strategy, stepping reactions, grasp with hand and protective extension of the upper extremities.

The ankle and hip strategies are used in order to maintain a fixed base of support, whereas the others relate to changing the base of support. They can be used interchangeably depending on the environment, but often patients with neurological dysfunction will over-rely on the hip strategy (Maki & McIlroy 1999). Also, the change-in-support strategies are often used prematurely due to a lack of appropriate antigravity activity and feed-forward controls.

Patterns of movement

All movements occur in patterns which are coordinated and follow an appropriate trajectory with respect to the task and the environment. Muscles are attached to the skeleton in such a way as to promote movements that combine flexion, extension and rotation. Rotation is particularly important when considering the interaction of the different body segments with each other and in relation to the midline. Patterns of movement relate to the timing and sequencing of movement, on an appropriate background of postural stability, and can be described as optimal muscle firing patterns for motor activity.

Mrs Bobath described patterns of movement as sequences of selective movement for function (Bobath 1990). They are described in the literature as having considerable flexibility and are primarily expressed in extrinsic muscles requiring a background of postural stability (Carson & Riek 2001). The sequence, timing and flow of movements are all need to be taken into account in the re-education of appropriate patterns of movement.

All muscles need to work from a stable base to allow them to be used to produce selective movement which is appropriate for the task and not be diverted to attempt to stabilise the body. The achievement of a functional range of movement, produced against a background of postural stability, is particularly important especially with respect to reach and grasp and stepping. This is often compromised in the patient with neurological dysfunction.

The strength of appropriate muscle recruitment in functional patterns is a crucial aspect of motor control and motor learning. It is also recognised that the ability of muscles to generate appropriate torque at one joint will be greatly affected by the torques produced at other joints (Mercier et al. 2005; Kibler et al. 2006). Thus, the production of selective movement in patterns is dependent on stability at adjacent joints.

Research into the patterns of movement of elite athletes found that they are not stereotypical, but individualistic and variable (Davids et al. 2003). The study found that subtle individualities or 'signature' patterns seem to exist even in highly constrained tasks. This suggests that the basis of skill acquisition should not be linked to 'normal profiles', but to specific requirements of motor control that allow the coordination of movement.

Patients who use sub-optimal movements for goal success alone may be able to perform tasks in the short term, but the presence of compensatory activity is associated with long-term problems such as pain, discomfort and joint contractures (Cirstea & Levin 2007). Clinically, patients with neurological dysfunction often present with excessive co-activation of antagonistic muscles, leading to co-contraction, poor recruitment of motor neurones and biomechanical changes in muscles, which all affect the production of selective movement in appropriate patterns.

Muscle strength and endurance

The need to integrate specific strength training as part of gaining efficient movement is seen by Bobath therapists as a key element of regaining efficient functional movement (Raine 2007). It is now recognised that weakness is an important factor limiting the recovery of motor performance following brain damage. (Flansbjer et al. 2005; Mercier et al. 2005; Pang et al. 2006; Yang et al. 2006). A better understanding of the neural mechanism of muscle recruitment and of muscle and nervous system plasticity has led to a greater awareness of the inevitable secondary weakness that will occur in muscles following nervous system damage. Disordered recruitment that occurs with nervous system damage will inevitably affect selective muscle function with plastic changes occurring quickly.

To appropriately perform functional tasks, muscles must be able to generate sufficient force and tension to overcome the resistance of the activity and also be able to create appropriate tensions, at specific lengths, so selective functional movements can be performed. Functional activities may involve production of a one-off activity, such as standing up from a chair, or a series of sub-maximum efforts over time, such as walking, going upstairs or running. The former will involve muscle strength, whereas the latter will involve both aspects of strength and endurance or stamina (Trew & Everett 2005).

General principles of muscle training are now widely accepted although due to the individual's response to training quantifying specific exercise prescription is not possible, even in non-neurologically damaged individuals (Bruton 2002).

In order to strengthen muscles within a rehabilitation programme, they have to be worked to fatigue with a load placed on them. Muscles that normally stabilise body parts such as multifidus, transversus, soleus, serratus anterior need to be appropriately recruited to achieve active stabilisation of body parts during strength training. This will ensure ongoing preservation of appropriate length–tension relationships, which is crucial for the preservation of efficient alignment and movement. Use of eccentric muscle work may lead to improvements in both concentric and eccentric strength and creates a greater generation of tension within the muscle.

Increasing the number of repetitions increases endurance. Muscle power can be improved by increasing the speed and explosiveness of the activity.

It is known that training effects of any activity is the result of many physiological sub-systems and involves appropriately ordered neural commands, as well as appropriate tension responses of the muscle structure. It is felt, where possible, that therapy routines should match the activities of daily living. If strength routines can be achieved in functional situations such as during stand to part sit to stand, this will have the greatest impact on both appropriate recruitment and appropriate stress and load on the muscle structure to induce the required plastic adaptation for improvement of function (Lieber 2002; Yang et al. 2006).

In muscle weakness, where there is an inability to generate the appropriate force for a task, there are three categories for muscle strength: assisted exercise, free active exercise and resisted exercise. Grading and increasing of appropriate loads are important sources of afferent information that will help increase recruitment of appropriate muscle activity within functional ranges of control. These loads can be given:

- directly by the therapist and/or carer;
- by the therapist using the environment and effects of gravity;
- by the use of the patient's own body weight (Raine 2007).

Repetition to improve stamina, changing speeds and additional loading are variables that can add increasing stress, provided that the ability of the muscles to respond appropriately is carefully monitored. Considerations of strength and stamina aspects of training are important in the design and progression of home programmes, ensuring that adequate and appropriate recruitment occurs alongside the strengthening activity. Neural changes have also been shown to occur using mental imagery which lead to improvements in strength without actually performing the activity (Yue & Cole 1992).

Speed and accuracy

The ability to appropriately adapt the speed and accuracy of movement is directly linked to the quality and selectivity of movements in functional patterns to achieve appropriate tasks. Movements in hemiparetic patients have been found to be more segmented, that is disjointed, slower and characterised by a greater variability, and by deflection of the trajectory from a straight line (Archambault et al. 1999). The relationship between speed and qualitative movement is clearly documented (Cirstea & Levin 2000; Zijlstra & Hof 2003) and is often very difficult for the neurological patient to achieve.

Speed is directly related to the task and so, for example, a different speed will be required when catching a falling object than to pick up a glass full of water.

Increasing walking speed influences inter-limb coordination in hemiplegic gait (Kwakkel & Wagenaar 2002). Increasing the speed of movement will generate more torque at adjacent body parts and therefore demand greater stability. It will, therefore, usually be associated with an increase in postural muscle tone. Increasing the speed of movement will necessitate greater flexibility and adaptability of muscle,

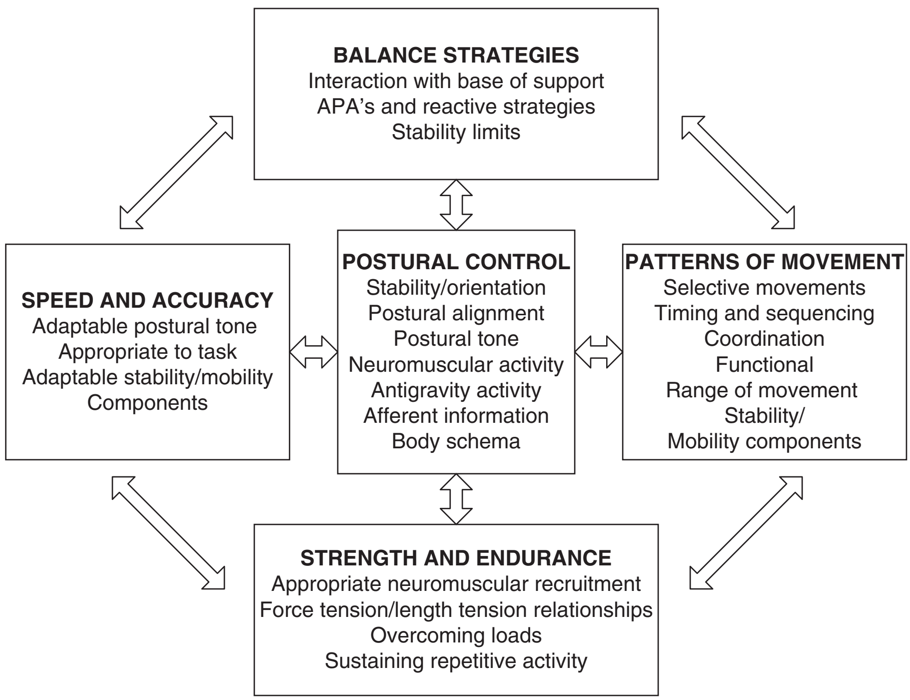


Fig. 2.3 Framework of requirements for movement efficiency.

which is often difficult for patients with tonal problems. The cerebellum is associated with the control of speed of movement (Halsband & Lange 2006) and plays a major role in the coordination and control of movement. Altering the speed of an activity can be a useful adaptation within therapy that can be used as an aspect of progression to assist creating more adaptable flexible movement.

Figure 2.3 outlines a framework of the requirements for movement efficiency based on the information discussed in this section.

Key Learning Points

- In the Bobath Concept, emphasis is given to improving the efficiency of functional movements in order to minimise compensatory strategies.
- Motor control and motor learning principles are incorporated into the Bobath Concept.
- A careful balance of explicit and implicit information is incorporated within therapy.
- Movement control is considered within the constraints of the environment in functional tasks.
- The interactions between perception, cognition and action are all considerations in the control of functional goal-directed movement.
- The systems control of skilled movement is complex and involves parallel processing at many different levels.
- In treatment, it is particularly important to have an understanding of the systems deficit relating to neurological damage in order to guide appropriate treatment interventions.
- Promoting efficient postural control mechanisms is a key requirement of the reacquisition of functional movement in maximising the potential of the individual.
- The internal representation of body posture and the interaction of appropriate somatosensory information – that is, body schema – develop a frame of reference for the control of movement.
- The potential of the individual is explored through the inherent plasticity of the neuromuscular system.
- Appropriate goal-orientated patterns of activity are produced against a background of appropriate postural control.
- Feed-forward/APAs as well as feedback/reactive strategies are involved in the control of the body within the force of gravity.
- The key requirements of efficient functional movement include adaptable postural control, appropriate balance strategies, coordinated patterns of movement, appropriate speed and accuracy with an appropriate level of strength and endurance for a given individual.

Summary

Therapists, using the Bobath Concept, seek to enable their patients to maximise the acquisition of postural control and efficient movement through the manipulation of improved feed-forward and feedback control, before and during functional activity. Development of the body schema, as a basis for perception and action, is essential for the development of skilled movement.

Intervention, involving preparation or acquisition of components, needs to be translated into active participation of goals. They use specific interventions adapting aspects of the individual, the environment and the task that are relevant to the patient's personal goals. These interventions will need to facilitate the dynamic interplay of stability and mobility on a macro and micro level. Within the process of rehabilitation, they will need to provide opportunity of movement experiences on a basis of developing postural stability and orientation, which will be essential for the reacquisition of APAs required for effective task-related training and specific practice.

Postural control is essential to all aspects of functional movement. An understanding of the key requirements of efficient movement including balance strategies, patterns of movement, strength and stamina, and speed and accuracy is incorporated into clinical reasoning. It is essential that the bridges between movement control and motor learning are made within clinical reasoning and therapy intervention (Fig. 2.4).

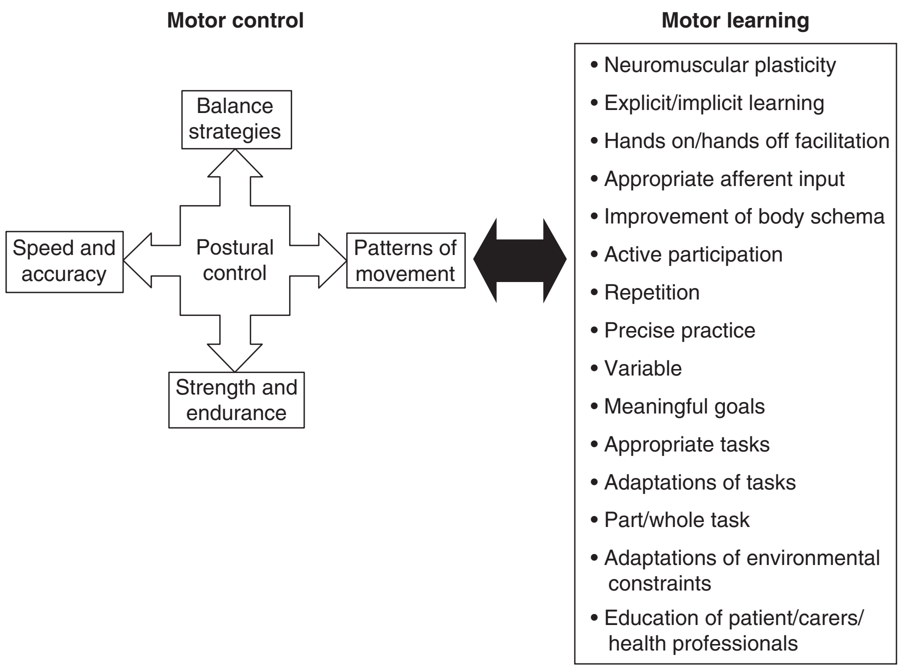


Fig. 2.4 Model outlining key features of motor control and motor learning used as a basis for clinical reasoning.

References

Archambault, P., Pigeon, P., Feldman, A.G. & Levin, M.F. (1999) Recruitment and sequencing of different degrees of freedom during pointing movements involving the trunk in healthy and hemiparetic subjects. *Experimental Brain Research*, **126** (1), 55–67.

Aruin, A.S. (2006) The effect of asymmetry of posture on anticipatory postural adjustments. *Neuroscience Letters*, **401** (1–2), 150–153.

Bernstein, N. (1967) *The Coordination and Regulation of Movement*. Pergamon Press, Oxford.

Bobath, B. (1990) *Adult Hemiplegia Evaluation and Treatment*, 3rd edn. Heinemann Medical Books, Oxford.

Bongaardt, R. (2001) How Bernstein conquered movement. In: *Classics in Movement Science* (eds M. Latash & V. Zatsiorsky), p. 59, Human Kinetics, Illinois.

Boyd, L.A. & Winstein, C.J. (2003) Implicit motor-sequence learning in humans following unilateral stroke: The impact of practice and explicit knowledge. *Neuroscience Letters*, **298**, 65–69.

Bruton, A. (2002) Muscle plasticity: Response to training and detraining. *Physiotherapy*, **88**, 398–408.

Carson, R.G. & Riek, S. (2001) Changes in muscle recruitment patterns during skill acquisition. *Experimental Brain Research*, **138** (1), 71–87.

Cirstea, M.C. & Levin, M.F. (2000) Compensatory strategies for reaching in stroke. *Brain*, **123** (5), 940–953.

Cirstea, M.C. & Levin, M.F. (2007) Improvement of arm movement patterns and endpoint control depends on type of feedback during practice in stroke survivors. *Neurorehabilitation and Neural Repair*, **21**, 398–411.

Cirstea, M.C., Mitnitski, A.B., Feldman, A.G. & Levin, M.F. (2003) Interjoint coordination dynamics during reaching in stroke. *Experimental Brain Research*, **151** (3), 289–300.

Davids, K., Glazier, P., Araujo, D. & Bartlett, R. (2003) Movement systems as dynamical systems: The functional role of variability and its implications for sports medicine. *Sports Medicine*, **33** (4), 245–260.

Dickstein, R., Sheffi, S. & Markovici, E. (2004) Anticipatory postural adjustments in selected trunk muscles in post stroke hemiparetic patients. *Archives of Physical Medicine and Rehabilitation*, **85** (2), 261–267.

Edwards, D.F. (2002). An analysis of normal movement as the basis for the development of treatment techniques. In: *Neurological Physiotherapy* (ed. S. Edwards), Harcourt Publishers Limited, Edinburgh.

Edwards, S. (1996) *Neurological Physiotherapy: A Problem Based Approach*. Churchill Livingstone, Edinburgh.

Flansbjer, U., Holmback, A.M., Downham, D. & Lexell, J. (2005) What change in isokinetic knee muscle strength can be detected in men and women with hemiparesis after stroke? *Clinical Rehabilitation*, **19**, 514–522.

Frank, J.S. & Earl, M. (1990) Coordination of posture and movement. *Physical Therapy*, **70** (12), 109–117.

Gjelsvik, B.E. (2008) *The Bobath Concept in Adult Neurology*, Georg Thieme Verlag, Germany.

Halsband, U. & Lange, R.K. (2006) Motor learning in man: A review of functional and clinical studies. *Journal of Physiology*, **99** (4–6), 414–424.

Hesse, S., Jahnke, M.T., Schaffrin, A., Lucke, D., Reiter, F. & Konrad, M. (1998) Immediate effects of therapeutic facilitation on the gait of hemiparetic patients as compared with walking with and without a cane. *Electromyography and Motor Control–Electroencephalography and Clinical Neurophysiology*, **109** (6), 515–522.

Horak, F.B. (2006) Postural orientation and equilibrium: What do we know about neural control of balance to prevent falls? *Age and Ageing*, **35** (2), ii7–ii11.

Jensen, G.M., Gwyer, J., Shepherd, K.F. & Hack, L.M. (2000) Expert practice in physical therapy. *Physical Therapy*, **80**, 28–43.

Kandel, E.R., Schwartz, J.H. & Jessell, T.M. (2000) *Principles of Neural Science*, 4th edn. McGraw Hill, New York.

Kebatse, M., McClure, P. & Pratt, N. (1999) Thoracic position effect on shoulder range of motion, strength and 3-D scapula kinematics. *Archives of Physical Medicine and Rehabilitation*, **80**, 945–950.

Kibler, W., Press, J. & Sciascia, A. (2006) The role of core stability in athletic function. *Sports Medicine*, **36** (3), 189–198.

Konczak, J. & Dichgans, J. (1996) The concept of 'normal' movement and its consequences for therapy. *Behavioral and Brain Sciences*, **19** (1), 79.

Kwakkel, G. & Wagenaar, R.C. (2002) Effect of duration of upper- and lower-extremity rehabilitation sessions and walking speed on recovery of interlimb coordination in hemiplegic gait. *Physical Therapy*, **82** (5), 432–448.

Lalonde, R. & Strazielle, C. (2007) Brain regions and genes affecting postural control. *Progress in Neurobiology*, **81**, 45–60.

Latash, M.L. & Anson, J.G. (1996) What are "normal movements" in atypical populations? *Behavioral and Brain Sciences*, **19** (1), 55.

Lee, D.N. & Lishman, J.R. (1975) Visual proprioceptive control of stance. *Journal of Human Movement Studies*, **1**, 87–95.

Lee, L.J., Coppieters, M.W. & Hodges, P.W. (2009) Anticipatory postural adjustments to arm movement reveal complex control of para spinal muscles in the thorax. *Journal of Electromyography and Kinesiology*, **19** (1), 46–54.

Lennon, S. & Ashburn, A. (2000) The Bobath Concept in stroke rehabilitation: A focus group study of the experienced physiotherapists' perspective. *Disability and Rehabilitation*, **22** (15), 665–674.

Lieber, R.L. (2002) *Skeletal Muscle Structure Function and Plasticity*, 2nd edn. Lippincott Williams & Wilkins, Philadelphia.

Liepert, J., Bauder, H., Miltner, W.H.R., Taub, E. & Weiller, C. (2000) Treatment-induced cortical reorganisation after stroke in humans. *Stroke*, **31**, 1210.

Lundy-Ekman, L. (2002) *Neuroscience: Fundamentals for Rehabilitation*, 2nd edn. W. B. Saunders, Philadelphia.

Lynch, M. & Grisogono, V. (1991) *Strokes and Head Injuries: A Guide for Patients, Families and Carers*. John Murray, London.

Maki, B.E. & McIlroy, W.E. (1999) Control of compensatory stepping reactions: Age related impairment and the potential for remedial intervention. *Physiotherapy Theory and Practice*, **15**, 69–90.

Marigold, D.S., Eng, J.J., Tokuno, C.D. & Donnelly, C.A. (2004) Contribution of muscle strength and integration of afferent input to postural instability in persons with stroke. *Neurorehabilitation and Neural Repair*, **18**, 222–229.

Massion, J. (1994) Postural control system. *Current Opinion in Neurobiology*, **4**, 877–887.

Massion, J., Alexandrov, A. & Frolov, A. (2004) Why and how are posture and movement coordinated. *Progress in Brain Research*, **143**, 13–25.

Mayston, M. (1999) An overview of the central nervous system cited in IBITA (2007) Theoretical assumptions and clinical practice. http://www.ibita.org/

Mercier, C., Bertrand, A.M. & Bourbonnais, D. (2005) Comparison of strength measurements under single-joint and multi-joint conditions in hemiparetic individuals. *Clinical Rehabilitation*, **19**, 523–530.

Miyai, I., Yagura, H., Oda, I., et al. (2002) Premotor cortex is involved in restoration of gait in stroke. *Annals of Neurology*, **52**, 188–194.

Mouchnino, L., Aurenty, R., Massion, J. & Pedotti, A. (1992) Coordination between equilibrium and head–trunk orientation during leg movement: A new strategy built up by training. *Journal of Neurophysiology*, **67** (6), 1587–1597.

Mulder, T. & Hochstenbach, J. (2001) Adaptability and flexibility of the human motor system: Implications for neurological rehabilitation. *Neural Plasticity*, **8** (1–2), 131–140.

Newell, K.M. (1986) Constraints on the development of coordination. In: *Motor Development in Children: Aspects of Coordination and Control* (ed. M.G. Wade), Whiting HTA, Dordrecht.

Nudo, R.J. (2003) Functional and structural plasticity in the motor cortex: Implications for stroke recovery. *Physical Medicine and Rehabilitation in Clinical Neurology America*, **14** (1 supplement), S57–S76.

Nudo, R.J. (2007) Post infarct cortical plasticity and behavioural recovery. *Stroke*, **38** (2), 840–845.

Oie, K.S., Kiemel, T. & Jeka, J.J. (2002) Multisensory fusion: Simultaneous re-weighting of vision and touch for the control of human posture. *Cognitive Brain Research*, **14**, 162–176.

Pang, M.Y.L., Eng, J.J., Dawson, A.S. & Gylfadottir, S. (2006) The use of aerobic exercise training in improving aerobic capacity in individuals with stroke: A meta-analysis. *Clinical Rehabilitation*, **20**, 97–111.

Perennou, D.A., Leblond, C., Amblard, B., Micallef, J.P., Rouget, E. & Pelissier, J.Y. (2000) The polymodal sensory cortex is crucial for controlling lateral postural stability: Evidence from stroke patients. *Brain Research Bulletin*, **53** (3), 359–365.

Pollock, A.S., Durward, B.R., Rowe, P.J. & Paul, J.P. (2000) What is balance? *Clinical Rehabilitation*, **14** (4), 402–406.

Raine, S. (2007) The current theoretical assumptions of the Bobath Concept as determined by the members of BBTA. *Physiotherapy Theory and Practice*, **23** (3), 137–152.

Ruhland, J. & Le van Kan, P. (2003) Medial pontine haemorrhagic stroke. *Physical Therapy*, **83** (6), 552–566.

Schepens, B. & Drew, T. (2004) Independent and convergent signals from the pontomedullary reticular formation contribute to the control of posture and movement during reaching in the cat. *Journal of Neurophysiology*, **92**, 2217–2238.

Schmidt, A. & Wrisberg, C.A. (2000) *Motor Learning and Performance*, 2nd edn. Human Kinetics, Illinois.

Shumway-Cook, A. & Woollacott, M.H. (2001) *Motor Control: Theory and Practical Applications*, 2nd edn. Lippincott Williams & Wilkins, Baltimore.

Shumway-Cook, A. & Woollacott, M.H. (2007) *Motor Control: Translating Research into Clinical Practice*, 3rd edn. Lippincott Williams & Wilkins, Philadelphia.

Slijper, H. & Latash, M. (2000) The effects of instability and additional hand support on anticipatory postural adjustments in leg, trunk, and arm muscles during standing. *Experimental Brain Research*, **135** (1), 81–93.

Stuart, D.G. (2005) Integration of posture and movement: Contributions of Sherrington, Hess and Bernstein. *Human Movement Science*, **24**, 621–643.

Takahashi, C.D. & Reinkensmeyer, D.J. (2003) Hemiparetic stroke impairs anticipatory control of arm movement. *Experimental Brain Research*, **149**, 131–140.

Trew, M. & Everett, T., eds. (2005) *Human Movement: An Introductory Text*, 5th edn. Elsevier Churchill Livingstone, Philadelphia.

van Emmerik, R.E.A. & van Wegen, E.E.H. (2000) On variability and stability in human movement. *Journal of Applied Biomechanics*, **16** (4), 394–406.

Winstein, C.J., Rose, D.K., Tan, S.M., et al. (2004) A randomized controlled comparison of upper-extremity rehabilitation strategies in acute stroke: A pilot study of immediate and long-term outcomes. *Archives of Physical Medicine and Rehabilitation*, **85** (4), 620–628.

Yang, Y.-R., Wang, R.Y., Lin, K.H., Chu, M.Y. & Chan, R.C. (2006) Task-oriented progressive resistance strength training improves muscle strength and functional performance in individuals with stroke. *Clinical Rehabilitation*, **20**, 860–870.

Yue, G.H. & Cole, K. (1992) Strength increases from the motor programme: Comparison of training with maximal voluntary and imagined muscle contractions. *Journal of Neurophysiology*, **67**, 1114–1123.

Zijlstra, W. & Hof, A.L. (2003) Assessment of spatio-temporal gait parameters from trunk accelerations during human walking. *Gait & Posture*, **18** (2), 1–10.

3. *Assessment and Clinical Reasoning in the Bobath Concept*

Paul Johnson

Introduction

Clinical decision-making is a complex process that includes aspects of reasoning, judgement and problem-solving (Gillardon & Pinto 2002). The increased research interest into the nature of clinical reasoning has been attributed to the increasing accountability of clinicians in the current health care climate, and independent decision-making is a key characteristic of autonomous practice (Edwards et al. 2004a).

Assessment represents a process of gathering information for a number of potential purposes (Wade 1992). In neurological rehabilitation, the aim is usually to identify the patient's problems, estimate an expected outcome of the rehabilitation process and enable the selection of appropriate interventions to achieve that outcome. Accurate assessment is fundamental to, and inextricably linked with, the clinical reasoning process. Conversely, the nature of the clinical reasoning process will influence the way in which the assessment is performed with respect to its content and progression.

The Bobath Concept, rather than simply being a treatment intervention, represents a framework for interpretation and problem-solving of the individual patient's presentation along with evaluation of their potential for improvement. Clinical reasoning is central throughout the whole process of assessment, intervention and evaluation. A summary of the assessment process can be found in Figure 3.1 which illustrates the progression from initial information gathering to the formulation of problem lists and selection of outcome measures. At the heart of the objective assessment is the specific analysis of the patient's abilities with respect to the efficiency of their movement and function. This would include analysis of posture, balance and voluntary movement, and the components that underpin them, along with appropriate and meaningful functional tasks for that person.

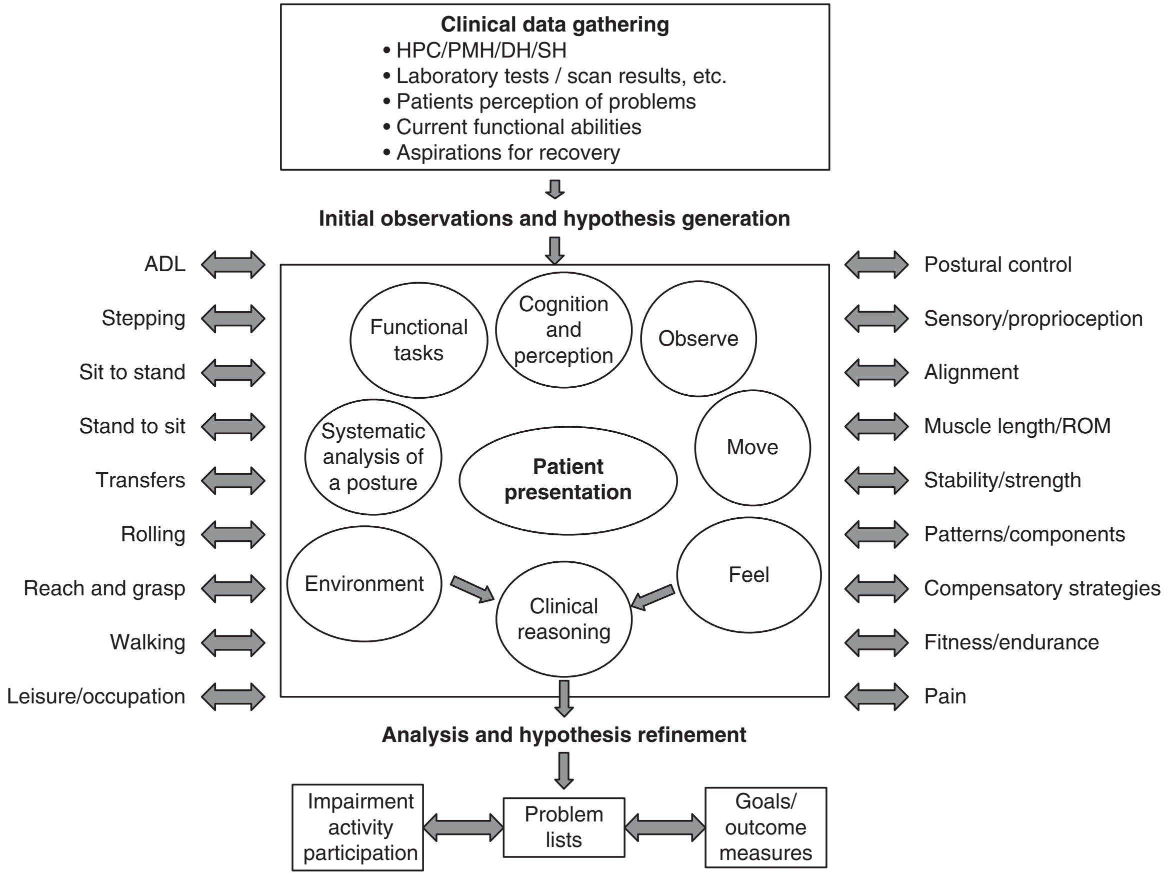


Fig. 3.1 Process of assessment. Reproduced wih permission from Liz MacKay 2009.

Assessment is a problem-solving process which enables the therapist to better understand the patient's problems as the patient is experiencing them. It should focus on intervention to enable it to be goal orientated and specific to that person. It is closely integrated with intervention and is ongoing and progressive to capture not only current abilities or problems but also the changing potential and emerging recovery. Assessment is holistic, and therefore it is crucial that working cooperatively with other members of the multidisciplinary team underpins the therapeutic process. The patient is recognised as being at the centre of this process and central to the therapist's contribution is their ability to reason and make clinical decisions. This requires a sound knowledge base and the ability to consider a variety of explanations for the individual's presenting problems. The clinical reasoning process is only completed when the therapist follows a process of reflection to evaluate the outcomes (Jensen et al. 2000; Resnik & Jensen 2003).

This chapter will not present a general description of the content of a neurological assessment as there are many examples of this that can be found in other texts (Freeman 2002; Kersten 2004). Instead, it will seek to illustrate the specific ways in which clinical reasoning takes place within the Bobath Concept and how this influences the way in which assessment is approached.

Models of clinical reasoning and the Bobath Concept

There are many potential influences on the decision-making process within clinical practice, and a number of models that underpin clinical reasoning have been identified and can be applied to the Bobath Concept. These models seek to explain the nature of clinical decision-making and provide a very useful means of reflecting upon current reasoning processes in order to further refine them. Higgs et al. (2008a) provide a comprehensive review of clinical reasoning in health care, and Edwards et al. (2004a) have explored clinical reasoning strategies used within neurological physiotherapy. The literature highlights the potential interplay between differing paradigms of inquiry and knowledge within the overall clinical reasoning process.

Diagnostic reasoning is identified as being rooted in a positivist paradigm and involves the assessment and measurement of specific clinical signs such as weakness, restriction in range of movement and reduction in postural control (Edwards et al. 2004a). Included under the umbrella of diagnostic reasoning are specific models such as hypothetico-deductive reasoning and pattern recognition reasoning (Higgs & Jones 2008). Hypothetico-deductive reasoning involves the clinician gathering multiple items of data and using these to generate hypotheses about a cause-and-effect relationship. These initial hypotheses direct further evaluation leading to refinement of a hypothesis which is ultimately tested by the application of some form of clinical intervention (Doody & McAteer 2002; Hayes Fleming & Mattingly 2008). The outcome may be assessed either formatively or quantitatively, and depending upon the result of the intervention there may be a requirement to re-evaluate the hypothesis or consider the effectiveness of the treatment intervention.

Pattern recognition reasoning is generally more evident amongst expert clinicians and involves the recognition of certain previously encountered clinical presentations (Doody & McAteer 2002; Jensen et al. 2000). It not only allows for a faster reasoning process but also represents a greater risk of reasoning error if domain-specific knowledge is inadequate. Pattern recognition reasoning will often be used interchangeably with hypothetico-deductive reasoning depending on the complexity of the clinical presentation.

The Bobath Concept is entirely compatible with hypothesis-driven reasoning, and this is strongly promoted within the teaching of the Concept. This demands that the therapist responds to the clinical presentation on the basis of detailed observation and analysis. In order for hypothesis-driven reasoning to be effective, however, the interpretation of clinical signs must be accurate. This clearly demands an appreciation of the current scientific knowledge base in areas such as motor control, the nature of neurological impairments, neuroplasticity and motor learning (Mayston 2002). There are inevitable implications for any conceptual framework for practice in that when new evidence emerges there may be subtle changes in emphasis regarding the application of the Concept. The Bobath Concept has been defined as a living concept that can, and should, go on developing (Raine 2006).

The Bobath Concept is a problem-solving approach (International Bobath Instructors Training Association (IBITA) 2007) which tailors its assessment and treatment process to the patient's individual problems and situational context. The influence of personal and contextual factors upon the impact of disability has been recognised (World Health Organization (WHO) 2002), and motivation is a key factor in engagement with motor learning and the rehabilitation process. Kwakkel et al. (1999) raises the question as to whether therapy is successful at enhancing true recovery of movement or whether it is merely effective in assisting the patient to adapt to a level of disability and therefore improve function through the use of compensatory strategies and assistive devices. Pomeroy and Tallis (2002a) make the distinction between therapeutic strategies aimed at enabling the patient to adapt to impairments so as to limit activity restrictions and strategies that seek to reduce impairments. The Bobath Concept would strongly recognise that the recovery of selective movement control is very motivating whereas only adapting to disability is not. This is not to suggest that there is no place for compensatory strategies and assistive devices but rather to highlight that the focus of assessment using the Bobath Concept is on exploring the potential for reducing the severity of impairments–and reducing the inefficiencies of compensatory strategies– in order to improve function. Importantly, assessment and treatment is focused on tasks that are motivationally significant and relevant to the patient ensuring that there is a 'social dimension' to the reasoning process (Hayes Fleming & Mattingly 2008).

An alternative to the more scientific forms of reasoning is narrative reasoning (Mattingly 1994; Edwards et al. 2004a). This is rooted in a more phenomenological paradigm and relates to the meaning of events to the individual as it explores the personal implications and impact of the resultant disability. Therefore in assessment, it encourages the identification of the patient's perceptions of their problems along with their hopes, needs and desires for their future recovery and lifestyle. This area of assessment and subsequent clinical reasoning is less conducive to objective measurement but is a crucial aspect of ensuring that therapeutic input is patient centred, meaningful and motivationally significant.

Edwards et al. (2004a) recognise the parallel existence of diagnostic and narrative forms of reasoning within skilled neurological physiotherapy practice and have termed this dialectical reasoning. This model recognises that skilled clinicians will demonstrate an 'interplay' between different paradigms of knowledge within their clinical decision-making processes. There is often a misconception that the focus of the 'Bobath therapist' is centred on movement performance and movement quality, sometimes at the expense of functional independence. Contrary to this view, the Bobath Concept recognises that skilled therapeutic practice involves a patient-centred and collaborative approach in order to ensure that the patient is always actively engaged in the therapeutic process (Jensen et al. 2000; Arnetz et al. 2004; Edwards et al. 2004b). Certainly, the nature and quality of movement performance is a key consideration in determining the efficiency of task performance along with the potential for further improvement and goal achievement. It is not, however, the 'goal itself', and the practical application of the Bobath Concept recognises the individual patient's situation and their needs. It is, therefore, entirely congruent with the dialectical model of clinical reasoning.

Key Learning Points

- The Bobath Concept promotes hypothesis-driven clinical reasoning based on the detailed analysis of presenting clinical signs.
- The objective aspects of reasoning are considered in respect of the individual's personal and environmental context, therefore incorporating a social dimension to the assessment and reasoning process.
- The Bobath Concept embraces a patient-centred approach such that assessment represents collaboration between therapist and patient in order to focus its direction and progression.

Key characteristics of assessment using the Bobath Concept

As stated earlier in this chapter, there will undoubtedly be broad similarities between the potential content of the assessment process using the Bobath Concept and that of other therapeutic approaches. This is inevitable given a general acknowledgement of recognised signs and symptoms along with functional restrictions commonly encountered by neurologically impaired patients. There is, however, value in trying to explain the way in which the Bobath therapist uses aspects of content within the clinical reasoning process as this 'defines' the Concept. In order to appreciate the individual nature of this approach to assessment, we must recognise the following key characteristics:

- The Bobath Concept seeks to explore the full potential for improvement within the patient's movement control as a basis for enhanced function.
- It is recognised that the nature of the patient's current movement strategies may have a positive or a negative impact upon the fulfilment of optimal functional potential. This involves the quality of movement as well as the quantity.
- Assessment and treatment are integrated with a continuous interaction between the two. This demands responsiveness on the part of the therapist and clinical reasoning 'in action' in order to determine critical movement interferences and evaluate them further.
- The assessment process is systematic but flexible as it does not follow the same sequence for each patient. The starting point for assessment will vary as will the progression, with both being determined in response to the individual's clinical presentation.

It is helpful to consider these aspects further in order to appreciate their influence upon the process of assessment and clinical reasoning. The most significant influence is the desire to fully explore the potential for improvement within the patient's movement abilities. There is a recognition that the production of movement is subject to a number of influences such as the individual's abilities in terms of motor, perceptual and cognitive systems along with environmental characteristics and task requirements (Shumway-Cook & Woollacott 2001). The manipulation of all three components may be utilised within treatment in order to effect a primary change in movement performance. The focus of the Bobath Concept is on increasing the individual's selective movement control by addressing those impairments that within the individual are most significant in causing functional limitation. Assessment, therefore, does not represent a desire to catalogue a set of clinical signs and symptoms describing the current status. Moreover, it seeks to inform the therapist (and the patient) of what improvements in function may be possible with a course of targeted intervention.

