COMPARING METHODS TO FACILITATE SIT TO STAND POST-STROKE

By © Jennifer S. Shears A Thesis submitted

to the School of Graduate Studies in partial fulfillment of the

requirements for the degree of

Master of Science in Medicine (Neuroscience)

Memorial University of Newfoundland

May 2018

St. John's Newfoundland and Labrador

Abstract

Introduction: Sit-to-stand (STS) is a prerequisite to walking and independent living. Following stroke, patients often perform STS asymmetrically. Physiotherapists use different techniques to help patients relearn symmetry in STS. The effects of two techniques, verbal and manual cueing on STS symmetry post-stroke were compared.

Methods: A randomized outcome-blinded intervention trial was conducted in a stroke rehabilitation unit. 10 participants were randomly assigned to a manual or verbal cue group. Participants completed 40 repetitions of STS daily for ten days. Sitting and standing symmetry, measures of lower limb mobility, balance and gait were assessed.

Results: Standing symmetry, balance and lower limb mobility significantly improved in both groups with no significant differences between groups. STS symmetry did not change following training.

Conclusion: Both verbal and manual cueing led to improved standing symmetry, however STS remained asymmetrical. The improvements observed in both manual and verbal cueing techniques suggest that effective cueing combined with massed-practice of STS result in improved overall functional mobility.

Acknowledgements

Jennifer Shears was supported by a NLCAHR (NL Centre for Applied Health Research) Masters-Grant and the Neurosciences Division Scholarship from the Physiotherapy Foundation of Canada. Firstly, I wish to thank my husband Paul, my two wonderful boys Andrew and Ian, and my mother for their unyielding love and support during these past four years. I know it wasn't easy. Special thanks to all the subjects who graciously participated in this project. To my supervisor Dr. Michelle Ploughman, thank you for believing in me, and for your encouragement, support and friendship for the last twenty years. My committee members: Drs. J.M. Byrne, a special thank you for your support and encouragement, J. Vanderluit and Jason McCarthy. A special thank you to Thelma Hardy RegPT, an amazing colleague and busy mom of three who so willingly made time in her schedule to help make this study possible. I also want to thank the students in the Recovery and Performance Laboratory: Megan Kirkland MSc. (Clinical Epidemiology), A.J Devasahayham PhD candidate (Clinical Epidemiology), Beraki Abraha MSc. (Neurosciences), and Alice Chen. I would also like to thank the staff: Michael King PhD, lab manager Elizabeth Wallack MSc. (Community Health), and Marie Curtis for all their patience and assistance over the course of this study. Last but not least, a very special thank you to the physiotherapists, occupational therapists and management team at the L.A. Miller Centre for all their support and encouragement over the course of this project.

I wish to dedicate this Thesis to my late father, Robert Carl Bursey who would have been very proud that I achieved my goal. Love and miss you.

Table of Contents

List of Tables

List of Figures

List of Abbreviations and Symbols

η^2	Partial Eta Squared
ADL	Activities of Daily Living
BBS	Berg Balance Scale
CMSA	Chedoke McMaster Stroke Assessment
COG	Center of Gravity
COM	Center of Mass
COP	Center of Pressure
iADL	Instrumental Activities of Daily Living
ICMS	Intracortical Micro-stimulation
IP	Integrated Pressure
KP	Knowledge of Performance
KR	Knowledge of Results
MOCA	Montreal Cognitive Assessment
NDT	Neuro-Developmental Treatment
NDTA	Neuro-Developmental Treatment Association
NLCAHR	NL Center for Applied Research
OT	Occupational Therapist
PKMAS	Protokinetics Movement Analysis System
PT	Physiotherapist
RMI	Rivermead Mobility Index
SIS	Stroke Impact Scale
STS	Sit to Stand

List of Appendices

Appendix A. Chedoke McMaster Stroke Assessment (CMSA) for Postural Control

Appendix B. MoCA (Montreal Cognitive Assessment)

Appendix C. Berg Balance Scale

Appendix D. Rivermead Mobility Index (RMI)

Appendix E. Script for Manual Group

Appendix F. Script for Verbal Group

Appendix G. Script for STS and Walking

Chapter 1: Introduction and Overview

Stroke is the leading cause of brain damage in adults and is one of the leading causes of death and disability (1). Because of loss of function in performing activities of daily living (ADL), walking, and speaking, it is estimated that approximately one third of stroke survivors will continue to be functionally dependent on others after one year (2). Reduced functional independence is a significant concern for patients, their families, and physiotherapists following stroke (3). The ability to stand from a seated position is a prerequisite for self-reliant locomotion and for many ADLs (4). Neurological physiotherapists working with post-stroke patients typically use sit to stand (STS) training in their treatment plan to improve weight distribution and lower limb function and promote symmetrical and efficient balance and gait. They employ different feedback techniques such as touch, visual, and auditory cues, to help people with stroke relearn the ability to STS. However, there is limited evidence supporting one method of STS training compared to another.

This thesis is divided into three chapters. Chapter One describes the impact of stroke, characteristics of stroke-related disability, and specific rehabilitation practices of STS. Chapter Two is written as a “stand alone” manuscript in the style of the journal Physiotherapy Canada and describes the study undertaken to test two methods of STS training. Chapter Three explores how the findings impact stroke rehabilitation practice and implications for future studies.

1.1 Impact of stroke-related disability

Almost everyone knows someone who has had a stroke or has themselves been directly impacted as a patient or caregiver of a person who has experienced a stroke. In Canada, about 50,000 people suffer a stroke each year, and in 2016 approximately 426,000 people were living with the effects of stroke (1). Improvement post-stroke is dependent on the nature and severity of the initial event. For example, it has been estimated that 35% of survivors with initial paralysis of the leg do not regain useful function, and 20-25% of all survivors are unable to walk without complete physical assistance (2). Lai et al. (5) reported in a study of 327 participants (81 who had suffered a stroke more than 3 months ago and 246 controls) that only 25% of the stroke patients returned to the level of everyday participation and physical functioning of the control group. In Canada, 3.6 billion dollars are spent annually on health care and lost productivity due to stroke (6). The cost of stroke is expected to increase because of an aging population and better clot-busting therapies that reduce stroke-related mortality (7). By 2030, it is estimated there will be approximately 70 million stroke survivors globally (7). The increase in the frequency of disability associated with stroke will become unmanageable for the current health care system unless survivors can achieve independent functioning to reduce the required burden of care.

1.2 Stroke and hemiparesis

Stroke is defined as an acute onset of neurological dysfunction due to an abnormality of cerebral circulation, resulting in clinical symptoms that correspond to injured focal areas in the brain (8, 9). The most common form of stroke is ischemic;

occurring when a thrombus or embolus blocks blood flow depriving brain cells of essential oxygen and nutrients. About 20% of stroke is of hemorrhagic origin, this is when blood vessels rupture resulting in abnormal bleeding also depriving brain cells of oxygen (8). If ischemia or hemorrhage is severe and prolonged, brain cell death occurs (10, 11). Impairments that compromise function of the stroke survivor include motor, sensory, cognition, perception, and language (3, 12).

The most common effect of stroke that limits functional independence is hemiplegia (13). Hemiplegia is unilateral paralysis (weakness and decreased sensation) on one side of the body, occurring contralateral to the lesion in the brain (14). Hemiplegia is found in 80-90% of patients post-stroke and is a major contributor to long term disability (14). Due to hemiplegia, stroke patients are unable to generate enough muscular force on the hemiplegic side to initiate and control movement. As mentioned, weakness occurs on the contralateral (opposite) side of the body; however, there can be ipsilateral (same side) weakness since 10-20% of descending corticospinal fibers do not cross in the brainstem (15). Because of the recognized effects of stroke (and other forms of focal brain injury) on the ipsilateral side, some researchers and clinicians describe the weaker side as the "more affected side" and stronger side as the "less affected side." For the purposes of clarity within this thesis, the term hemiplegia will be used to describe the "more affected side." In addition to the loss of muscular force, sensation (i.e. light touch or perception of sharp/dull) is often impaired, but not entirely absent in approximately 53% of stroke patients on the hemiplegic side (14).

Along with weakness and sensory loss, poor proprioception impairs the fluidity of movement (16). Proprioception is defined as the ability to sense movement of the body within one's own joints and joint position, enabling us to know where we are in space (8, 17). Position and movement sense is provided by muscle spindles (receptors within the belly of a muscle that primarily detect changes in muscle length) and receptors within the joint that detect load (17). Subsequently, sensory neurons carry this information to the central nervous system which is processed by the brain to determine the position of respective body parts (18). Post-stroke proprioceptive impairments have been found to exist in approximately two-thirds of stroke survivors (19).

Studies have found that following stroke, patients with proprioceptive impairments have reduced functional independence (20-22). For example, Tyson et al. (22) found a moderate but significant relationship between sensory impairments, poor mobility and decreased independence in ADLs within 3-month period post-stroke and a low-to-moderate significant relationship at follow-up three months after stroke.