The key questions described by Bobath (1990) – 'What can the patient do now?' and 'What can the patient do with a little help from the therapist?' – still apply in the assessment of potential within the contemporary Bobath Concept. There may be a need to define, however, the nature of the therapist's 'help' in that it represents the manipulation of afferent input to the central nervous system in order to offer the patient an opportunity to produce a more efficient movement strategy in relation to a given functional task (Raine 2007).

Closely linked to the assessment of potential is the ability to predict recovery levels. Whilst this is not an exact science, the therapist can use the knowledge of the progression of movement control along with a holistic view of the patient, including factors such as cognition, motivation, carer support in order to predict outcomes secondary to intervention or no intervention. This requires clinical reasoning around key 'building blocks' for progressive stages in recovery and therefore makes relevant the nature and quality of movement control.

A common enquiry from patients and carers following stroke is the capacity for upper limb recovery. Consider the patient, for example, who demonstrates some preservation of distal movement within the limb such that finger movement is possible but only when in a supported posture. The fact that hand movement is present is seen by the patient (and often medical and therapy staff) as a positive indicator of recovery with an expectation that practise of such movement will improve control and function. The therapist who can apply knowledge of movement control, however, will recognise sparing distal activity as a positive feature but will immediately be considering the key indicator that this movement is only demonstrated within supported postures. The key requirements of postural control for independent upper limb movement would be evaluated in order to determine the potential for the patient to access independent limb movement and function in the longer term. There may, in fact, be significant weakness of the trunk and lower limb on the side of the lesion with resultant compensatory fixation over the less-affected lower limb in a standing posture. This would severely limit the patient's ability to cope with postural displacement (either internally or externally produced) and may well result in an associated reaction within the affected upper limb whereby the distal activity is 'used' as a means of maintaining 'postural stability'.

In this case, the therapist not only recognises the potential for further hand movement and function but also acknowledges that this cannot be realised unless the efficiency of the current postural control and balance strategy is improved. In fact, there would be a recognition that hand movement may well deteriorate unless the underlying postural control deficits, for example, ipsilateral lower limb weakness, are addressed. The attention to quality of movement, therefore, is not necessarily about a quest for aesthetically pleasing movement but more about the movement control requirements that will positively influence the fulfilment of future potential in activities of daily living.

The exploration of potential for improvement with the manipulation of afferent input during assessment results in an inevitable interaction and integration of assessment and treatment. Impairments that are observed as being critical to current movement performance are prioritised and evaluated with the aim of reducing their impact. If, for example, the therapist observes the patient moving from sitting to standing with limited involvement of the affected lower limb, she may consider a number of possible reasons for this based upon her observations. These could include:

- mal-alignment within the foot interfering with its active interaction with the support surface;
- lack of activity within the affected lower limb such that adequate force generation for extension cannot occur;
- established compensatory strategies of fixation through the unaffected side and resultant reduction in sensory and motor representation (body schema) of the

affected lower limb mean that it is not 'challenged' appropriately to be part of the movement pattern;
- lack of core stability affecting the ability to coordinate forward displacement of the trunk and head with recruitment of lower limb extension.

This list is not exhaustive but highlights the consideration of factors, both directly related to the observed problem, in this case the lower limb weakness, and factors that can indirectly affect the problem such as lack of core stability or loss of perceptual representation of body parts within the central nervous system (body schema).

A decision may be made as to which impairment the therapist feels is the most significant interference, and this can be explored with a brief but immediate intervention. Using the examples given earlier, the foot mal-alignment could be addressed with active mobilisation in order to make possible a better foot-to-floor contact as a basis for selective extension to be accessed in the lower limb. The outcome is immediately observed during repetition of the sit-to-stand task post this intervention in order to establish the significance of this particular impairment. Alternatively, if a lack of core stability is thought to be the main interference, the therapist may use specific handling in order to facilitate an increase in postural muscle activity within the lumbopelvic/hip complex and observe whether this enables more involvement of the less active lower limb during sitting and standing. Therefore, aspects of intervention are used in order to assist the clinical reasoning process within the assessment (Doody & McAteer 2002; Hayes Fleming & Mattingly 2008). Mattingly (1994) describes this as 'active reasoning' or the 'use of action' as a part of the reasoning process. This process is outlined in Figure 3.2.

Clinical practice involves a systematic approach to the identification and appraisal of key impairments related to significant functional limitations. It requires the formulation of hypotheses and their 'testing' via intervention, and very importantly requires the therapist to have in mind an anticipated outcome of the given intervention as a reference for evaluation. Assessment, therefore, is not a 'trial-and-error' process but rather a systematic decision-making activity with constant evaluation of the outcome of intervention. The responsiveness of the therapist to use critical cues related to movement efficiency is fundamental to this aspect of practice and is enhanced by a detailed knowledge and understanding of human movement production and motor control (Jensen et al. 2000; Fell 2004).

Finally, due to the fact that assessment is individual to each person and their individual presentation, and because it can take place within a range of environments it must be flexible with regard to content and progression whilst retaining its systematic element. The starting point for assessment will be governed by the patients' functional level, identified concerns and current environment rather than a preset requirement to follow a particular order of evaluating impairments or postures. The ability to combine this responsive and flexible approach to systematic enquiry is demanding in terms of clinical reasoning skills and once again is facilitated by a sound knowledge base.

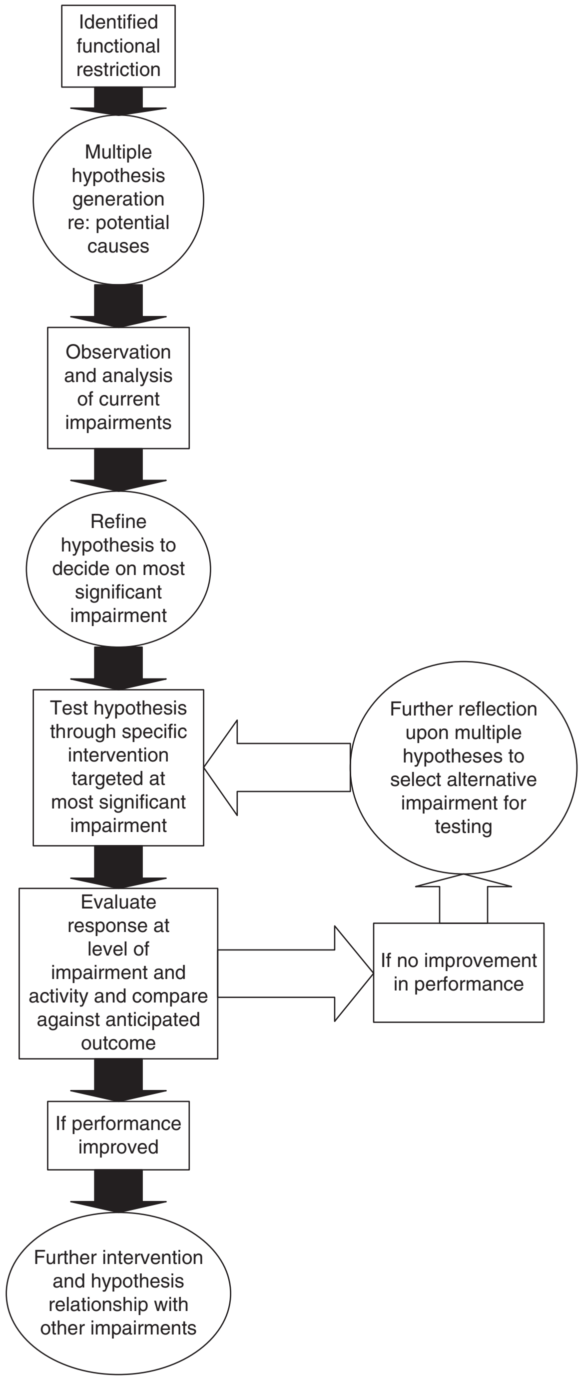


Fig. 3.2 Active reasoning process – hypothesis testing.

Key Learning Points

- The primary focus within assessment using the Bobath Concept is the exploration of the individual's potential for improvement in movement control as a basis for increased functional independence.
- Clinical reasoning is an active process involving continuous interaction of assessment and treatment in order to produce a clear hypothesis, which is then tested in respect of the individual's clinical presentation.
- Assessment is flexible, responsive and patient centred with its starting point and progression influenced by factors such as functional level, environmental context and the individual's perceived needs.

Basis for clinical reasoning

There is current debate within the physiotherapy literature as to the potential incongruence of 'named' therapy approaches with the current paradigm of evidence-based practice and a science-based approach (Pomeroy & Tallis 2002b, 2003; Mayston 2006). There is a suspicion that named approaches such as the Bobath Concept represent guru-led philosophies and the perpetuation of traditional beliefs related to the nature and impact of presenting impairments on function, the specific effects of therapeutic intervention and the actual goals of the intervention process (Turner & Allan Whitfield 1999; Rothstein 2004). In addition to this, there are significant problems in using a positivist research methodology such as the randomised controlled trial to test the effectiveness of a theoretical framework for assessment and treatment (Higgs et al. 2008b). The necessary constraint of a controlled trial in standardising intervention for a given homogenous group of subjects is a direct contradiction of the application of a set of principles to individual clinical presentations and social and psychological circumstances. Attempts have been made to compare the effectiveness of the Bobath Concept with control interventions or other methodologies. As one may predict, these have essentially been inconclusive (Paci 2003; van Vliet et al. 2005) or of questionable methodology (Langhammer & Stanghelle 2000).

Evidence-based practice has been defined as 'the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients, integrating individual expertise with the best available external clinical evidence from systematic research' (Bury 1998). The Bobath Concept as currently practised is entirely supportive of the philosophy of evidence-based practice and fully embraces the use of clinical evidence in the treatment and management of patients. It recognises, however, the limitations of current research and the need for the application of knowledge from the basic sciences to individual clinical situations. The fundamental areas of knowledge underpinning assessment and decision-making using the Bobath Concept are movement analyses, including kinetics, kinematics and biomechanics, allied to an appreciation of associated neuroscience in the areas of motor control, neuroplasticity and muscle and motor learning (Raine 2006, 2007). These subjects have received detailed coverage in Chapters 1 and 2 and, therefore, do not need to be repeated in depth within this chapter. It is vital to recognise, however, that practice grounded in the application of these core knowledge areas, applied within a hypothesis-orientated model of practice whilst recognising individual contexts, represents an approach to assessment and clinical reasoning that is 'knowledge based' (Bernhardt & Hill 2005).

Key Learning Points

- The Bobath Concept fully embraces an evidence-based practice paradigm, recognising the necessity to underpin clinical decisions with the best available evidence.
- The Bobath Concept represents a framework for clinical reasoning that integrates knowledge gained from the basic sciences and clinical research with the personal and social context of the individual patient to produce individually tailored assessment and intervention.

Illustrating clinical reasoning using the Bobath Concept

This section will seek to provide a brief example of the clinical reasoning process within an assessment situation in order to demonstrate the way in which underpinning knowledge is used to direct the systematic enquiry and evaluation of the clinical presentation. The clinical reasoning process includes factors such as:

- initial data gathering based on movement analysis;
- initial hypothesis generation;
- refinement and testing of hypothesis with specific intervention;
- evaluation of outcome and further hypothesis generation.

Mr CL presented with a left hemiparesis sustained 2 years previously following the removal of a frontal meningioma and associated haemorrhage. He was slowly ambulant with the aid of a walking stick. Mr CL reported that he was very conscious of the associated reaction in his left upper limb during walking, along with movement of his left toes into flexion which caused him some discomfort. He had no functional use of his left upper limb and some non-neural muscle adaptation in the elbow flexors limiting full extension. Key observations relating to assessment of movement dysfunction are detailed within Figure 3.3.

Fig. 3.3 Key observations in the assessment of movement dysfunction for Mr CL (gait):

- Inadequate movement of the centre of gravity over the left lower limb during stance phase.
- Associated lateral placement of the walking stick to the right to increase biomechanical stability and provide postural support taken through the right upper limb.
- Left lower limb being maintained in an alignment of knee hyperextension and relative internal rotation/flexion of the hip.
- Reduced extension and abduction at the left hip resulting in a lack of selective lateral pelvic tilt within stance phase.
- Posterior rotation of the left upper trunk/shoulder girdle.
- Significant associated reaction to flexion within the left upper limb.

Analysis and initial hypothesis generation

- A primary problem of postural hypotonia principally affecting the left lower limb and trunk resulting in reduced postural stability over the left lower limb in stance is observed.
- During locomotion, this loss of stability is compensated for by active limitation of the movement of the centre of gravity towards the left lower limb in stance and by using a walking stick for a degree of postural support.

- The degree of lateral placement of the walking stick provides a larger biomechanical base of support in order to compensate for the reduction in inherent postural stability.
- The left lower limb is only able to 'support' some of the body weight in stance with an alignment of internal rotation and flexion at the hip and hyperextension of the knee.
- This produces not only a level of mechanical support but also a fixed alignment which severely limits postural adjustments and balance.
- The left lower limb alignment also negates the potential for forward transition of body weight over the left foot during stance phase. There is a subsequent posterior displacement of the centre of gravity in stance which produces both an associated reaction of the left upper limb into flexion and a posture of flexion/inversion within the left foot, leading to adaptive shortening of plantar structures.
- The secondary adaptation within the left foot further interferes with the recovery of selective postural activity in the left lower limb and trunk due to the lack of active interaction with the support surface in stance.
- The associated reaction to flexion within the left upper limb produces interference to gaining appropriate alignment and stability of the left scapula on the thorax which further limits the development of efficient postural activity.
- The lack of selective extension (weakness) within the left upper limb and repeated movement into flexion has resulted in adaptive muscle shortening.

The initial clinical hypothesis, therefore, in respect of addressing the movement dysfunction would suggest the following:

- An improvement in distal mobility within the foot and ankle allied to increased left hip and core stability will provide a better basis for efficient weight bearing during the left stance phase of locomotion.
- This will be facilitated by the potential for enhanced feed-forward postural control and improved stability in stance such that there may be more efficient forward progression of the centre of gravity over the left foot.
- This will result in less dependence upon the walking stick for postural support and in a reduction in the associated reaction within the left arm as an involuntary response to postural instability.

Refinement and testing of hypothesis through specific intervention

Assessment of specific movement components with associated intervention enables further refinement and testing of the clinical hypothesis. This is detailed in Figures 3.4–3.9.

Evaluation of outcome and further hypothesis generation

Key changes in clinical presentation and the subsequent development of the clinical hypothesis is detailed below:

- Increased movement of the centre of gravity towards the left lower limb in stance.

- More selective control of the left knee with subsequent reduction of hyperextension.
- Improved left hip extension/abduction at the left hip with improved pelvic alignment.
- Reduced associated reaction within the left upper limb.
- Walking stick is not placed as far laterally; therefore, walking with a narrower biomechanical base of support.
- Confirmation of initial hypothesis in respect of movement dysfunction. Further hypothesis generation may relate to the extent of left shoulder girdle instability and its potential interference to further development of left hip and lower trunk stability. The improvement in postural stability and weight bearing over the left lower limb gains greater control over the associated reaction in the left upper limb. This would enable more specific assessment and evaluation of scapula stability and the potential for selective activity within the left upper limb. If it is possible to gain placement of the left upper limb to a support for hand contact,

Fig. 3.4 Key observations in the assessment of movement dysfunction for Mr CL (supine):

- Degree of positional external rotation of the left lower limb consistent with an element of proximal low tone.
- Reduced length in the left tendo-achilles.
- Adaptive shortening of the left medial arch of the foot.
- Increased ankle plantarflexion with associated great toe extension.

Fig. 3.5 Key observations in the assessment of movement dysfunction for Mr CL (supine with left lower limb in crook):

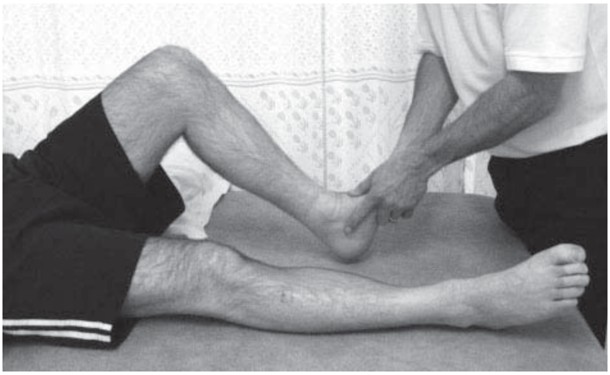
- Lateral rotation at the left hip suggestive of reduced proximal stability.
- Inversion at the left ankle/foot with great toe extension and adduction resulting in poor foot contact to the plinth.

this could enhance postural orientation to the left lower limb in order to further develop postural control as a basis for more fluent locomotion.

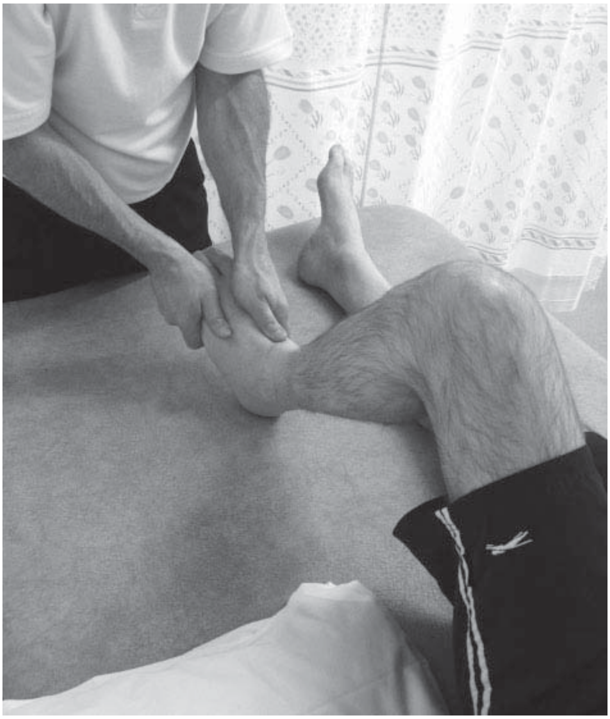
This case presentation provides a brief example of the systematic decision-making process and the interaction between assessment and treatment. This active reasoning process will be further illustrated in subsequent chapters in relation to key aspects of functional movement.

Summary

The Bobath Concept represents a holistic approach to assessment recognising the interaction of physical, psychological and social factors. Undoubtedly, its primary



(a)



(b)

Fig. 3.6 (a and b) Use of distal facilitation of left lower limb to re-align foot and ankle and gain recruitment of postural activity at left hip and selective movement of limb:

- Facilitation involves lengthening of the medial arch of the foot with stabilisation of lateral aspect of the foot to enable movement towards dorsiflexion and eversion.
- Distal initiation of limb movement will facilitate anticipatory activation of abdominal and hip musculature (core stability).

Fig. 3.7 Progression of facilitation of postural stability within left hip and lower limb:

- Left lower limb is actively 'placed' in crook posture whilst the right lower limb is facilitated through selective flexion and extension.
- Selective movement of right lower limb is used as a facilitator of postural stability within left hip and lower limb.
- Postural stability within the left hip is gained relative to the left foot in efficient contact with the plinth and therefore context based to stance phase for corresponding 'swing' of the contralateral limb during gait.

focus is on the exploration of the individual's potential for improved movement control and function. This process may take place in various environments recognising the individual's perception of their key problems and the context(s) within which they are experienced.

Clinical reasoning is facilitated by means of a systematic, flexible and responsive approach to the assessment process. The integration and interaction of specific aspects of intervention within the assessment demands an active reasoning process in order to fully establish potential for improvement. This is underpinned and enhanced by a sound knowledge of movement science and relevant neuroscience.

Fig. 3.8 Positive change in postural stability within left lower limb:
- Midline alignment of the left lower limb in crook posture.
- Improved ankle/foot alignment and more efficient contact with support surface.

Key Learning Points

- The primary focus in assessment using the Bobath Concept is the exploration of the individual's potential for improvement in movement control as a basis for increased functional independence.
- Clinical reasoning is an active process involving continuous interaction of assessment and treatment, produce a clear hypothesis in respect of the individual's clinical presentation.
- Assessment is flexible, responsive and patient centred such that its starting point and progression are influenced by factors such as functional level, environmental context and the individual's perceived needs.
- The Bobath Concept fully embraces an evidence-based practice paradigm recognising the necessity to underpin clinical decisions with the best available evidence.
- The Bobath Concept represents a framework for clinical reasoning that integrates knowledge gained from the basic sciences and clinical research, with the personal and social context of the individual patient to produce individually tailored assessment and intervention.

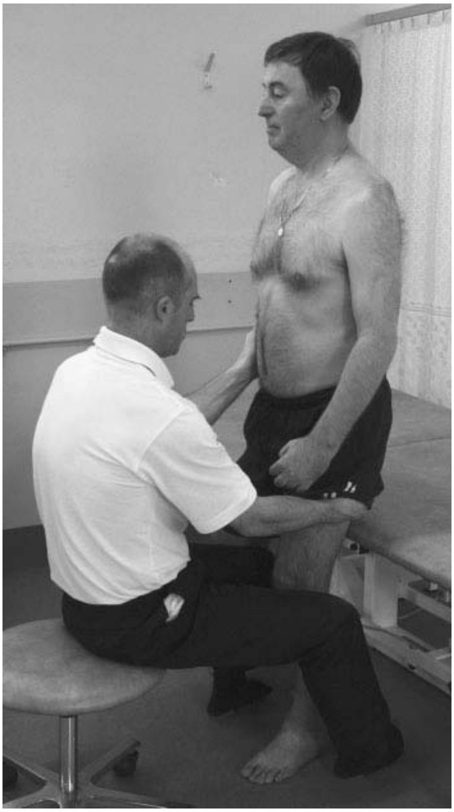


Fig. 3.9 Facilitation of left single leg stance to enhance postural activity and control:

- Facilitation from sitting to left single leg stance from higher plinth (right foot resting on therapist's left foot where relative pressure can be monitored).
- Length maintained within the left foot for good heel contact and control of involuntary toe flexion.
- Control of associated reaction within the left upper limb with mild elbow flexion secondary to non-neural muscle tightness in the elbow flexors.
- Strong tactile and proprioceptive input along with appropriate ground reaction forces promoting anti-gravity activity for stance on the left lower limb.

References

Arnetz, J.E., Almin, I., Bergstrom, K., Franzen, H. & Nilsson, H. (2004) Active patient involvement in the establishment of physical therapy goals: Effects on treatment outcome and quality of care. *Advances in Physical Therapy*, **6**, 50–69.

Bernhardt, J. & Hill, K. (2005) We only treat what it occurs to us to assess: The importance of knowledge-based assessment. In: *Science-Based Rehabilitation Theories into*

Practice (eds K. Refshauge, L. Ada & E. Ellis), pp. 15–48. Elsevier Butterworth-Heinemann, Oxford.

Bobath, B. (1990) *Adult Hemiplegia Evaluation and Treatment*, 3rd edn. Butterworth-Heinemann, Oxford.

Bury, T. (1998) Evidence-based healthcare explained. In: *Evidence Based Healthcare: A Practical Guide for Therapists* (eds T. Bury & J. Mead), pp. 3–25. Butterworth–Heinemann, Oxford.

Doody, C. & McAteer, M. (2002) Clinical reasoning of expert and novice physiotherapists in an outpatient orthopaedic setting. *Physiotherapy*, **88** (5), 258–268.

Edwards, I., Jones, M., Carr, J., Braunack-Mayer, A. & Jensen, G.M. (2004a) Clinical reasoning strategies in physical therapy. *Physical Therapy*, **84** (4), 312–330.

Edwards, I., Jones, M., Higgs, J., Trede, F. & Jensen, G. (2004b) What is collaborative reasoning? *Advances in Physical Therapy*, **6**, 70–83.

Fell, D.W. (2004) Progressing therapeutic intervention in patients with neuromuscular disorders: A framework to assist clinical decision making. *Journal of Neurological Physical Therapy*, **28** (1), 35–46.

Freeman, J. (2002) Assessment, outcome measurement and goal setting in physiotherapy practice. In: *Neurological Physiotherapy* (ed. S. Edwards), 2nd edn, pp. 21–34, Churchill Livingstone, Edinburgh.

Gillardon, P. & Pinto, G. (2002) A proposed strategy to facilitate clinical decision making in physical therapist students. *Journal of Physical Therapy Education*, **16** (2), 57–63.

Hayes Fleming, M. & Mattingly, C. (2008) Action and narrative: Two dynamics of clinical reasoning. In: *Clinical Reasoning in the Health Professions* (eds J. Higgs, M.A. Jones, S. Loftus & N. Christensen), 3rd edn, pp. 55–64, Elsevier Butterworth-Heinemann, Oxford.

Higgs, J. & Jones, M. (2008) Clinical decision making and multiple problem spaces. In: *Clinical Reasoning in the Health Professions* (eds J. Higgs, M.A. Jones, S. Loftus & N. Christensen), 3rd edn, pp. 3–18, Elsevier Butterworth-Heinemann, Oxford.

Higgs, J., Jones, M.A., Loftus, S. & Christensen, N. (2008a) *Clinical Reasoning in the Health Professions*, 3rd edn. Elsevier Butterworth-Heinemann, Oxford.

Higgs, J., Jones, M.A. & Titchen, A. (2008b) Knowledge, reasoning and evidence for practice. In: *Clinical Reasoning in the Health Professions* (eds J. Higgs, M.A. Jones, S. Loftus & N. Christensen), 3rd edn, pp. 151–162, Elsevier Butterworth-Heinemann, Oxford.

International Bobath Instructors Association (2007) Theoretical assumptions and clinical practice. www.ibita.org

Jensen, G.M., Gwyer, J., Shepard, K.F. & Hack, L.M. (2000) Expert practice in physical therapy. *Physical Therapy*, **80** (1), 28–43.

Kersten, P. (2004) Principles of physiotherapy assessment and outcome measures. In: *Physical Management in Neurological Rehabilitation* (ed. M. Stokes), pp. 29–46, Elsevier Mosby, London.

Kwakkel, G., Kollen, B.J. & Wagenaar, R.C. (1999) Therapy impact on functional recovery in stroke rehabilitation. *Physiotherapy*, **85** (7), 377–391.

Langhammer, B. & Stanghelle, J.K. (2000) Bobath or motor relearning programme? A comparison of two different approaches of physiotherapy in stroke rehabilitation: A randomised controlled study. *Clinical Rehabilitation*, **14**, 361–369.

Mattingly, M. (1994) The narrative nature of clinical reasoning. In: *Clinical Reasoning: Forms of Inquiry in a Therapeutic Practice* (eds C. Mattingly & M. Hayes Fleming), pp. 239–269, F.A. Davis, Philadelphia.

Mayston, M. (2002) Problem solving in neurological physiotherapy: Setting the scene. In: *Neurological Physiotherapy* (ed. S. Edwards), 2nd edn, pp. 3–19, Churchill Livingstone, Edinburgh.

Mayston, M. (2006) Raine: A response. *Physiotherapy Research International*, **11** (3), 183–186.

Paci, M. (2003) Physiotherapy based on the Bobath Concept for adults with post-stroke hemiplegia: A review of effectiveness studies. *Journal of Rehabilitation Medicine*, **35**, 2–7.

Pomeroy, V. & Tallis, R. (2002a) Neurological rehabilitation: A science struggling to come of age. *Physiotherapy Research International*, **7** (2), 76–89.

Pomeroy, V.M. & Tallis, R.C. (2002b) Restoring movement and functional ability after stroke: Now and the future. *Physiotherapy*, **88** (1), 3–17.

Pomeroy, V.M. & Tallis, R.C. (2003) Avoiding the menace of evidence-tinged neuro-rehabilitation. *Physiotherapy*, **89** (10), 595–601.

Raine, S. (2006) Defining the Bobath Concept using the delphi technique. *Physiotherapy Research International*, **11** (1), 4–13.

Raine, S. (2007) The current theoretical assumptions of the Bobath Concept as determined by the members of BBTA. *Physiotherapy Theory and Practice*, **23** (3), 137–152.

Resnik, L. & Jensen, G.M. (2003) Using clinical outcomes to explore the theory of expert practice in physical therapy. *Physical Therapy*, **83** (12), 1090–1106.

Rothstein, J. (2004) The difference between knowing and applying. *Physical Therapy*, **84** (4), 310–311.

Shumway-Cook, A. & Woollacott, M. (2001) *Motor Control: Theory and Practical Applications*, 2nd edn. Lippincott Williams & Wilkins, Philadelphia.

Turner, P.A. & Allan Whitfield, T.W. (1999) Physiotherapists' reasons for selection of treatment techniques: A cross-national survey. *Physiotherapy Theory and Practice*, **15**, 235–246.

van Vliet, P.M., Lincoln, N.B. & Foxall, A. (2005) Comparison of Bobath based and movement science based treatment for stroke: A randomised controlled trial. *Journal of Neurology Neurosurgery and Psychiatry*, **76**, 503–508.

Wade, D.T. (1992) *Measurement in Neurological Rehabilitation*. Oxford University Press, Oxford.

World Health Organization (2002) *Towards a Common Language for Functioning, Disability and Health*. ICF, Geneva.

4. *Practice Evaluation*

Helen Lindfield and Debbie Strang

Introduction

The Bobath Concept has always stressed the individual nature of each person's problems, and this is strongly linked to specific goal setting for patients (International Bobath Instructors Training Association (IBITA) 2004). The relevance of organising therapy around the individual was stressed as early as 1977 by Berta Bobath. When considering the selection of outcome measures, the Bobath therapist needs to identify what is relevant and meaningful in conjunction with the individual whom they are treating.

In the current climate of evidence-based practice, there is a strong drive for physiotherapists to determine the effectiveness of their interventions by measuring patient outcomes (Sackett et al. 1996; Van der Putten et al. 1999). The Bobath Concept is practised throughout the world in the treatment of a variety of neurological conditions (Lennon 2003; IBITA 2004), but despite its popularity there remains a lack of research evidence supporting the efficacy of the approach above other interventions (Paci 2003). All neurological approaches have this problem. This was demonstrated in studies by van Vliet et al. (2005) and Langhammer and Stanghelle (2003) which failed to identify specific differences in the short- and long-term outcomes of patients receiving treatment based on the Bobath Concept and the movement science approach. There are a number of reasons for this, not least of which is that patients are individuals and have a range of presentation needs, drives and desires. The complexity of the interventions used by neurological physiotherapists makes it difficult to assess the relative merits of different approaches. Attempts to simplify the interventions for the purpose of research mean they often become unrepresentative (Marsden & Greenwood 2005). The lack of specific evidence for the Bobath Concept from high-quality randomized trials means that the use of clinical outcome measures is important to allow the Bobath therapists to evaluate their practice (Herbert et al. 2005).

It is not the aim of this chapter to provide a comprehensive review of measurement instruments used in rehabilitation but to consider the use of outcome measures in the context of the Bobath Concept. The World Health Organization's International Classification of Function, Disability and Health (ICF) (WHO 2001) will be discussed in reference to the selection of outcome measures in the rehabilitation of adults with neurological dysfunction. Factors influencing the selection of outcome measures will be discussed, and the measurement properties required by therapists will be presented. The Canadian Occupational Performance Measure (COPM) and Goal Attainment Scaling (GAS) will be discussed as they allow the therapist to consider the individual needs of patients at a variety of levels. Both the COPM and GAS involve patients in identifying and prioritising goal areas. The use of these measures will be explored using patient examples.

Evaluation in the context of the International Classification of Function, Disability and Health

The selection of suitable measures to evaluate practice is critical in enabling therapists to accurately characterise and monitor changes occurring during rehabilitation. However, selecting appropriate measures can be difficult for the clinician faced with a plethora of measures to choose from. Therapists need to define the construct they wish to evaluate, consider their psychometric properties and identify the information they require from the measure. A neurological condition leads to a range of consequences at a variety of levels of the patient's function. Impairments of range of movement and power can lead to limitations in function and in turn impact on social participation. Table 4.1 defines the dimensions functioning and disability

Table 4.1 Definitions of the dimensions functioning and disability of the ICF.

Dimension	Definition	Disability	Definition
Body structure and function	Physiological or psychological functions of body systems. Body structures refer to anatomical parts of the body such as organs, limbs and their components.	Impairment	Is a loss or abnormality of body structure or of a physiological or psychological function
Activity	The execution or performance of a task or action by an individual	Activity limitation	Negative aspects of the interaction between an individual with a health condition and their contextual factors
Participation	Involvement of an individual in a life situation in relationship to impairments, activities, health conditions and contextual factors	Participation restriction	

of the ICF. Therapists working in neurology need to evaluate the impact of their interventions on all of these consequences. For many years, clinicians have focused on treating and evaluating impairment, assuming that a change at this level will impact on activity and participation; however, this relationship is not borne out in the literature (Sullivan et al. 2000; Geyh et al. 2007). It is important to consider that one of the key theoretical assumptions underpinning the Bobath Concept is the recognition of the entirety of human function in all spheres of life (IBITA 2004). Bobath therapists work with the patient and their carers and family to identify goals that are individual to them and recognise their participation restrictions and underlying functional deficits.

The WHO ICF classification provides us with a useful framework to assess and evaluate systematically at all levels of function (Mudge & Stott 2007). When using this framework to assist in the selection of an appropriate measure to evaluate change in the target outcome, it is important to recognise that patients may have the capacity to carry out an activity in an optimal rehabilitation environment, but external and internal factors can limit their performance in the real world. This problem will be familiar to practising clinicians and should be considered when measures are being selected. An example of this in practice is that 70% of stroke patients are reported to be able to walk independently; however, only a small percentage can walk functionally in the community (Mudge & Stott 2007). This discrepancy might be explained by the measures chosen by physiotherapists to reflect change in a patient's walking performance. If the patient's goal is to be able to cross the road to go to the shops, it may not be appropriate to evaluate this with a 10-metre walk test in a gym environment. A more appropriate approach would be to select the Community Balance and Mobility Scale as it includes multitasking and sequencing of movement components and is more representative of the activity of walking outdoors (Lord & Rochester 2005; Howe et al. 2006).

The ICF can be used to help therapists consider patient outcomes in the context of the individual and their environment. This is of particular relevance within the Bobath Concept in which the therapist aims to treat the individual with disturbances of function, movement and postural tone within changing environments (IBITA 2004). Table 4.2 provides examples of measures that are available to therapists using the Bobath Concept to reflect change in these areas.

Factors influencing measurement selection

Defining outcomes

Before a measure can be selected, the therapist needs to qualify what it is they are trying to have an influence on. The outcome target needs to be defined and this can be done operationally or constitutively (Ragnarsdottir 1996). Operationalising a concept anchors it to measurable and observable events, whereas defining it constitutively describes its meaning. For example, balance can be defined constitutively as the ability to maintain a posture and deal with internal and external

Table 4.2 Examples of measures that can be used by therapists using the Bobath Concept.

<table>
<tr><th>Body structures and function</th><th>Activities</th><th>Participation</th></tr>
<tr>
<td>Tone
Modified Ashworth Scale
(Bohannon & Smith 1987)
Tardieu Scale (Morris 2002)

Goniometry
Strength
Medical Research Council
(MRC 1978)

Pain
Visual Analogue Scales (Collins et al.
1997)

Sensory functions
Proprioception
Touch
Temperature
Two point discrimination</td>
<td>Balance
Functional Reach (Duncan et al. 1990)
Berg Balance Scale (Berg et al. 1989)
Postural Assessment Scale for Stroke
(Benaim et al. 1999)

Walking/ Mobility
Timed Up and Go (Podsiadlo &
Richardson 1991)
Stroke Rehabilitation Assessment of
Movement (Daley et al. 1997)

Upper limb
Motor Assessment Scale (Carr et al.
1985)</td>
<td>Short Form 12 (Ware et al. 1996)
Nottingham Health Profile (Hunt &
McEwen 1980)</td>
</tr>
<tr><td colspan="3">GAS (Gordon et al. 1999)

COPM (Law et al. 1998)</td></tr>
</table>

perturbation (Berg et al. 1989). The operational definition reflects this constitutive one by timing the patient's ability to maintain a posture and ordinally scoring the quality of the patient's response to internal and external perturbation. Once the outcome target has been defined, the therapist can further refine it by deciding with the patient the elements of it that are particularly important to them within the context of their individual environment. For example, if improved walking is the outcome target, this can be further refined by considering whether speed, distance or the level of assistance is the most important element to the patient. The therapist is now in a position to select the most appropriate outcome measure to reflect change in the selected target.

Measurement purpose

Measures are developed for a range of reasons including discrimination, prediction and evaluation (Kirshner & Guyatt 1985). Discriminative measures aim to describe individuals within a specific construct at one point in time; they allow clinicians to distinguish between respondents. Predictive measures predict an outcome in the future based on the results of measuring a construct in the present. For example, Verheyden et al. (2004) discussed the predictive nature of the Trunk Impairment Scale on functional outcome based on the Barthel Index in patients post stroke. These types of measures are not useful to the therapist who wishes to evaluate a change in a patient's presentation caused by their intervention. For this purpose, an evaluative measure is needed. It is designed to measure change over time and need to have excellent reliability, validity and responsiveness.

Measurement properties

Levels of data

There are four levels of data that can be collected by outcome measures: nominal, ordinal, interval and ratio. Being able to distinguish between the different levels of data has implications for the ability of the user to statistically analyse and interpret the data collected.

Nominal data can only categorise outcome, for example the patient does or does not achieve his/her goals.

Ordinal data is collected using a scale, for example the Berg Balance Scale (BBS). Each of its components is scored on a 5-point ordinal scale, where a score of 4 means the patient performs movements independently or holds positions for the prescribed time and 0 means the patient is unable to perform that particular component at all. Ordinal scales have an order or hierarchy of response options. It is, however, important to note that the interval between scores is not uniform. For example, in the BBS, the distance between 4 and 3 does not necessarily reflect the same as the distance between 1 and 0. These scales are commonly used in rehabilitation and these limitations need to be recognised; in particular, a change of 5 points in one patient does not mean they have made the same improvement as another patient with a 5-point change in score. This has implications for the practitioner who wants to compare changes in a range of patients on a scale.

Interval and ratio scales are the highest level of measurement, providing data that can be rigorously interrogated. Interval scores have known incremental distances between each point on the scale but do not have a true zero. An example of interval data might be a self-report quality-of-life scale where a score of 0 cannot indicate no quality of life.

A ratio scale provides the most superior level of data as it has a true zero as well as having equal distances between each part of the scale. An example of this in therapy measurements would be timing an activity.

It is important to consider what level of data is being collected when evaluating physiotherapy interventions. The lowest acceptable level of data to evaluate change is ordinal, but it should not be over-interpreted.