Stroke-induced impairments in sensation, proprioception, and strength are compounded by the development of post-stroke spasticity. Spasticity is a velocity (speed/directional) dependent increase in muscle tone, with heightened tendon reflexes resulting from hyper-excitability of the stretch reflex and a lack of descending control (inhibition) from higher centers (23). Essentially, rather than muscles being tonically active and prepared for movement, muscles are overactive. Spasticity can be specific within a focal muscle or can include a group of synergistic muscles producing mass patterns of movement (24). Muscles involved in these synergistic patterns are linked strongly together such that movement outside of these obligatory patterns is not possible. In the hemiplegic arm, the elbow, wrist, and hand are typically flexed and difficult to straighten. This is called flexion synergy. In the hemiplegic leg, an extension synergy is most common with difficulty bending at the hip, knee, and ankle. These synergies emerge in approximately 90% of patients and present on the hemiplegic side (25, 26). In the patient, post-stroke spasticity appears as an abnormal positioning of limbs often leading to painful muscle spasms and contractures (24). These fixed and stereotyped movement synergies often make the execution of effective and efficient movement patterns very difficult and can result in behavioural compensation strategies (26).

Behavioural compensation occurs when the individual begins to rely on muscles that are less affected by the stroke. Therefore a person with stroke often adopts an asymmetrical movement pattern during sitting, standing and walking as a result of the primary sensorimotor impairment (hemiplegia) combined with behavioural compensation (27). For example, patients may shift more weight to the stronger leg to achieve standing, thereby making the weaker leg even weaker from disuse.

1.3 Recovery versus compensation post-stroke

With knowledge of common complications due to stroke, next, it is important to review the physiology behind recovery and compensation of movement. A consideration for research on functional recovery after stroke is differentiating between improvements resulting from changes in the underlying neurological networks and those that reflect behavioural compensation. It is convenient to refer to gains in post-stroke performance as recovery, but it is necessary to distinguish between true recovery and compensatory responses adopted by the patient.

‘Recovery’ means that patients perform movements and functional tasks in a way that is indistinguishable from their original (pre-stroke) actions (28). In the field of stroke, the term ‘compensation’ is used in two ways. First, as patients utilize other muscles (often proximal and trunk muscles) to achieve a functional goal, such as walking, they do so without achieving the precision of pre-stroke performance (29). Secondly, ‘compensation’ is also used to describe the changes in brain networks underlying recovered movements (30).

Studies have shown that the brain is able to compensate by reorganizing its functional networks following stroke (27, 28, 31). For example, Wahl et al. (31) report that after stroke the central nervous system reveals a wide range of inherent capacities to react as a highly dynamic system which can change the properties of its circuits, form new connections, erase others, and remap associated cortical and spinal cord regions. Similarly, Krakhauer et al.(28) suggest that axonal sprouting occurs in the same circuits that relate to recovery in human brain imaging studies. New patterns of cortical connections have been induced in rodent models and nonhuman primates suggesting that sprouting and formation of new connections appears to contribute to stroke recovery. They suggest that stroke stimulates new connections to form within the periinfarct cortex, including projections from the cortex contralateral to the infarct. The emergence of “recovered” movement is likely due to plastic compensation within redundant or adjacent brain regions (32). For the purpose of this thesis the term “compensation” will mean functional or behavioural compensation (e.g. what we see clinically) rather than neuroplastic changes within the brain. Although compensation will allow patients to complete functional tasks, it is often inefficient using more time and energy. The consensus among most experts is that recovery is never complete; there is always some degree of behavioral compensation along with true recovery (28).

Recent research has provided a clearer understanding of how recovery occurs post-stroke. Over the last decade, research using rodent and primate models have identified an important period of spontaneous biological recovery during which effects of training are heightened (30). Innovative techniques such as intracortical micro-stimulation (ICMS) and motor mapping are providing new perspectives on the events that occur in the injured brain, opening a “real-time” window into post-injury plasticity (11, 33-35). For example, Jackson et al. (34) employed an independent operating electronic implant that used action potentials recorded in one electrode to trigger electrical stimuli delivered at another location in the primate brain. They identified that over a period of one or more days of continuous operation, the output evoked from the recording site shifted to resemble the output from the corresponding stimulation site, in a manner consistent with the potentiation of synaptic connections between the artificially linked populations of neurons. In addition, Capaday et al. (33) identified that motor maps are fractionated and include multiple overlapping representations of movements. They also suggest that adjacent areas within cortical motor maps are highly interconnected by means of a dense network of intracortical fibers which are extremely dynamic and can be modulated by a number of intrinsic and extrinsic stimuli. These characteristics provide a framework that facilitates the acquisition of novel muscle synergies through changes in the intracortical connectivity of individual movement representations. Rodent models have also shown there is approximately one month of heightened synaptic plasticity after stroke that is accompanied by peak recovery from impairment (28). There is a consensus in the field that the quantity and quality of motor practice is the most significant modulator of brain plasticity (36-38). As high intensity motor practice drives dendritic spine morphogenesis, axonal sprouting, and induction of neuronal growth factors after stroke (28). For example, Karni et al. (36), found that a few minutes of daily practice on a sequential finger opposition task induced large and incremental performance gains over a few weeks of training.

It is important to remember, however, that any movement that is practiced during the period of heightened plasticity will improve; this includes both desirable (original, pre-stroke movement) and undesirable (compensatory) movements. For example, as a right-handed person with right hemiplegia begins to use the less affected left hand to complete daily tasks such as eating and dressing, the motor pathways corresponding to the left hand become more efficient. In this way, the patient can maximize this short period of plasticity to improve the less affected limb. Jones and group (35), in a number of experiments with a rat model of stroke, have shown that training the less affected upper limb impedes motor recovery of the more affected side. Therefore, based on the quantity and quality of patients' motor experience, the brain can change after injury in either adaptive or maladaptive ways (11). This suggests the importance of appropriate timing, quality, and quantity of therapy that occurs during the rehabilitation phase.

1.4 Access to rehabilitation post-stroke

Several systemic barriers exist within the health care system that affects the quality of rehabilitative care patients receive. Delayed access to rehabilitation is a problem resulting from both inefficient referral processes and a limited number of beds reserved for rehabilitative purposes. Delayed access is compounded by shortened lengths of stay as a result of insufficient availability of beds in public rehabilitation facilities (39).

This delay in access to, and shorter lengths of stay in, rehabilitation may result in patients not receiving the treatment they need during the optimal period to stimulate plasticity. Additionally, present day delivery of rehabilitation is generally considered to be of low intensity; patients are not sufficiently challenged to maximize their full functional potential during therapeutic sessions (40). Based on a study by the Glasgow Augmented Physiotherapy Group (41) it appears that even in dedicated rehabilitation units, patients may spend as little as fifteen minutes a day engaged in mobility tasks. However, both human and animal studies show that a high degree of task-specific (meaningful function) practice is required for brain plasticity to occur (39, 42). Furthermore, multiple studies using the rodent model demonstrate that housing animals in enriched environments produce dendritic growth, new dendritic spine formation, and synaptogenesis (43-45). Stroke patients seem to be housed in impoverished rather than enriched environments. For example, Bernhardt and colleagues (40) identified that patients were only active 3% of the time and inactive 60% of the time and concluded that many patients are “inactive and alone” for most of their waking hours. Sjoholm et al. (46) in a large study involving rehabilitation hospitals in Sweden, showed that stroke patients are also sedentary for most of their time. This highlights the need for intensive and high-quality rehabilitation interventions at the earliest possible opportunity.

One way to drive plasticity toward recovery rather than compensation is to practice everyday tasks in such a way that patients are encouraged to perform the task as close to their normal movement pattern as possible; a pattern that is usually symmetrical, energy efficient, and performed with ease (47, 48). Being the prerequisite to all locomotor tasks, STS is one of the potential routine tasks that should be targeted by therapists during rehabilitation (47). Therefore, considering the “real-time” window of post-injury plasticity, it seems timely that STS practice is maximized during this period of recovery.

1.5 Symmetrical movement post-stroke

Whole body balance, both dynamically as in transitioning from sitting to standing and statically in standing, the gravity line has the mass of the body distributed symmetrically over both feet. In such a balanced posture, if one were to drop the plumb line from the pelvis it would land at a point within the base of support, the center of gravity (COG) (49, 50). The area bounded by the feet on each side is termed the base of support (51). Any movement of the center of pressure (COP) out of the base of support will result in a fall unless mitigated by a step or hand hold.

It is common for patients with hemiplegia to demonstrate considerable asymmetry of weight distribution post-stroke. The degree of weight shift can be measured by calculating the COP displacement within the base of support or by determining the total amount of force being supported by each limb. Both measures require the use of force plate technology (52-54). For example, Cheng and colleagues (55) reported that only 24-29% of body weight (substantially less than the expected 50%) was shifted to the more affected limb during the STS task in patients post-stroke. Hesse et al. (56) showed that patients with hemiparesis shifted their center of pressure (COP) laterally to the less affected side; transferring 78% of their weight before they initiated standing rather than the 50% weight shift observed in healthy subjects. The human body propels itself in a symmetrical fashion, effectively using momentum, minimizing joint stresses and optimizing economy of muscular effort (57). Symmetry in posture is an essential component for optimal functioning of the locomotor system. Asymmetry is considered to be the most common locomotor deficit identified with hemiparesis as a result of stroke (58). Following stroke, patients have decreased balance (including asymmetry of weight shift and postural instability), which contributes to decreased functional independence, such as difficulty moving from STS and increased risk of falls (59).

1.6 The task of sit to stand

STS is a routine task that involves a complex biomechanics, is the task of STS. Rising from a seated position is a complex motor activity requiring coordination between the trunk and lower extremity movements, muscle strength, control of equilibrium, and postural stability (57, 60). All of these factors contribute to postural control throughout the transfer, from a stable three-point base of support a seated position (with both feet on the ground) to a two-point base of support in the standing position (two feet on the ground) (61). This shift from a large three-point base of support to a smaller two-point base of support requires precision and balance. Furthermore, in healthy individuals, effortless STS is attributed to a symmetry of concentric and eccentric muscle contractions of both lower limbs. The muscles in both legs must push the body symmetrically upward to stand and then lower the body in a manner to carefully sit again. In healthy individuals, these components of the movement occur with automaticity and little effort (57).