Validity

A measure is valid to the extent that it successfully assesses what it purports to measure. There are a growing number of validities being introduced in the literature, but the most commonly discussed are face, content, construct and criterion (Fitzpatrick et al. 1998). Face validity is judged on the scale's manifest content: does it appear to measure what it is intended to measure? Content validity is based on how comprehensively a measure covers the key elements of the concept it has been designed to measure. Both face and content are inspected by literally examining the measure and are therefore relatively qualitative in nature. Construct validity is a more quantitative form of testing the validity of a measure. It is examined by exploring the relationships between the underlying constructs of the outcome target (Streiner & Norman 1995). For example, if a measure purports to measure community mobility, it needs to reflect the constructs of speed, dual tasking, manoeuvring around obstacles and endurance. Finally, criterion validity is when a new measure correlates with a gold standard measure of the target outcome. However, gold standard measures rarely exist, hence the development of new measures. For example, a new balance measure may be correlated against a range of other measures including walking speed, functional scales as well as other balance measures.

Reliability

Reliability relates to the measure's internal consistency and reproducibility. An evaluative measure is useful to the therapist only if it is reliable. It is essential if changes in the target outcome are to be related to the intervention being evaluated. Internal consistency is based on the fact that most scales related to measuring a concept will have more than one component that measures the same aspects of the target outcome. For example, the BBS has a number of items that measure the ability to maintain a posture. The consequence of this is that these items will have a high correlation to each other, demonstrating a level of internal consistency. Reproducibility relates to the ability of a measure to repeatedly yield the same results. When looking for a measure that can be used in a department by a range of therapists inter-rater reliability is important. This relates to the degree of agreement between different observers. This means that one therapist can collect data at the beginning of a treatment period while another therapist can carry out the measure following treatment, and changes can be accepted as detecting real change in the target outcome and cannot be due to any difference in the interpretation of the different observers. Intra-rater or test–retest reliability relates to the agreement of repeated observations made by the same observer.

Sensitivity to change/responsiveness

A measure can be valid and reliable, but if it is not sensitive to change then it is of little use as an evaluative tool. Responsiveness relates to whether the measure detects change over time that is relevant to the patient (Fitzpatrick et al. 1998). One of the main limitations of responsiveness is the floor and ceiling effects exhibited by many measures used in practice. The design and scoring of a measure can affect its ability to show further improvements or deterioration in a patient's presentation. An example of the ceiling effect is the Postural Assessment Scale for Stroke, which has been found to be most useful 14–30 days post stroke but is less responsive after this period (Mao et al. 2002). The floor effect can be found in many of the balance scales regularly found in practice, for example the BBS's lowest level of activity is maintaining a sitting position; therefore, acute patients may not be able to score on the scale at all.

In summary, the selection of an appropriate measure to evaluate changes in a patient's clinical presentation relies on all of the properties discussed being in place. The therapist needs to consider the quality of the data being collected in the light of the validity, reliability and responsiveness of their measurement. This can occur only if the therapist is aware of the key measurement properties and has the ability to recognise them effectively. This recognition is the first step to evaluating therapeutic practice systematically.

Measures

This section discusses COPM and GAS, both of which allow the therapist to work with the patient to identify individualised goals that are relevant to their lives. The goals set are measurable and repeatable and this allows the rehabilitation process to be evaluated. The process of goal setting is central to both of these measures, and the patient is at the centre of this activity.

Canadian Occupational Performance Measure

The COPM, a client-centred measure, was developed to allow occupational therapists to determine the effectiveness of their work (Law et al. 1998). The COPM uses a semi-structured interview to assist the patient in identifying their main occupational performance problems. The areas considered are as follows:

- *Self-care*, which includes personal care, functional mobility and community management.
- *Productivity*, which includes paid or unpaid work and household management.
- *Leisure*, which includes quiet recreation, active recreation and socialisation.

The patients are asked to identify daily activities that they want, need or are expected to do by encouraging them to consider a normal day. Once the patient has identified their key occupational performance issues, they are then asked to rate the relative importance of them.

From this rating, the five main performance issues selected by the patient are identified. The patients are then asked to rate their satisfaction and performance for each issue on a score of 1–10, where 1 is not satisfied at all and 10 is extremely satisfied. The scoring is facilitated with a visual scoring card. This information then provides a score for the patient's self-perceived satisfaction with their current ability and a score for their actual performance.

An example of this is a patient who has identified getting up the stairs to their bed at night as a key self-care activity. They may identify their satisfaction with their current performance as 4 out of 10 because they take a long time to carry out the activity and need the assistance of their partner. Despite this low score in satisfaction, they give themselves a score of 7 out of 10 for performance because they can carry out the activity successfully. This dual scoring of satisfaction and performance is useful because it allows the patient to express the areas of change they most value. The patient in this example can walk upstairs but has identified that this is an area they wish to continue to work on. A retrospective study by Phipps and Richardson (2007) identified differences in the satisfaction score changes between right- and left-sided stroke patients with right-sided stroke patients expressing higher levels of change in satisfaction than left-sided stroke patients. The researchers hypothesised that right-sided stroke patients may have less self-awareness than left-sided stroke patients and this meant they might overestimate their abilities. This element of the COPM can be very informative for the therapist, providing them with insight into the patient's awareness, moods and motivations.

The COPM is intended for use as an outcome measure and is generally administered at the beginning of a period of rehabilitation and at regular intervals throughout intervention. It has a scoring system that allows a comparison of results, indicating improvement or deterioration in the patient's perception of their own abilities. If the patient is not able to complete the assessment, it can be used with the carer or appropriate family member with the aim of achieving a consensus between the patient and carer's expectations. By using it with the carer and the patient, it can be used to facilitate communication about problems and expectations. Figure 4.1 provides a framework for how the COPM could be used by therapists using the Bobath Concept to develop their clinical reasoning skills, treatment planning and evaluation.

The COPM has been widely researched in a number of client groups including neurological rehabilitation (Bodiam 1999; Chen et al. 2002; Phipps & Richardson 2007).

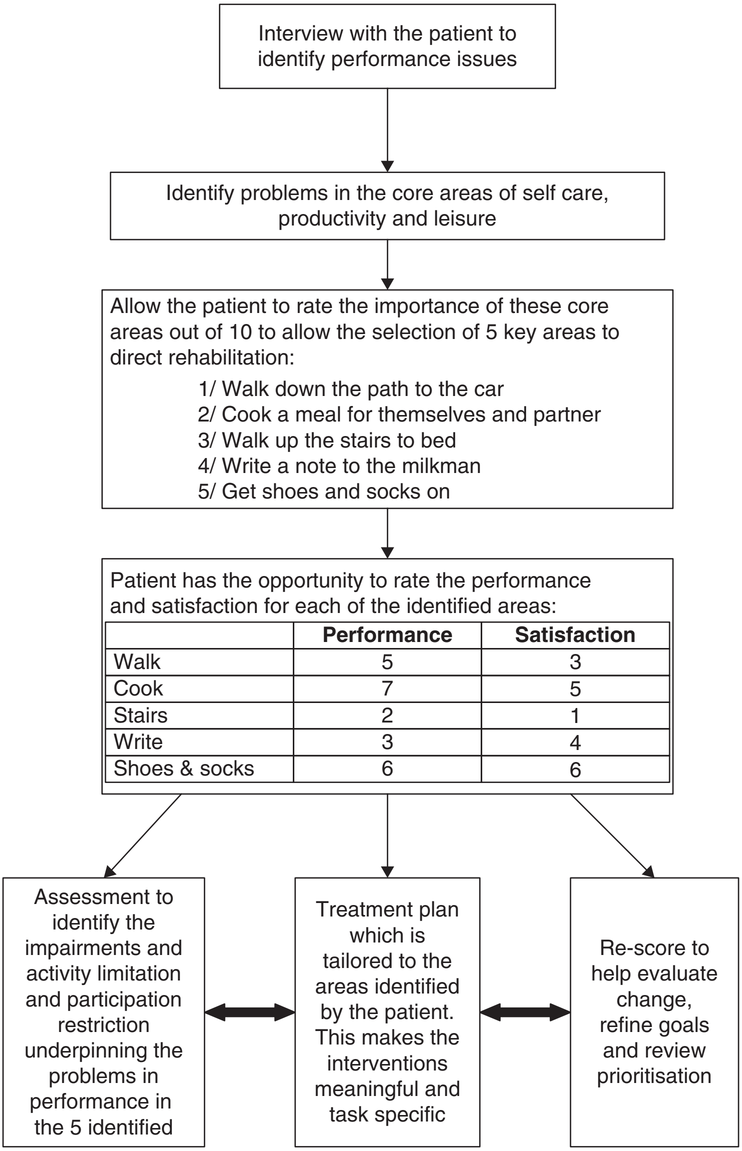


Fig. 4.1 Process of using the COPM in rehabilitation.

It demonstrates acceptable test–retest and inter-rater reliability and validity (McColl et al. 1999; Cup et al. 2003; Carswell et al. 2004). Nevertheless problems have been identified with using this measure, with neurological patients in particular, the difficulty of facilitating patients with cognitive and perceptual problems to identify specific goals and use the scoring system (Bodiam 1999; Phipps & Richardson 2007).

Another consideration is that the COPM was developed for occupational therapists to evaluate their practice (Edwards et al. 2007). This would seem to exclude other rehabilitation practitioners from using this tool. However, the framework and approach provided by the COPM is so useful, that we should consider how it might be used to support the practice of other therapists involved in neurological rehabilitation. The focus on the patient identifying his/her main problems and rating their relative importance could be used by all members of the rehabilitation team, although interviewing skills would need to be developed. By gaining a score of satisfaction and performance from the patient, the focus of rehabilitation is immediately directed to the activity/participation level that is relevant to the patient. The scoring system provides a quick and easy way to evaluate change in the identified areas.

Goal Attainment Scaling

GAS was originally developed in the mental health care setting in response to a lack of sensitive measures in this area (Malec et al. 1991). When GAS was initially used, the goals were identified by the therapist or doctor; however, as it has moved into the rehabilitation setting, the goals have been jointly decided by the therapist, clients and/or family members, thus making it more client centred (Donnelly & Carswell 2002).

GAS can be used to measure the results of treatment intervention at both the impairment and the functional level. It can be used with patients who have different treatment issues and different number of goals. When using GAS, the sum of all the patients' goals is added to produce a total score, which allows the therapist to track treatment progress (Yip et al. 1998; Gordon et al. 1999).

In order to use GAS, patients and therapist jointly set up to five goals and set levels of expected outcome for each goal using the format demonstrated in Table 4.3. The expected outcome is set at 0 and +2 is given for the most favourable outcome possible and −2 for the least favourable. The patient's starting level must be at the −1 or −2 to allow scope for improvement. However, it should be considered that some patients may deteriorate, and if this is a possibility a score of −1 allows this to be measured. This process of setting levels of outcome is based on the clinician's

Table 4.3 GAS scoring system.

GAS score	
−2	Much worse than expected
−1	Worse than expected
0	Expected outcome
+1	Better than expected outcome
+2	Much better than expected outcome

experience and aspects such as the patient's previous status, cognition and current clinical problems.

When setting goals with the patient, it is important to ensure that they include information about who is involved in the goal, what they are supposed to be achieving, where they should be doing it and by when should it occur. For example, Mr BL will be able to use his right hand for three functional tasks during washing and dressing by discharge. Goals should not contain more than one variable. Variables can include:

- *competency factors* – ability to perform a task ; increased level of ability;
- *frequency factors* – how often a client does something;
- *support factors* – level of assistance;
- *duration factors* – how long a client can do a task or how fast can they do.

Following goal setting, treatment is carried out. Then at a predetermined time, the goals are re-measured to determine change (Heavlin et al. 1982; Grenville & Lyne 1995). At this point new goals can be set with the patient.

While there are a number of ways of scoring the GAS, this chapter uses the method described by Gordon et al. (1999) (Table 4.4). In this method, scores for each of the goals set are added together. For example, if a patient sets 4 goals and scores −2 on each, their combined score will be −8. The pre-calculated table is then used to provide an overall score, which in this example is 21.

GAS has been shown to be valid, reliable and responsive in a number of settings, including care of the elderly, cognitive rehabilitation, brain injury, mental health, paediatrics, pain and amputees (Malec 1999; Joyce et al. 1994; Gordon et al. 1999; Stolee et al. 1999; Rushton & Miller 2002; Ashford &Turner-Stokes 2006; Hum et al. 2006).

A study of patients with brain injury by Joyce et al. (1994) noted that many standardised outcome measures were insensitive to change, often missing goals that were unique to the patient. Rockwood & Stolee (1997) also used the GAS with brain injury patients; results indicated that it had a moderate correlation with a range of other validated outcome measures. They concluded that GAS is an important supplement to standard outcome measures as it presents the patient's views and values, an area important to the Bobath Concept.

Stolee et al. (1992) reported that for patients in a geriatric rehabilitation, hospital GAS change scores showed strong concurrent validity with the Barthel Index, a measure used throughout rehabilitation. In this study, all patient goals were achieved within the time frame and the agreement between raters was high. In a repeat study, Stolee et al. (1999) examined the goals set with 173 patients in hospital and at follow-up. When compared with a battery of physical and cognitive measures, GAS was found to be reliable and valid. Significantly, it was found to be strikingly more responsive than the other measures. The authors suggest that this is due to the ability of GAS to assess change in the individual and recognise the multiple problems with which patients present. This finding was reiterated by Rockwood et al. (2003) in a randomised controlled trial of geriatric assessment. Results showed that GAS was more responsive than the standard measures used. The authors felt that in this setting the GAS was able to measure what was important to the patient.

Table 4.4 Pre-calculated scoring table.

Sum of goals score	**1**	**2**	**3**	4	**5**	**6**	**7**	**8**
−16								18
−15								20
−14							18	22
−13							21	24
−12						19	23	26
−11						22	25	28
−10					20	24	27	30
−9					23	27	30	32
−8				**21**	26	29	32	34
−7				25	29	32	34	36
−6			23	28	32	35	36	38
−5			27	32	35	37	39	40
−4		25	32	35	38	40	41	42
−3		31	36	39	41	42	43	44
−2	30	38	41	43	44	45	45	46
−1	40	44	45	46	47	47	48	48
0	50	50	50	50	50	50	50	50
1	60	56	55	54	53	53	52	52
2	70	62	59	57	56	55	55	54
3		69	64	61	59	58	57	56
4		75	68	65	62	60	59	58
5			73	68	65	63	61	60
6			77	72	68	65	64	62
7				76	71	68	66	64
8				79	74	71	68	66
9					77	73	70	68
10					80	76	73	70
11						78	75	72
12						81	77	74
13							79	76
14							82	78
15+16								80+82

While GAS does appear to have many of the criteria necessary to meet an outcome measure for the Bobath Concept, it has some limitations. A review of the literature related to GAS highlights its lack of evidence within neurology (Reid & Chesson 1998). One of the drawbacks of GAS is that choosing and setting of goals can be time-consuming. However, the use of generic GAS goals for specific activities like sit to stand may allow time to be saved. A retrospective review by Yip et al. (1998) with 143 patients in a geriatric rehabilitation unit showed that the use of standardised GAS goals was valid and responsive. They proposed the standardised menu to be a feasible alternative to the traditional GAS goals while retaining much of its individualised properties. Table 4.5 provides an example of how this might be used in clinical practice, where the patient has identified standing up independently as a goal area. The variable considered in this goal is level of assistance.

Table 4.5 An example of how a generic GAS goal can be developed for an upper limb task.

GAS score	Upper limb function
−2	Mr BL will be able to pick up a glass in their right hand ,with hands on support from a carer, and take a drink out of it in 2 weeks
−1	Mr BL will be able to pick up a glass in their right hand with verbal prompts and take a drink out of it in 2 weeks
0	Mr BL will be able to pick up a glass in their right hand supported by their left hand and take a drink out of it in 2 weeks
+1	Mr BL will be able to pick up a glass in their right hand and take it to their mouth but not drink in 2 weeks
+2	Mr BL will be able to pick up a glass in their right hand and take a drink out of it in 2 weeks

Reid and Chesson (1998) are the only authors to study GAS in stroke. They studied the similarities and differences in patient-set versus physiotherapist-set goals. Therapists frequently choose impairment-level goals and patients more frequently set activity level goals. Findings showed that goals set by therapists were more often achieved than the ones set by patients. A strategy to address this issue might be that the patient and therapist set an activity/participation-level goal that reflects the patient's choice. In conjunction with this, the therapist sets an impairment-level goal which supports the achievement of the activity the patient has identified. This process can be a useful tool to enhance the therapist's clinical reasoning while continuing to recognise the importance of activity/participation outcomes.

Table 4.5 shows an example of how a generic GAS goal can be developed for an upper limb task. Table 4.6 provides an example of goals developed to evaluate change in sit to stand written at activity and at participation level.

From this activity goal, the therapist is then able to identify the key factors interfering with the patient's ability to sit to stand. Tables 4.7 and 4.8 provide goals that

Table 4.6 An example of a sit to stand goal written at an activity/participation level.

GAS score	Sit to stand
−2	Mrs AS will be unable to sit to stand from their wheelchair without the maximal assistance of another person in 2 weeks (therapist doing more than 75% of the work)
−1	Mrs AS will be unable to sit to stand from their wheelchair without the moderate assistance of another person in 2 weeks (therapist doing more than 50% of the work)
0	Mrs AS will be able to sit to stand from their wheelchair independently with maximal use of their upper limbs in 2 weeks (more than 75% of the work done by upper limbs)
+1	Mrs AS will be able to sit to stand from their wheelchair independently with moderate use of their upper limbs in 2 weeks (50% of the work done by upper limbs)
+2	Mrs AS will be able to sit to stand from their wheelchair independently with minimal use of their upper limbs in 2 weeks (25% or less of work done by upper limbs)

Table 4.7 An example of an impairment-level goal related to improving hip stability to enable sit to stand.

GAS score	Hip stability
−2	Mrs AS will be able to maintain their right (affected) hip in a mid-line position in crook lying with the pelvis neutral with moderate hands on assistance in 1 week (firm contact from therapist)
−1	Mrs AS will be able to maintain their right (affected) hip in a mid-line position in crook lying with the pelvis neutral with minimal hands on assistance in 1 week (light contact from therapist)
0	Mrs AS will be able to maintain their right (affected) hip in a mid-line position in crook lying with the pelvis neutral in 1 week
+1	Mrs AS will be able to maintain their right (affected) hip in a mid-line position in crook lying with the pelvis neutral and move the left leg into abduction in 1 week
+2	Mrs AS will be able to maintain their right (affected) hip in a mid-line position in crook lying with the pelvis neutral while flexing and extending the left leg in 1 week

Table 4.8 An example of an impairment-level goal related to improving ankle range of movement to enable sit to stand.

GAS score	Ankle range of movement
−2	Mrs AS will require a 2 cm heel wedge to maintain foot contact during sit to stand in 1 week
−1	Mrs AS will require a 1 cm heel wedge to maintain foot contact during sit to stand in 1 week
0	Mrs AS will be able to maintain a plantigrade position of the right ankle during sit to stand in 1 week
+1	Mrs AS will be able to gain 100° of right ankle dorsiflexion during sit to stand in 1 week
+2	Mrs AS will be able to gain 110° of right ankle dorsiflexion during sit to stand in 1 week

identify hip stability and ankle range of movement as the core components interfering with Mrs AS's ability to sit to stand independently.

Summary

The lack of quality research supporting the practice of neurological therapists means that it is imperative that we evaluate our interventions if we are to be evidence based (Greenhalgh et al. 1998). Therapists need to be able to define the construct they wish to evaluate and have the knowledge base which allows them to select measurements appropriately. The WHO ICF provides a useful structure to facilitate this process.

At the core of the Bobath Concept is the recognition that each patient needs to be treated as an individual. Functional measurements alone are not representative of the patient's views and values. The GAS and COPM are valid, reliable and responsive client-centred measures which allow the patient to be central to the rehabilitation process at all times.

A further issue with standardised measures is that they often lack the ability to show change in the efficiency of qualitative functional movement which treatment strives to promote (Paci 2003). In this chapter, we have demonstrated how the GAS, with its ability to quantify an individual's goals, can then be used by the therapist to identify the qualitative steps needed to achieve the goal. GAS can be used to measure quality of movement, where the goals agreed are individualised to each patient and not dictated by a generic static standard measure.

Key Learning Points

- The ICF is a useful framework to facilitate therapists to consider the patient at the levels of impairment, activity and participation in the context of the person and the environment.
- Therapists need to develop the skills that will allow them to choose measurement tools based on knowledge of their psychometric and clinical properties.
- The COPM and GAS are patient-centred measures which can be used as important supplements to standard outcome measures as they present the patient's views and values, an important aspect of the Bobath Concept (Rockwood & Stolee 1997).
- One of the aspects of rehabilitation using the Bobath Concept is the recognition of the need for qualitative change in the patient's movement and function. The GAS provides a framework to evaluate quality in the context of patient-generated goals.

References

Ashford, S. & Turner-Stokes, L. (2006) Goal attainment for spasticity management using botulinum toxin. *Physiotherapy Research International*, **11** (1), 24–34.

Benaim, C., Perennou, D., Villy, J., Rousseaux, M. & Pelissier, J. (1999) Validation of a standardized assessment of postural control in stroke patients (PASS). *Stroke*, **30** (9), 1862–1868.

Berg, K., Wood-Dauphinee, S., Williams, J. & Gayton, D. (1989) Measuring balance in the elderly: Preliminary development of an instrument. *Physiotherapy Canada*, **41**, 304–311.

Bobath, B. (1977) Treatment of adult hemiplegia. *Physiotherapy*, **62**, 310–313.

Bodiam, C. (1999) The use of the Canadian Occupational Performance Measure for the assessment of outcome on a neurorehabilitation unit. *British Journal of Occupational Therapy*, **62** (3), 123–126.

Bohannon, R. & Smith, M. (1987) Interrater reliability of a modified Ashworth scale of muscle spasticity. *Physical Therapy*, **67**, 206–207.

Carr, J., Shepherd, R., Nordholm, L. & Lynne, D. (1985) Investigation of a new motor assessment scale for stroke patients. *Physical Therapy*, **65**, 175–180.

Carswell, A., McColl. M., Baptiste, S., Law, M., Polatajko, H. & Pollock, N. (2004) The Canadian Occupational Performance Measure: A research and clinical literature review. *Canadian Journal of Occupational Therapy*, **71** (4), 210–222.

Chen, Y.-H., Rodgers, S. & Polatajko, H. (2002) Experiences with the COPM and client-centred practice in adult neurorehabilitation in Taiwan. *Occupational Therapy International*, **9** (3), 167–184.

Collins, S., Moore, A. & McQuay, H. (1997) The visual analogue scale: What is moderate pain in millimetres? *Pain*, **72**, 95–97.

Cup, E., Scholte op Reimer, W., Thijssen, M. & van Kuyk-Minis, M. (2003) Reliability and validity of the Canadian Occupational Performance Measure in stroke patients. *Clinical Rehabilitation*, **17**, 402–409.

Daley, K., Mayo, N., Wood-Dauphinee, S., Danys, I. & Cabot, R. (1997) Verification of the stroke rehabilitation assessment of movement (STREAM). *Physiotherapy Canada*, **49**, 269–278.

Donnelly, C. & Carswell, A. (2002) Individualised outcome measures: A review of the literature. *The Canadian Journal of Occupational Therapy*, **69** (2), 84–95.

Duncan, P., Weiner, D., Chandler, J. & Studenski, S. (1990) Functional reach: A new measure of balance. *Journal of Gerontology*, **45**, M192–M197.

Edwards, M., Baptiste, S., Stratford, P. & Law, M. (2007) Recovery after hip fracture: What can we learn from the Canadian Occupational Performance Measure. *American Journal of Occupational Therapy*, **61** (3), 335–344.

Fitzpatrick, R., Davey, C., Buxton, M. & Jones, D. (1998) Evaluating patient-based outcome measures for use in clinical trials. *Health Technology Assessment*, **2** (14), 19–45, NHS R&D HTA Programme.

Geyh, S., Cieza, A., Kollerits, B., Grimby, G. & Stucki, G. (2007) Content comparison of health related quality of life measures used in stroke based on the international classification of functioning, disability and health (ICF): A systematic review. *Quality Life Research*, **16**, 833–851.

Gordon, J., Powell, C. & Rockwood, K. (1999) Goal attainment scaling as a measure of clinically important change in nursing home patients. *Age and Ageing*, **28**, 275–281.

Greenhalgh, J., Long, A.F., Brettle, A.J. & Grant, M.J. (1998) Reviewing and selecting outcome measures for use in routine practice. *Journal of Evaluation in Clinical Practice*, **4** (4), 339–350.

Grenville, J. & Lyne, P. (1995) Patient-centred evaluation and rehabilitative care. *Journal of Advanced Nursing*, **22**, 965–972.

Heavlin, W.D., Lee-Merrow, S.W. & Lewis, V.M. (1982) The psychometric foundations of goal attainment scaling. *Community Mental Health Journal*, **18**, 230–241.

Herbert, R., Jamtvedt, G., Mead, J. & Hagen, K. (2005) Editorial: Outcome measures measure outcome, not effects of intervention. *Australian Journal of Physiotherapy*, **51**, 3–4 (Editorial).

Howe, J., Inness, E., Venturini, A., Williams, J. & Verrier, M. (2006) The community balance and mobility scale: A balance measure for individuals with traumatic brain injury. *Clinical Rehabilitation*, **20**, 885–895.

Hum, J., Kneebone, I. & Cropley, M. (2006) Goal setting as an outcome measure: A systematic review. *Clinical Rehabilitation*, **20**, 756.

Hunt, S. & McEwen, J. (1980) The development of a subjective health indicator. *Social Health Illness*, **2**, 231–246.

International Bobath Instructors Training Association (2004) Theoretical assumptions and clinical practice (Internet). http://www.ibita.org (Accessed 10 January 2005).

Joyce, B.M., Rockwood, K. & Mate-Kole, C. (1994) Use of goal attainment scaling in brain injury in a rehabilitation hospital. *American Journal of Physical Medicine and Rehabilitation*, **73**, 10–14.

Kirshner, B. & Guyatt, G. (1985) A methodological framework for assessing health indices. *Journal of Chronic Disability*, **38**, 27–36.

Langhammer, B. & Stanghelle, J. (2003) Bobath and motor relearning programme? A follow up one and four years post stroke. *Clinical Rehabilitation*, **17** (7), 731–734.

Law, M., Baptiste, S., Carswell-Opzoomer, A., McColl, M., Polatajko, H. & Pollock, H. (1998) *Canadian Occupational Performance Measure*, 3rd edn. CAOT Publications, Ottawa.

Lennon, S. (2003) Physiotherapy practice in stroke rehabilitation: A survey. *Disability and Rehabilitation*, **25**, 455–461.

Lord, S. & Rochester, L. (2005) Measurement of community ambulation after stroke. Current status and future developments. *Stroke*, **36**, 1457–1461.

Malec, J.F. (1999) Goal attainment scaling in rehabilitation. *Neuropsychological Rehabilitation*, **9** (3/4), 253–275.

Malec, J.F., Smigielski, D. & DePompolo, R.W. (1991) Goal attainment scaling and outcome measurement in postacute brain injury rehabilitation. *Archives of Physical Medicine and Rehabilitation*, **72**, 138–143.

Mao, H.F., Hseuh, I.P., Sheu, C.F. & Hsieuh, G.Y. (2002) Analysis and comparison of the psychometric properties of three balance measures for stroke. *Stroke*, **3**, 1022.

Marsden, J. & Greenwood, R. (2005) Physiotherapy after stroke: Define, divide and conquer. *Journal of Neurology Neurosurgery and Psychiatry*, **76**, 465–466.

McColl, M., Paterson, M., Davies, D., Doubt, L. & Law, M. (1999) Validity and community utility of the Canadian Occupational Performance Measure. *Canadian Journal of Occupational Therapy*, **67**, 22–30.

Medical Research Council (MRC) (1978) *Aids to the Examination of the Peripheral Nervous System*. Baillere Tindall, Eastbourne.

Morris, S. (2002) Ashworth and Tardieu scales: Their clinical relevance for measuring spasticity in adult and paediatric neurological populations. *Physical Therapy Reviews*, **7**, 53–62.

Mudge, S. & Stott, S. (2007) Outcome measures to assess walking ability following stroke: A systematic review of the literature. *Physiotherapy*, **93**, 189–200.

Paci, M. (2003) Physiotherapy based on the Bobath Concept for adults with post stroke hemiplegia: A review of effectiveness studies. *Journal of Rehabilitation Medicine*, **35**, 2–7.

Phipps, S. & Richardson, P. (2007) Occupational therapy outcomes for clients with traumatic brain injury and stroke using the Canadian Occupational Performance Measure. *The American Journal of Occupational Therapy*, **61** (3), 328–334.

Podsiadlo, D. & Richardson, S. (1991) The timed up and go: A test of basic functional mobility for frail elderly persons. *Journal of American Geriatric Society*, **39**, 142–148.

Ragnarsdottir, M. (1996) The concept of balance. *Physiotherapy*, **82**, 368–375.

Reid, A. & Chesson, R. (1998) Goal Attainment Scaling: Is it appropriate for stroke patients and their physiotherapists? *Physiotherapy*, **84** (3),136–144.

Rockwood, K. & Stolee, P. (1997) Use of goal attainment scaling in measuring clinically important change in cognitive rehabilitation patients. *Journal of Clinical Epidemiology*, **50** (5), 581–588.

Rockwood, K., Howlett, S., Stadnyk, K., Carver, D., Powell, C. & Stolee, P. (2003) Responsiveness of goal attainment scaling in a randomized controlled trial of comprehensive geriatric assessment. *Journal of Clinical Epidemiology*, **56**, 736–743.

Rushton, P. & Miller, W. (2002) Goal Attainment Scaling in the rehabilitation of patients with lower extremity amputations: A pilot study. *Archives Physical Medicine and Rehabilitation*, **83**, 771–775.

Sackett, D., Richardson, W., Rosenberg, W. & Haynes, R. (1996) *How to Practice and Teach Evidence Based Medicine*. Churchill and Livingstone, Edinburgh.

Stolee, P., Rockwood, K., Fox, R. & Streiner, D. (1992) The use of goal attainment scaling in the geriatric care setting. *Journal of American Geriatrics Society*, **40**, 574–578.

Stolee, P., Stadnyk, K., Myers, A. & Rockwood, K. (1999) An individualised approach to outcome measurement in geriatric rehabilitation. *Journal of Gerontology*, **54A** (12), 641–647.

Streiner, D. & Norman, G. (1995) *Health Measurement Scales: A Practical Guide to Their Development and Use*, 2nd edn. Oxford University Press, Oxford.

Sullivan, M., Shoaf, L. & Riddle, D. (2000) The relationship of lumbar flexion to disability in patients with low back pain. *Physical Therapy*, **80**, 240–250.

Van der Putten, J., Hobart, J., Freeman, J. & Thompson, A. (1999) Measuring change in disability after inpatient rehabilitation: Comparison of the responsiveness of the Barthel Index and functional independence measure. *Journal of Neurology Neurosurgery and Psychiatry*, **66**, 480–484.

Van Vliet, P., Lincoln, N. & Foxall, A. (2005) Comparison of Bobath based and movement science based treatment for stroke: A randomised controlled trial. *Journal of Neurology Neurosurgery and Psychiatry*, **76**, 503–508.

Verheyden, G., Nieuwboer, A., Mertin, J. et al. (2004) The Trunk Impairment Scale: A new tool to measure motor impairment of the trunk after stroke. *Clinical Rehabilitation*, **18**, 326–334.

Ware, J., Kosinski, M. & Keller, S. (1996) A 12 item short form health survey. Construction of scales and preliminary tests of reliability and validity. *Medical Care*, **34**, 220–233.

World Health Organization (2001) *International Classification of Functioning Disability and Health*. ICF Geneva: WHO.

Yip, A., Gorman, M., Stndnyk, K., et al. (1998) A standardized menu for goal attainment scaling in the care of frail elders. *Gerontologist*, **38** (6), 735–742.

5. *Moving Between Sitting and Standing*

Lynne Fletcher, Catherine Cornall and Sue Armstrong

Introduction

The Bobath Concept considers independent sit to stand (STS) as an essential goal for rehabilitation as it underpins independent locomotion and the ongoing functional recovery of the upper limb and hand. STS has been identified as an important prerequisite for achieving independent upright mobility and an important factor in independent living (Lomaglio & Eng 2005). Inability to rise from a sitting position is recognised by the World Health Organization as a disabling condition and is considered a predictor of future disability. Its qualitative performance has implications for many other activities and has also been linked with prediction of efficiency in gait (Chou et al. 2003), risk of falls (Cheng et al. 2004) and discharge location (Guralnik et al. 1994).

In daily life, moving between sitting and standing is performed many times a day in many different contexts. The STS transition also forms an integral part of two key aspects of normal human movement, locomotion, and reach and grasp, since we commonly sit to walk (STW) and STS to enable reaching beyond the stability limits in sitting (Magnan et al. 1996; Dean et al. 2007). This complex and biomechanically challenging task may be performed in isolation but is more commonly completed as part of other functional tasks such as toileting, dressing and getting out of a car.

The postural control elements which underpin STS are anticipatory in nature and allow its performance to be relatively automatic. These aspects of postural control have been learned, developed and modified based on prior movement experiences. This allows the individual to perform two or more tasks concurrently. However, with ageing, injury or impaired movement control, the normal components and sequencing may be lost resulting in the use of different compensatory strategies to regain function.

The challenge for the therapist is to help the individual improve control of the component parts of STS optimising the automatic performance, minimising inefficient compensatory strategies and maximising transferability of skill into different contexts. This fundamental activity with its implications for independence and quality of life requires considerable therapy time, with as much as 25% reported to be devoted to this area (Jette et al. 2005). Observational analysis of a patient's ability to STS can be seen as an effective paradigm by which to study the coordination between posture and movement (Mourey et al. 1998).

Based on clinical reasoning, the Bobath therapist can focus therapy on the acquisition of specific components of the movement sequence in different postures, environments and contexts. Emphasis is placed on:

- alignment,
- range and pattern of movement,
- timing,
- speed,
- strength,
- postural control.

Integration of these components into the performance of the task in a variety of settings is essential for carry over into function.

Clinical considerations from the literature

Movement between sitting and standing has been extensively studied in the literature, including investigation of the kinematics, kinetics and EMG activity. Comparisons have been made between 'normal' subjects and other groups such as the elderly (Mourey et al. 1998; Dubost et al. 2005), the obese (Sibelia et al. 2003), individuals with stroke (Chou et al. 2003; Cheng et al. 2004) and other neurological conditions (Bahrami et al. 2000). Clinicians may need to be aware of the constraints used to standardise the subjects' movement patterns in research studies and consider how these may influence the ability to apply the information effectively. Common constraints in the literature include starting position, seat height, foot position and upper limb position.

Starting position

The ability to sit unsupported on a backless seat is a prerequisite for inclusion in many studies investigating STS; however, clinical experience indicates that patients with neurological dysfunction may use a number of inappropriate strategies in the maintenance of unsupported sitting. Therefore, the clinical assessment of the ability to STS from a chair may initially involve consideration of the efficiency of postural control and ability to transfer weight within the chair.

Seat height

A number of researchers have considered this aspect not only in terms of setting the level as a standard relative to the length of levers in the individual, but also comparing the efficiency and effort level at different heights (Mazza et al. 2004;

Yamada & Demura 2004; Roy et al. 2006). Within the Bobath Concept, modification of the environment may be considered to enable the patient to learn the necessary components of STS. This should be progressively adapted to allow the patient to achieve optimal motor performance. Mazza et al. (2004) described different compensatory strategies employed by individuals at varying functional levels and demonstrated that as seat height was reduced, greater compensation was required. Within the Bobath Concept, these compensatory strategies are also minimised by therapeutically improving motor performance.

Foot position

The majority of studies have evaluated STS from a position where the feet are flat on the floor. A number of authors have considered the specific effects of foot placement on STS, for example when comparing foot forward or back position, symmetry or asymmetry (Khemlani et al. 1999; Roy et al. 2006).

In normality, foot placement frequently occurs simultaneously with the forward transfer of the centre of mass (COM). Determining the foot posture before the onset of STS may alter the parameters of the movement (Fig. 5.1). The initiation of the movement with heels either up or down is an important aspect for consideration of propulsion in STS, an area in which there has been very limited research. This will be further discussed in the clinical section of this chapter.

Fig. 5.1 Patient with ataxia moving between sitting and standing.

Upper limb position

In many studies, the upper limbs are folded across the body as a standardised posture; this has limited the investigation of the role of the upper limb in STS. Studies by Carr and Gentile (1994) and Mazza et al. (2004) are two notable exceptions which focused on the role of the upper limb during this activity. Carr and Gentile (1994) demonstrated that when the upper limbs were restricted, normal subjects transferred their body mass forward less at thigh-off, and there was a greater challenge to balance. Clinically, if upper limb involvement is impeded, for example by low postural activity, malalignment, hypertonia or biomechanical changes, the qualitative performance will be reduced. The upper limbs are often unable to contribute actively to the transfer and may even interfere with it as illustrated in the clinical example at the end of this chapter.

Carr and Gentile (1994) concluded that the upper limbs play a role not only in balancing the body during STS but also facilitate lower limb propulsion. A strong temporal coupling of activity between upper and lower limb was identified. More recent studies on interlimb neural coupling (Zehr 2005; Kline et al. 2007) support the clinical practice of appropriate activation and alignment of one body part to enhance activity in another, which is a fundamental principle in the clinical practice of the Bobath Concept. Normally, upper limb use depends on a number of factors including how far back the individual is in the seat, slope of the seat or height of the seat relative to leg length. The upper limbs may be used to assist the trunk moving forward, to provide momentum or to assist in raising the body at seat off. This has been shown to reduce the workload of the lower limbs (Mazza et al. 2004). The upper limbs are always an active part of the transfer, whether directly in generating propulsion or momentum, or more indirectly in terms of their compliance or 'cooperative alignment' with the movements of other body segments. Constraining upper limbs from any involvement in the postural transition from STS changes the nature of the task considerably (Carr & Gentile 1994).

Phases of sit to stand

The sequence of rising from STS has been variably divided into phases with the following four stages being the most commonly used (Schenkman et al. 1990). These are referred to as:

1. flexion momentum,
2. momentum transfer,
3. extension,
4. stabilisation.

Although these stages are often described separately, they form a continuum with the whole sequence often performed in less than 2 seconds (Chou et al. 2003). Therefore, the task requires the individual to overcome inertia, gain momentum, and control acceleration and deceleration. For the purposes of this chapter, we will use these stages as a framework to expand the analysis of each stage based upon observation of patients and normal subjects.

Stage 1: Flexion momentum
begins with initiation of the movement and ends just before the buttocks lift from the chair (seat off)

This description is based upon the subject starting from an unsupported sitting position. In relaxed sitting, the pelvis is often in a degree of posterior tilt and the pelvis moves towards anterior tilt during this phase of forward flexion of the trunk.