1.6.1 Biomechanics of sit to stand

Describing and defining common human movement tasks is challenging, as individuals differ in shapes and sizes and have their own unique and distinctive movement styles. Also, people do not tend to repeat movement strategies in the same exact way with each successive performance (62). Variability occurs due to environmental constraints (for example, the condition of the seated surface) and purpose of the intended movement task (for example, standing up to reach for a glass or standing up to walk to the bathroom) (63).

STS is a biomechanically demanding task requiring more lower extremity joint torque and range of motion than either walking or climbing stairs (57, 64). Essential characteristics of the STS movement include the ability to generate enough extensor torque around the hip, knee and ankle joints to enable the body to rise and to ensure stability by moving the center of mass (COM) from one base of support (seated surface) to another (two feet). Also important is the ability to adapt movement strategies according to environmental constraints such as the compliance and height of a chair and friction co-efficient of the floor (65).

The transition from STS consists of horizontal and vertical momentum generated by movements of the head, arms, trunk, and body segments around the hip, knee, and ankle joints during the performance of flexion and extension (62). Previous studies have defined STS as moving the body's COM upward from a sitting position to a standing position without losing balance (66). However, Vander Linden and colleagues (67) stated that STS is, more specifically, a transitional movement to the upright posture requiring movement of the COM from a stable position to a less stable position over the extended lower extremities.

According to Schenkman et al. (68), STS transition is marked by four kinematic events: (See Figure 1.1) <u>Phase One</u> (flexion- momentum) starts with initiation of the movement and involves flexion of the trunk and hips while seated, causing the body to lean forward. The phase ends just before the buttocks lift from the seated surface. Phase Two (momentum – transfer) begins as the buttocks are lifted and end when maximum dorsiflexion of the ankles is achieved – when the body is in a crouched position. Phase Three (extension) begins just as maximum dorsiflexion of ankles is achieved and knees, hips, and trunk begin to extend to lift the body upward. Lastly, Phase Four (stabilization), begins after hip extension and ends when all motion required for stabilization through the two-point base of support is complete.

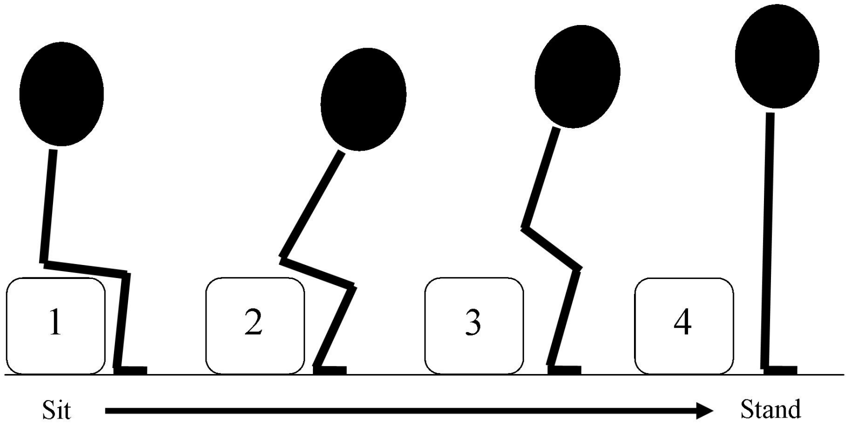


Figure 1.1. Sequential Kinematic events for the Sit to Stand Movement: (1) Flexion momentum phase, (2) Momentum transfer phase, (3) Extension phase, (4) Stabilization phase.

1.6.2 Muscles involved in the execution of STS

Electromyography (EMG)-based analysis of the task has shown that STS requires the coordinated effort of many muscles, some of them responsible for postural adjustments and others acting as prime movers (69-71). The primary movers responsible for producing the STS motion have been identified as the trunk lumbar spine paraspinals, and the lower limb quadriceps and hamstrings muscles (70, 72). Postural adjustment muscles: leg tibialis anterior and soleus, and abdominal muscles, are active during STS in order to produce displacement of the body's COG to the appropriate position for STS (73, 74). According to Goulart et al. (70), these muscles were consistently activated in a patterned sequence around the time of take-off from the seat suggesting that this pattern is likely a centrally programmed sequence of activation. See Table 1.1 for a more detailed summary of the muscles active during the different phases of STS. Therefore, a well-coordinated sequence of muscular activity is required to perform STS in an efficient manner.