STS requires the coordinated interaction of linked body segments to transport the body's COM in both horizontal and vertical directions (Tully et al. 2004). This ensures that the body weight is raised by segmental, synergistic trunk and pelvic activity. Trunk extensor muscles and abdominal muscle co-activation are required to produce linear extension on a stable base created through the alignment and activation of the lower limbs. A small study by Dean et al. (2007) clearly showed that improvements in reaching activities in sitting correlated with increased activation of the lower limbs. There are strong biomechanical similarities and some common components in the patterns of activity in taking the body weight forward to reach and taking the body weight forward in STS (Papaxanthis et al. 2003). Clinically, therefore, the facilitation and practice of components of one task, for example reaching, may enhance the performance of another such as STS and vice versa. In this phase, it is also important to consider the head, trunk and upper limbs in combination with selective extension and forward transfer through the pelvis. Tully et al. (2004) emphasise the importance of segmental trunk activity in the acquisition of a stable extended trunk. Clinical experience suggests that gaining this efficiency in recruitment of trunk activity to transfer the body weight upwards and forwards requires a number of factors to be considered. These include:

- starting posture,
- degree of support,
- postural alignment and activity,
- relative seat height and surface.

Patients with poor postural control of the trunk and associated difficulty creating an optimal alignment may need preparation of activity at this stage. Hirschfeld et al. (1999) described the isometric 'rising forces' exerted under the buttocks in preparation for seat off which raise the centre of gravity before forward flexion begins. This underpins the clinical role of facilitation of antigravity activity exerted from the pelvis and hips in a lateral or antero-posterior direction necessary *before* forward flexion of the trunk. This improves timing and feed-forward control and may minimise unwanted compensatory strategies.

Stage 2: Momentum transfer
... begins at seat off and ends at maximal ankle dorsiflexion

This is the stage of the transfer which requires maximum power in the lower limbs, and STS has been shown to be more biomechanically demanding than walking or stair climbing (Berger et al. 1988).

Weakness can significantly impact on this phase. As the COM is now over the smaller base of support of the feet, there is also a greater challenge to stability, and clinically this is where the transition often fails.

Since the new base of support is relatively small, alignment, activity and stability in the ankles and feet are crucial. The dorsiflexors have been identified as the first muscle group to be active in STS drawing the tibial shank forward. This is often absent or delayed in stroke patients (Cheng et al. 2004), yet stability depends upon coordinated activity of tibialis anterior and soleus (Goulart & Valls-Sole 1999, 2001).

Commonly, individuals may not have heels in contact with the floor until the COM begins to move over the feet. Therefore, it is not essential for the whole foot to be in contact with the floor at *initiation* of STS, but there must be the potential to reach the floor *during* the transfer. The timing of this event is a key component of propulsion gained from the foot in STS. Dynamic stability and adaptability within the foot is required throughout all stages of the transitions. Interference factors such as limited range of movement or altered tone must be considered along with the choice and use of orthoses which may impact on foot mobility.

Appropriate alignment of the lower limbs can have a significant effect on the timing and pattern of muscle activation at this stage and into the extension phase. For example, a patient with multiple sclerosis, with increased muscle tone in the hip adductors, may use a strategy of increased hip flexion and anterior tilt during the forward momentum phase, increasing the difficulty of the rise into extension.

Stage 3: Extension phase
just after maximal ankle dorsiflexion until cessation of hip extension

This stage also demands a high level of postural control. Therapists must consider the whole kinetic chain in the maintenance of stability as the movement evolves. Coordinated activation of the hip, knee and ankle extensors raises the body up against gravity. As the body rises, the degree of anterior pelvic tilt reduces as the pelvis moves towards a more neutral alignment whilst the hips and knees extend.

In posturally unstable patients, such as those with ataxia, various strategies may be used to control the COM displacement, for example:

- adopting a wide base of support;
- increasing forward flexion;
- hyperextending knees;
- exaggerating dorsiflexion;
- bracing legs back against the seat edge (see Fig. 5.1).

The use of such short-term strategies may impede long-term recovery of STS. A reduced rate of force and greater postural sway, while rising into standing, has been shown to correlate with patients who are at risk of falling (Cheng et al. 1998).

Stage 4: Stabilisation
… from when hip extension ceases until all movement has stopped.

This phase has been identified as the most difficult to define, because the movement often forms a continuum with other functions such as walking (Kouta et al. 2006). The degree of postural sway in this phase increases in healthy elderly subjects, as well as in pathology (Mourey et al. 1998). In pathology, exaggerated strategies to increase momentum such as swinging the arms forward or excessive trunk flexion to STS can cause individuals to 'overshoot', with associated difficulty in arresting forward movement in a controlled manner, particularly common in ataxic patients.

Key Learning Point

- Appropriate alignment and activity of all body parts in the kinetic chain must be considered at each stage of the transition.

Movements from standing to sitting

Figures 5.1 and 5.2 show STS and moving from standing to sitting in a patient with mild ataxia and a normal subject, illustrating differences in foot placement, degree of forward flexion of the trunk, head alignment and use of upper limbs. Movement from standing to sitting is as important in daily function as STS but has been less frequently studied; controlling the descent into sitting is as challenging as rising to standing. Studies in the elderly have identified particular problems with maintenance of stability during this transition (Ashford & De Souza 2000; Dubost et al. 2005).

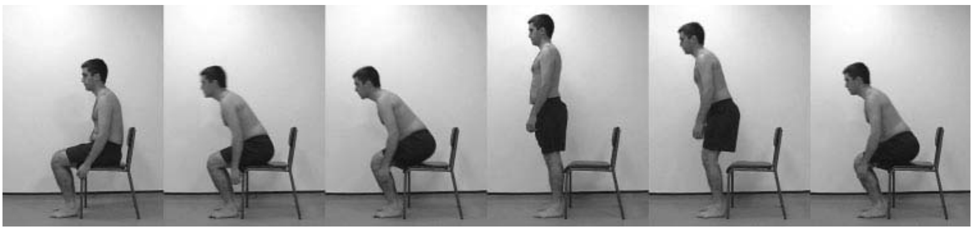


Fig. 5.2 Normal model moving between sitting and standing.

Standing to sitting takes significantly longer than STS (Papaxanthis et al. 2003; Roy et al. 2006), and this has been considered to be, in part, due to the need for accuracy in placing the pelvis without the help of visual guidance (Fig. 5.3). It has been described as a complex and potentially destabilising task as it is superimposed on a standing position, with an inherently small base of support (Dubost et al. 2005). The transition requires the ability to maintain postural stability, whilst allowing a graded lowering of the body mass using eccentric muscle activity. More variability in patterns of activity during sitting from standing compared to STS has been identified.

Moving from standing to sitting is not a simple reversal of STS as the activity of the trunk serves different functions in both. At the beginning of STS, the forward trunk inclination generates the horizontal momentum of the COM, whereas in stand to sit this correlates with the stability control in the anterior–posterior plane. In studies of muscle activation patterns in both transitions, results have been limited by the use of surface EMG where deep postural muscle activity could not be clearly identified (Ashford & De Souza 2000).

Fig. 5.3 Patient with ataxia falling to right side when moving from standing to sitting.

Variability of performance is influenced not only by levels of postural control but also by other factors such as body dimensions (Sibelia et al. 2003), age (Mourey et al. 1998; Dubost et al. 2005), sensory and psychological processes (Lord et al. 2002), other musculoskeletal issues such as low back pain (Shum et al. 2007), and the type of seat. If an individual is moving into a seat perceived to be unstable or which is particularly low, a stable upright posture is required to keep the COM higher for longer, until the buttocks take the support. 'Dropping' into your favourite armchair would be performed in a very different manner! Use of the upper limbs may be an alternative strategy to ensure a controlled descent (Fig. 5.4).

Although many studies have shown the forward movement of the trunk as the first component of moving from standing to sitting, postural preparation in the foot and ankle precedes this action in an efficient transition. In the 'stereotypical motor strategy' of standing to sitting described by Hase et al. (2004), increased activity of gastrocnemius was coupled with deactivation of erector spinae producing an initial forward translation of the centre of pressure with simultaneous

Fig. 5.4 Patient with ataxia controlling descent into sitting.

'unlocking of the trunk'. Dynamic stability around the ankle and foot is crucial for forward translation of the knees, which ensures the COM remains appropriately positioned within the base of support until the buttocks are placed onto the seat.

As in the preparation for the first stage of STS, it may be necessary to gain a more appropriate level of postural activity prior to the initiation of movements to sitting. When standing for long periods, 'locking' of the knees is a commonly adopted strategy used to reduce muscular activity. Moving efficiently from this alignment requires an initial increase in postural activity, preparatory anticipatory postural adjustments (pAPAs) (see Chapter 2) to bring the COM appropriately forward over the feet prior to a controlled descent. Patients who lock the knees for stability have particular difficulty in this initial stage. In the clinical setting, 'hands-on' facilitation increases sensory awareness of postural orientation. This promotes postural activity leading to dynamic stability of the trunk and pelvis. This ensures that forward translation of the knees does not cause the individual to 'drop' into flexion, but rather creates a stable reference point from which the eccentric activity within the lower limbs can evolve.

Key Learning Points

Neurological patients frequently demonstrate difficulty in controlling the movement from standing to sitting for a variety of reasons:

- Reduced mobility, stability and/or sensory feedback from the foot and ankle complex.
- Poor dynamic stability of trunk and pelvis.
- Reduced co-activation between quadriceps and hamstrings.

Effects of ageing

In the natural ageing process, changes occur in the sensorimotor systems leading to a gradual decline in strength, joint mobility and balance, as well as a reduction in multimodality sensory processing, with consequent challenges to the performance of these transitions. Comparative studies of the transitions between sitting and standing have explored differences in performance between younger subjects and older subjects (with and without pathology).

Elderly subjects were found to:

- adopt a more flexed posture with increased posterior tilt of the pelvis (Ikeda et al. 1991);
- increase range and speed of trunk forward flexion at seat off (Papa & Cappozzo 2000);
- place feet further forward correlating with reduced joint flexibility, hence inability to bring the feet back (Papa & Cappozzo 2000);
- have reduced thoracic extension resulting in an increased tendency to face down at lift off (Tully et al. 2004);
- take longer to achieve extension in STW, those at risk of falling taking five times longer (Kerr et al. 2007);
- have difficulty combining STS and gait initiation into a fluent STW strategy (Kerr et al. 2007);
- have reduced tactile sensation, ankle flexibility and toe strength correlating with decreased balance and functional abilities including STS (Menz et al. 2005);
- have increased dependence on upper limb compensatory strategies which correlated with decreased physical ability or lower seat height (Mazza et al. 2004);
- generate a lower knee extension torque (Lomaglio & Eng 2005) which correlated with increased risk of falls (Yamada & Demura 2007);
- have increased postural instability at seat off and just prior to seat on (Mourey et al. 1998) such that some elderly individuals who are independent in ambulation may still require help to STS;

- have increased difficulty in movements back to sitting comparable to a backward fall, particularly in frail elderly (Dubost et al. 2005).

Adaptations in the transfer are common in older individuals and require specific consideration in patients with additional neurological dysfunction.

Sit to walk

STW is a complex transitional task challenging both locomotor and postural control. At seat off, the discrete task of STS is merged with the rhythmic task of walking, requiring integration of the two tasks by the neural control system (Magnan et al. 1996).

The literature identifies some areas for clinical consideration:

- The horizontal velocity of the COM, normally arrested or constrained in STS (Schenkman et al. 1990), must continue unchecked.
- Smooth initiation of walking occurs before full extension is reached due to a significant increase of the speed of forward movement of the COM. This continued forward movement over a single leg makes the transition inherently more unstable (Kouta et al. 2006).
- Observation of normal subjects indicates that this transition typically begins with the feet placed asymmetrically as a preparatory postural adjustment for the initial step. Magnan et al. (1996) identified that the leg which would initiate the first step was loaded preferentially. Therapists may therefore organise an asymmetrical foot placement to facilitate increased loading, direction and fluency in STW.

The particular challenges of STW, indicated by a lack of fluidity, have been demonstrated in stroke patients (Malouin et al. 2003) and elderly patients at risk of falling (Kerr et al. 2007).

Clinical aspects

Mrs Bobath said of patients with neurological damage 'the movement goes wrong before it starts' (Mayston 2007). Contemporary teaching of the Bobath Concept still emphasises the impact an individual's prior movement experiences will have on both their current and future movement performance. This is due to the interaction between feed-forward postural control/anticipatory postural adjustments (APAs) and appropriate sensory motor feedback. In the clinical example (Mr FD), the early experience of pulling himself to standing with a standing aid, without adequate postural control, may have contributed to his asymmetrical compensatory behaviour in attempting to STS. Analysis of an individual's movement potential seen in movements between sitting and standing begins with observation of the starting posture and continues as the movement evolves. In Figure 5.5 initial observation may consider aspects such as level of postural activity, his relationship with the support provided by the chair and alignment.

Fig. 5.5 Using the clinical example consider:

- level of postural control;
- relationship with bases of support;
- key point alignment;
- limb alignment.

Further analysis would require evaluation of his response to being moved or handled within the posture, his ability to move voluntarily and his perceptual and cognitive orientation to the task.

Based on clinical reasoning, therapists can facilitate a patient's performance in a variety of ways. They may use visual or task-orientated cues such as placing an object for a reaching task in a seated patient to influence lower limb loading or incorporate verbal facilitation. This would consider choice of words, for example 'heels down to stand' rather than 'bend forward over your feet' and also different emphasis and/or timing of instructions to provide feedback, motivation and augment performance and learning. However 'hands-on' facilitation has always been an important part of the clinical application of the Bobath Concept and it is fundamental to both assessment and treatment intervention. This should not be misinterpreted as passive guidance with the patient being supported or lifted. 'Hands-on' facilitation may be used to:

- assess the postural response in moving from the back of the chair;
- limit degrees of freedom of the trunk for selective postural preparation by stabilising the thorax to allow more selective pelvic movement;
- optimise alignment through specific muscle mobilisation;
- provide specific support through the stabilisation of the knees for more selective hip extension;
- change timing and sequencing by gaining heel down at appropriate phase;
- provide specific proprioceptive cues for muscle activation through the co-activation of gastrocnemius and soleus for propulsion (Zajac et al. 2002);
- influence compensatory strategies by reducing effort through active 'de-weighting' of the trunk.

Movement in functional contexts

Movement involves complex interactions between the *task*, the *individual* and the *environment*. Efficient interaction of these components allows us to adapt our performance to different demands. These interactions may provide considerable challenges for our patients in moving between sitting and standing efficiently, effectively and safely. Table 5.1 illustrates aspects which may be considered regarding the task, the individual and the environment. Optimal movement control enables the individual to perform the transitions in a wide variety of environmental and functional contexts. Table 5.2 illustrates elements which may be considered within the therapy setting.

Table 5.1 Aspects which may be considered regarding the task, the individual and the environment.

Task/goal	Individual	Environment
• Sit to walk • Dressing • Transfer between seats • Stand to reach • STS while using upper limb functionally	• Body size and shape • Postural control • Perception/spatial awareness • Strength/flexibility • Age • Pain/anxiety/confidence	• Constraints and affordances of the immediate and wider environment. For example differences in seat height, depth, stability, arm supports, relationship with other elements such as a table/desk

Table 5.2 Elements which may be considered within the therapy setting.

Considerations within the therapy setting		
Task	**Specific impairments**	**Use of the environment**
• Whole/part task practice? • Repetition? • Variation? • Timing, speed, range? • Increase/decrease the demands of the task? • Increase/decrease cognitive challenges? • Dual tasking? • Context?	• Reduced ROM in the ankle for appropriate foot placement • Reduced trunk alignment for weight transfer • Postural activity in a low-toned upper limb	• Increase orientation and confidence • Context-based practice • Adjust the complexity of the environment considering, for example, attention/ cognition/dual tasking

In the clinical example the *individual* (Mr FD) could achieve the *task* of getting out of his chair in a very limited *environment* such as when pulling to standing with a standing aid. This, however, would not lead to improvement at an impairment level or enable the transition to be performed in 'a wide variety of environmental and functional contexts'.

Individual goals may include:

- to be assisted safely from sitting to standing by one person in order to allow return home with a spouse;
- to rise independently to walk;
- to get in and out of a car;
- to cope with a variety of seating to allow return to social and work environments.

Provision of assistance

For optimal recovery of efficiency in movements between sitting and standing, it is essential that the patient's movement experiences are positive, safe and therapeutic.

Demands for early independence in transfers from bed to chair or toilet may result in an emphasis on a sit-to-sit transfer where the patient largely remains in a flexed posture or develops compensatory strategies to achieve the task. However, incorporating as many components of an optimally efficient movement strategy as possible, especially facilitation of selective extension, maximises potential for recovery. Efficiency and independence in transfers may reduce secondary complications such as hemiplegic shoulder pain, which has been shown to be more prevalent in patients needing help to transfer (Wanklyn et al. 1996). These principles should be considered in transfers both with and without assistive devices. As discussed earlier in this chapter, the use of the upper limbs is not uncommon in the transitions between sitting and standing. Appropriate placement of the hands to a supporting surface can be used positively in therapy to:

- provide strong sensory information to help orientate the patient in space (see Fig. 5.12 in the clinical example);
- the creation of a contactual hand orientating response can enhance postural orientation and postural control (see Fig. 5.15);
- influence alignment within the upper limb and trunk (see clinical example);
- enhance postural control (Jeka 1997);
- give confidence and provide stability during the transition.

Figures 5.6 and 5.7 illustrate how repositioning the hands has a direct effect on the pattern of activity in the upper limbs and consequently on the improved recruitment of extensor activity in the trunk, pelvis and lower limbs. It is important to consider if the hands are interactive with the surface, so acting as part of a proprioceptive base of support, or simply pulling or pushing (see Mr FD in the clinical

Fig. 5.6 Pulling into stand.

Fig. 5.7 Reorientated hands for improved extension.

example). The alignment of the upper limbs can be facilitatory to, or interfere with, the activity and their use to provide orientation and stability rather than weight bearing is desirable. A range of equipment is available to facilitate safe moving and handling of patients which can also be used therapeutically in conjunction with careful assessment, clinical reasoning and intervention for optimal carry-over.

Clinical example

This section describes two treatment sessions with one patient who was unable to STS. Figures 5.8–5.24 relate to the first session and Figures 5.25–5.32 relate to a later session. The patient (Mr FD) had, 2 weeks previously, sustained a stroke leading to a left hemiparesis. Mr FD had been transferred into the rehabilitation ward from an acute medical unit. At this stage, he was unable to STS, and was being moved with a hoist on the ward. He was making attempts at this point to pull himself into standing with a standing aid.

He presented with very poor postural stability in the trunk (Figs 5.8 and 5.9) and required maximum assistance to rise from the seat. He uses a strong pull into

Fig. 5.8 Patient sits asymmetrically within the wheelchair.

Fig. 5.9 Postural low tone and asymmetry in trunk evident when feet placed onto the floor.

flexion with his right side leading to his right foot leaving the floor as he attempts to move his body forward from the back of the seat. This strategy was necessary to overcome the inertia from the hypotonic left side. Low postural tone created a tendency to 'fall' towards his left side in every situation and produced compensatory fixation from the right side, resulting in 'pushing' himself over to his left side, in an attempt to overcome the inertia in his left side, when being assisted to stand. Once in standing he could not orientate to midline, became anxious, and the increased fixation and push from the right foot made it impossible to maintain left foot contact with the floor (Fig. 5.10).

Fig. 5.10 Initial attempts at standing with support result in pushing behaviour from the right lower limb leading to increasing flexion of left lower limb resulting in difficulty maintaining foot contact with the floor.

His wheelchair offered inadequate support for an optimal sitting alignment as a basis for STS (Fig. 5.8). His trunk alignment was poor, tending to fall backwards and to the left which in part related to the weight of a very inactive left upper limb. This was exacerbated by the height of the footrests which increased hip flexion and posterior pelvic tilt, although trunk asymmetry persisted, even when his feet were on the floor (Fig. 5.9). Any attempts to change his orientation away from the fall to the left side were met by resistance from fixation into side flexion of the right side of his trunk. Initial assessment also showed that his ability to organise his postural orientation and support himself in standing was dominated by right upper limb fixation and an inability to gain midline and head orientation without help (Fig. 5.11).

Fig. 5.11 Providing an environmental reference to his right side demonstrated that he could fixate on his right hand but was still unable to orientate to midline or achieve a vertical orientation.

He appeared to have a predominant presentation of impairment of the postural control systems (see Chapter 2) and poor distal interaction of his hand to the plinth further impeding his postural orientation. His limited awareness and integration of the left side of the body into his body schema resulted in inadequate feed-forward control to create a more appropriate postural set for movements within and from the chair. Afferent information to his nervous system is dominated by stereotypical sensory information from his active right side but relatively little information from the inactive left side. Feed-forward postural control to body parts which have a poor representation in the body schema would be difficult and so it can be hypothesised that by changing his orientation to the left and improving integration between the two sides, there would be a positive impact on his midline orientation.

It was found that changing the orientation of his right hand by modifying the environmental support (Fig. 5.12) and creating a hand contactual orientation with the support (Porter & Lemon 1993), rather than passively placing it there, enhanced sensory and perceptual awareness, facilitating improved interaction of two sides of the body.

Fig. 5.12 Changing the orientation of the environment from a horizontal to a vertical support enhanced his extensor activity.

Key elements of initial presentation

- Postural inertia – hypotonic left side. Trunk and both left limbs feel very heavy.
- Poor interaction of right and left sides of the body.
- Lack of appropriate body schema.
- Poor midline orientation.
- Current seating does not provide adequate support or promote postural activity.
- Maladaptive movement strategies to initiate and maintain posture.
- Pulling himself to standing for personal care activities on the ward.

Initial treatment hypotheses:

- Integration of afferent information from both sides would improve as fixation from the right is reduced and activity on the left increased.
- Compensatory strategies being used in the ward situation will reduce if staff are guided to provide appropriate assistance to both sides of his body until adequate postural control is acquired.

Treatment intervention began by providing a reference of orientation to his right side to enable the acquisition of a more appropriate supporting strategy. This enabled assessment of potential to facilitate improved left scapulothoracic alignment in preparation for involving the left upper limb in placing for improved trunkal orientation. Pillow support was provided behind the trunk to help maintain extension as he became more appropriately postured. Head orientation to the right side is seen as a compensatory strategy, and this continued malalignment may lead to restriction of range and interfere with interpretation of vestibular information from the cervical afferents. Improvement in scapula setting on the left enabled increased weight transfer to the right side and reduction in the compensatory flexion. Normally, activity of one upper limb demands increased trunkal activity of both the ipsilateral and contralateral trunk (APAs), and so postural preparation to activate the left shoulder facilitates enhanced right trunk extension. This was more effective when his head was stabilised in midline so that his trunk orientation adapted rather than be dominated by an overactive head righting response (see Figs 5.13 and 5.14).

Fig. 5.13 Realignment of left shoulder girdle for thoracic stability and reorientation of trunk towards midline.

Fig. 5.14 Stabilisation of head helps facilitate more selective weight transfer in the trunk component.

Having improved orientation to the right side, it was now possible to begin to gain more interaction between the two sides. Provision of another support on the left side and activation of the left wrist and hand to gain a hand contactual orientating response whilst providing support to the upper arm enables him to begin to activate symmetrical independent extension (Figs 5.15 and 5.16).

Hypothesis refinement
The positive response to reducing his fixation strategy in the right side and orientation to the left hand improved his postural symmetry. Further activation of his right upper limb would allow active weight transfer towards his right side without flexion and so improve preparation to stand.

Moving a limb away from the body requires both preparatory and accompanying postural activity, a function of the reticulospinal pathways (Schepens & Drew 2006). Consequently, movements of the right upper limb demand preparatory postural activation bilaterally but particularly in the left side of trunk. Clinically, the limited repertoire of movement seen in the patient's less affected limbs, involved in fixation patterns, limits the expression of this contralateral and bilateral postural

Fig. 5.15 Activation of the distal key point for hand contactual orientating response to assist recruitment of postural control (Porter & Lemon 1993).

Fig. 5.16 Trunkal facilitation was given with slight downward compression in mid-thoracic area to increase thoracic extension until therapist's hands could be withdrawn and he could stabilise independently.

activity. In Mr FD, improved trunk and pelvic activity released his right upper limb from its fixation role, allowing it to be used as a key point of control to access further improvements in core stability. Once Mr FD's midline orientation improved, it was possible to increase the stability of his right shoulder girdle through improved scapula setting. This further enhanced trunk extension and enabled placing of his arm against a stable background (Figs 5.17 and 5.18) and enhanced trunk stability and the ability to begin selective weight transfer through right side.

Fig 5.17 Right scapula setting was facilitated to prepare for taking the arm from the support.

Fig. 5.18 Preparation for placing through repetitive activation of posterior deltoid and triceps until independent placing is achieved.

Further Hypothesis refinement
The more symmetrical activity of the trunk would be maintained in standing if Mr FD had specific activation of left foot to enhance sensory awareness before the dominant activity of right side began.

This improved postural control in the trunk allowed therapy to address more specific activation of lower limbs in preparation for STS. Clinical experience has shown that sensory stimulation of the foot for improved segmental interaction with the floor can improve activation in the limb to create standing. With direct facilitation of gastrocnemius, soleus has a reference from which to lengthen. Gaining heel contact with an appropriate stretch of soleus creates a strong proprioceptive drive for the propulsion into standing (Fig. 5.19). Maintenance of the length of the quadriceps also creates a drive to heel contact for initiation of standing activity (Fig. 5.20). It became clear that in Mr FD, strong peripheral input particularly in either hand or foot has a profound effect in enhancing body schema as evidenced by the improved postural integration.

Fig. 5.19 Activation of triceps surae for foot/floor interaction with gastrocnemius co-activating with eccentric soleus for heel down.

As he achieved standing, his control was further facilitated by modification of the adduction strategy in the right hip, combined with activation of left hip extension

Fig. 5.20 Lengthening distal quadriceps in combination with heel to floor to gain an appropriately patterned and timed response to initiate standing.

during part task practice as he lowered and regained extension between sitting and standing (Fig. 5.21). His standing stability improved to the point where he could free his head and maintain balance (Fig. 5.22), and then use only light touch contact with right hand to orientate himself (Jeka 1997). His stability and weight transfer towards the right side was enhanced by facilitation of abdominal activity on the left side when he no longer had left-hand stability provided by plinth (Fig. 5.23). At the completion of this session he had achieved the ability to stand symmetrically with light support (Fig. 5.24).

In the next filmed session, 10 days later, further progress was evident in his improved sitting posture. He could STS more easily with little facilitation but still had a tendency to overuse flexion and adduction in the right hip. He was therefore facilitated into supine, both to specifically address this issue and to create hip extension activity as a preparation for increased stability in standing. Stability of the right side of the trunk was maintained to prevent compensatory pelvic movement (Fig. 5.25) and better isolate hip extensors. This was combined with facilitation of forward weight transfer over the foot in crook lying as a basis for selective

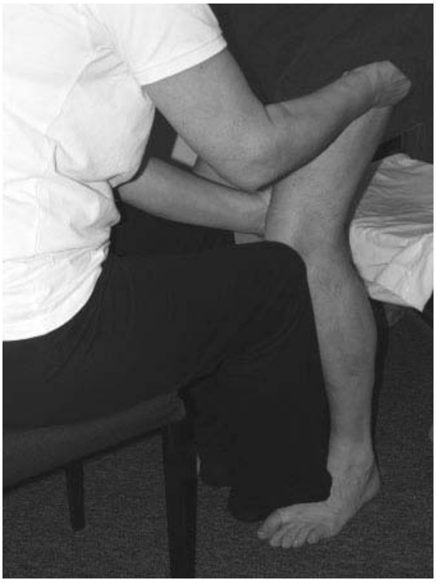


Fig. 5.21 Control of adduction right leg with back of therapists hand helps the left hip move forward actively into extension over knee.

Fig. 5.22 Once upright, the patient was encouraged to explore movements with a free head to develop orientation to midline in a vertical posture.

Figs. 5.23 Light touch contact from right hand and abdominal activation with slight compression of left ribs helps create orientation to midline.

Fig. 5.24 Symmetrical abdominal activation reduces tendency to hang forward and builds extension in his hips.

Fig. 5.25 Trunk stabilisation creates a reference for selective transfer forward of knee over foot for selective hip extension and discourages push back into upper trunk and resultant exaggerated lumbar lordosis.

pelvic tilt in bridging (Fig. 5.26). This activity shares specific components with STS including a transfer of weight from pelvis to feet.

The patient's strategy of pushing the trunk back to raise his pelvis was controlled by another therapist who limited the degrees of freedom in the trunk in order to maximise specific pelvic activity (Fig. 5.27). He was then able to achieve selective independent bridging (Fig. 5.28). Increased stability at the pelvis allowed him to improve his control in forward translation of the knee, a vital component in efficient movement from standing to sitting (Fig. 5.29). This component was also practised in the context of standing, using the wall as an environmental support

Fig. 5.26 Facilitation of active lengthening of right distal quadriceps to transfer weight to foot.

Fig. 5.27 Closed chain, inner range activity with additional trunk stabilisation was needed to give the patient the initial symmetrical activity of pelvic tilt to raise hips from plinth.

Fig. 5.28 Ability to isolate pelvic lifting was then achieved without the stable reference provided by the second therapist.

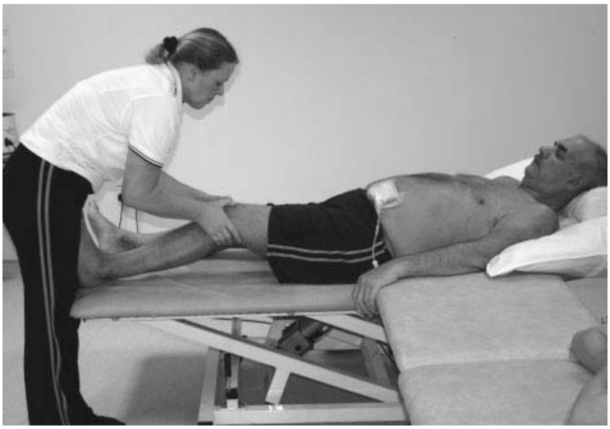


Fig. 5.29 Closed chain activity to use the distal key point orientation as preparation for knee transfer forward in standing.

for extension as the knee translated forward and regained extension in part task practice (Fig. 5.30). By the end of this session, Mr FD had achieved independent standing and could be facilitated to take some steps (Figs 5.31 and 5.32).

Summary points from the clinical example

- The early hypotonic patient provides a challenge in rehabilitation.
- Minimising the learning of inefficient compensation and yet maximising independence is a primary goal.

Fig. 5.30 Part task practice for moving within standing using forward translation of the knee, while still weight bearing, builds the eccentric control of the knee extensors for controlled descent.

- Systematic evaluation and specific intervention to influence *orientation*, *postural stability* and *activation* enables optimal performance as a basis for continued progression towards functional independence.
- Individual components can be addressed in a variety of postural sets before putting them into the performance of STS in different functional activities.
- Part task and whole task practice in a variety of settings will aid transferability of the skill.
- Achieving the appropriate alignment and activity of all body segments is necessary both prior to and during execution of the transfer.

A strong relationship between sensory input and motor output exists, for example the heels actively moving down to the floor is facilitatory to activation of the lower limb extensor musculature, optimising a more automatic drive to raise the body.

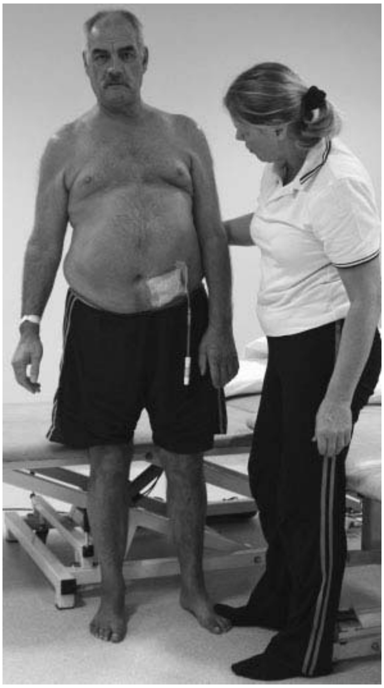
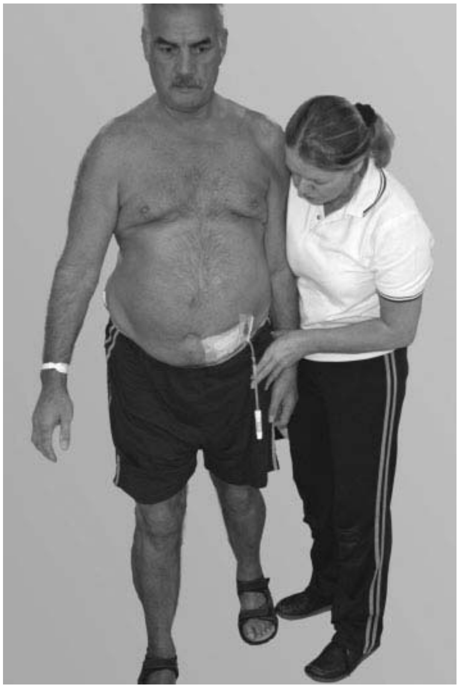



Fig. 5.31 and **5.32** Outcome of the treatment intervention. Independent standing and early facilitated stepping for transfer with increased confidence and stability.

Key Learning Points

- Acquiring independence in moving between sitting and standing is essential for achieving independent mobility.
- The extensive body of literature available gives an overview of the elements of the transfer, but to apply this information in a clinical setting the limitations imposed by the research methodology must be considered.
- A clear understanding of the interaction between postural stability and selective movement is needed to guide clinical reasoning and intervention.
- Achieving functional independence at the earliest opportunity is a key goal of rehabilitation but must be combined with the relearning of appropriate movement components if continued recovery is to be optimised and secondary adaptive changes minimised.
- As can be seen in the clinical example, many different factors may need to be taken into consideration in developing an individualised treatment intervention to optimise their potential at all stages of rehabilitation.

References

Ashford, S. & de Souza, L. (2000) A comparison of the timing of muscle activity during sitting down compared to standing up. *Physiotherapy Research International*, **5** (2), 111–128.

Bahrami, F., Riener, R., Jabedar-Maralani, P. & Schmidt, G. (2000) Biomechanical analysis of sit-to-stand transfer in healthy and paraplegic subjects. *Clinical Biomechanics*, **15**, 123–133.

Berger, R.A, Riley, P.O., Mann, R.W. & Hodge, W.A. (1988) Total body dynamics in ascending stairs and rising from a chair following total knee arthroplasty. *Transcript Orthopaedic Research Society*, **13**, 542.

Carr, J.H. & Gentile, A.M. (1994) The effect of arm movement on the biomechanics of standing up. *Human Movement Science*, **13**, 175–193.

Cheng, P.T., Liaw, M.Y., Wong, M-K., Tang, F.-T., Lee, M-Y. & Lin, P.-S. (1998) The sit-to-stand movement in stroke patients and its correlation with falling. *Archives of Physical Medicine and Rehabilitation*, **79** (9), 1043–1046.

Cheng, P.T., Chen, C.L., Wang, C.M. & Hong, W.H. (2004) Leg muscle activation patterns of sit-to-stand movements in stroke patients. *American Journal of Physical Medicine and Rehabilitation*, **83**, 10–16.

Chou, S.W., Wong, A.M.K., Leong, C.P., Hong, W.S., Tang, F.T. & Lin, T.H. (2003) Postural control during sit-to-stand and gait in stroke patients. *American Journal of Physical Medicine and Rehabilitation*, **82**, 42–47.

Dean, C.M., Channon, E.F. & Hall, J.M. (2007) Sitting training early after stroke improves sitting ability and quality and carries over to standing up but not to walking: A randomised controlled trial. *Australian Journal of Physiotherapy*, **53**, 97–102.

Dubost, V., Beauchet, O., Manckoundia, P., Herrmann, F. & Mourey, F. (2005) Decreased trunk angular displacement during sitting down: An early feature of aging. *Physical Therapy*, **85**, 404–412.

Goulart, F. & Valls-Sole, J. (1999) Patterned electromyographic activity in the sit to stand movement. *Clinical Neurophysiology*, **110** (Suppl. 9), 1634–1640.

Goulart, F. & Valls-Sole, J. (2001) Reciprocal changes of excitability between tibialis anterior and soleus during the sit-to-stand movement. *Experimental Brain Research*, **139**, 391–397.

Guralnik, J.M., Simonsick, E.M. & Ferrucci, L. (1994) A short physical performance battery assessing lower extremity function: Association with self-reported disability and prediction of mortality and nursing home admission. *Journal of Gerontology*, **49**, M85–M94.

Hase, K., Sako, M., Ushiba, J. & Chino, N. (2004) Motor strategies for initiating downward oriented movements during standing in adults. *Experimental Brain Research*, **158** (1), 18–27.

Hirschfeld, H., Thorsteinsdottir, M. & Olsson, E. (1999) Coordinated ground forces exerted by buttocks and feet are adequately programmed for weight transfer during sit-to-stand. *Journal of Neurophysiology*, **82**, 3021–3029.

Ikeda, E.R., Schenkman, M.L., Riley, P.O. & Hodge, W.A. (1991) Influence of age on dynamics of rising from a chair. *Physical Therapy*, **72**, 473–481.

Jeka, J.J. (1997) Light touch contact as a balance aid. *Physical Therapy*, **77** (5), 476–487.

Jette, D.U., Latham, N., Smout, R., Gassaway, J., Slavin, M. & Horn, S. (2005) Physical therapy interventions for patients with stroke in inpatient rehabilitation facilities. *Physical Therapy*, **85**, 238–248.

Kerr, A., Rafferty, D., Kerr, K.M. & Durward, B. (2007) Timing phases of the sit-to-walk movement: Validity of a clinical test. *Gait & Posture*, **26**, 11–16.

Khemlani, M.M., Carr, J.H. & Crosbie, W.J. (1999) Muscle synergies and joint linkages in sit-to-stand under two initial foot positions. *Clinical Biomechanics*, **14**, 236–246.

Kline, T.L., Schmit, B.D. & Kamper, D.G. (2007) Exaggerated interlimb neural coupling following stroke. *Brain*, **130** (Pt 1), 159–169.

Kouta, M., Shinkoda, K. & Kanemura, N. (2006) Sit-to-walk versus sit-to-stand or gait initiation: Biomechanical analysis of young men. *Journal of Physical Therapy Science*, **18**, 201–206.

Lomaglio, M.J. & Eng, J.J. (2005) Muscle strength and weight-bearing symmetry relate to sit-to-stand performance in individuals with stroke. *Gait & Posture*, **22**, 126–131.

Lord, S.R., Murray, S.M., Chapman, K., Munro, B. & Tiedemann, A. (2002) Sit-to-stand performance depends on sensation, speed, balance and psychological status in addition to strength in older people. *Journal of Gerontology: Medical Science*, **57A**, M539–M543.

Magnan, A., McFadyen, B.J. & St Vincent, G. (1996) Modification of the sit-to-stand task with the addition of gait initiation. *Gait & Posture*, **4**, 232–241.

Malouin, F., McFadyen, B., Dion, L. & Richards, C.L. (2003) A fluidity scale for evaluating the motor strategy of the rise-to-walk task after stroke. *Clinical Rehabilitation*, **17**, 674–684.

Mayston, M. (2007) Personal communication. Bobath 50 Conference.

Mazza, C., Benvenuti, F., Bimbi, C. & Stanhope, S. (2004) Association between subject functional status, seat height, and movement strategy in sit-to-stand transfer. *Journal of the American Geriatric Society*, **52**, 1750–1754.

Menz, H.B., Morris, M.E. & Lord, S.R. (2005) Foot and ankle characteristics associated with impaired balance and functional ability in older people. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, **60A**, 1546–1552.

Mourey, F., Pozzo, T., Rouhier-Marcer, I. & Didier, J.-P. (1998) A kinematic comparison between elderly and young subjects standing up from and sitting down in a chair. *Age and Ageing*, **27**, 137–146.

Papa, E. & Cappozzo, A. (2000) Sit-to-stand motor strategies investigated in able-bodied young and elderly subjects. *Journal of Biomechanics*, **33**, 1113–1122.

Papaxanthis, C., Dubost, V. & Pozzo, T. (2003) Similar planning strategies for whole-body and arm movements performed in the sagittal plane. *Neuroscience*, **117**, 779–783.

Porter, R. & Lemon, R. (1993) *Corticospinal Function and Voluntary Movement – Monographs of the Physiological Society*. Clarendon Press, Oxford.

Roy, G., Nadeau, S., Gravel, D., Malouin, F. & McFadyen, B.J. (2006) The effect of foot position and chair height on the asymmetry of vertical forces during sit-to-stand and stand-to-sit tasks in individuals with hemiparesis. *Clinical Biomechanics*, **21** (6), 585–593.

Schenkman, M., Berger, R.A., O'Riley, P., Mann, R.W. & Hodge, W.A. (1990) Whole body movements during rising to standing from sitting. *Physical Therapy*, **70**, 638–651.

Schepens, B. & Drew, T. (2006) Descending signals from the pontomedullary reticular formation are bilateral, asymmetric, and gated during reaching movements in the cat. *Journal of Neurophysiology*, **96** (5), 2229–2252.

Shum, G.L.K., Crosbie, J. & Lee, R.Y.W. (2007) Three dimensional kinetics of the lumbar spine and hips in low back pain patients during sit-to-stand and stand-to-sit. *Spine*, **32**, 211–219.

Sibelia, F., Galli, M., Romei, M., Montesano, A. & Crivellini, M. (2003) Biomechanical analysis of sit-to-stand movement in normal and obese subjects. *Clinical Biomechanics*, **18**, 745–750.

Tully, E.A., Fotoohabadi, M.R. & Galea, M.P. (2004) Sagittal spine and lower limb movements during sit-to-stand in healthy young subjects. *Gait & Posture*, **22**, 338–345.

Wanklyn, P., Forster, A. & Young, J. (1996) Hemiplegic shoulder pain: Natural history and investigation of associated features. *Disability and Rehabilitation*, **18**, 497–501.

Yamada, T. & Demura, S. (2004) Influence of the relative difference in chair seat height according to different lower thigh length on floor reaction forces and lower limb strength during sit-to-stand movement. *Journal of Physiological Anthropology and Applied Human Science*, **23**, 197–203.

Yamada, T. & Demura, S. (2007) Relationships between ground reaction force parameters during a sit-to-stand movement and physical activity and falling risk of the elderly and a comparison of the movement characteristics between the young and the elderly. *Archives of Gerontology and Geriatrics*, **48**, 73–77.

Zajac, F.C., Neptune, R.R. & Kaitz S.A. (2002) Biomechanics and muscle coordination of human walking Part II: Lessons from dynamical simulations and clinical implications. *Gait & Posture*, **17**, 1–17.

Zehr, E.P. (2005) Neural control of rhythmic human movement: The common core hypothesis. *Exercise and Sport Sciences Reviews*, **33**, 54–60.

6. *The Control of Locomotion*

Ann Holland and Mary Lynch-Ellerington

Introduction

Walking is often one of the most important goals for patients with neurological conditions participating in rehabilitation (Mudge & Stott 2007). This chapter will consider key aspects of locomotion and the clinical application. The explicit aims of the chapter are to:

- introduce key aspects of bipedalism;
- explore specific features of motor control;
- consider gait initiation;
- highlight clinical problems and interventions that can be used in the hemiparetic population;
- adapt clinical interventions for persons with other neurological conditions.

Key aspects of bipedalism

Human erect locomotion is unique among living primates and demonstrates specific biomechanical features that make it mechanically efficient and enduring (Lovejoy 2004). The regulation of bipedal stance and gait requires specific neuronal mechanisms to maintain the body in an upright position (Dietz & Duysens 2000). Humans have developed an upright stance capable of endurance walking over very long distances. These features, in accordance with the laws of form and function, are neuroplastically matched by the motor patterns generated in the nervous system (Grasso et al. 2000).

Man is capable of locomotion over a wide range of velocities, from very slow speeds to short time performance at speeds up to and above 10 metres per second

(Neptune & Sasaki 2005). Key evolutionary aspects underpinning bipedalism (Lovejoy 2004) are:

- the unique human abductor apparatus providing pelvic stabilisation during single leg stance;
- the development of a lordosis and the repositioning of the centre of mass;
- the expanded role of gluteus maximus from which to control trunk extension at heel strike.

Proper execution of locomotion requires integration of neuronal subsystems involved in the creation of postural and locomotor control (Mori et al. 1998). The evidence now strongly supports the concept that the trunk is an active component of postural control preceding the initiation of walking and not a passenger as may have originally been thought (Perry 1992). Locomotion must assure a forward progression compatible with dynamic equilibrium, adapting to potentially destabilising factors in an anticipatory fashion by means of coordinated synergies of the upper limbs, trunk and lower limbs (Grasso et al. 2000). Integrated control of posture and walking is made possible because these two motor functions share some common organisational principles. Firstly, the frame of reference for the kinematic coordination for both postural responses and locomotion seems to be anchored to the vertical. Secondly, control of the position of the centre of mass for static or dynamic equilibrium is involved in both gait and posture (Grasso et al. 2000). The concept of integrated control of posture and locomotion is central to the clinical practice of the Bobath Concept. This stems from neurophysiological evidence with respect to nervous system control and its relationship with afferent information updating body schema. This is a fundamental aspect of efficiency in postural control. Neurophysiological studies indicate that the control of posture and locomotion are interdependent, and interdependency exists at many different levels in the nervous system (Patla 1996).

Essential requirements for locomotion

Walking is a complicated motor act requiring the coordination of trunk and limb muscles crossing many joints (Mackay-Lyons 2002). It is a basic prerequisite of daily life as well as one of the most automatic, and is the functional result of the interaction of biomechanical, neurophysiological and motor control systems. The desire to regain walking ability after neurological dysfunction is often the primary goal of rehabilitation, and as a consequence much time and energy is devoted to its retraining.

> *'The only thing I wanted to do after my stroke was walk to the toilet, nothing else mattered until I had achieved my goal alone' …*
>
> *Mrs AJ*

The pattern of human locomotion is unique and determinants of gait include:

- heel strike at initial contact;
- a loading response in early stance;
- heel rise from flat foot at the end of stance (Kerrigan et al. 2000);

- pelvic/trunk rotation;
- a synchronised out-of-phase activity of lower extremity extensor and flexor muscles (MacKay-Lyons 2002).

Successful human locomotion is characterised by a basic locomotor pattern which moves the body in the desired direction and postural control to support the body against gravity (Shumway-Cook & Woollacott 2007). Walking must also be adaptable to meet the needs of the individual and the demands of the environment. This is achieved through the regulation of postural tone, particularly in the extensor antigravity musculature, and correct foot placement (Grillner et al. 1997). In order for these task requirements to be met, a non-hierarchical tripartite control system is required.

Tripartite control

The tripartite control system consists of supraspinal input from cortical and subcortical structures, spinal central pattern generating (CPG) circuits and sensory feedback, primarily somato sensory from afferents innervating skin and muscle that are activated by rhythmic arm and leg movement (Zehr & Duysens 2004). The term locomotor CPG refers to a functional neuronal network which can generate a rhythmical repetitive stepping pattern (Grillner 2002). In this context, locomotion is triggered by descending commands instigated by the cortex delegating the motor command to CPGs controlling the upper and lower limbs. Locomotor activity follows and peripheral feedback informs the nervous system of local conditions to shape CPG output. The nervous system exploits the effector system to provide efficient control. Supraspinal and sensory influences are extremely powerful and facilitate the ability to modify limb movements while ensuring the maintenance of balance and posture (Sorensen et al. 2002).

The cortical control of walking is complex with respect to the relationship of cortical and subcortical structures involved. Once initiated, however, locomotion does not require conscious direction other than to terminate, to change direction and to negotiate obstacles (Jahn et al. 2004). As cortical involvement lessens, it is possible to attend to other things and leave the relative automaticity of walking to the spinal circuits and the cerebellum. For walking to be truly functional, it has to be of reasonable speed and distance, for example to allow crossing the road in a given time at a pedestrian crossing. In terms of domestic walking, the minimum distance required to walk may be from the sitting room to the toilet (Bohannon 2001). Walking in a simple environment of open space is often challenging for patients, and walking in the complex environment of a busy street or shopping centre may be impossible without the component of automaticity. Taking the patient to a dual tasking level is an essential role of rehabilitation, because it represents life in the real world.

Cortical control of gait initiation

'I find it's so hard to get going and once I do it's even harder to stop' …

Mr S

Taking the first step is a significant goal to achieve in rehabilitation. Cortical drive is an essential component for the initiation and termination of CPG activity

(Jahn et al. 2004). Although CPG activity remains controversial, there appears to be a consensus based on animal studies that the mesencephalic locomotor region (MLR) initiates locomotion through activation of the pontomedullary reticular formation in the brainstem, with the nucleus gigantocellularis cited as an important structure of initiation (Armstrong 1986; Jordan 1991; Brocard & Dubuc 2003). Feed-forward input from the reticulospinal neurons can have a variable effect on CPGs (Mackay-Lyons 2002). Feedback via spinoreticular neurons and inputs from other regions of the brain appear to be necessary to stabilise the locomotor rhythm (Mackay-Lyons 2002).

In summary, the sensorimotor cortex, cerebellum and basal ganglia are involved in:

- activating the spinal locomotor CPGs;
- controlling the intensity of CPG operation;
- maintaining dynamic equilibrium during locomotion;
- adapting limb movement to external conditions;
- coordinating locomotion with other motor acts (Mackay-Lyons 2002; Paul et al. 2005).

Clinical relevance

Initiation of the first step from a quiet stance involves moving the centre of mass outside the base of support, transferring weight over the support limb and moving the swing limb forward (Patla 1996).

Corticospinal drive is involved in the initiation of the gait cycle through flexion of the swing leg towards the first heel strike (Fig. 6.1). The first step is accompanied by feed-forward postural control which counteracts perturbation to the body caused by activating flexion of the lower limb. The demands on the postural control mechanism for the first step are very specific and clinically relate to the ability of the hemiparetic patient to attain single leg stance on both sides. Achievement of single leg stance on both the non-hemiparetic and hemiparetic lower limbs means that the resultant perturbation, caused by the moving leg, does not cause excessive displacement which will have to be compensated for. It is necessary therefore to:

- have feed-forward control anticipating the expected perturbation;
- create axial extension on the standing limb with the harmonious integration of the ipsilateral antigravity systems of the corticopontine reticulospinal and vestibulospinal systems;
- unload the lower limb to be moved and develop initial propulsion;
- have reciprocal inhibition of the antagonists to the prime movers of the lower limb to be moved;
- have flexion of the hip of the lower limb to be moved and online accompanying postural adjustments for the first heel strike (Fig. 6.1).

Ideation of the goal of walking and creation of the initial postural set are essential for the initiation of the first step. The resultant disinhibition of the substantia nigra pars reticularis and activation of the MLR then follow. A simple continuous

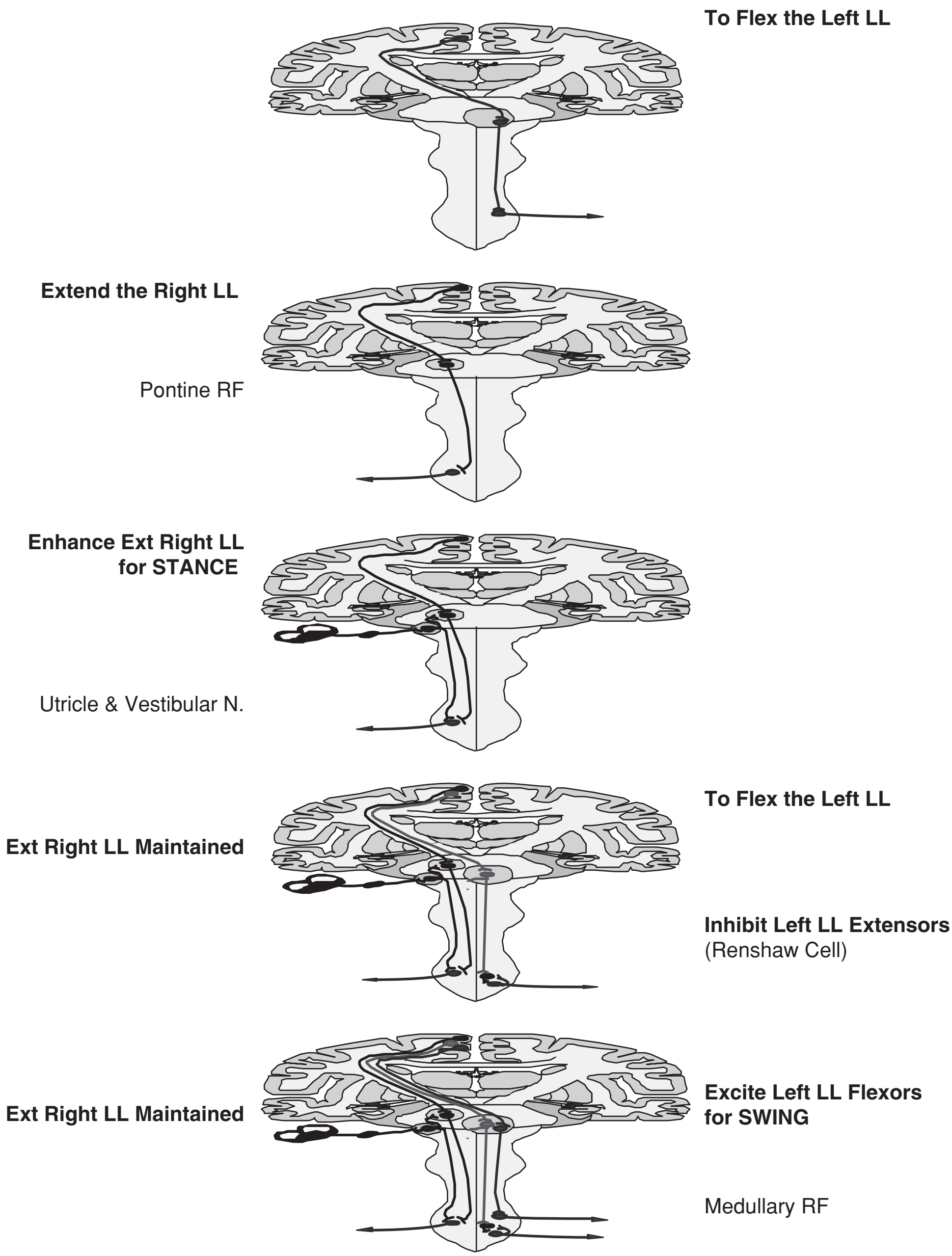


Fig. 6.1 Systems control of locomotion. Reproduced with permission from Nigel Lawes. The diagram has been adapted for clarity in this book.

stimulation of the MLR can elicit locomotion which involves the activation of many different muscles in patterns (Brocard & Dubuc 2003). It has been demonstrated in decerebrate models of cats, rats and primates that the more intense the stimulation, the faster the animal locomotes. The MLR projects to reticulospinal neurons in the lower brainstem via the nucleus gigantocellularis and exhibits potent control over the locomotor pattern (Grillner et al. 1997; Brocard & Dubuc 2003) (Fig. 6.2).

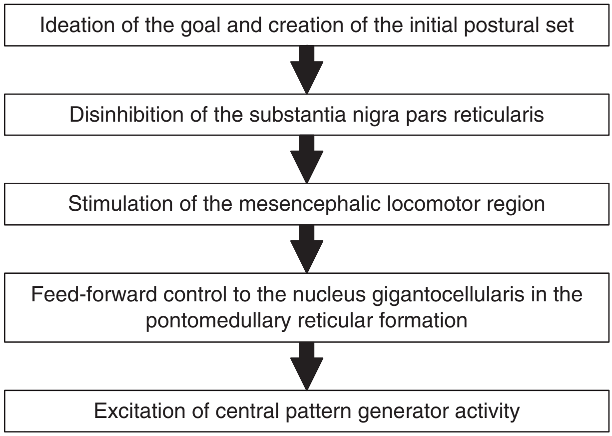


Fig. 6.2 Cortical control of gait initiation.

The gait cycle

'When my knee locks back I think that it will make me fall over' …

Ms ABP

Walking requires repetitive movements of the lower limbs and includes a period of double support when both feet are in partial contact with the ground followed by periods when only one foot is supporting the body while the other is being moved above the ground. A single limb gait cycle consists of stance and swing phases and can be considered in functional terms of weight acceptance, single limb support and limb advancement (Ayyappa 2001).

The single limb gait cycle is often described in phasic terms of initial contact, loading response, mid-stance, terminal stance, pre-swing, initial swing, mid-swing and terminal swing. Pre-swing is the transitional phase between single leg stance on one limb and limb advancement on the other.

A clear description of the kinematics of stance phase has been provided by Moseley et al. (1993). For most of stance phase, the hip is in extension requiring full eccentric control and length of the hip flexors. Hip extension and ankle dorsiflexion transport the vertical trunk segment from behind to in front of the stance foot, and rapid ankle plantarflexion at the end of stance further propels the body forward. Early in stance the trunk is displaced laterally, accompanied by adduction on the stance hip and eversion of the stance foot (lateral pelvic displacement), so that the centre of mass is moved to a point nearly over the stance foot for the duration of the single support phase. The knee remains relatively extended throughout the single support phase but flexes a small amount in early stance. During the final phase of stance, the knee flexes in preparation for swing (Moseley et al. 1993).

Swing phase begins at toe-off and ends at heel strike as the foot is moved forward to a point in front of the hips (Moore et al. 1993). During swing, the lower limb shortens adequately to allow the swinging foot to clear the ground. Hip and knee flexion is followed by knee flexion to knee extension and dorsiflexion. The knee begins to flex in the last third of stance and continues flexing for the first quarter of swing. Thereafter, the knee extends until just before heel strike when slight flexion occurs in preparation for the next stance phase. The hip begins to flex in the later part of stance and completes flexion in the first half of swing. Ankle dorsiflexion begins just after toe-off and peak dorsiflexion is reached by mid-swing and maintained throughout the remainder of the swing phase (Moore et al. 1993).

The role of the foot as a source of sensory input

'I wish I could lift my toes it would make walking so much easier' …

Mrs O

'If I could feel my heel hit the ground then my leg would be much stronger' …

Mr S

The foot is a key source of peripheral input to control and adjust the muscle activation pattern of the lower limb, particularly during stance phase. The intrinsic muscles within the foot are essential for the adequate performance of ground reaction forces and the development of the appropriate kinetic chain of muscle activation to create adequate stance for sufficient swing. 'The forces applied to the foot during contact with the ground are called ground reaction forces (GRF)' (Simoneau 2002).

The force platform allows the assessment of the total force applied by the foot to the ground (Winter 1995). In quiet stance, the pressure is evenly distributed and the centre of pressure is positioned posterior to the ankle, midway between the two feet.

Ground reaction forces reflect accelerations of the centre of mass and are not influenced by changes in footwear (Kirtley 2007). The ground reaction forces become very different when trunk accelerations are modified. A strong reaction with the ground through heel contact is an essential component of producing efficient ground reaction forces and muscle activation patterns.

Adequate heel contact with the ground is a major point of stability for ankle movement, and therefore selective dorsiflexion and plantarflexion. Stable heel contact with the ground is also essential for selective knee and hip movement in mid-stance. The single limb support phase is fundamental for generating and building up the kinetic energy for the next swing. Clinical observation suggests that the stronger and longer the stance phase, the better the swing.

Achievement of single leg stance through activation of the foot

Following stroke, the creation of single leg stance for locomotion is often difficult because:

- preparatory anticipatory postural adjustments in respect of trunk activity on the stance side are reduced;
- accompanying anticipatory postural adjustments in respect of the feed-forward control of axial extension are decreased;
- corticospinal activation of the foot is often diminished;
- an ankle strategy is absent and control of the forward movement of the tibia is therefore reduced;
- there is poor reciprocal activity of the quadriceps and hamstrings;
- weakness of hip and pelvic extension allows too much lateral displacement of the pelvis on the stance side and therefore poor acquisition of mid-stance;
- there is loss of afferent information and reduced sensory awareness.

Damage to the corticospinal system can produce long-term loss of the activation of the intrinsic musculature of the foot, which is necessary to create the postural stability for selective flexion and extension of the toes. Clinical observation suggests that the ability to extend the toes contributes to selective dorsiflexion as does the postural activity of abductor digiti minimi. Abductor digiti minimi is a key component of movement control of the foot as it supports the weight of the lateral border and contributes to the comparatively weak peronei everting the foot, which is important for ground clearance and step initiation.

Loss of length and strength in soleus as an antagonist will also significantly contribute to poor dorsiflexion of the foot. Unopposed dorsiflexion without eversion often becomes inversion because of unopposed activity in tibialis anterior, especially when driven cortically.

Influencing the foot therapeutically after a stroke includes:

- provision of sensory information to the foot;
- stretch to the intrinsic muscles of the foot in order to selectively activate the foot;
- improving alignment at the talocrural joint;
- activation of gastrocnemius facilitates eccentric control of soleus;
- facilitation of ankle strategy.

Taking the first step and influencing the specificity of the swing phase is possible through:

- the creation of active stance phase;
- controlling lateral displacement of the pelvis on the stance side so that swing can begin by selective hip flexion;
- facilitation of eccentric control of hip flexion for knee extension to begin;
- having sufficient muscle and neural length to gain an adequate step length and active dorsiflexion for heel strike.

Creating a backward step for the initiation of locomotion

Walking can be considered as the task of leaving one leg behind (Bobath 1990). There are many advantages to creating a stable upright bipedal stance from which the patient can experience a backward step for the initiation of locomotion. In therapy, bilateral active extension in the trunk can be facilitated by actively placing the upper limbs in a reach position and supporting them appropriately. A neutral position of the pelvis will switch on core stability musculature providing the postural basis for initiating hip and knee extension. Hip and knee extension can be timed temporally to reflect the walking pattern. The foot when maintained in dorsiflexion will influence reciprocal activity of the quadriceps and hamstrings and promote appropriate neural length. Therapeutic stretch through dorsiflexion stimulates improved proprioceptive awareness (see Figs 6.10–6.12). A key compensation for diminished body schema is the overuse of vision to check on foot position. An advantage for working for the development of a backward step is that it is without vision and could progress into a dual task, and therefore the development of automaticity in walking. Improved step length can also be gained from this position of stability.

The use of side lying as a postural set

Side lying can be used to effectively create the perception of the relationship between a stance leg and a moving leg, which is context based on locomotion. The advantages of side lying as a postural set in order to retrain components of locomotion include the ability to:

- create stability of the ipsilateral leg, usually the non-hemiparetic side, through the facilitation of extension with dorsiflexion of the ankle when turning from supine (see case study Figures 6.18 and 6.19);
- increase the stability component with a reach alignment of the non-hemiparetic upper limb;
- explore scapula setting on the hemiparetic side;
- posturally activate the hemiparetic upper limb and develop a contactual hand-orientating response (Porter & Lemon 1993);
- selectively activate the hip, knee and foot within the hemiparetic lower limb;
- strength train quadriceps, hamstrings and hip abductor stability;
- improve core stability.

When rhythmical reciprocal gait is cessated for a period of time, then neither lower limb can be considered any longer 'normal' in its efficiency and movement patterns. Muscle activation will have altered through the use of cortical and subcortical compensatory mechanisms for essential daily life functions such as transferring. The key to working in side lying effectively is to use the non-hemiparetic leg as the key source of stability. Keeping the non-hemiparetic leg active with extension at the hip and knee and maintaining dorsiflexion give stability to the postural set in which selective movement of the hemiparetic leg can be explored actively rather than passively. For many patients it may be necessary to stabilise the trunk.

The use of supine as a postural set to create stable crook lying and work for core stability

Supine is a postural set in which components of movement related to locomotion can be explored provided the set is created dynamically and used to activate and strengthen key muscles and patterns. The postural set of side lying can be used to prepare for supine, especially if the key relationships of hamstrings and quadriceps have been explored. From side lying the creation of active supine can be attained through hip and knee extension with the foot in dorsiflexion and the maintenance of reach of the upper limb to allow the thorax to move backwards selectively and the head to follow last.

The creation of active supine should ideally start with the facilitation of stop standing to sit to supine in one continuum of movement in order to maintain and/or attain aspects of core stability (Kibler et al. 2006). The attainment of active supine may specifically include:

- facilitation of stand to asymmetrical sitting through eccentric muscle control and for an optimal starting position;
- in sitting training of abduction of the non-hemiparetic leg onto the plinth for trunk stabilisation on the hemiparetic side with the hemiparetic arm posturally and actively placed;
- initiation through dorsiflexion of the non-hemiparetic foot that facilitates abduction of the non-hemiparetic leg to achieve asymmetrical long sitting;
- creation of an active trunk in long sitting for reciprocal innervation of core stability musculature into supine;
- reaching activities of the upper limbs that promotes optimal core stability.

In supine, consideration of the postural alignment of the head, neck and shoulder complex as well as the length of the back extensor musculature is critical prior to activation of either the core stability or the lower limbs. Improving core stability can have a positive effect upon:

- increasing verticality in the trunk for improved cadence;
- developing hip extension for heel strike;
- increasing step length (Wilson et al. 2005).

Creating the postural set of single leg stance from high sitting to 'stand down'

During the initial acute phase after a stroke, most patients will naturally be more orientated to their non-hemiparetic side. If this is allowed to persist and rehabilitation adopts a compensatory approach, the hemiparetic side is unlikely to recover pattern-generated activity. In the therapeutic situation, afferent input to the hemiparetic side, more than to the non-hemiparetic side, is therefore emphasised. Following stroke, stance on the unaffected leg is often increased, with less time spent in single leg stance on the hemiparetic side (Bohannon 2001).

Facilitation from high sitting by preferentially standing down onto the hemiparetic leg is a key aspect of training single leg stance as a basis for a reciprocal gait pattern. Importance is placed on initial heel contact to the ground using concentric dorsiflexion to achieve ground contact and to reciprocally inhibit mass dysynergic plantarflexion, often seen in patients with neurological dysfunction. Appropriate lengthening of the medial hamstrings and tensor fascia latae may be necessary in cases where aberrant ambulation strategies have been learned. Attention may need to be given to the alignment of the knee to the foot and stabilisation of the patella for excitation of the distal quadriceps to allow lengthening of the proximal aspect of rectus femoris. Controlled hip extension from the high surface is achieved through proximal hamstring and gluteal muscles and is reflective of the selective movements required to achieve mid-stance in the locomotion cycle.

Use of the postural set of prone and standing down from prone lying

Prone is used selectively rather than routinely for patients with loss of selective lower limb movement. In order to optimise performance, prone should be created actively from either supine through selective hip extension or side lying through selective leg extension with dorsiflexion of the foot. In this way flexor activity can be minimised and the potential for extensor activity evaluated.

Clinically one of the most limiting factors to the use of prone may be the range of movement of the hemiparetic shoulder complex, and therefore time may have to be given to facilitate optimal alignment of this area to achieve this postural set. Aspects of muscle length and neural tension can be addressed in this postural set, especially when dorsiflexion of the hemiparetic limb (or indeed non-hemiparetic limb in some instances) with extension of the knee and hip can be achieved actively (see Figs 6.20 and 6.21).

From an actively extended lower limb, fractionation of the pattern through selective knee movement can be explored without vision and is reliant entirely on proprioceptive body schema. If the previous facilitation has been accomplished, then it is beneficial to bring the patient directly into single leg stance on the prepared lower limb from prone to:

- exclude vision – find the floor through proprioception with your heel;
- create stance distal to proximal;
- align the body to the vertical with respect to the stance leg;
- free the upper limbs for functional activity.

Use of body weight support treadmill training in the Bobath Concept

Automaticity of walking following neurological dysfunction may be difficult when locomotor networks are no longer used in terms of pattern generation and in respect of the loss of the specific demands walking makes on the postural control system. However, plasticity can be exploited in rehabilitation when specific individualised training approaches are used (Dietz 2003).

Body weight support treadmill training (BWSTT) provides an environment in which one can facilitate balance control and manually assist trunk and leg movement when stepping and standing (Kern et al. 2005). It involves unloading the lower limbs by supporting a percentage of the body weight (up to 40%). It has been suggested that a maximum of 30% deweighting enables activation of muscles at normal amplitude (Hesse & Werner 2003). In the stroke population, the percentage of body weight supported should facilitate appropriate trunk and limb alignment and allow transfer of weight onto the hemiparetic lower limb. If body weight is decreased too much, there is a reduction in ground reaction forces and sensory feedback. It has been suggested that BWSTT discourages the development of compensatory strategies compared with gait training with walking aids (Visintin et al. 1998).

The rationale for the use of the treadmill is to drive spinal motor programmes through proprioceptive inputs and modulate central pattern-generated activity (Dietz 2003). Afferent feedback regarding the position of the extended hip initiates the ipsilateral swing phase and cutaneous receptors, which are sensitive to load, activate lower limb extensor muscles during stance (Van de Crommert et al. 1998). Adaptation of the locomotor pattern to changes in speed is modulated by sensory feedback. Facilitation of walking on the treadmill can influence the degree of loading and joint position.

BWSTT is an efficient way of promoting task-specific training; however, it is not without its practical difficulties. Strain on the therapist is a major limiting factor to its use, especially in the non-ambulant patient. If the ability to move from sit to stand independently is present, then this would suggest adequate postural control mechanisms for BWSTT to begin successfully. Consideration is also given to the ability to achieve single leg stance on one leg for the development of appropriate stride length.

A systematic review of the literature has concluded that treadmill training with or without body weight support may be preferable to no intervention but that there was no support for choosing this approach over conventional therapy (Manning & Pomeroy 2003). A Cochrane review also found no significant difference between treadmill and other methods of gait training (Moseley et al. 2005). However, for already mobile patients, there was a trend towards improvement in gait speed, although this was not statistically significant. Treadmill training has additionally been shown to enhance cardiovascular fitness and overcome deconditioning (Hesse et al. 2003).

If an intensive, task-orientated intervention for walking, such as BWSTT, is to encourage experience-dependent plasticity, then this should be built on the principles of motor learning and include (Sullivan et al. 2002):

- normal walking inputs, for example heel strike;
- performance at variable speeds;
- differing lower extremity loads;
- limb kinematics that optimise what the spinal and supraspinal locomotor networks can interpret.

Determination of which patients are most likely to benefit from this specific intervention needs to be addressed. Appropriate selection is currently a key component of clinical reasoning in the Bobath Concept.

Assistive devices

Assistive devices such as sticks and canes may be a necessary adjunct to gain independence. They are frequently employed to further an earlier discharge from hospital to home and to progress to community ambulation. Such mobility aids are often required by older persons with balance impairments (Bateni & Maki 2005).

When walking has been achieved, the use of light touch as a balance aid can positively reduce postural sway and improve postural stability (Jeka 1997). Therefore, the use of a high stick as a balance aid can reduce visual dependence.

The use of assistive devices, such as ambulation in parallel bars, can lead to overcompensation and limited adaptive capacity (Barbeau 2003). Using a stick or cane may also limit recovery through the promotion of compensatory fixation and negation of feed-forward trunk activation, which is important for unloading the stance lower limb.

It is essential to reassess and evaluate how the aid is used in relation to its effect on function over time (Gjelsvik 2008). Fixation through the use of an aid may have a number of consequences:

- shift of the stability limits to the non-hemiparetic side, further reducing the loading of the hemiparetic leg;
- non-neural changes in muscle;
- reduction of range of movement;
- loss of stereognosis and dexterity in the non-hemiparetic hand;
- reduced interplay between the two sides of the body which is necessary for other aspects of function, for example turning over in bed;
- joint pain due to malalignment and inappropriate muscle activation patterns.

Case Study

This case study demonstrates how an integrated systems approach to movement analysis is a core component of the Bobath Concept based on motor learning principles.

Ms ML presented with a left-sided weakness and sensory impairment postoperatively following an endoscopic retrograde cholangiopancreatography and endoscopic sphinctectomy. An MRI showed a watershed infarct in the right anterior cerebral and parieto-occipital areas. Following a period of inpatient rehabilitation, she returned home walking with a high stick as a balance aid and managing stairs. She was independent in self-care and light domestic tasks and had resumed some of her previous leisure activities. She planned to return to work as a process systems designer. The following is an account of daily intervention and clinical reasoning over a 5-day period.

In the initial interview Ms ML reported that:

- her foremost concern was her balance and walking, as both required her continuous attention, and her left foot was inactive;
- dexterity and timing of her upper limb and hand movements were problematic;
- she was easily fatigued and could not yet walk long distances;
- she had residual problems relating to judgement of space on her left side.

Assessment and initial working hypotheses

Ms ML moved from sitting to standing with a wide base of support using her right hand to initiate the movement. Her gait pattern was high stepping on the left and cortically driven. Stance phase was poor on both sides (Milot et al. 2006). Fixation through the right upper quadrant was observed and the left upper limb was abducted. Ms ML used her vision for foot placement and balance. Visual dependence for postural stability and orientation is common following a stroke (Bonan et al. 2004a; Yelnik et al. 2006); however, it can interfere with the initial setting of the body posture and ongoing dynamic stability (Patla 1996). When vision was obscured, Ms ML lost the flexion component to her posture, and there was potential for left heel strike although she reported she felt fearful. Facilitation of walking and stand to sit highlighted a degree of asymmetry and residual weakness on the left side. The following movement control problems were observed whilst Ms ML undressed:

- inappropriate backward displacement of the trunk in order to lift the left leg in standing;
- left hip and pelvis instability;
- hyperactive tibialis anterior drive with the foot pulled into a pattern of inversion;
- atrophy of the medial gastrocnemius muscle;
- difficulty keeping the hind foot on the floor;
- asymmetry of sit to stand with midline shift to the right;
- increased postural sway in standing synchronous with compensatory balance activity in the upper limbs.

Treatment goals

- To increase muscle length and strength for improved control of ankle strategy to reduce postural sway in standing.
- To improve midline orientation and reduce fixation on the right.
- To achieve stop standing for symmetrical sitting.

Treatment intervention (Figs 6.3–6.7)

In standing with light touch support, active plantarflexion was facilitated. Limiting the degrees of freedom at the knees enhanced afferent input to the foot. Shortening and weakness in the calf musculature, especially medial gastrocnemius, resulted in reduced ability for triceps surae to act as an effective antagonist to tibialis anterior

Figs 6.3–6.5 Assessment of weakness, malalignment and muscle activation.

and control postural sway. The capacity to produce force or strength involves structural, mechanical and neural factors (Patten et al. 2004).

Activation of pelvic tilt and forward translation of the knees during stand to sit created a more active sitting posture. The shoulder complex was assessed and the scapula actively realigned on the thorax through mobilisation of soft tissue structures. The ability to control movements of the scapula is a critical component for optimal upper limb function (Mottram 1997).

Post intervention, Ms ML reported more balanced foot activity and increased ease in tying her laces. Her walking was more rhythmical, and she reported increased awareness of her left leg.

Figs 6.6 and **6.7** Assessment of left scapula-thoracic component and shoulder complex.

Initial working hypotheses:

- Increased sensory awareness and activation of the left lower limb musculature will facilitate a more efficient sit to stand and walking pattern.
- Improved scapula alignment for scapula setting will facilitate better timing of left upper limb movements and activation of the left hand during functional tasks.
- Decreased fixation through the right upper quadrant will improve weight transfer and reduce the need to use a stick.

Day 2

Ms ML moved from sit to stand with a smaller base of support and demonstrated a more upright midline posture in standing. Initiation of walking from stance was reassessed. Walking requires moving the centre of mass outside the base of support and transferring weight over the stance limb to move the swing limb forward (Patla 1996). This involves momentarily standing on one leg whilst controlling the forward momentum of the body. A sequence of postural adjustments precedes lower limb movement and culminates in the forward step (Elble et al. 1994). These postural adjustments usually involve a backward and lateral displacement of the centre of pressure towards the swing limb prior to shifting towards the stance limb (Shumway-Cook & Woollacott 2007). It was observed that Ms ML always initiated walking with the left leg. After stroke, postural adjustments are reduced or absent (Hesse et al. 1997). A more efficient single leg stance on the right may be why Ms ML spontaneously uses her left leg as the stepping limb. When placed in single leg stance on the left, she was posturally unstable.

Treatment goal

- To improve left single leg stance.

Treatment intervention (Figs 6.8 and 6.9)

Ms ML was facilitated into standing and left single leg stance. The facilitation highlighted that the left hip was limited in range. Transferring from sitting to lying was chosen to actively lengthen the left iliopsoas/rectus femoris. In supine, a degree of underlying low tone and weakness at the left hip was observed, and the left shoulder complex was retracted necessitating realignment of the scapula in its postural relationship to the thorax for selective activation of the left lower limb. Facilitation of single crook lying addressed:

- realignment of the left ischial tuberosity and proximal hamstrings to gain more extensor/abductor activity;
- that length through left side of trunk was maintained and further reduction of the lordosis gained.

The left lower limb was loaded through the heel to give a feeling of strength and the quadriceps activated. Motor unit recruitment thresholds and firing rates are significantly compromised following stroke (Patten et al. 2004) and contributed to

Figs 6.8 and **6.9** Creation of active crook lying through activation of the foot and facilitation of selective hip activity.

Ms ML's pattern of weakness. Repetition and strength training resulted in a better recruitment of activity.

Ms ML was facilitated into prone through right side lying to stand down onto the left lower limb. Improved hip stability translated into an ability to initiate walking with the right lower limb and reduced visual dependence.

Reflection on action:

- Realignment of key points provides an appropriate postural alignment for strengthening specific lower limb musculature.
- Facilitation between postural sets keeps Ms ML active and selectively strengthens muscles.
- Reassessment of left single leg stance to subjectively evaluate the treatment session.

Day 3

Ms ML reported that following yesterday's treatment session, turning in bed was easier and she was less reliant on vision for balance when walking. Objectively she demonstrated improved interlimb coordination during self-initiated walking, and it was easier to transfer weight to the left when walking was facilitated. Scapula instability was present despite the left shoulder complex being better aligned.