Table 1.1. Main muscular activity of body segments during STS maneuver. (Muscular activity as per references cited in section 1.6.2)

Body Segment	**Muscles**	**Phase One Muscular Action**	**Phase Two Muscular Action**	**Phase Three Muscular Action**	**Phase Four Muscular Action**
Trunk	Lumbar Spine Paraspinals	Antagonist to trunk flexion	Maintain extension and stiffen the trunk	Main agonist to extend hips	Maintain extension and stiffness of the trunk to stabilize in standing position
	Abdominals	Main agonist to flex the trunk over the hips	Flex the trunk over the hips		
Hips	Psoas/ Rectus Femoris	Main agonist to flex hips	Flexion of hips		
	Gluteals/ Hamstrings	Antagonist/ eccentric to control speed and range of movement	Main agonist to extend hips	Main agonist to extend hips	Maintain extension of hips to stabilize in standing position
Knees	Quadriceps	Agonist to prepare weight acceptance through the lower extremities	Main agonist to extend knees	Main agonist to extend knees	Maintain extension of knees to stabilize in standing position
Ankles	Tibialis Anterior	Agonist Dorsiflexion	Dorsiflexion	Dorsiflexion	Stabilize in standing position
	Gastrocs/ Soleus	Antagonist Plantarflexion			

1.6.3 STS post-stroke

The evidence suggests that paretic muscle strength and the ability to load the more affected limb are important factors that contribute to the ability to rise from a chair in individuals post-stroke (57). Prudente and colleagues (75) compared electromyographic activity between and within more affected and less affected lower limbs during the STS in stroke patients, observing neuromuscular impairment in both lower limbs. In the more affected lower extremity individuals were unable to recruit the quadriceps and hamstrings muscle in a timely manner, nor generate the force required to execute the STS task. Further, significant compensation occurred on the less affected lower extremity (patients were observed to shift towards stronger side). Lomaglio et al. (57) found that average joint torques for the more affected lower extremity ranged from 50-90% of those on the less affected side. Several authors have reported that individuals with hemiparesis demonstrated an increase in time to complete STS when compared to age-matched adults without neurological impairment (54, 55, 60). This is not surprising, considering the compensatory movements that occur post-stroke. According to the literature, individuals with hemiparesis present with a weight bearing asymmetry when performing an unplanned unassisted STS (4, 57). Patients place more weight on the less affected side than on the more affected one (76). Compensation involves shifting the patients' weight to the less affected side when moving their hip or trying to stand up. The patient may further compensate by re-positioning the less affected foot behind the more affected foot in order to provide better push off with the stronger limb. Stroke patients also commonly use the less affected arm to assist-in achieving the STS position (77). STS is typically smooth and efficient so adding compensatory movement such as exaggerated weight shifts add time, requires more muscle activation and runs the risk of moving the COM outside the base of support lending to a loss of balance (54, 55, 57, 60).

As discussed, these compensatory strategies may seem reasonable if there was no further recovery to be obtained. The challenge is that these adaptations begin very early post-stroke; the stronger side is used more and the weaker side is used less, contributing to the non-use on the more affected limb (4). Early disuse of the more affected side can lead to compromised balance capabilities and an increased risk of falls, which also translate into deficits in gait (77). Cheng et al. (55) found that stroke patients with more asymmetrical body weight distribution, increased COP sway, and a lower rate of rising in force as measured on a force plate while doing STS movements, had an increased incidence of falls. They also found that the stroke patients who have fallen shifted less weight on the more affected limb during STS than those stroke patients who have not fallen. According to Nyberg and Gustafson (78), 37.2% of falls in stroke patients occur during transfers, while changing positions from sitting to standing and while initiating walking. This inability to voluntarily control weight shift to the more affected limb may be a result of poor sensory and neuromuscular control. In any event, falling is a major contributor to morbidity, hospitalization, and mortality among older adults as well as stroke patients and should be prevented if possible (79).

Several research groups have confirmed that STS training improves balance, weight distribution, and lower limb function (56, 80) and leads to improved function and independence for patients. Neurological physiotherapists working with post-stroke patients typically use STS training in their treatment plan to improve weight distribution and lower limb function to promote improvements in balance and gait.

1.7 Role of physiotherapy post-stroke

Physiotherapists are primary health care professionals who play a significant role in health promotion and treatment of injury and disease. Physiotherapy is a physical medicine and rehabilitation specialty combining an in-depth knowledge of the body and how it functions with specialized hands-on clinical skills. These individuals are trained to assess, diagnose and remediate impairments, promote mobility and quality of life of their patients (81). Brooks et al. (82) referred to physiotherapists as “applied motor control physiologists.” This is because physiotherapists spend most of the clinician-patient interaction retraining impairments associated with loss of motor control and functional movement (65).