Treatment goals

- To improve left scapula setting as a component of anticipatory postural stability for stepping.
- To create asymmetrical sitting and improve core stability for an efficient transfer into supine.
- To increase sensory awareness and activation of the left foot to enhance single leg stance and balance.
- To selectively strengthen the left hip.

Treatment interventions

In standing the shoulder complex was mobilised and the scapula set on the thorax, which resulted in an increased range at the glenohumeral joint for reach. Facilitation of lateral weight transfer through the left upper limb was used to take Ms ML into asymmetrical sitting, and the left upper limb was placed into a weight-bearing situation to provide stretch to the forearm musculature. Supine was actively created and the left knee was positioned out of hyperextension whilst the foot was more specifically assessed. Clinical observation indicates that a high stepping gait pattern is in part due to lack of intrinsic foot activity. Activity in the toes was achieved using a combination of sensory stimuli, including distraction, compression and movement. Somatosensory impairments have been shown to benefit from specific sensory training (Celnik et al. 2007; Lynch et al. 2007). Abductor digiti minimi was also selectively activated to provide stability to the lateral border of the foot (Figs 6.10–6.12).

Ms ML was facilitated into prone and the hamstrings were strengthened at velocity incorporating mental rehearsal (Figs 6.13 and 6.14). It has been suggested that strength increases when trained at velocity, and training is facilitated by preparatory imagery and thought (Behm & Sale 1993).

Soleus length was also explored. Specific mobilisation techniques considered the muscle architecture of the muscle fibres. Muscle architecture determines a muscle's force and excursion capability (Lieber & Frieden 2001).

Ms ML was facilitated to stand down from the plinth with her right foot on a block encouraging left heel down with foot up. This was also done without vision to generate somatosensory inputs to reduce visual overuse (Bonan et al. 2004b).

Reflection on action:

- Consider increasing the intensity of sensory training.
- Further mobilisation and activation of the muscles of the foot and calf.
- Selective activation of the hip extensors in prone to address weakness and muscle imbalances around the left hip.

Day 4

Ms ML reported that she could now separate the left hip and knee in her body schema (Massion 1994) and had more awareness of her left foot which she found 'a little disconcerting'. She was unable to put her left foot on the edge of the bed to take off her left shoe due to lack of selective plantarflexion despite increased stability of her left hip. In standing there were still problems loading the left leg because of a lack of dynamic foot activity. Moving from stand to sit was easier with an improved pelvic stability and the transfer into supine was more efficient. There was improved alignment of the shoulder complex.

Treatment goal

- Activation of the foot and single leg stance as a preparation for treadmill training.

Treatment intervention

In supine, treatment was initially directed to activating the foot (Figs 6.15–6.17).

Ms ML was facilitated into prone through right side lying activating left hip extensor/abductor musculature in the movement sequence (Figs 6.18 and 6.19). In prone, gastrocnemius was activated with the limb loaded (Figs 6.20 and 6.21). Ms ML was taken through prone kneeling to stand down on the left lower limb (Figs 6.22 and 6.23).

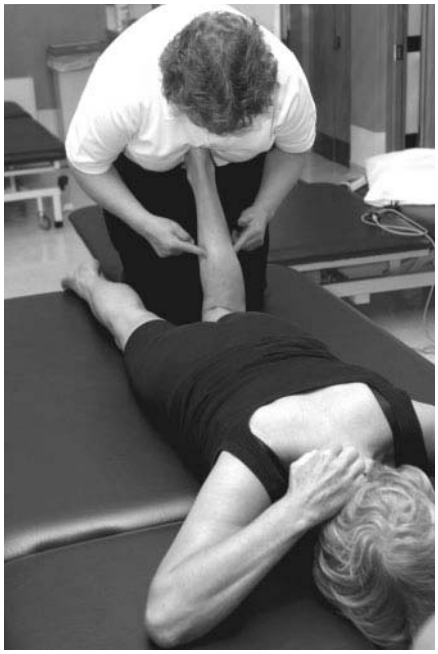
In standing, with a wall behind, Ms ML was placed in an ankle strategy position and the ability for her to be on the left heel without pushing with the right lower limb was explored. Facilitated stepping was also assessed. Ms ML then walked on the treadmill, with facilitation for heel strike, at a velocity of 2.5 miles per hour for 3 minutes (Figs 6.24–6.26).

Figs 6.10–6.12 Using sensory stimulation to activate the foot.

Figs 6.13 and **6.14** Selective hamstring strengthening at differing velocities.

Figs 6.15–6.17 Facilitation of the intrinsic muscles of the foot to activate the toes.

Figs 6.18 and **6.19** Movement from supine to prone lying using hip extension.
Fig. 6.18. Demonstrates specific activation of the proximal hamstrings and abductor musculature.



Figs 6.20 and **6.21** Strengthening gastrocnemius.

Post treatment intervention, Ms ML reported that she felt 'tired but lighter'. Walking appeared more automatic and less cortical due to increased sensory awareness of the foot and improved heel strike.

Day 5

Subjectively Ms ML reported that she walked 2 kilometres home after yesterday's treatment because she felt 'so good'. She was tired initially, but after resting the left leg felt lighter and 'more normal'. Today the left foot feels heavy, but she reports a better awareness of the left ankle. As she took off her shoes and socks, a key change was the degree of spontaneity of movement of the left lower limb when she crossed it over the right leg. It was still difficult to keep the left heel on the ground as she lifted the right foot to take off her sock.

Treatment goals

- Sensory training and activation of the left foot as a preparation for treadmill training.
- Increased sensorimotor integration of the left/right side.

Figs 6.22 and **6.23** Movement sequence supine to prone kneeling prior to stand down.

Figs 6.24–6.26 Treadmill training with facilitation of heel strike.

Treatment intervention (Figs 6.27–6.35)

Ms ML was facilitated into supine to further address length issues with respect to calf musculature and stiffness in the midfoot. The metatarsals were supported and the toes flexed to stretch soft tissues on the dorsum of foot. Cutaneous stimulation was applied to elicit toe extension. Working with an increased range of movement at the talocrural joint, the toes were repeatedly flexed at velocity to gain toe extension with dorsiflexion.

Hip and trunk musculature were activated in side lying. Ms ML was then given the experience of rotation around body axis to the right and left through facilitated rolling to give an experience of moving at speed in direct preparation for the treadmill. Treadmill training was then carried out again with facilitation.

Fig. 6.27 Stabilising the pelvis to lengthen the back extensors.

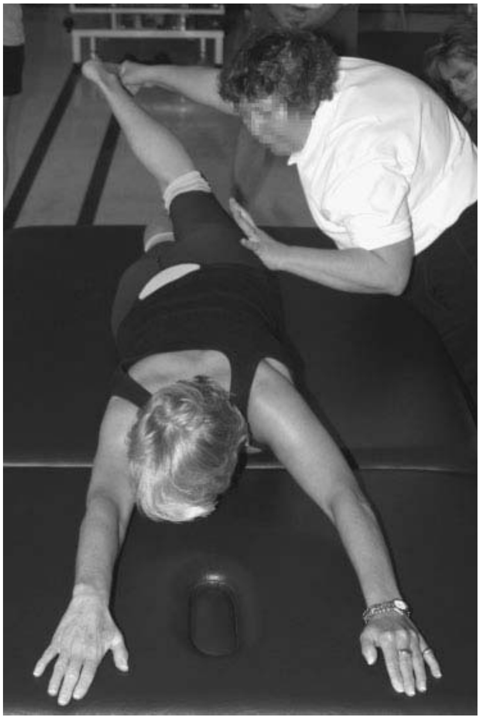


Fig. 6.28 Handling the proximal and distal key points to activate extension throughout the lower limb.

Fig. 6.29 Strengthening the hip abductors.

Fig. 6.30 Gaining heel contact with the therapist to load the lower limb.

Fig. 6.31 Lower limb extension to turn from prone to supine to prone to develop rotation around the midline and improve sensory motor integration.

Fig. 6.32 Selective eccentric control of the knee whilst maintaining heel contact.

Fig. 6.33 De-weight and activate from the foot first.

Fig. 6.34 Leave the leg behind in preparation for treadmill training.

Fig. 6.35 Control of push off.

Outcome measures (Tables 6.1–6.4)

Quantitative gait analysis

Quantitative gait analysis was performed pre and post intervention and compared with normative data. Three pre and post intervention trials were compared using paired t-tests and the following results showed a significant difference ($P < 0.05$).

- The line of action of the ground reaction force now passes closer to the centre of the hip joint resulting in a decrease in the hip extensor moment.;
- a reduction in the maximum internal knee flexor moment at the start of left single limb support with increased control of knee flexion during the loading response;
- a reduction in the initial ankle plantarflexion moment at the start of stance phase correlating with a decrease in premature power generation;
- a change in ankle rotation moment during mid-stance from internal to external allowing the tibia to rotate externally as the stance phase progresses.

Table 6.1 Mobility scores.

Date	10 metre timed walk test	Timed up and go	Walking impact scale
Day 1	20 paces in 11 seconds	18 seconds	58/100
Day 5	16 paces in 8 seconds	9 seconds	39/100*

*Both Ms ML and the therapist rated walking as being significantly better.

Table 6.2 Goal attainment scaling goal 1.

GAS score	Selective weight transfer in standing
−2	Ms ML will be able to reach the left arm across midline without prior weight transfer to the left in standing
−1	Ms ML will be able to reach the left arm forward in midline without prior weight transfer to the left in standing
0	Ms ML will be able to selectively weight transfer to the left in standing prior to reaching the left arm forward in midline
+1	Ms ML will be able to selectively weight transfer to the left in standing prior to reaching the left arm into abduction
+2	Ms ML will be able to selectively weight transfer to the left into a single leg stance while reaching the left arm into abduction

Table 6.3 Goal attainment scaling goal 2.

GAS score	Gait quality
−2	Ms ML will be able to walk independently indoors with a high stepping gait, visual dependency, fixed head posture and lacking arm swing
−1	Ms ML will be able to walk independently indoors without a high stepping gait but still with visual dependency, fixed head posture and lacking arm swing
0	Ms ML will be able to walk independently indoors without a high stepping gait or visual dependency but still with fixed head posture and lacking arm swing
+1	Ms ML will be able to walk independently indoors without a high stepping gait, visual dependency or fixed head posture but still lacking arm swing
+2	Ms ML will be able to walk independently indoors without a high stepping gait, visual dependency or fixed head posture and have appropriate arm swing

Table 6.4 Goal attainment scaling change score.

Pre-treatment GAS score	25
Post-treatment GAS score	69

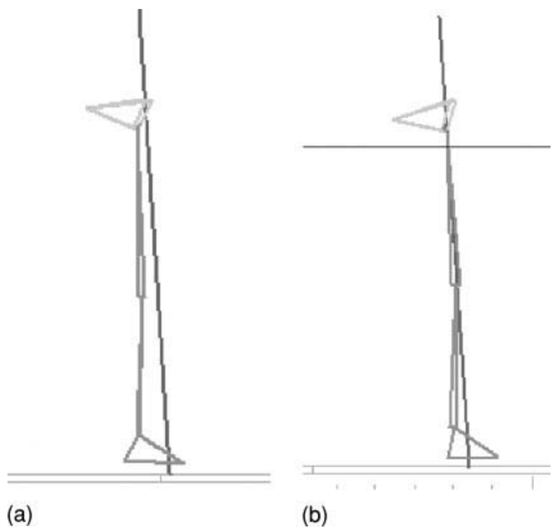


Fig. 6.36 Pre (a) and post (b) treatment position of centre of pressure relative to the left lower limb at the start of swing phase.

Ms ML made objective improvements during the period of intervention as demonstrated by the change in outcome measures. This enabled Ms ML to achieve her goals of more automatic walking and more efficient use of her left arm. The working hypothesis for treatment was that improved foot and lower limb sensorimotor components would lead to more automatic walking. Improved postural control mechanisms reduced the need for visual dependency. The evidence base supported the clinical decisions made and resulted in an outcome which supported the hypothesis.

Key Learning Points from the Case Study

- Addressing the asymmetry of the sit to stand transfer and dependence on the right upper limb for fixation, augmented by the use of a high stick.
- Changing muscle length of soleus and muscle strength of gastrocnemius to control postural sway.
- Facilitating postural stability for distal selective movement and strengthening hip extension for selective dorsiflexion.
- Improving concentric and eccentric strengthening of key muscles in the control of the locomotor pattern.
- Consistent with Engardt et al. (1995), gains in eccentric strength, in particular of the quadriceps, facilitated an improved sit to stand and locomotor pattern.
- Improving reach against the background of a dynamic foot intrinsically active for ground reaction forces.
- Improving body schema for feed-forward postural control.

Summary

This chapter has explored key features of bipedal locomotion during which the limbs move in a symmetrical alternating relationship (Shumway-Cook & Woollacott 2007). Motor control is highly distributed, and maintenance of dynamic stability is required throughout the locomotor task. Importance is placed on accessing pattern-generated activity to facilitate efficient walking and automaticity. Common clinical problems have been highlighted, and aspects of assessment and treatment have been considered.

References

Armstrong, D.M. (1986) Supraspinal contributions to the initiation and control of locomotion in the cat. *Progress in Neurobiology*, **26**, 273–361.

Ayyappa, E. (2001) Normal human ambulation. *Orthopaedic Physical Therapy Clinics of America*, **10**, 1–15.

Barbeau, H. (2003) Locomotor training in neurorehabilitation: Emerging rehabilitation concepts. *Neurorehabilitation and Neural Repair*, **17** (1), 3–11.

Bateni, H. & Maki, B.E. (2005) Assistive devices for balance and mobility: Benefits, demands and adverse consequences. *Archives of Physical Medicine and Rehabilitation*, **86**, 134–145.

Behm, D.G. & Sale, D.G. (1993) Intended rather than actual movement velocity determines velocity specific training response. *Journal of Applied Physiology*, **74** (1), 359–368.

Bobath, B. (1990) *Adult Hemiplegia: Evaluation and Treatment*. Butterworth-Heinemann, Oxford.

Bohannon, R. (2001) Gait after stroke. *Orthopaedic Physical Therapy Clinics of America*, **10**, 151–170.

Bonan, I., Colle, F., Guichard, J.P., et al. (2004a) Reliance on visual information after stroke. Part I: Balance on dynamic posturography. *Archives of Physical Medicine and Rehabilitation*, **85**, 268–273.

Bonan, I., Yelnik, A., Colle, F., et al. (2004b) Reliance on visual information after stroke. Part II: Effectiveness of a balance rehabilitation programme with visual cue deprivation after stroke: A randomized controlled trial. *Archives of Physical Medicine and Rehabilitation*, **85**, 274–278.

Brocard, F. & Dubuc, R. (2003) Differential contribution of reticulospinal cells to the control of locomotion induced by the mesencephalic locomotor region. *Journal of Neurophysiology*, **90**, 1714–1727.

Celnik, P., Hummel, F., Harris-Love, M., Wolk, R. & Cohen L.G. (2007) Somatosensory stimulation enhances the effects of training functional hand tasks in patients with chronic stroke. *Archives of Physical Medicine and Rehabilitation*, **8**, 1369–1376.

Dietz, V. (2003) Invited review: Spinal cord pattern generators for locomotion. *Clinical Neurophysiology*, **114**, 1379–1389.

Dietz, V. & Duysens, J. (2000) Significance of load receptor input during locomotion: A review. *Gait & Posture*, **11**, 102–110.

Elble, R.J., Moody, C. & Leffler, K.R. (1994) The initiation of normal walking. *Movement Disorders*, **9** (2), 139–146.

Engardt, M., Knutsson, E., Jonsson, M., et al. (1995) Dynamic muscle strength training in stroke patients: Effects on knee extension torque, electromyographic activity and motor function. *Archives of Physical Medicine and Rehabilitation*, **76**, 419–425.

Gjelsvik, B.E. (2008) *The Bobath Concept in Adult Neurology*, Thieme, Stuttgart.

Grasso, R., Zago, M. & Lacquaniti, F. (2000) Interactions between posture and locomotion: Motor patterns in human walking with bent posture versus erect posture. *Journal of Neurophysiology*, **83**, 288–300.

Grillner, S. (2002) The spinal locomotor CPG: A target after spinal cord injury. *Progress in Brain Research*, **137**, 97–110.

Grillner, S., Georgopoulos, A.P. & Jordan, L.M. (1997) Selection and initiation of motor behaviour. In: *Neurons, Networks and Motor Behaviour* (eds P.S.G. Stein, S. Grillner, A. Selverston & D.G. Stuart), pp. 4–19, MIT, Cambridge.

Hesse, S. & Werner, C. (2003) Partial body weight supported treadmill training for gait recovery following stroke. *Advances in Neurology*, **92**, 423–428.

Hesse, S., Reiter, F., Jahnke, M., et al. (1997) Asymmetry of gait initiation in hemiparesis stroke. *Archives of Physical Medicine and Rehabilitation*, **78**, 719–724.

Hesse, S., Werner, C., Von Frankenberg, S. & Bardeleben, A. (2003) Treadmill training with partial body weight support after stroke. *Physical Medicine and Rehabilitation Clinics of North America*, **14** (1 Suppl), S111–S123.

Jahn, K., Deutschlander, A.D., Stephen, T., Strupp, M., Wiesmann, M. & Brandt, T. (2004) Brain activation patterns during imagined stance and locomotion in functional magnetic resonance imaging. *NeuroImage*, **22** (4), 1722–1731.

Jeka, J.J. (1997) Light touch contact as a balance aid. *Physical Therapy*, **77** (5), 476–487.

Jordan, L.M. (1991) Brainstem and spinal cord mechanisms for the initiation of locomotion. In: *Neurobiological Basis of Human Locomotion* (ed. M. Shimamura), Japan Scientific Press, Tokyo.

Kern, H., McKay, W. & Dimitrijevic, M. (2005) Motor control in the human spinal cord and the repair of cord function. *Current Pharmaceutical Design*, **11**, 1429–1439.

Kerrigan, D., Della Croce, U., Marciello, M. & Riley, P.O. (2000) A refined view of the determinants of gait: Significance of heel rise. *Archives of Physical Medicine and Rehabilitation*, **81**, 1077–1080.

Kibler, W.B., Press, J. & Sciasscia, A. (2006) The role of core stability in athletic function. *Sports Medicine*, **36** (3), 189–198.

Kirtley, C. (2007) The origin of ground reaction forces. www.univie.ac.at/cga/faq/grfs.html, accessed 26/11/07

Lieber, R.L. & Frieden, J. (2001) Functional and clinical significance of skeletal muscle architecture. *Muscle & Nerve*, **23** (11), 1647–1666.

Lovejoy, C.O. (2004) The natural history of human gait and posture. Part 1: Spine and pelvis. *Gait & Posture*, **21** (1), 95–112.

Lynch, E.A., Hillier, S.L., Stiller, K. & Campanella, R.P. (2007) Sensory retraining of the lower limb after acute stroke: A randomized controlled pilot trial. *Archives of Physical Medicine and Rehabilitation*, **88**, 1101–1107.

Mackay-Lyons, M. (2002) Central pattern generation of human locomotion: A review of the evidence. *Physical Therapy*, **82** (1), 69–83.

Manning, C.D. & Pomeroy, V.M. (2003) Effectiveness of treadmill retraining on gait of hemiparetic stroke patients: Systematic review of current evidence. *Physiotherapy*, **89** (6), 337–349.

Massion, J. (1994) Postural control system. *Current Opinions in Neurobiology*, **4**, 877–887.

Milot, M., Nadeau, S., Gravel, D. & Requiao, L.F. (2006) Bilateral level of effort of the plantarflexors, hip flexors and extensors during gait in hemiparetic and healthy individuals. *Stroke*, **37**, 2070–2075.

Moore, S., Schurr, K., Wales, A., Moseley, A. & Herbert, R. (1993) Observation and analysis of hemiplegic gait: Swing phase. *Australian Journal of Physiotherapy*, **39** (4), 271–278.

Mori, S., Matsui, T., Kuze, B., Asanome, M., Nakajima, K. & Matsuyama, K. (1998) Cerebellar-induced locomotion: Reticulospinal control of spinal rhythm generating mechanism in cats. *Annals of the New York Academy of Sciences*, **860**, 94–105.

Moseley, A., Wales, A., Herbert, R., Schurr, K. & Moore, S. (1993) Observation and analysis of hemiplegic gait: Stance phase. *Australian Journal of Physiotherapy*, **39** (4), 259–267.

Moseley, A.M., Stark, A., Cameron, I.D. & Pollock, A. (2005) Treadmill training and body weight support for walking after stroke. *Cochrane Database of Systematic Reviews*, Issue 4. Art No. CD002840. DOI: 10.1002/14651858.CD002840.pub2.

Mottram, S. (1997) Dynamic stability of the scapula. *Manual Therapy*, **2** (3), 123–131.

Mudge, S. & Stott, N.S. (2007) Outcome measures to assess walking ability following stroke: A systemic review of the literature. *Physiotherapy*, **93** (3), 173–232.

Neptune, R.R. & Sasaki, K. (2005) Ankle plantar flexor force production is an important determinant of the preferred walk-to-run transition speed. *Journal of Experimental Biology*, **208** (5), 799–808.

Patla, A.E. (1996) Neurobiomechanical bases for the control of human locomotion. In: *Balance Posture and Gait* (eds A. Bronstein, T. Brandt & M. Woollacott), pp. 19–40, Arnold, London.

Patla, A.E. (1997) Understanding the roles of vision in the control of human locomotion. *Gait & Posture*, **5**, 54–69.

Patten, C., Lexell, J. & Brown, H.E. (2004) Strength training in persons with post stroke hemiparesis: Rationale, method and efficacy. *Journal of Rehabilitation Research Development*, **41** (3A), 293–312.

Paul, S., Ada, L. & Canning, C. (2005) Automaticity of walking-implications for physiotherapy practice. *Physical Therapy Reviews*, **10**, 15–23.

Perry, J. (1992) *Gait Analysis: Normal and Pathological Function*, 1st edn. Book states publisher, SLACK Inc., Thorofare.

Porter, R. & Lemon, R. (1993) *Corticospinal Function and Voluntary Movement*. Clarendon Press, Oxford.

Shumway-Cook, A. & Woollacott, M. (2007) *Motor Control Theory and Practical Applications*, 3rd edn. Lippincott Williams & Wilkins, Philadelphia.

Simoneau, G.G. (2002) Kinesiology of walking. In: *Kinesiology of the Musculoskeletal System: Foundations for Physical Rehabilitation* (ed. D. Neumann), Mosby, St. Louis.

Sorensen, K., Hollands, M. & Patla, A. (2002) The effects of human ankle muscle vibration on posture and balance during adaptive locomotion. *Experimental Brain Research*, **143**, 24–34.

Sullivan, K.J., Knowlton, B.J. & Dobkin, B.H. (2002) Step training with body weight support: Effect of treadmill speed on practice paradigms on poststroke locomotor recovery. *Archives of Physical Medicine and Rehabilitation*, **83**, 683–691.

Van de Crommert, H.W.A.A., Mulder, T.W. & Duysens, J.E.J. (1998) Neural control of locomotion: Sensory control of the central pattern generator and its relation to treadmill training. *Gait & Posture*, **7** (3), 251–263.

Visintin, M., Barbeau, H., Bitensky, N. & Mayo, N. (1998) Using a new approach to retrain gait in stroke patients through body weight support and treadmill training with partial body-weight support. *Stroke*, **29**, 1122–1128.

Wilson, J.D., Dougherty, D.D., Ireland, M.L. & Davis, I.M. (2005) Core stability and its relationship to lower extremity function and injury. *Journal of American Academy of Orthopaedic Surgeons*, **13**, 316–325.

Winter, D.A. (1995) Human balance and posture control during standing and walking. *Gait & Posture*, **3**, 193–214.
Yelnik, A., Kassouha, A., Bonan, I., et al. (2006) Postural visual dependence after recent stroke: Assessment by optokinetic stimulation. *Gait & Posture*, **24** (3), 262–269.
Zehr, E.P. & Duysens, J. (2004) Regulation of arm and leg movement during human locomotion. *The Neuroscientist*, **10** (4), 347–361.

7. *Recovery of Upper Limb Function*

Janice Champion, Christine Barber and Mary Lynch-Ellerington

Introduction

One of the biggest challenges for many patients is regaining functional use of their upper limbs. Often, upper limb recovery is sacrificed in order to concentrate on mobility and transfers. The Bobath Concept focuses on the interrelationship of all areas of the body to optimise overall function in lower and upper limb recovery. Due to such close interrelationship, neither is treated independently without consideration of the other's impact on functional recovery.

In daily life, we are capable of performing a considerable range of activities with our upper limbs. These activities include the hands to be placed in optimal positions in relation to the stability of the rest of the body. Activities vary from requiring strength but little dexterity, such as carrying a heavy case or using a hammer, to those requiring selective grasp and dexterity, such as threading a needle. This involves the interweaving of gross and fine motor activities into a seamless sequence of events.

The upper limbs are involved in numerous functions which allow us as individuals to participate within our own particular environment. The arm transports the hand to objects that can be held, grasped or manipulated. The hand also rests on surfaces, explores the environment, gestures and in conjunction with the upper limb and trunk may provide support for the body (Fig. 7.1).

The hand is not only capable of fine finger movement and skilled manipulation but also provides the nervous system with extensive sensory information about the environment. It therefore, plays an essential role in updating the body schema and facilitating an individual's postural orientation. The clinical and functional implications of decreased sensorimotor control and eventual learned non-use of the hand are vast.

Efficient upper limb function requires upper limbs that are able to move freely away from the body and be used independently of each other. Dynamic stability is required locally at the thoracoscapular interface, on the contralateral and ipsilateral

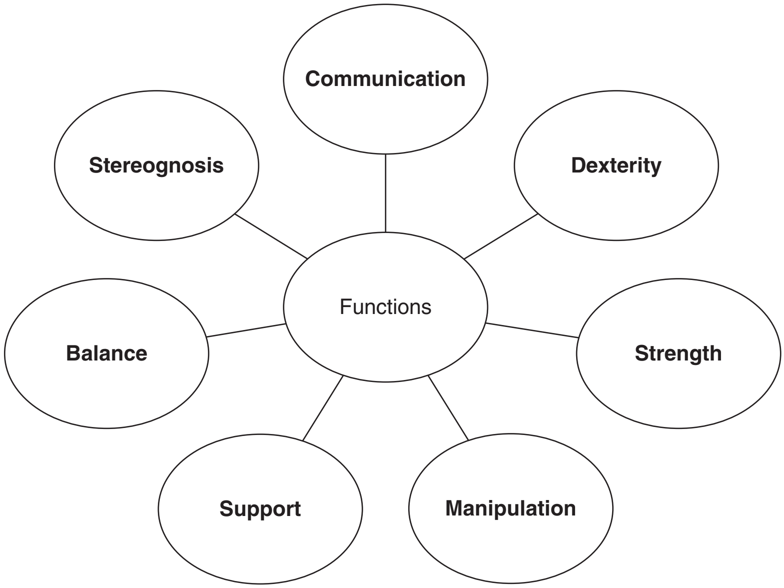


Fig. 7.1 Functions of the upper limb.

sides of the body, and more distally at the pelvis and lower limbs. Exploring the recovery of upper limb function must take into account the important role of the hand as a major sense organ, the hand and upper limb in postural orientation, as well as the holistic nature of the postural control required throughout the body. The clinical reasoning process considers how the ventromedial systems (responsible for postural control and balance) and the dorsolateral systems (responsible for selective goal-orientated movement of the hand) work together to allow for efficient functioning of the upper limb. It is important to recognise that not all patients will have the potential for a fully functioning hand but many will have the potential for upper limbs which cooperate, assist and adapt as part of a variety of functional activities. The potential for a fully functioning hand very much depends on having an intact corticospinal system for single digit control in conjunction with postural control mechanisms.

The importance of postural control in upper limb function

> 'I have had to walk to this seat and adopt an appropriate position next to the laptop. In short, almost every part of my body is implicated in an action for which my fingers take the lion's share of credit.'
>
> (Tallis 2003).

Undertaking activities in any posture but especially in sitting or standing requires variable activity in the body musculature to support the individual up against gravity. Proximal stability is necessary for upper limb function (Edwards 2002) and conversely instability imposes stresses on the upper limbs during function (Kibler 1998; Magarey & Jones 2003), which limits their freedom to move away from the body. In a patient with truncal ataxia, the upper limbs may be held close to the body to try and provide stability through fixation so that some functional activities can be achieved. These fixation strategies, although an answer in the short term, may prevent the individual exploring their potential for optimising upper limb recovery.

Clinically, it is also important to consider the implications of using walking aids in the hand on postural control and balance (see Chapter 6). Sharing the weight-bearing through a walking aid held in the hand may interfere with the hand's dexterity, stereognosis and freedom of the upper limb for protective extension and balance. This has both short- and long-term implications for the upper limb. The compensatory, more flexed posture usually associated with the use of walking aids will also reduce the efficiency of balance strategies further interfering with upper limb function. Therefore, there are times when it is important to improve walking independence in order to optimise upper limb function.

Dynamic stability of the upper and lower trunk, with a stable scapula on the thoracic cage, allows the upper limb to move away from the body, freeing the hand to reach. This fundamentally demonstrates the importance of core stability (Massion et al. 2004; Brown 2006). Hodges (1996) has shown that both lower limb and trunk muscles fire prior to reaching with the upper limb. Clinically, this is an important consideration as the therapist must not destabilise the patient, by passively taking the upper limb away from the body, but promote the firing of the postural muscles within the trunk for the upper limb to move and be moved away from the body.

It appears that deeper trunk muscles activate to stiffen the spine irrespective of the direction that the upper limb moves in, but the more superficial trunk muscles are direction specific (Richardson 2002; Barr et al. 2005; Lee et al. 2005). The nervous system uses these muscle synergies, or patterns of activation, for efficiency (Kavcic et al. 2004; Barr et al. 2005), recruiting appropriate trunk muscles automatically in anticipation of the displacement and perturbation caused by moving limb (MacDonald et al. 2006). Clinically, these anticipatory postural adjustments (APAs) mean the upper limb feels 'light' and 'effortless to move' when the individual reaches because the proximal trunk stability provides the foundation for the shoulder muscles to then efficiently take the hand forward. Figure 7.2 highlights a patient with an ineffective reach. Evidence supports the provision of a restraining support to the trunk which allows for a greater excursion of upper limb movement (Michaelsen et al. 2006).

Thoracic spine mobility provides a basis for shoulder activity and is essential for movement of the upper body and orientation of the upper extremities for use of the hands (Lee et al. 2005). The mid-thoracic region of the spine between T4 and T8 is considered to have the greatest range of rotation (Willems et al. 1996), and as the scapula orientates over T2–T7 (Levangie & Norkin 2001), there is a need for precise neuromuscular control to provide appropriate stability and mobility for

Fig. 7.2 The lack of proximal stability with inappropriate APAs leads to an exaggeration of a distal 'lift' through wrist extension.

upper limb function. Therefore, in considering recovery of upper limb function, it is necessary to have an understanding of the impact of appropriate thoracic alignment on the dynamics of the shoulder complex.

The shoulder complex

The shoulder complex consists of many articulations, muscles, ligaments, bursae and capsules (Mottram 1997; Hess 2000). The mobility of the shoulder complex is 'dependent on coordinated, synchronous motion in all the joints' (Culham & Peat 1993). The glenohumeral joint is the centre of movement at the shoulder complex (Hess 2000), and it contributes the largest component of the range of motion at the shoulder complex through its anatomical structure. Efficient neuromuscular activity especially from the rotator cuff muscles is required for this motion to be controlled and to maintain the congruency of the head of humerus in the glenoid fossa. This mechanism is impaired in patients with a subluxation of the shoulder (Fig. 7.3).

Mottram (1997) describes efficient movement as the integrated and coordinated interaction of the articular, myofascial and neural systems of the body. The patient with neurological pathology may have decreased muscular activity and changes in sensory and proprioceptive awareness that will impact on the dynamic stability of the shoulder complex. If muscles are not active, the system is deprived of afferent information including that from muscle spindles and Golgi tendon organs.

Glenohumeral stability is dependent on the position of the scapula on the rib cage, the activity of the supraspinatus muscle and the taut superior aspect of the capsule when the upper limb is at rest beside the trunk. However, as soon as the upper limb moves away from the trunk, more active control is required and the deltoid and

Fig. 7.3 The subluxed glenohumeral joint of a patient with a right hemiplegia. This highlights the lack of congruency between the head of humerus and glenoid fossa which will create an inability to selectively activate the rotator cuff musculature.

rotator cuff muscles must coordinate their action to support the shoulder complex in its goal of taking the upper limb and hand into space (Basmajian 1981; Davies 2000; Morley et al. 2002; Tetreault et al. 2004). The important muscles providing this dynamic stability are subscapularis, supraspinatus, infraspinatus and teres minor (Dark et al. 2007). The synchronous contraction of these muscles creates a compressive force, enabling the humeral head to pivot and glide in the glenoid fossa.

Clinically, it is important to consider the alignment of the shoulder complex in the patient who has decreased muscle activity around this area. The main goal of treatment is to improve the patient's awareness and activity of the upper limb. Careful positioning and handling of the shoulder complex during both rest and personal care tasks, such as washing and dressing, helps maintain involvement of the upper limb and may prevent trauma to this vulnerable area (see Chapter 8). When a patient is positioned by stabilising the trunk, for example at rest in side lying, the upper limb is allowed to accept the support of the pillow and not the upper limb supporting an unstable trunk (Fig. 7.4).

The scapula

The resting position of the scapula on the thorax varies within individuals and is influenced by posture, for example being slumped and 'round shouldered', and also by different background activity levels between postures such as sitting and standing. Many authors support the theory that the scapula position on an upright trunk provides an upward, anterior, lateral-facing glenoid fossa which offers an automatic locking mechanism for the shoulder joint with the upper limb in adduction preventing downward subluxation of the glenohumeral joint (Basmajian 1981;

Fig. 7.4 An example of external postural support during rest.

Morley et al. 2002). The posture of the cervical and thoracic spine has a strong influence on the position and mobility of the scapula and therefore the glenohumeral joint (Culham & Peat 1993; Magarey & Jones 2003).

The clinical implications of decreased antigravity activity in the trunk include a loss of scapula alignment and instability of the glenohumeral joint. Conversely, a heavy, hypotonic shoulder complex will inhibit efficient trunk extension and therefore impact on APAs and balance. During transfers from one postural set to another, handling to realign and activate the shoulder complex will facilitate postural activity by 'lightening the load'. This also applies to positioning the patient in the acute and subacute stages and supporting the hypotonic upper limb, and more importantly, the trunk, with pillows and/or a table to reduce the traction on the soft tissue and muscles of the upper quadrant.

Dysfunction, for example weakness in the scapula musculature, will result in an alteration in scapula stability leading to shoulder function becoming less efficient, reducing performance and pre-disposing the individual to injury (Voight & Thomson 2000). Stability at the scapulothoracic joint depends not only on the surrounding musculature (Mottram 1997; Voight & Thomson 2000), notably trapezius and serratus anterior, but also on rhomboid major and minor and levator scapulae. These stabilising muscles must be recruited prior to movement of the upper limb to anchor the scapula (Mottram 1997; Voight & Thomson 2000), and while maintaining dynamic stability, they must also provide controlled mobility. A lack of appropriate activation leads to an inability to achieve an efficient reach pattern (Fig. 7.5). However, changing the direction of movement may allow for a more appropriate pattern of activity and is a useful assessment tool (Fig. 7.6). Maintaining the appropriate alignment of the shoulder complex on the trunk whilst facilitating context-based task practice will create a demand for APAs. Incorporating this into daily functional activities is crucial for carry-over (Fig. 7.7).

Fig. 7.5 Impaired reaching pattern due to lack of appropriate APAs.

Fig. 7.6 Changing the direction for the reach pattern is more successful but patient still demonstrates hip strategy to overcome the limitation of APAs.

The scapula is able to move in many directions on the thoracic cage, including elevation, depression, abduction, adduction and rotation (Mottram 1997; Voight & Thomson 2000) and this mobility is important for:

- improving the congruity of the glenohumeral joint during movement;
- allowing the acromial arch to elevate, so preventing impingement of the humeral tubercles during elevation of the upper limb;

Fig. 7.7 Incorporating more efficient reach pattern of the upper limb into a functional activity.

- increasing range of motion at the shoulder and therefore allowing the hand to travel further;
- providing a 'pillar of support' under the humeral head for overhead activities of the upper limb.

The repeated use of compensatory movement strategies by the patient will affect the balance of muscle activity around the shoulder complex, and this will have an impact on functional recovery in the upper limb. The interrelationship, whereby the scapula can stabilise to allow the initiation of the hand moving away from the body, and then follow the humerus to increase the range of movement available in the shoulder complex, is called the scapulohumeral rhythm (SHR).

Scapulohumeral rhythm

The SHR is the integration of the scapulothoracic, glenohumeral, acromioclavicular and sternoclavicular joints, and it is the coordinated interaction of these joints that results in smooth movement of the shoulder complex (Hess 2000). This is an area which is particularly difficult to address due to the complex nature of the neurological damage to the systems involved in postural control and efficient coordination of the patterns of movement necessary for upper limb function. Early work by Inman in 1944 proposed a ratio of 2:1 for glenohumeral-to-scapulothoracic movement, meaning that when considering 90° elevation of the upper limb, 60° comes from glenohumeral movement and 30° from scapula movement. As mentioned previously in this chapter, it is important to consider the role of postural stability for mobility and the role of the scapula in achieving range and refinement of movement of the upper limb. There are many influences on SHR which the therapist should consider, including compensatory movements of the trunk, inefficient initiation of the reaching pattern, poor scapulothoracic stability or mobility, change in muscle activation patterns, and specific joint stiffness. Investigations into the effect of age on movement found that total range decreased with age but the SHR ratio was unchanged (Talkhani & Kelly 2001). Importantly, McQuade and Schmidt (1998) found that when the upper limb was loaded, the ratio changed to 4.5:1 where the scapula had to provide a greater stabilising force. This may explain why the patient with neurological impairment, resulting in the upper limb feeling 'heavy', presents with a changed SHR as the pattern of muscle activation changes to support the perception of a heavy load.

The thoracic alignment must also be considered as the scapula must travel around the thoracic cage to allow greater range of movement in the shoulder complex. A kyphotic thoracic spine or broad posterior aspect of the thorax will affect this journey and therefore the dynamics of scapula stability.

The SHR requires the harmonious interplay of the muscles around the scapula. This is characterised by force couples of paired muscles that control the movement or position of a joint or body part (Kibler 1998; Voight & Thomson 2000), maintaining maximal congruency between the glenoid fossa and the humeral head. Scapular stabilisation requires a force couple between the upper and lower portions of trapezius and the rhomboids coupled with serratus anterior, and then as the upper limb is elevated, activity of the lower trapezius and serratus anterior muscles is coupled with upper trapezius and rhomboids. Clinically working on specificity of activation and strengthening of these muscles is very important (Figs 7.8–7.10).