Physiotherapy is one of the key disciplines involved in organized interdisciplinary stroke rehabilitation (83). The primary aim of physiotherapy is to restore and maintain mobility, usually starting within the first days following stroke and often continuing into the chronic phase post-stroke (83). Physiotherapists use various neuro-facilitation techniques to restore motor recovery during rehabilitation of patients with hemiparesis. Facilitation refers to a type of intervention technique that encourages the patients’ ability to move in more normal patterns (84). Conversely, inhibitory techniques are used to minimize movement patterns that are considered to be abnormal (84, 85). There are several philosophical approaches to retraining movement after stroke. Neurodevelopmental Treatment/Bobath (NDT) and Motor Learning are examples of facilitation approaches that are commonly used in therapy to promote recovery (65, 84). However, which approach works best remains unknown.

1.7.1 Approaches to Neurorehabilitation

Therapeutic interventions commonly used in neurorehabilitation have evolved over the years from an emphasis on muscle re-education to a focus on neurophysiological and neurodevelopmental strategies based on our greater understanding of motor learning and neuroplasticity. A commonly used approach is Neurodevelopmental Treatment (NDT) (84, 85). According to the Neurodevelopmental Treatment Association (NDTA), NDT is an individualized therapeutic handling of patients based on movement analysis for habituation and rehabilitation of individuals with neurological impairment (86). This approach is based on the work of Berta Bobath and Dr. Karl Bobath. Within the NDT approach, strategic therapeutic handling is used throughout both the examination and intervention. It consists of constant reciprocal interaction between the patient and the therapist in order to optimize sensorimotor processing. In the context of this treatment, sensorimotor processing refers to a process whereby sensory input is linked to a related motor response in the central nervous system (87). Sensorimotor integration is required to perform a specific task and ultimately achieve the skills required to participate in meaningful activities (88, 89). Fundamental to teaching or “facilitating” appropriate movement is the use of touch over the target muscle or joint. The use of touch is also termed manual facilitation, handling or haptics. Physical contact with the human body results in an exchange of information with the nervous system, both providing input to the body and receiving input from it (90). In the context of an STS task, physiotherapists teach patients to re-learn STS using handling skills to facilitate the appropriate muscle groups required to achieve the desired movement patterns. This treatment technique is widely applied by clinicians working in stroke rehabilitation even though there is little empirical evidence to prove its effectiveness (91, 92). Therefore, the basis of therapeutic handling to facilitate the re-learning of STS will be one of the therapeutic techniques compared in this study.

A more recent approach in neurorehabilitation is Motor Learning. This approach considers how humans acquire and modify movement (65). Motor learning involves more than just the motor processes of movement, but also includes the cognitive component of learning new strategies for recognizing one's environment and being able to move within it (65). When learning new motor skills, the learner finds task solutions by developing new strategies for perceiving and acting (65, 93). When employing the motor learning approach, verbal guidance rather than manual facilitation is provided. For example, a therapist may use a verbal prompt such as "sit tall, lean forward, place equal weight between two feet and stand up," to teach a patient to re-learn the STS task. Motor learning and NDT are commonly used in conjunction with each other in practice and re-learning STS post-stroke often includes components of each approach.

Another approach to help patients with stroke regain function is task-specific training. Task-specific training involves practicing real-life tasks (such as walking or dressing) with the intention of learning or re-learning a skill. The tasks should be challenging and progressively adapted with active participation (94). An important consideration with this approach is that the task is usually divided into component parts and then put together for completion of the overall task once each component is learned (94). Task-specific training uses meaningful, goal-directed practice of functional tasks as opposed to impairment-reducing exercises such as range of motion and isolated joint strengthening exercises during therapeutic sessions (95-97). In recent years, emphasis has shifted towards functional, task-specific training using intense practice along with environmental enrichment because of its beneficial effects on plasticity in animal models of stroke (11, 39, 42, 98). The task-specific approach is a departure from older, traditional, impairment-focused approaches like passive range of motion techniques where therapists move affected limbs of the patients in the hopes of activating neural circuitry responsible for the movement thereby helping the patient regain function in the limbs (99). Currently, there is mounting evidence of the value of task-specific training in rehabilitation and for its accompanying neuroplastic benefits in the brain (38, 100). Further, exercise programs including movements related to functional activity, that are directly trained (task-specific training), have shown better results than impairment-focused programs (101). Task-specific training should be: relevant to the patient, relevant to the context of the intended goal, repetitive and massed-practiced, aimed towards reconstruction of the whole task, and reinforced with timely feedback (102). It is obvious that task-specific training, manual facilitation and motor learning methods have overlapping methods. As previously identified, being able to perform a STS transfer is required for all locomotor tasks and is thus a mobility goal for many stroke patients. Therefore, STS has to be considered by rehabilitation therapists in the context of task-specific training with intensive, massed-practice in order to promote functional recovery. This approach will be incorporated into the present study.

As previously described, research in neuroplasticity has shown that one of the most potent modulators of cortical reorganization and function is the repeated practice of the targeted movement behaviour (11, 36, 37, 102). Skilled motor activities requiring precise temporal coordination of muscles and joints must be practiced repeatedly (11).