In the patient with neurological impairment, changes in muscle tone and coordination may result in impaired SHR that can limit the range of movement available and importantly be one of the causes of shoulder pain which can have a detrimental impact on rehabilitation (Roy et al. 1994, 1995).

Functional reach

Although there are occasions when the upper limb is taken away from the body with no direct goal of using the hand, for example to wash under your upper limb with your other hand, many upper limb movements are for the purpose of transporting

Fig. 7.8 Selective strengthening of the shoulder depressors.

Fig. 7.9 Selective strengthening of shoulder stabilisers.

Fig. 7.10 Selective activation of serratus anterior and lower fibres of trapezius for scapular stabilisation.

the hand to an object or using the hand in an open chain either to point, gesture or to attract attention.

When the task is pointing, all segments of the upper limb are controlled as one unit (Shumway-Cook & Woollacott 2007); however, when the task is to reach and hold an object, the hand is controlled independently of the other upper limb segments. Therefore, reach to grasp can be divided into two components, the transportation phase and the grasp phase. These two components occur synchronously and appear to be controlled by different neural mechanisms. Some evidence suggests that the rubrospinal and reticulospinal pathways may control the more proximal movements involved in reaching, whereas the corticospinal pathways are necessary for the control of manipulation (Kandel et al. 2000). However, evidence suggests that activation of the wrist and metacarpophalangeal joint extension via the rubrospinal system has a key role to play in goal-orientated activities where reaching to grasp rather than reaching is involved (Van Kan & McCurdy 2000). Increased activity of the wrist component facilitates greater shoulder stability (Figs 7.11 and 7.12). It has also been shown that when grasp requires a greater degree of dexterity, the reflex connections from the hand and forearm to the shoulder musculature are evident (Alexander et al. 2005). Therefore, the choice of object to grasp is not just with the function in mind but with the specific muscle activation patterns.

Target location

Vision plays a crucial role in target location and the selection of the appropriate motor programme for reach to grasp. The effect of figure-ground is particularly significant because the clearer the parameters of the target, the more precise the hand pre-shaping. If the task involves reaching to an object in the central visual field where focusing is optimal, then movement of the eyes alone may locate the target.

Fig. 7.11 Patient attempting to lift glass without appropriate activation of wrist stabilisers to activate proximal stability of the shoulder.

Fig. 7.12 Therapist providing proprioceptive input to facilitate activation of wrist extensors to stabilise the wrist to enable the patient to lift the glass.

If the object is in the peripheral visual field, locating it will require head and eye movement to ensure accurate reaching. Therefore, if components of shoulder and neck movements are impaired, alternative strategies may be adopted to locate the target, for example, the trunk may turn to allow visual regard. Once the target has been located and the motor programme selected, vision is no longer essential for the performance of reach (Santello et al. 2002). However, in its absence, there will be a slower approach of the hand towards the object.

Reaching

The path of the hand towards an object is always relatively straight; however, to achieve this efficiency, rotation at different joints in the upper limb must occur simultaneously (Kandel et al. 2000). If there are any limitations of movement within the segments of the upper limb, the straight path will be disrupted resulting in possible failure in completing the task, clumsy execution or the use of compensatory strategies. Careful assessment of all the joints of the upper limb including the elbow, and proximal and distal radio-ulnar joints is required.

For reach, grasp and manipulation to be effective, the hand needs to be transported accurately to the target. A key consideration in working for transportation towards a target is to gain selective activation of triceps for stability of both the shoulder and the elbow. Reciprocal activation of biceps and triceps is essential for the control of reach and also demands enhanced scapula setting (Fig. 7.13). Following target location, the appropriate selection of motor programme to transport the hand to the target is made as all components of the movement are controlled by these sets of motor commands structured before the movement begins (Kandel et al. 2000). Hence, before the upper limb reaches for an object, the selected motor programme is coupled with APAs in the trunk. If these are not readily available, then the patient may find a different strategy (Fig. 7.14).

Fig. 7.13 Selective strengthening and co-activation of biceps and triceps to influence shoulder stability and scapular setting.

In reaching to grasp, the hand starts to open at the beginning of the reaching pattern and, in fact, it has been found that after visualising the target, the excitation of corticospinal neurones which will activate hand musculature begin up to 600 milliseconds before the movement begins (Castiello 2005). Therefore, clinically, it is important to coordinate the facilitation of the pattern of reach with activation of the wrist and hand. It has been found in a heterogenous group of patients with various lesion sites that the temporal coordination between reach and grasp was largely preserved (Michaelsen et al. 2004).

Fig. 7.14 Inability to achieve an appropriate reach pattern. Patient demonstrates trunk displacement to achieve the range of reach.

The trajectory, speed, acceleration and deceleration of the hand moving towards an object/surface are scaled without specific sensory input from the limb. However, once the hand makes contact with the surface, afferent information provides feedback for modifying the motor pattern and with repetition improves the efficiency and accuracy of the movement (Fig. 7.15). Clinically, it is important to provide the opportunity to practise reaching for different objects that require different spatial coordinates. The speed of the transportation phase varies, initially

Fig. 7.15 Improved shoulder stabilisation with hand placement.

accelerating and then decelerating on approach to the target which occurs in phase with the pre-shaping of the hand for grasping. The acceleration phase of 'reach to grasp' is shorter than the deceleration phase, whereas in 'reaching to point' the acceleration phase is longer (Jeannerod 1999). If the task requires hitting a target rather than pointing at it, the acceleration phase is again longer with the target being hit at a relatively high velocity. This is important in the clinical setting as the choice of task will influence the transportation phase.

Reach has a strong cognitive component that must be considered in treatment. The individual initially needs to be motivated to move, then needs to recognise the components required for the task, the task itself and the context within which it is performed. For example, reaching for a plant cutting by a keen gardener requires recognition of the need for a graded precision grasp and controlled transportation which must take place against a background of postural control.

The coordination of movement between the trunk and upper limbs is vital for efficient reaching to be possible in a variety of functional situations. The feed-forward postural adjustments in the trunk which influence the control of reach are affected by a variety of factors including body posture, speed, mass and context (Urquhart et al. 2005). Clinically, it is important to differentiate which neural systems may have primarily been affected by the lesion of underlying pathology and which remain relatively intact. This will underpin the clinical reasoning process.

Skilled grasp

Evolution has created a five-digit orchestra that is a highly refined intricate sensorimotor tool and provides important sources of sensory information to the brain. Cortical representation of the human hand is vast and complicated (Kandel et al. 2000; Nudo 2006). The corticospinal system supporting hand function is distinctly different from the postural control system that so closely supports its functional use.

The corticospinal system is formed from many major sensorimotor integration areas of the brain, such as the thalamus, dorsolateral pre-frontal cortex, cingulate gyrus, limbic system and parietal cortex. They all play a role in developing the ideation and creation of the components of the functional task. The system, therefore, operates on the principle of divergence to convergence, taking a large amount of sensory information from the brain to a relatively small area of the spinal cord and onto a small but very significant aspect of the muscular apparatus, namely the intrinsic muscles of the hand. Although the corticospinal system was previously thought to mainly have a motor role, it is the sensory component that is particularly significant in treatment and recovery of function of the upper limb (Kandel et al. 2000). Clinical implications following damage to these areas include deficits in the following areas:

- skilled movement;
- stereognosis;
- body schema;
- perception;

- exploration of the environment;
- communication;
- emotional expression.

Afferent information from the hand is a major contributor to the development of our body schema which is essential for feed-forward postural control, especially in the creation of the postural set for the hand to be used in both open and closed chain activities. This information is transmitted to the brain as separate modalities of fractionated stimuli, and like pieces of a jigsaw, it must then be made into a complete picture. For functional use of the grasped object, consideration must also be given to the components of movement of the elbow, forearm and hand.

Pre-shaping of the hand occurs during reaching (Jeannerod 1999). This process is initiated at the beginning of reach and results in the correct orientation of the hand to the object and will be influenced by the object's shape and the task to be undertaken (Shumway-Cook & Woollacott 2007). Selective extension of the wrist with selective abduction and extension of the thumb are crucial components of the stability needed for shaping of the hand (Rosenkrantz & Rothwell 2004).

Grasp aperture increases during the acceleration phase of reaching to wider than the object to be grasped, and then narrows as the hand approaches the object. The ability to recruit appropriate postural stability within the hand in relation to the rest of the body and then to control the contact with the object is a key goal of treatment. Particularly important is the ability to achieve appropriate sensory interaction with the object without the overdependence on vision. Many of our skilled activities require the hands to work cooperatively; they are coupled together in activity while performing different tasks, often with one hand stabilising the object with the other hand manipulating. This is important to consider within the treatment setting (Rose & Winstein 2004), especially with respect to midline orientation and appropriate interlimb coordination, and retraining patterns of activity in functional settings.

Neural and non-neural aspects may reduce the ability for the hand to conform to the contours of the object to be grasped. During grasping activities, afferent feedback grades the force with which objects are gripped, allowing for weight, texture and structure. Feed-forward mechanisms organise available information for selective grasp; for example, visual recognition of a wet, cold milk bottle in the refrigerator will prepare the sensory receptors for the 'shock' of the cold sensation as well as the need for a more controlled grip to prevent the wet bottle slipping through the fingers. There is evidence to support that planning of grasp specifics such as speed and placement of fingers is determined by the intended goal that will follow the grasping action (Ansuini et al. 2008) and the predicted weight and centre of mass of the object (Lukos et al. 2007).

The elbow and radio-ulnar joints play a key role in the orientation of the hand to the task. Functionally, taking a drink demands stability from the hand holding the glass while the radio-ulnar joints rotate to access the pattern of movement to take the glass to the mouth. The glass then needs to be angled to take a drink, and the hand and wrist rotate while the forearm provides more stability.

The hand

> "The hand has several advantages over the eye, it can see in the dark and it can see round corners; most important of all it can interact with the environment, rather than just observe it"
>
> (Napier 1980).

Activities involving the hand rarely take place in isolation; they occur in conjunction with other tasks which require cognitive, perceptual and postural control such as driving a car, playing a musical instrument or buttoning a shirt. Hand movement is shaped not only by the specific characteristics of the individual but also by the task and the environment within which it is performed (Shumway-Cook & Woollacott 2007). For example, when writing on a whiteboard, the choice of grip will be dictated by the shape and size of the marker pen and the degree of upper limb elevation will be determined by the relative height of the individual to the whiteboard, whereas writing the same words on paper on a desk will require a different set of movement parameters.

Recovery of function in the hand after a lesion of the brain will require:

- specificity;
- intensity;
- motivation on the part of both the therapist and the patient;
- a rich and novel environment;
- opportunities for varied practice.

Early treatment and management of the hand

What happens in the early stages of rehabilitation is believed to have a considerable impact on long-term potential (SUTC 2001). Decreased sensation due to primary sensory impairments or secondary to reduced motor activity, such as in learned non-use, results in reduced feedback (Taub 1980). Constraint-induced movement therapy is based on the theory of learned non-use. During the early stages of recovery after neurological damage, the individual begins to compensate for the loss of their impaired limb by using the less-affected limb more and differently. This behavioural change is reinforced by the difficulties encountered using the affected upper limb and hand compared with the less impaired limb. If the latter limb is constrained and the former is challenged to participate in function, motor behaviour can be changed (Taub et al. 1994; Grotta et al. 2004). This is also a key factor in designing appropriate treatment using the Bobath Concept. Often, the compensatory body part is stabilised, so that it is not 'interfering', in order to focus on control of movement through the more affected body part. Teaching the patient how to adapt their behaviour outside of treatment is an integral part of their rehabilitation. Learned non-use is an all-too-common sequelae to neurological dysfunction, with the loss of stereognosis, manipulation and dexterity being the most difficult to recover.

Early rehabilitation should consider the whole body but often focuses on ambulation at the expense of the upper limb. From the onset of the rehabilitation process, treatment and management of the upper limb and hand is imperative. From day one, the patient's upper limb should be postured and activated so that the hand is placed in positions that will help to orientate the patient in space and can be located easily in the visual field. The position of the hand should preserve the arches/postural framework of the hand and maintain its functional range. The loss of posture in the hand is directly related to the loss of excitation of the intrinsic muscles, which leads to weakness. The flexed posture, often seen in the neurological patient, is therefore produced through increased activity of the extrinsic muscles which control the hand.

Changes in orientation of the hand to the supporting surface will facilitate the maintenance of range of movement. Frequent changes to the immediate sensory environment of the hand can provide novel experience. This may include firm handling and contact with contrasting materials. The provision of a systematic programme of sensory stimulation and heightened awareness of the hemiparetic hand is very important if there are positive indications for functional recovery. Early recovery of localisation of touch and two-point discrimination is very positive and may require an alteration of the direction of the treatment programme to include activation of the hand in facilitation of reaching for standing and locomotion.

Appropriate, specific and directed handling of the hand during everyday activities such as washing should enhance the patient's sensory experience. All members of the rehabilitation team including relatives and carers play an important role in actively promoting sensorimotor opportunities for the patient (see Chapter 8).

Assessment of the hand

It must be recognised that for a number of reasons, not all patients will be able to recover function in their hand after neurological pathology, especially if the sensorimotor integration within the brain and the summation for the areas supplying the corticospinal system are damaged. Accurate assessment is required to select appropriate patients for intensive training, which is required to overcome the dysfunction. Assessment of sensation is optimally carried out when the influence of the extrinsic wrist flexors is reduced by taking the muscles off stretch (Fig. 7.16). Localisation of touch and two-point discrimination are essential for stereognosis and manipulation and, therefore, are the foundation of the assessment and treatment process. However, stimulation of the hand may be required before sensory testing can give an accurate picture.

Figure 7.17 outlines some of the different components of the hand, which need to be considered. In addition, the following aspects of assessment should be included:

- the ability to create through stimulation and activation, a contactual hand-orientating response (CHOR) (Denny-Brown 1966);
- independence in sit to stand (STS) to assess the postural component for hand function (see Chapter 5);

Fig. 7.16 Assessment of localisation of touch.

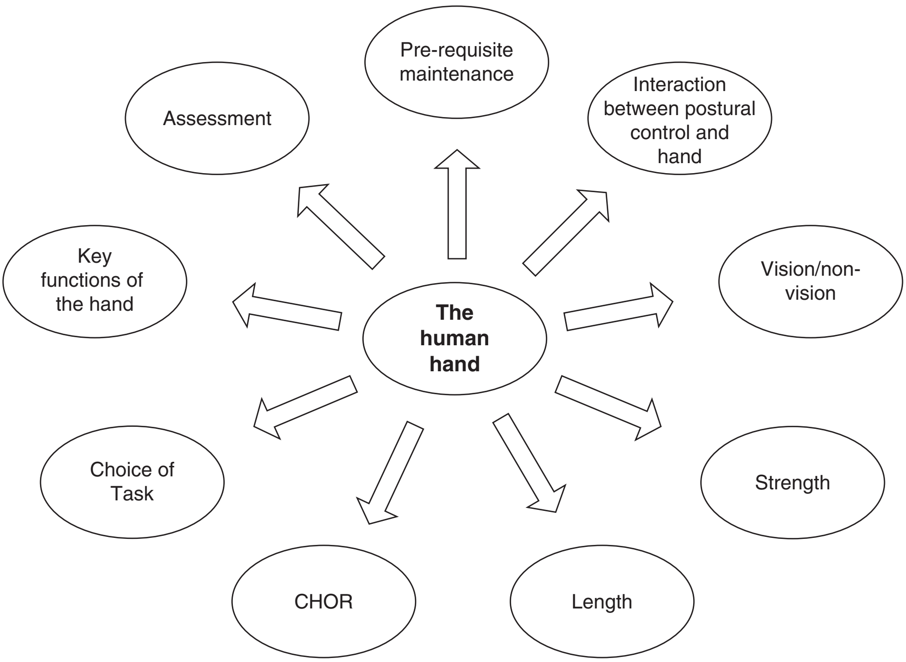


Fig. 7.17 Components for recovery of hand function.

- the status of non-neural changes in the upper limb;
- the presence of atrophy in the intrinsic muscles.

Contactual hand-orientating response

The CHOR is a frictional contact of the hand to a surface that allows for the hand to begin its functional roles (Porter & Lemon 1995). The maintenance of a CHOR is a key component that needs to be considered within the rehabilitation process from day one. The CHOR facilitates:

Fig. 7.18 Preparation for STS by gaining a CHOR in an acute hemiparetic patient.

- midline orientation;
- 'light touch contact' as a balance aid (Jeka 1997);
- limb support and limb loading;
- postural stabilisation for selective wrist, elbow and shoulder movement of the same limb;
- contralateral upper limb across midline tasks.

The maintenance and use of CHOR may facilitate, for example, preparation for STS in the early acute hemiparetic patient (Fig. 7.18).

Selective strength training of the intrinsic muscles of the hand

The human hand is both powerful and dextrous. As previously stated, it is important to recognise the role of intensity in promoting recovery of function in the hand which includes the intensity of:

- Sensory stimulation to bring about summation and integration.
- Strength training of key muscular areas of the hand for selectivity of movement, dexterity and power.

- Guided practice, preferably errorless. Research evidence shows that intensity of practice is underpinned by adequate motivation on the part of the patient, carer and therapist (Winstein et al. 2003; Kwakkel et al. 2004). Tasks need to be structured, relevant and part of daily life.
- Practice may need to be augmented by a programme of extrinsic stimulation and mental imagery.

Mental imagery can increase the patient's 'self-therapy' time considerably, as the patient is not reliant on time spent in the treatment setting with therapists, but can exercise safely any time, anywhere, giving the patient more motivating autonomy over the rehabilitation process. Motor imagery alone seems to be sufficient to promote the modulation of neural circuits, as the sensorimotor cortex has been related to both execution and imagination of movements, leading to the same plastic changes in the motor system as those following repeated physical practice (Jackson et al. 2003; Braun et al. 2007). Therefore, it is an excellent way to practise movement skill for rehabilitation. Yue and Cole (1992) report an increase in muscle strength through imagined strength training, and Rogers (2006) showed that performance improves even if imagery is used concurrent to intensive physical training.

Patients educated and familiarised with the technique are more likely to practise in general and correctly by themselves, and therefore they need the ongoing 24-hour-concept support of the interdisciplinary team with this practice programme (Braun et al. 2007).

The intrinsic muscles of the hand, lumbricals and interossei contribute to the shaping of the hand and the strength of the grasp. The postural stabilisation provided by the intrinsic muscles of the hand gives the basis for individual digit movement. The muscles that form the hypothenar and thenar eminence work in both synchrony and asynchrony to produce a great variety of grips and postures for functional activities. Pincer and power grips involve the important muscular control of abductor digiti minimi, first dorsal interosseus and abductor pollicis, and extensor and flexor pollicis longus. Strengthening of the thumb musculature is essential for both the function of the hand and the movement of supination and pronation of the forearm. These components must be available for active wrist extension and progression into task practice. Examples of treatment to gain shaping of the hand through specific activation of intrinsic muscles can be seen in Figures 7.19–7.25.

In conjunction with a strengthening programme, consideration must be given to adequate repetition of the muscle activity at variable speeds and velocities. Therapeutic stretch may be required to facilitate activity and improve range which may be incorporated into task practice. The choice of the task should be individualised to the patient. Consideration of whether the task should start intrinsically with self-ideation or extrinsically in response to external stimuli (for example, catching an object) is important.

There are several key aspects which need to be considered in relation to the selection of the task:

- available movement components and strength of the hand;
- supporting postural control components;

Fig. 7.19 Specific activation of lumbricals.

Fig. 7.20 Specific activation of abductor digiti minimi.

Fig. 7.21 Specific activation of first dorsal interosseus for index finger movement.

Fig. 7.22 Strengthening of the muscles of the thenar eminence for strength of grasp.

Fig. 7.23 Strengthening grip within function.

Fig. 7.24 Precision grip in function.

Fig. 7.25 Coordination of grasp and release in functional activity involving lower limb activity as well.

- limiting and constraining the freedom of degrees of movement to prevent compensatory activity;
- size, shape and weight of the object;
- vision for feed-forward and shaping in a reaching activity;
- no vision for stereognosis and manipulative practice;
- structured environment including figure-ground;
- verbal and manual guidance to improve performance and increase motivation.

In summary, there are three key areas underpinning selective strength training: patient selection, intensity of practice and choice of task.

Summary

This chapter has given an overview of how functional recovery of the upper limb is addressed using the Bobath Concept. This is a particularly difficult area to address due to the inherent instability of upright bipedal stance and the involvement of the upper limbs in fixation strategies. Facilitation of appropriate APAs can have a marked effect on the individual's ability to free the upper limbs for function. If the balance between postural control and functional reach is not addressed effectively, then the full potential for recovery of the upper limb cannot be realised. The link between motor control and functional recovery including an understanding of the systems involved has been highlighted. An understanding of how stereotypical patterns of activity that become established can interfere with this process is crucial. The importance of afferent information received specifically through the hands is a key component in improving body awareness.

There are many areas of research that are directed at improving upper limb recovery in the neurological patient and they need to be considered not only within the context of the individual's presentation but also in the context of the benefits they may or may not give with respect to an understanding of the nervous systems control of movement.

Key Learning Points

- Understanding the coordinated interaction of the upper limbs with the rest of the body is crucial in order to achieve the full potential for upper limb recovery.
- Understanding the link between postural control and goal-orientated upper limb activity and in particular the appropriate choice of goal.
- Identifying the components of movement necessary for proximal and distal interactions and the neural basis.
- Importance of the relationship between activity and sensation at all stages of rehabilitation.
- Avoid and overcome learned non-use of the hand.
- Rehabilitation of reach, grasp and manipulation requires practice within functional tasks.
- Use of the environment to optimise and refine the task.
- Intrinsic hand activity provides stability for the digit movement of the hand.

References

Alexander, C.M., Miley, R. & Harrison, P.J. (2005) Functional modulation of shoulder girdle stability. *Experimental Brain Research*, **161**, 417–422.

Ansuini, C., Giosa, L., Turella, L. et al. (2008) An object for an action, the same object for other actions: Effects on hand shaping. *Experimental Brain Research*, **185** (1), 111–119.

Barr, K.P., Griggs, M. & Cadby, T. (2005) Lumbar stabilization: Core concepts and current literature, Part 1. *American Journal of Physical Medicine and Rehabilitation*, **84**, 473–480.

Basmajian, J.V. (1981) Biofeedback in rehabilitation: A review of principles and practices. *Archives of Physical Medicine and Rehabilitation*, **62**, 469–475.

Braun, S.M., Beurskens, A.J., Kroonenburgh, S.M., Demarteau, J., Schols, J. & Wade, D.T. (2007) Effects of mental practice embedded in daily therapy compared to therapy as usual in adult stroke patients in Dutch nursing homes: Design of a randomized controlled trial. *BMC Neurology*, **7** (34). DOI: 10.1186/1471-2377-7-34.

Brown, T.D. (2006) Getting to the core of the matter. *Strength and Conditioning Journal*, **28** (2), 1524–1602.

Castiello, U. (2005) The neuroscience of grasping. *Nature Review Neuroscience*, **6**, 726–736.

Culham, E. & Peat, M. (1993) Functional anatomy of the shoulder complex. *Journal of Sports Physical Therapy*, **18** (1), 342–350.

Dark, A., Ginn, K. & Halaki, M. (2007) Shoulder muscle recruitment patterns during commonly used rotator cuff exercises: An electromyographic study. *Physical Therapy*, **87** (8), 1039–1046.

Davies, P. (2000) *Steps to Follow*: *The Comprehensive Treatment of Patients with Hemiplegia*, 2nd edn. Springer Verlag, Berlin, Heidelberg, and New York.

Denny-Brown, D. (1966) *The Cerebral Control of Movement*, pp. 34, 110, 315, Liverpool University Press, Liverpool.

Edwards, D.F. (2002) An analysis of normal movement as the basis for the development of treatment techniques. In: *Neurological Physiotherapy* (ed. S. Edwards), pp. 35–67, Harcourt Publishers Limited, Edinburgh.

Grotta, J., Noser, E., Ro, T., et al. (2004) Constraint-induced movement therapy. *Stroke*, **35** (supp1), 2699–2701.

Hess, S. (2000) Functional stability of the glenohumeral joint. *Manual Therapy*, **5** (2), 63–71.

Inman, V.T., Saunders, J. & Abbott, L. (1944) Observations on the function of the shoulder joint. *Journal of Bone and Joint Surgery*, **26A**, 1–30.

Jackson, P.L., Lafleur, M.F., Malouin, F., Richards, C.L. & Doyon, J. (2003) Functional cerebral reorganization following motor sequence learning through mental practice with motor imagery. *Neuroimage*, **20**, 1171–1180.

Jeannerod, M. (1999) Visuomotor channels: Their integration in goal directed prehension. *Human Movement Science*, **18**, 201–218.

Jeka, J.J. (1997) Light touch contact as a balance aid. *Physical Therapy*, **77** (5), 476–487.

Kandel, E.R., Schwartz, J.H. & Jessel, T.M. (2000) *Principles of Neural Science*, 4th edn. McGraw-Hill, New York.

Kavcic, N., Grenier, S. & McGill, S. (2004) Determining the stabilizing role of individual torso muscles during rehabilitation exercises. *Spine*, **29** (11), 1254–1265.

Kibler, W.B. (1998) The role of the scapula in athletic shoulder function. *The American Journal of Sports Medicine*, **26** (2), 325–337.

Kwakkel, G., van Peppen, R., Wagenaar, R.C., et al. (2004) Effects of augmented exercise therapy time after stroke: A meta-analysis. *Stroke*, **35**, 2529–2539.

Lee, L., Coppieters, M.W. & Hodges, P. (2005) Differential activation of the thoracic multifidus and longissimus thoracis during trunk rotation. *Spine*, **30** (8), 870–876.

Levangie, P. & Norkin, C. (2001) *Joint Structure and Function: A Comprehensive Analysis*, 3rd edn. F.A. Davis, Philadelphia.

Lukos, J.R., Ansuini, C. & Santello, M. (2007) Choice of contact points during multidigit grasping effect of predictability of object centre of mass location. *Journal of Neuroscience*, **27** (14), 3894–3903.

MacDonald, D.A., Mosley, L.G. & Hodges, P.W. (2006) The lumbar multifidus: Does the evidence support clinical belief? *Manual Therapy*, **11**, 254–263.

Magarey, M.E. & Jones, M. (2003) Dynamic evaluation and early management of altered motor control around the shoulder complex. *Manual Therapy*, **8** (4), 195–206.

Massion, J., Alexandrov, A. & Frolov, A. (2004) Why and how are posture and movement coordinated? *Progress in Brain Research*, **143** (2), 13–27.

McQuade, K. & Schmidt, G. (1998) Dynamic scapulohumeral rhythm. *Journal of Sports Physical Therapy*, **27** (2), 125–133.

Michaelsen, S.M., Dannenbaum, R. & Levin, M. (2006) Task-specific training with trunk restraint on arm recovery in stroke. *Stroke*, **37**, 186–192.

Michaelsen, S.M., Jacobs, S., Roby-Brami, A. et al. (2004) Compensation for distal impairments of grasping in adults with hemiparesis. *Experimental Brain Research*, **157** (2), 162–173.

Morley, A., Clarke, A., English, S., Helliwell, S. (2002) Management of the subluxed lowtone shoulder: Review of the evidence. *Physiotherapy*, **88** (4), 208–216.

Mottram, S. (1997) Dynamic stability of the scapula. *Manual Therapy*, **2** (3), 123–131.

Napier, J. (1980) *Hands*. George Allen and Unwin, London.

Nudo, R.J. (2006) Mechanisms for recovery of motor function following cortical damage. *Current Opinion in Neurobiology*, **16**, 638–644.

Richardson, D. (2002) Physical therapy in spasticity. *European Journal of Neurology*, **9**, 17–22.

Rogers, R.G. (2006) Mental practice and acquisition of motor skills: Examples from sports training and surgical education. *Obstetrics and Gynecology Clinics of North America*, **33**, 297–304.

Rose, D.K. & Winstein, C.J. (2004) Bimanual training after stroke: Are two hands better than one? *Topics in Stroke Rehabilitation*, **11**, 20–31.

Rosenkrantz, K. & Rothwell, J.C. (2004) The effect of sensory input and attention on the sensorimotor organisation of the hand area of the human motor cortex. *Journal of Physiology*, **561** (1), 307–320.

Roy, C., Sands, M. & Hill, L. (1994) Shoulder pain in acutely admitted hemiplegics. *Clinical Rehabilitation*, **8**, 334–340.

Roy, C., Sands, M., Hill, L., Harrison, A. & Marshall, S. (1995) The effect of shoulder pain on outcome of acute hemiplegia. *Clinical Rehabilitation*, **9**, 21–27.

Santello, M., Flanders, M. & Soechting, J.F. (2002) Patterns of hand motion during grasping and the influence of sensory guidance. *Journal of Neuroscience*, **22** (4), 1426–1435.

Shumway-Cook, A. & Woollacott, M. (2007) *Motor control: Translating Research into Clinical Practice*, 3rd edn. Lippincott Williams and Wilkins, Philadelphia.

Stroke Unit Trialists Collaboration (SUTC) (2001) Organised inpatient (stroke unit) care for stroke. *The Cochrane Database of Systematic Reviews*.

Talkhani, I.S. & Kelly, C.P. (2001) Movement analysis of asymptomatic normal shoulders: A preliminary study. *Journal of Shoulder and Elbow Surgery*, **10** (6), 580–584.

Tallis, R. (2003) *The Hand: A Philosophical Inquiry into Human Being*. Edinburgh University Press, Edinburgh.

Taub, E. (1980) Somatosensory deafferentation research with monkeys: Implications for rehabilitation medicine. In: *Behavioural Psychology in Rehabilitation Medicine: Clinical Applications* (ed. L. Ince), pp. 371–401, Williams and Wilkins, Baltimore.

Taub, E., Crago, J.E., Burgio, T., et al. (1994) An operant approach to rehabilitation medicine: Overcoming learned non-use by shaping. *Journal of the Experimental Analysis of Behaviour*, **61**, 281–293.

Tetreault, P., Krueger, A., Zurakowski, D. & Gerber, C. (2004) Glenoid version and rotator cuff tears. *Journal of Orthopaedic Research*, **22** (1), 202–207.

Urquhart, D.M., Hodges, P.W. & Story, I.H. (2005) Postural activity of the abdominal muscles varies between regions of these muscles and between body positions. *Gait and Posture*, **22**, 295–301.

Van Kan, P.L.E. & McCurdy, M. (2000) Role of primate magnocellular red nucleus neurons in controlling hand during reaching to grasp. *The Journal of Neurophysiology*, **85**, 1461–1478, www.jn.physiology.com.

Voight, M. & Thomson, B. (2000) The role of the scapula in the rehabilitation of shoulder injuries. *Journal of Athletic Training*, **35** (3), 364–372.

Willems, J.M., Jull, G.A. & Ng, J.K. (1996) An in vivo study of the primary and coupled rotations of the thoracic spine. *Clinical Biomechanics*, **11**, 311–316.

Winstein, C., Wing, A.M. & Whitall, J. (2003) Motor control and learning principles for rehabilitation of upper limb movements after brain injury. In: *Handbook of Neuropsychology* (eds J. Grafmann & L.H. Robertson), Vol. 9, 2nd edn, pp. 77–137, Elsevier Science, Edinburgh.

Yue, G. & Cole, K.J. (1992) Strength increases from the motor program: Comparison of training with maximal voluntary and imagined muscle contractions. *Journal of Neurophysiology*, **67**, 1114–1123.

8. *Exploring Partnerships in the Rehabilitation Setting: The 24-Hour Approach of the Bobath Concept*

Clare Fraser

Partnerships in the rehabilitation environment

In this chapter we will consider the macro environment of the rehabilitation setting and its content, and the micro environment of seating, positioning and practical implementation of the 24-hour concept. We will also consider the experiences our patients are subject to within the 'learning environment', and the partnerships that should be formed to enable effective rehabilitation to take place. For clarity we will consider the acute, sub-acute and longer-term rehabilitation stages.

The patients' rehabilitation journey should be guided by the 'best practice' rather than by fragmented interventions of the multidisciplinary team coming into contact with the patient. A high level of skilled delivery and practice within the team will require educational knowledge, training and skills practice. The team must be motivated to work closely together, learn together and invest in protected educational time, enabling a dynamic, specialist and productive workforce to facilitate the patient throughout the rehabilitation process. Throughout the continuum of recovery, achieving the most efficient posture, movement and function will be the responsibility of the partnerships formed between the team members.

These partnerships ebb and flow between different members of the team, depending on where within the journey of recovery the patient lies. For example, with the minimally conscious or the acute patient, the partnership between the patient, relatives, nurse and doctor may be the strongest. Through interactions in this partnership the promotion of maximum participation is explored. The shifting bias that exists within the rehabilitation process creates changes within these partnerships. As well as delivering therapeutic intervention and enabling the patient to learn within their environment, the therapist will also be required to offer guidance about other partnership interventions, facilitating the best outcome of the rehabilitation process.

Rehabilitation is an ongoing continuum along which patients move from the very acute phase through to the end stages of achieving their full potential. It is the interdisciplinary teams' role, through their partnerships with each other and the patient, to ensure that they 'enable' and not 'disable' the patient by way of interacting and supporting them to learn and develop new skills. For example, enabling a patient to move their leg out of bed on their own during lying to sitting by understanding and facilitating their weight transference, rather than someone lifting both their legs simultaneously out of bed to 'save time'. This aims to enhance learning and therefore the recovery process.

Opportunities to practise application of skills into function should be underpinned by the partnerships between the patient and the relevant members of the interdisciplinary team. The key members within the rehabilitation team are nurses and support staff, physiotherapists, occupational therapists, speech and language therapists, neuro-psychologists, stroke coordinators, medical staff, and family and friends.

The patient's role within the rehabilitation process is to interact and relearn their functional control within the limitations of their impairments. They need to be informed and supported through the rehabilitation process and whenever possible involved in decision-making. Application of the Bobath Concept seeks to enable the patient to interact within their environment, producing an effective, desirable and appropriate response to their surroundings. Motor recovery and control is developed via the successful execution of an intended task within the environment, through the processes of neuroplasticity.

Rehabilitation on a stroke unit has been shown to reduce mortality significantly (by approximately 28%) compared to general medical wards (Langhorne et al. 1995; Stroke Unit Trialists Collaboration 2007). Consistent team input, providing expert 24-hour management, and therefore carry-over in an organised stroke unit, is the vital ingredient for better survival, recovery and regaining independence to return home (Langhorne et al. 1995; Kalra et al. 2000).

Task-specific training and repetition have demonstrated cortical functional reorganisation (Nelles et al. 2001; Jang et al. 2003). Studies show training, or rehabilitation, increases cortical representation with subsequent functional recovery, whereas a lack of rehabilitation or training decreases cortical representation and delays recovery (Teasell et al. 2005). The consistent 24-hour approach within the rehabilitation setting will enable maximum neuroplastic reorganisation to take place for the patients' beneficial recovery.

The Bobath Concept recognises that the patient needs to become an 'active learner' to make the rehabilitation process successful. The relevance and appropriateness of the task makes all the difference to the sensory guidance required and motor patterns that are produced, therefore enhancing motor recovery. For the individual involved in rehabilitation, reaching into the air for an imaginary meaningless object will not produce the same movement patterns, and therefore learning, as reaching to take a tissue from a box or to put an arm in a sleeve. Tasks must be meaningful to the individual.

Motor learning theories inform therapists about what makes an effective learning environment and how to design a rehabilitation programme to meet the needs of the individual. It is the interdisciplinary teams' role to help the patient become an active learner and to create an environment that supports this. A passive recipient will never be an active learner and will never get the most out of rehabilitation (Bobath 1990). The active learner needs to be engaged, challenged and involved in meaningful task training.

Practising an activity of relevance is probably the most effective therapeutic technique available for successful rehabilitation (Tromby & Wu 1999). Practical applications of the principles of motor learning must be sought throughout the patients' activities of daily living (ADL), for example during washing and dressing, transferring and mastering hand function at meal times. Transfer of skills through opportunities to practise is a vital consideration when scheduling the patients' day.

The early days

The patient who has neurological dysfunction enters a period of initial cerebral and/or spinal shock and is unable to integrate the systems control of posture and movement. They will have difficulty in maintaining and sustaining upright posture against the force of gravity and will be unable to create appropriate alignment and activity levels. The presence of hypotonia and weakness automatically gears the neuromuscular system to compensate for lack of postural stability which can lead to fixation. This prevents the recruitment of selective movement to attain functional skills (Edwards 2002).

Postural management

Rehabilitation of postural control is essential, allowing interaction with the patients' environment through improved stability and orientation. When considering posturing of an individual or body part, this is an active component on which selective movement is based. Factors that influence the recovery of postural control, and therefore function, include support, seating and appropriate alignment and realignment of the patient (Amos et al. 2001). The way the patient is handled, transferred and enabled to move within their environment optimises success at all stages of recovery.

The patient's environment is important in promoting active learning and therefore recovery, and must be adapted in order to make movement easier, thus fostering success and motivation. An individual's cognitive and perceptual deficits must be considered. Therapeutic use of potential environmental constraints such as plinths, pillows, doorframes and walls can assist with spatial, visual and perceptual deficits. As movement performance improves, the environmental supports can gradually be adapted to create greater challenges.

As the patient becomes increasingly independent, we need to consider the safety of the patient ensuring that the level of compensatory activity does not compromise their rehabilitation. The decision to reduce or withdraw facilitation appropriately during task practice allows the patient to make, recognise and correct errors in the process of achieving goals. The facilitator influences not only the individual and the environment but also the choice of functional goal that the patient is working towards, which must be realistic and meaningful.

Bobath therapy works through the application of appropriate modalities of sensory and proprioceptive information, to improve efficiency of movement relevant to functional ADL.

- the careful use of exposure to gravity and a changing base of support (BOS) through, for example, early facilitated standing and stand to sit;
- the use of selective movement and functional tasks to create cooperative activation for stability and mobility (e.g. patient drying themselves with a towel in sitting or standing position);
- eccentric muscle control and length through rotation, alignment and compression (e.g. facilitated moving between supine to side lying);
- speed and timing of facilitation and movement (e.g. functional reach and grasp activities).

Regular early standing within 48 hours of stroke has been shown to be safe for homeostasis (Panayiotou et al. 2002). This is important for the acute patient as early standing is essential for promoting recovery of postural tone, increasing ascending information to the nervous system and aiding postural orientation (Edwards 2002), as well as maintaining normality of the 'unaffected side'.

Positioning and seating for recovery

The goal of good seating and positioning is to provide adequate postural support to enable appropriate alignment and stability of the trunk and limbs, therefore reducing the fear of falling and need for compensatory fixation appropriate to that postural set. This will give the patient the foundation BOS on which to move actively and appropriately within their chair and wider environment. Seating and positioning may require the use of external scaffolding specifically to support hypotonic areas using towels and pillows (see Figs 8.1 and 8.2 of sub-acute patient). This is especially important in the patient with low arousal/minimally conscious state.

Armchair or wheelchair seating must provide adequate support to maximise comfort and enhance postural and functional activity (Reid 2002). Without appropriate and stable positioning during seating, the patient is at risk of developing postural dysfunctions, which can interfere with the accomplishment of functional skills and ongoing recovery. Discomfort and back pain is common in wheelchair users (Samuelsson et al. 2001). A thorough assessment must be completed to determine the optimal seating and mobility system for each patient (Taylor 2003).

The therapist must consider the provision of powered wheelchairs to patients for whom this may be beneficial (Canning & Sanchez 2004; Massengale et al. 2005). This would increase the patients' level of independence without demanding an increase in compensatory strategies to do so. The patient would have to have the necessary perceptual and cognitive ability to use the powered chair safely.

Fig. 8.1 Fixation of left trunk and upper limb, in response to dense low tone in right proximal girdles, with poor extensor activity on both sides of trunk.

Fig. 8.2 Use of towel scaffold under right pelvis and thigh, and pillow support to right upper limb (UL), reduces fixation and improves trunk activity. Left UL is now more appropriately used to support weak trunk, rather than fix and grasp into flexion as previously. De-weighting the heavy right UL onto a plinth and closing in the perceptual and physical environment enable more linear extension to be gained and a freer head for movement. Therapist provides proprioceptive and sensory input to facilitate the exploration of postural and movement control within an improved alignment and interaction with BOS.

The performance of functional activities in sitting is greatly influenced by the quality of the support given to the pelvis, producing more vertical postural alignment and therefore trunk alignment, stability and ability to reach (Hastings et al. 2003). In addition to optimising functional reach with appropriate back support (May et al. 2004), posturally supportive seating has been shown to influence head control and therefore swallowing and feeding skill (Redstone & West 2004), tidal volume and ventilation measures (Landers et al. 2003).

Research supports the importance of providing postural support to the trunk, to enable the patient to free their arms for functional activities (Michaelsen & Levin 2004). This may also reduce the patient's level of fatigue. Using a pillow or sheet to control excessive perturbation of the trunk is an ideal way to provide stability for the early patient, thus allowing at least one functional arm (Fig. 8.3).

Fatigue is an important factor in the acute and sub-acute patient, and must be managed effectively to prevent fixation strategies worsening as postural muscles tire. Individual positioning programmes for the variety of postures the patient will be in throughout the 24-hour period should be devised and followed by the interdisciplinary team, including families and carers. Positions of rest within treatment sessions may be necessary for some patients so that maximum benefit from therapy is achieved (Fig. 8.4).

Patients with severe disability may benefit from a 'tilt-in-space' wheelchair back for comfort, improved postural support, enhanced seating stability, relief of pressure and resting options out of bed (Dewey et al. 2004). The 24-hour approach promotes recovery through the use of varied appropriate postures, activation against gravity and facilitation of task practice.

There is a lack of evidence, consensus and guidance surrounding optimal positioning and its impact on outcome for the neurological patient (Siew & Hwee 2007). The patient needs to explore a variety of optimal positions in order to maintain an efficient neuromuscular and musculoskeletal system.

Moving between postures to address potential joint and soft tissue changes

Positioning must maximise the functional alignment of joint and soft tissue structures, to prevent the loss of range of movement (ROM) from time spent in an end range position. Interdisciplinary team knowledge of human movement will facilitate changing from one postural alignment to another through segmental control, incorporating the appropriate aspects of stability and mobility, and encouraging initiation and participation on the part of the patient. Moving from posture to posture through an interactive process with the carer, nurse or therapist can address specific problems of reduced ROM and muscle length changes such as the development of adaptive shortening. Distal key points are particularly vulnerable to trauma such as the inverted ankle and foot in sitting and during transfers and the hyper-flexed wrist held by the patient in sitting, or neglected in bed. The interdisciplinary team approach to moving from posture to posture can incorporate activation from distal key points.

Fig. 8.3 Pillow splinting trunk in wheelchair has allowed left compensating upper limb to rest more freely in sitting posture.

Fig. 8.4 Forward lean sitting with careful handling and positioning of vulnerable low-toned right shoulder complex, allows fatigue management within therapy session.

Figures 8.5 Inadequate postural support of the trunk especially on the left side creating poor limb alignment.

Figure 8.6 Appropriate use of pillows providing trunk stability and support of the hemiplegic upper limb, and neutral alignment of the head and neck.

Hemiplegic shoulder pain is a common complication of stroke (Turner-Stokes & Jackson 2002). It can interfere with rehabilitation and has been associated with poorer outcomes and extended hospital stay. Shoulder pain may be due to prolonged stretch on low-toned soft tissues and joint capsule (Sahrmann 2002; Turner-Stokes & Jackson 2002), and may be associated with trauma imposed on a subluxed glenohumeral joint (see Fig. 8.5). Ada et al. (2005) recommend at least 30 minutes a day of positioning the affected shoulder in external rotation, commencing as soon as possible, to prevent the effect of muscle contracture on ROM, pain and future functional outcome. However, de Jong et al. (2006) suggest that 30 minutes twice a day may not be enough for a functionally relevant effect. Each of the above aspects needs to be considered in addition to incorporating functional activities which promote desirable movement patterns. Careful handling of the glenohumeral joint, that supports the head of the humerus within the fossa and facilitates humeral movement as part of the movement pattern, is essential by all the inter-disciplinary team members, especially during activities such as washing and dressing. The arm must be well supported to prevent adverse stretch and impingement on the capsule and surrounding tissues (see Fig. 8.3 and 8.6).

Overcoming sensory deprivation and stimulating body schema

Ensuring that the patient involves their affected body parts as fully as possible in ADL will help to overcome sensory deprivation and provide some ongoing information towards maintaining a body schema. All modes of sensory input should be reinforced, such as visual and somatosensory information, appropriate to the context of the activity. The arm and hand should be kept within the patients' visual field through appropriate positioning for example, while resting in a chair or during mealtimes by placing it on the table. Using ADL to provide afferent information to the patient is an example of how the 24-hour management of a patients' rehabilitation programme can make a difference to their experience. During personal care activities, nursing and occupational therapy staff can assist the patient with their affected arm and hand to use the towel to dry the face or other arm during washing.

Dressing is a challenging and complex task consisting of physical, cognitive and perceptual components, and may require considerable part-task practice, before whole task practice can be accomplished. In this way the patients' participation is increased. One key goal in the facilitation of dressing, as previously described, is to activate the limb into the garment rather than passively put the garment onto the limb.

Post-stroke hand oedema is common (Geurts et al. 2000). Oedema may reduce joint range, and limit the sensory interaction between the body part and the environment, thus reducing effective afferent information ascending to the nervous system, decreasing cortical representation and therefore disrupting body schema. Oedema can be managed through less gravity-dependent positioning, functional activities and exercises, compression and use of a pressure garment where appropriate, and the achievement of the contactual hand orientation response (CHOR) (see Chapter 7).

Sensory rehabilitation programmes are also essential within the patients' treatment interventions to promote recovery of sensory integration. An intensive hand programme that incorporates a variety of sensory modalities aims to reduce the impact of learned non-use (van der Lee et al. 1999). This must be incorporated from the outset of the rehabilitation process. Often the sensory rehabilitation programme is a component of practice that can be taught to a carer, a relative or a friend.

The patient who is unable to orientate themselves towards midline due to perceptual disorientation will feel fearful when moving. It is important to minimise this fear by making them more secure within their immediate physical and perceptual environment. This can be achieved by reducing the open space around the patient both within the chair and in the immediate surrounding area by 'boxing' them in with pillows or furniture support (see Fig. 8.3). Allowing the patient as much control and decision-making as possible during transfers and movement will help to manage this fear further.

Scheduling the day – opportunities for practice

Following initial assessment, the therapy team must use their combined clinical reasoning skills to discuss and plan the scheduling and implementing of the patients' timetable. This requires evaluation of the patients' individual needs based on their postural limitations, fatigue levels and the goals of the therapeutic programme. It may, for example, be most therapeutically beneficial if the physiotherapist works to facilitate the patients' participation in getting up out of bed in the morning, so that preparation for sit to stand and early standing work can be explored. Dressing practice should include working towards better integration of the neglected arm and may be an ideal preparation for full interaction at the breakfast table and facilitated management of the meal. Furthermore, the same 'clinical reasoning' approach to the order of therapy interventions should be considered as careful scheduling of the day by the interdisciplinary team will provide opportunities for practice so that the patient is more able to engage in a functional activity directly after having worked on a movement or postural challenge. For example, having a meal after working in occupational therapy on unilateral neglect issues in which the affected hand was stimulated and the use of functional objects facilitated would be an ideal way to combine these skills together for an end functional goal. Similarly, attending a speech therapy session after having gained greater postural control, head and neck alignment and sitting balance, in a physiotherapy session, is an excellent day plan that will promote practice opportunities and carry-over. Through team partnerships and clinical reasoning, the best recovery outcome for the patient is promoted (Fig. 8.7).

It is essential that the patient spends appropriate time up against gravity in a satisfactory way to aid postural control recovery. They must also have adequate rest periods to allow a change in position so that they can pace themselves throughout the day, therefore building postural and exercise stamina. Therapy sessions must be considerate of rest periods and also visiting times so that, if appropriate, family members and carers can attend the sessions, building their partnerships with the team.

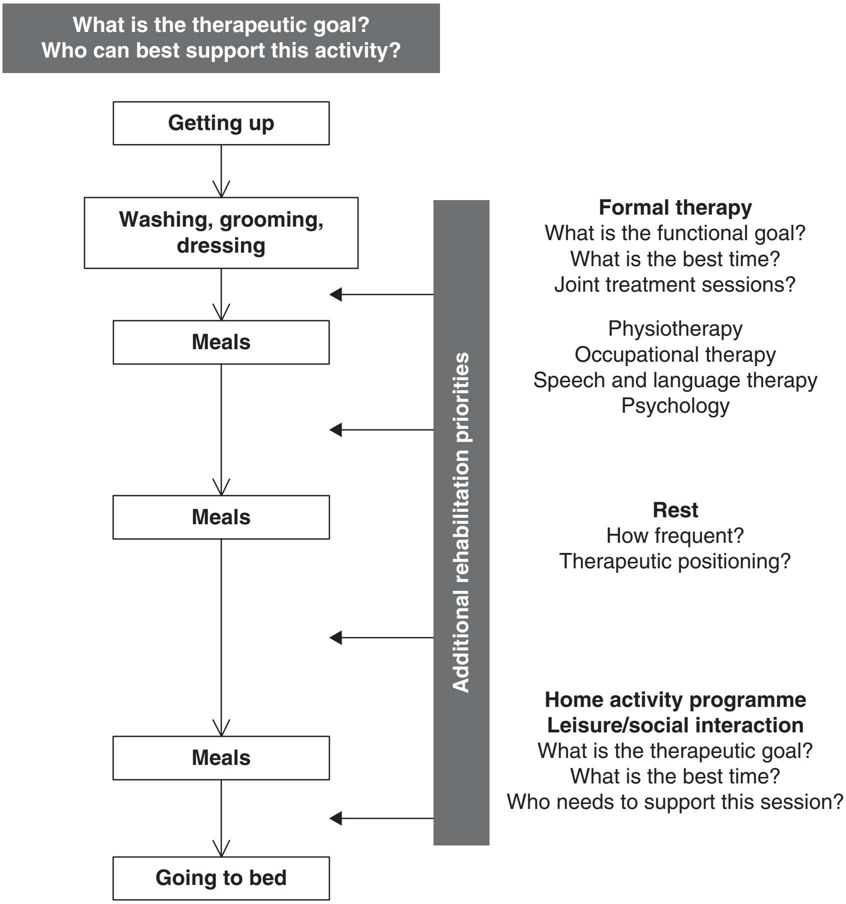


Fig. 8.7 The Day Schedule. The boxed areas indicate essential activities of daily living. These can be facilitated to maximise the patients rehabilitation goals. Additional rehabilitation priorities are agreed by the interdisciplinary team and are individual to the patients needs. Reproduced with permission of Sue Raine.

Joint treatment sessions – consistent approaches

Working together in joint treatment sessions promotes a consistent approach across the patients' day and the teams' practice. Joint sessions may involve, for example, occupational therapists and nursing staff in partnership with the patient during a washing and dressing activity, or physiotherapists and occupational therapists working together with the patient in a kitchen activity. This adds quality interventions into the patients' day, whereby the postural control needed, for example, in the transfer of weight while reaching into a kitchen cupboard can be facilitated by the therapist, while the sequencing and participation of a task such as making a cup of tea is explored.

Intensity of treatment delivery

The question of how much treatment, and how often, is one that the evidence is yet to answer conclusively. While expert care is known to have an effect on recovery compared to traditional care (Wagenaar & Meyer 1991a, b), it is still unclear which part of expert care makes a difference such as team care, active family participation, special staff education, early start of treatment and/or intensity of treatment.

Both Langhorne et al. (1996) and Kwakkel et al. (1997) conclude that more intensive physiotherapy input is associated with a reduction in the poor outcomes of death or deterioration, and may actually enhance the rate of recovery.

Evidence supports that more intensive delivery of therapy within the rehabilitation period will have a positive effect on impairments and activity levels. Increased intensity of specialised rehabilitation is enabled by the interventions of the whole interdisciplinary team throughout the 24-hour concept of rehabilitation. Intensity has been found to show improvements in ADL and gait speed (Kwakkel et al. 2004) and reduce stay in a rehabilitation setting (Slade et al. 2002); however, the type of therapy used has not been clearly identified within the literature.

Home programmes

Effective rehabilitation from the acute stages right through to community-based physical activity programmes is important, and a tailored home programme is part of the 24-hour approach that can make this transition more seamless (Engardt & Grimby 2005). Training and home programmes have value in rehabilitation and published results are, in general, promising (Ramas et al. 2007).

It is important for the patient to recognise that there is no need to have a physiotherapist present every time they engage in physical therapy activities (Olney et al. 2006). Patients need to build their confidence in being an active participant in order to have control over their own rehabilitation. Indeed a well-designed programme which is focused on their functional goals and is meaningful to their current rehabilitation interventions is an excellent motivator and will help to empower the patient and their family (Jones et al. 2000; Williams 2007).

The patient needs to be actively involved in directing the use of their 'free time', both on the ward and at home, to gain the benefits of practice and ongoing exercise (Olney et al. 2006). This should be part of their daily routine.

Managing personal laundry and kitchen activities and engaging in a 'breakfast', 'coffee shop' or 'news group' enrich the rehabilitation environment, and are an excellent use of leisure time, preparing the patient for discharge and a return to previous activities (Sargeant et al. 2000). Use of rehabilitation gym equipment and circuit training practice for patients who are more able to practise without therapy assistance can be useful (Carr & Shepherd 2003), and direction to achieve ADL is excellent 'back to life' rehabilitation experience. However, all patients are individuals and need to be engaged in activities that are both interesting and motivating to them.

The patient will feel the effect of secondary de-conditioning, and so it is important that the therapy team consider a return to cardiovascular fitness as a priority for reintegration to the 'real world', both during inpatient stay and on discharge home. A home programme must address this issue which will impact on fatigue, stamina levels, an ability to pace energy expenditure throughout the day and quality of life. Challenges such as outdoor walking, hills, slopes, uneven ground (such as sand, grass and gravel), stairs and escalators are essential experience, both for motor control and fitness. The careful and appropriate use of standard gym equipment such as static bikes and treadmills can be used as adjuncts to the therapy programme for some patients (Engardt & Grimby 2005). Following discharge, and as a regular part of the outpatient rehabilitation programme, return to leisure activities such as gyms and swimming pools in leisure centres can be addressed (Engardt & Grimby 2005). Where appropriate it is important that therapy assessment occurs within these areas, so that direction and attention to detail concerning the exercise programme can be ensured.

Return to work

Between 41% and 49% of patients of working age return to work following a stroke rehabilitation programme (Vestling et al. 2003). The majority of those return within 18 months of discharge. Being able to walk, along with preserved cognitive capacity, correlated with the greatest chance of returning to work (Vestling et al. 2003). Patients with aphasia, significant muscle weakness or a longer length of stay were less likely to return (Black-Schaffer & Osberg 1990).

People back at work have significantly higher levels of well-being and life satisfaction compared to those who do not return to work, whose quality of life scores are known to decline substantially and therefore require greater community and support services (Hopman & Verner 2003).

The interdisciplinary team must liaise closely over individual issues, such as returning to employment, retraining and further education, domestic roles, sexual relationships, driving, use of public transport and personal leisure interests, in order to develop a patient-centred rehabilitation programme, with the relevant supporting agencies, which addresses these goals.

Case study

Biographical data

Mr JS Age 66.
Partial anterior circulatory syndrome (PACS) May 2006.
Lives alone, family nearby.
Independently mobile
Retired academic, writer and musician (plays the guitar).

Impairment	**Activity goals**
Lower limb • Weakness left hip/pelvis • Decreased single leg stance (SLS)	Gardening, balance, stairs skill, functional gait including turning on differing terrains.
Trunk (bilaterally) • Lack of selectivity and linear extension control, and therefore poor feed-forward stability for limb activity	
Upper limb • Unstable left scapulothoracic joint • Weakness rotator cuff • Impingement pain • Associated reaction (AR) • Anterior subluxation of carpals • Weakness intrinsic muscle groups of hand • Soft tissue adaptations in forearm and hand	Improve kitchen activities, computer keyboard skills, activities of daily living (including bathing), guitar playing.

Clinical hypothesis

The lack of postural control at the proximal girdles (pelvic/hip and shoulder) leads to inappropriate anticipatory postural adjustments (APAs). This impacts on the sensory interaction of the distal key points in functional walking and upper limb activities.

The involvement of the upper limbs in compensatory fixation strategies impacts on the recovery of the upper limb and in particular recovery of hand function.

Hypothesis

Improved APAs which facilitate greater postural control proximally, together with an improved alignment and selectivity of movement at the glenohumeral joint, would allow the development of a more functional hand. The development of improved hand interaction with the environment (CHOR) would in turn create opportunities for the continued development of proximal control and strength within the upper limb.

Treatment intervention

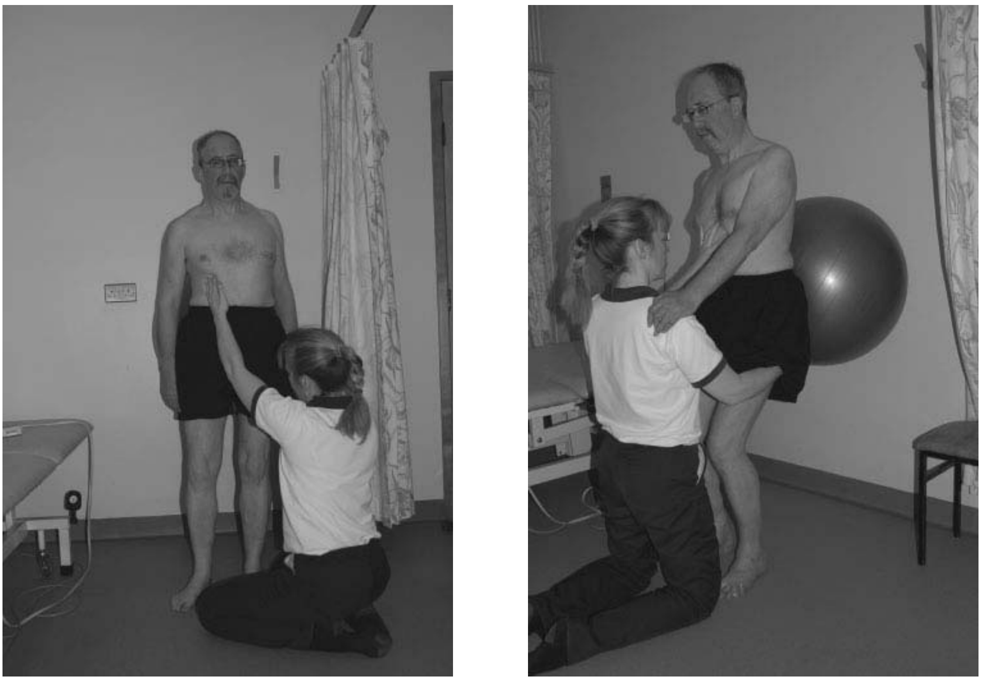
Working in supine with towel scaffolding to the scapula to ensure neutral alignment at rest and greater congruency with the thorax, a more acceptable initial reach pattern was facilitated through handling the glenohumeral joint. Specific input to promote extensor control at the elbow and consequent stability at the shoulder was achieved while gaining a softer wider hand. This developed an improved CHOR with accompanying selective extension of the fingers, wrist and elbow. This was successfully developed into closed chain activity to allow interaction of the hand with the environment and appropriate strength training opportunities.

Maintaining an appropriate alignment and utilising extension at the hip, the patient was facilitated into right side lying, using the left upper limb reach pattern to create proximal shoulder girdle activity during the transfer. A towel was added to the trunk in contact with the BOS to provide greater stability and encourage improved interaction with the right trunk and BOS for postural adaptations (Fig. 8.8).

Fig. 8.8 Right side lying. Stabilising the ipsilateral side for appropriate postural stability for contralateral upper limb activity.

Using a narrow plinth in front of the patient allowed the left hand to interact with a surface during the facilitation of the reach pattern sequence, improving scapulothoracic joint stability. Often the stability on the less affected side is impaired, and careful consideration needs to be taken in order to achieve the functional recovery of the upper limb. For example, efficient SLS on the less affected side for recovery of the contralateral more affected upper limb. Where there is insufficient postural control to work in this postural set effectively, rolled towels can be used to provide additional stability until the individual has sufficient control.

The improved girdle interaction was further explored in standing and during weight transfer, through the use of a gym ball against the wall (Figs 8.9 and 8.10). This variable support encouraged the constant and adaptable core stability activity while recruiting girdle activity to produce weight transfer. Cueing the patient to guide the extent of weight transfer and engage linear extension control in girdles and trunk produced an interactive and challenging exercise which linked well into the patients' goals. In this position, strength and stamina training were improved, together with balance and postural control.



Figs 8.9 and **8.10** Gaining improved linear extension in stance. Therapist is facilitating active extension from the hip.

Working to engage and develop this control further on the stairs was an important part of the patients' treatment, gaining left hip extension for SLS. Dynamic control and strengthening throughout full ROM facilitated transfer of these skills to the outdoor environment, such as kerbs, slopes and uneven ground (Fig. 8.11).

Fig. 8.11 Facilitation of dynamic hip extension control for improved functional performance. Therapist stabilising the left hip laterally from the greater trochanter to facilitate hip abductor, extensor activity.

In addition the recruitment of linear extension throughout the lower limb, pelvic girdle and trunk provided a foundation of stability for the upper limb to function. The 'real' aspect of the outdoor environment was challenging and stimulating, and together with developing greater movement control it also allowed greater depth of functional movement analysis (Fig. 8.12).

Having gained improved scapulohumeral rhythm and reach initiation through greater rotator cuff involvement the AR was reduced. The treatment programme gave considerable attention to hand activity and worked within the patients' kitchen environment to develop improved intrinsic muscle strength. Intensive hand stimulation, palmar posturing and stability improved function in tasks (Fig. 8.13).

Work to develop a useful CHOR was important so that the patient could maintain contact within his environment through light touch and improve postural

Fig. 8.12 Functional reach and grasp in a challenging environment.

Fig. 8.13 Practicing postural control of the hand for functional tasks.

control through an orientating stimulus. The patient wanted to be able to 'put' his arm and hand somewhere and expect it to stay there keeping 'out of the way', while he did other tasks. With light facilitation during the reach pattern to extend his arm into his coat, for example, and assistance to initially place his hand onto and stay in contact with a nearby surface, the patient was able to create 'length' in his arm musculature and use extensor muscle control to stay in contact with the surface.

In combination with the CHOR and hand strengthening work for posturing of the hand, attention was also given to the maintenance of a foundation posture to enable single digit selectivity. Issues of musculoskeletal shortening within the thenar eminence and palmar structures were addressed through the facilitation of length on a more appropriately aligned wrist joint (generally anteriorly subluxed). While promoting this improved postural control of the wrist and hand, the index finger was able to express emerging selective movement for function on the keyboard (Figs 8.14 and 8.15).

Figs 8.14 and **8.15** Working in a meaningful environment to achieve a functional task. Therapist provides initial stability of the second proximal interphalangeal joint for appropriate force and activation of the index finger.

The patients' goal of transferring into the bath was used to improve scapular setting for the control of movement in relation to the bath handles. Gaining his centre of mass over his feet within the constraints of this environment was the patient's main difficulty and required facilitation of rotation to involve upper limbs in a dynamic balancing and stabilising task. The transfer revealed difficulties with musculoskeletal structures (knee pain) as well as strength issues (Figs 8.16–8.18). Work is continuing to achieve this goal more independently; however this is limited to therapeutic practice within the treatment sessions as continuing this task practice alone at home for this gentleman is not practical.

Figs 8.16–8.18 Activate facilitation out of the bath.

Specific mobilisation and strengthening of his hand, functional task practice and mental imagery formed the basis of a home programme. Effective results included improved lateral rotation at the shoulder, which helped in holding his guitar, together with a greater digitisation and selectivity of the left hand (Fig. 8.19).

Fig. 8.19 Mr JS playing the guitar following treatment.

Evaluation of outcomes

The patient was assessed at the start and end of an 8-week period. The Bohannon Ordinal Sway Test is a 7-point ordinal scale designed to assess a subject's standing balance (Bohannon et al. 1993). This specifically measures bilateral stance progressing to SLS and was sensitive to the patients' changing functional control. Mr JS progressed from a score of 4 to 6, recording the improved dynamic control and stability in SLS, and its impact on function.

The Motor Club Assessment measure is a 30-point test, 10 of which are for the upper limb, and focuses on shoulder, arm and hand activity (Ashburn 1982). Mr JS improved from 21 to 30, recording the improved selectivity particularly at his shoulder complex and functional hand control.

Goal Attainment Scaling (GAS) (Gordon et al. 1999) was used to measure the patients' goal of reaching his hand to a surface with less AR. See Table 8.1 for GAS results. Table 8.2 provides a summary of the results for each of the outcome measures.

Following the 8-week course of outpatient physiotherapy, Mr JS has increased his participation in outdoor activities, such as gardening, and confidence in outdoor mobility. He has a more efficient reach pattern with a reduced AR. Gains include pinch grip, the early pre-shaping of his hand for chord positions on the guitar and improved use of kitchen objects such as using a tin opener.

Summary

The Bobath Concept considers the importance of a '24-hour' approach and recognises the importance of optimising opportunities for the patients' recovery throughout the whole day, not just within the therapy session. All interactions

Table 8.1 GAS results.

GAS measure	
−2	Able to reach with assistance, with an AR, but hand cannot be placed on a surface in 8 weeks
−1	Able to reach with assistance, with an AR, and place closed hand on a surface in 8 weeks
0	Able to reach with an AR, and place closed hand on a surface in 8 weeks
+1	Able to reach with assistance, without an AR, and place open hand on a surface in 8 weeks
+2	Able to reach without an AR, and place open hand on a surface in 8 weeks

Table 8.2 Summary of the result for each of the outcome measures.

Measures	Start of programme	End of programme
Bohannon Ordinal Sway	4 (able to stand with feet together for 60 seconds)	6 (able to SLS for 60 seconds)
Motor Club Assessment (upper limb)	Score 21	Score 30
GAS	−1 (score 40) (see Chapter 4)	+2 (score 70)

patients have within their environment should aim to promote optimum movement, thus producing desirable neuroplastic adaptation and maximise recovery. Effective education in areas such as positioning and ADL must be established within the rehabilitation setting, including the family and carers, in order to achieve best outcome (Jones et al. 2005).

The patient needs to be able to develop and maintain the quality of movement in a range of different environments for tasks to become truly functional and transferable to everyday life. Making progressive adaptations to the environment provides enriched sources of afferent control whilst varying the challenges of the task for the patient. Opportunities for practice in order to develop the patients' movement repertoire and to consolidate learning during the 24-hour period are essential within the rehabilitation environment delivered by the interdisciplinary team.

Key Learning Points

- The Bobath Concept is a 24-hour concept aiming to promote a positive learning environment in order to maximise functional recovery.
- Creating functionally relevant situations, which encourage the patient to be an active learner, promotes motor learning. This involves creating opportunities for practice and includes involving all members of the multidisciplinary team when appropriate.
- Treatment should aim to achieve a positive experience with respect to postural activity, incorporating postural management and early standing into the rehabilitation programme.
- Maintaining the patient's awareness of their whole body and orientation to midline in all activities prevents sensory deprivation and improves the patient's body schema.
- Intensity of therapy input has a positive effect on recovery as does the incorporation of home programmes to enable the patient to consolidate learning.
- Quality of life factors including getting back to work and participation in social activities are key aims of the Bobath therapist, incorporating an understanding of efficient movement into the treatment of the individual.

References

Ada, L., Goddard, E., McCully, J., Stavrinos, T. & Bampton, J. (2005) Thirty minutes of positioning reduces development of shoulder external rotation contracture. *Archives of Physical Medicine and Rehabilitation*, **86** (2), 230–234.

Amos, L., Brimner, A. & Dierckman, I. (2001) Effects of positioning on functional reach. *Physical and Occupational Therapy in Geriatrics*, **20** (1), 59–72.

Ashburn, A. (1982) A physical assessment for stroke patients. *Physiotherapy*, **68**, 101–113.

Black-Schaffer, R.M. & Osberg, J.S. (1990) Return to work after stroke: Development of a predictive model. *Archives of Physical Medicine and Rehabilitation*, **71** (5), 285–290.

Bobath, B. (1990) *Adult Hemiplegia: Evaluation and Treatment*, 3rd edn. Heinemann Medical Books, London.

Bohannon, R.W., Walsh, S. & Joseph, M.C. (1993) Ordinal and timed balance measurements: Reliability and validity in patients with stroke. *Clinical Rehabilitation*, **7**, 9–13.

Bosco, G. & Poppele, R. (2001) Proprioception from a spinocerebellar perspective. *Physiological Reviews*, **81**, 539–567.

Canning, B. & Sanchez, G. (2004) Considering powered mobility for individuals with stroke. *Topics in Stroke Rehabilitation*, **11** (2), 84–88.

Carr, J. & Shepherd, R. (2003) *Stroke Rehabilitation: Guidelines for Exercise and Training to Optimize Motor Skill*. Butterworth-Heinemann, London.

Dewey, A., Rice-Oxley, M. & Dean, T. (2004) A qualitative study comparing the experiences of tilt-in-space wheelchair use and conventional wheelchair use by clients severely disabled with multiple sclerosis. *British Journal of Occupational Therapy*, **67** (2), 65–74.

Edwards, S. (2002) *Neurological Physiotherapy: A Problem Solving Approach*, 2nd edn. Churchill Livingstone, London.

Engardt, M. & Grimby, G. (2005) Adapted exercise important after stroke, acute and long-term effects of different training programs. *Lakartidningen*, **102** (6), 392–394.

Geurts, A.C., Visschers, B.A., van-Limbeek, J. & Ribbers, G.M. (2000) Systematic review of aetiology and treatment of post-stroke hand oedema and shoulder-hand syndrome. *Scandinavian Journal of Rehabilitation Medicine*, **32** (1), 4–10.

Gordon, J., Powell, C. & Rockwood, K. (1999) Goal attainment scale as a measure of clinically important change in nursing-home patients. *Age and Ageing*, **28**, 275–281.

Hastings, J.D., Fanucchi, E. & Burns, S. (2003) Wheelchair configuration and postural alignment in persons with spinal cord injury. *Archives of Physical Medicine and Rehabilitation*, **84** (4), 528–534.

Hopman, W.M. & Verner, J. (2003) Quality of life during and after inpatient stroke rehabilitation. *Stroke*, **34**, 801–805.

Jang, S.H., Kim, Y.H., Cho, S.H., Lee, J.H., Park, J.W. & Kwon, Y.H. (2003) Cortical reorganisation induced by task-orientated training in chronic hemiplegic stroke patients. *Neuroreport*, **14**, 137–141.

Jones, A., Tilling, K., Wilson-Barnett, J., Newham, D.J. & Wolfe, C.D.A. (2005) Effect of recommended positioning on stroke outcome at six months: A randomized controlled trial. *Clinical Rehabilitation*, **19**, 138–145.

Jones, F., Mandy, A. & Partridge, C. (2000) Who's in control after a stroke? Do we disempower our patients? *Physiotherapy Research International*, **5** (2), 249–253.

de Jong, L.D., Nieuwboer, A. & Aufdemkampe, G. (2006) Contracture preventive positioning of the hemiplegic arm in subacute stroke patients: A pilot randomized controlled trial. *Clinical Rehabilitation*, **20**, 656–667.

Kalra, L., Evans, A., Perez, I., et al. (2000). Alternative strategies for stroke care: A prospective randomised controlled trial. *The Lancet*, **356**, 894–899.

Kwakkel, G., Wagenaar, R., Koelman, T.W., Lankhorst, G.J. & Koetsier, J.C. (1997) Effects of intensity of rehabilitation after stroke: A research synthesis. *Stroke*, **28**, 1550–1551.

Kwakkel, G., van Peppen, R., Wagenaar, R.C., et al. (2004) Effects of augmented exercise therapy time after stroke: A meta-analysis. *Stroke*, **35**, 2529.

Landers, M., Barker, G., Wallentine, S., McWhorter, J.W. & Peel, C. (2003) A comparison of tidal volume, breathing frequency, and minute ventilation between two sitting postures in healthy adults. *Physiotherapy Theory and Practice*, **19** (2), 109–119.

Langhorne, P., Dennis, M.S. & Williams, B.O. (1995) Stroke units: Their role in acute stroke management. *Vascular Medical Review*, **6**, 33–44.

Langhorne, P., Wagenaar, R.C. & Partridge, C. (1996) Physiotherapy after stroke: More is better? *Physiotherapy Research International*, **1**, 75–88.

van der Lee, J.H., Wagenaar, R.C., Lankhorst, G.J., Vogelaar, T.W., Deville, W.L. & Bouter, L.M. (1999) Forced use of the upper extremity in chronic stroke patients: Results from a single-blind randomized clinical trial. *Stroke*, **30** (11), 2369–2375.

Massengale, S., Folden, D., McConnell, P., Stratton, L. & Whitehead, V. (2005) Effects of visual perception, visual function, cognition, and personality on power wheelchair use in adults. *Assistive Technology*, **17** (2), 108–121.

May, L.A., Butt, C., Kolbinson, K., Minor, L. & Tullock, K. (2004) Wheelchair back-support options: Functional outcomes for persons with recent spinal cord injury. *Archives of Physical Medicine and Rehabilitation*, **85** (7), 1146–1150.

Michaelsen, S.M. & Levin, M.F. (2004) Short term effects of practice with trunk restraint on reaching movements in patients with chronic stroke: A controlled trial. *Stroke*, **35** (8), 1914–1919.

Nelles, G., Jentzen, W., Jueptnes, M., Mueller, S. & Diener, H.C. (2001) Arm training induced brain plasticity in stroke studied with serial positron emission tomography. *Neuroimage*, **13**, 1146–1154.

Olney, S.J., Nymark, J., Brouwer, B. et al. (2006) A randomized controlled trial of supervised versus unsupervised exercise programs for ambulatory stroke survivors. *Stroke*, **37** (2), 476–481.

Panayiotou, B., Saeed, S., Fotherby, M., Al-Allaf, K. & Crome, P. (2002) Antihypertensive therapy and orthostatic hemodynamic responses in acute stroke. *American Journal of Hypertension*, **15**, 37–41.

Ramas, J., Courbon, A., Roche, F., Bethous, F. & Calmels, P. (2007) Effect of training programs and exercise in adult stroke patients: Literature review. *Annales de Readaptation et de Medecine Physique*, **50** (6), 438–444.

Redstone, F. & West, J.F. (2004) The importance of postural control for feeding. *Pediatric Nursing*, **30** (2), 97–100.

Reid, D.T. (2002) Critical review of the research literature of seating interventions: A focus on adults with mobility impairments. *Assistive Technology*, **14** (2), 118–129.

Sahrmann, S.A. (2002) *Diagnosis and Treatment of Movement Impairment Syndromes*. Mosby, Missouri.

Samuelsson, K., Larsson, H., Thyberg, M. & Gerdle, B. (2001) Wheelchair seating intervention. Results from a client-centred approach. *Disability and Rehabilitation*, **23** (15), 677–682.

Sargeant, R., Webster, G., Salzman, T., White, S. & McGrath, J. (2000) Enriching the environment of patients undergoing long-term rehabilitation through group discussion of the news. *Journal of Cognitive Rehabilitation*, **18** (1), 20–23.

Siew, M.L.Y. & Hwee, B.W. (2007) A comparison study on nurses' and therapists' perception on the positioning of stroke patients in Singapore General Hospital. *International Journal of Nursing Practice*, **13** (4), 209–221.

Slade, A., Tennant, A. & Chamberlain, M.A. (2002) A randomized controlled trial to determine the effect of intensity of therapy upon length of stay in a neurological rehabilitation setting. *Journal of Rehabilitation Medicine*, **34** (6), 260–266.

Stroke Unit Trialists Collaboration (SUTC) (2007) Organised inpatient (stroke unit) care for stroke. *The Cochrane Database of Systematic Reviews*. Art No. CD000197. DOI: 10.1002/14651858.CD000197.pub2.

Taylor, S.J. (2003) Innovations in practice. An overview of evaluation for wheelchair seating for people who have had strokes. *Topics in Stroke Rehabilitation*, **10** (1), 95–99.

Teasell, R., Bitensky, J., Foley, N. & Bayona, A. (2005) Training and stimulation in post-stroke recovery brain reorganization. *Topics in Stroke Rehabilitation*, **12**, 37–45.

Trombly, C.A. & Wu, C.Y. (1999) Effect of rehabilitation tasks on organization of movement after stroke. *American Journal of Occupational Therapy*, **53** (4), 333–344.

Turner-Stokes, L. & Jackson, D. (2002) Shoulder pain after stroke: A review of the evidence base to inform the development of an integrated care pathway. *Clinical Rehabilitation*, **16**, 276–298.

Vestling, M., Tufvesson, B. & Iwarsson, S. (2003) Indicators for return to work after stroke and the importance of work for subjective well-being and life satisfaction. *Journal of Rehabilitation Medicine*, **35** (3), 127–131.

Wagenaar, R.C. & Meyer, O.G. (1991a) Effects of stroke rehabilitation, I: A critical review of the literature. *Journal of Rehabilitation Science*, **4**, 61–73.

Wagenaar, R.C. & Meyer, O.G. (1991b) Effects of stroke rehabilitation, II: A critical review of the literature. *Journal of Rehabilitation Science*, **4**, 97–109.

Williams, S. (2007) The role of patient education in the rehabilitation of people with spinal cord injuries. *British Journal of Neuroscience Nursing*, **3** (2), 48–53.

Index

Note: page numbers in *italics* refer to figures, those in **bold** refer to tables

Index