The STS task is such a skilled motor activity requiring precise temporal coordination of muscles and joints for successful execution. Over the past 15 years, rehabilitation trials have confirmed that more intensive therapy improves the rate of recovery in ADLs, especially if a functional approach is embraced (103, 104). Intensive, high repetition and task-specific training post-stroke have been proven to be effective (103, 104). However, there continues to be a gap between what is recommended for stroke patients based on research and what they actually receive in practice. In a study by Lang et al. (105) investigating how much movement practice is provided during both inpatient and outpatient rehabilitation, the authors found that actual practice of task-specific, aiming at functional upper extremity movements occurred in only 51% of the sessions with only 32 repetitions performed per session. Data from animal studies suggest that this number of repetitions is not enough. For example, in a reaching task, changes in synaptic density in the primary cortex is shown to occur after 400 repetitions (106, 107). Clearly, massed-practice would be required to facilitate change when teaching a stroke patient to execute an efficient and effective STS task; therefore, massed-practice is incorporated into the methodology of this study.

This section has identified commonly used neurorehabilitative approaches used by physiotherapists post-stroke. The literature is not robust with which approach is most effective, thus warranting more research in this area. How therapists deliver feedback to the patient regarding their performance is also an important aspect to promote carryover of movements practiced in therapy sessions to everyday functional tasks. This next section will discuss the importance of feedback.

1.8 Providing feedback in therapy

Within most training approaches, it has been established that the provision of feedback enhances skill learning (108). The effect of verbal, visual, and auditory feedback has been shown to improve and assist in the recovery of symmetrical weight shifting post-stroke (109-112).

The nature of feedback provided in rehabilitation is likely important (113-115). As stated previously, physiotherapists can use manual handling and verbal facilitation to provide feedback. First described in psychology research, feedback in the field of rehabilitation has been classified as being either intrinsic or extrinsic (113-115). Patients receive intrinsic feedback from biological sources such as sensory receptors in joints and contracting muscles and extrinsic feedback from therapists or equipment (113). Intrinsic feedback is considered to originate from the learner's own sensory-perceptual experience received from biological sensors (113). This feedback provides the learner with information on a performed movement via sensory processes including vision, proprioception, touch, pressure, and audition (113). During rehabilitation, various modes of extrinsic feedback include physiotherapists verbally commenting on performance, visual feedback (i.e. video demonstration), biofeedback instrumentation (115), audiovisual feedback (116) and manual cueing (56). To correct movement asymmetries, physiotherapists often address mobility and function primarily through extrinsic feedback methods such as verbal feedback regarding performance and motivational statements and manual cues. For example, in a study by Ploughman et al. (117) both verbal and manual cueing improved gait of chronic stroke patients. Similarly, Stanton et al. (113) showed that extrinsic feedback using verbal cueing during rehabilitation received by people who have had a stroke enhanced their ability to stand, walk, reach and grasp. Hence, a primary goal in the field includes improving proprioception by utilizing manual, hands-on facilitation as utilized by NDT/Bobath treatment to promote joint compression by external feedback to the limbs when training normal movement patterns post-stroke. The superiority of one method over another in achieving weight-bearing symmetry in STS has not yet been proven, hence, this will be one of the focuses of this study. Specifically, for STS, there is little evidence in the literature comparing a hands-on versus hands-off feedback approach in rehabilitation for individuals with neurological impairment. This study aims to contribute to the modest evidence in this area of neurorehabilitation.

1.9 Determining the optimal method to train STS after stroke

Since STS is such a fundamental task, there are several studies examining training of STS and measurement of parameters without an intervention period among the elderly and stroke populations. The effects of changing the alignment of the feet, arms, and trunk, (76, 118), and altering the height of the seat have been examined in terms of the effects on STS performance (112, 119). More specifically, there are studies by Kim et al. (118), Liu et al. (120), Tung et al. (80), Britton et al. (121), and Hesse et al. (56) suggesting that STS training that featured greater loading on the more affected limb promoted increased joint compression, increased muscle strength, improved weight distribution, symmetry and balance. In a study by Kim et al. (118) the participants underwent repetitive STS training five times a week for six weeks in addition to regular therapies. The STS training was divided into five different tasks, 10 repetitions each. Progression of number of repetitions was built in over the course of six-week study period with a total of 1850 STS trials performed. Manual and verbal cues were incorporated into the protocol, but not compared. The authors found significant improvements in balance and symmetry as measured by a decrease in total path length of the COP and weight distribution between the feet respectively. Similarly, in a study by Liu et al. (120), an experimental group of 50 subacute stroke patients, 25 in each of the experimental and control groups, each group underwent four weeks of daily STS training in addition to standard care. The experimental group placed the more affected lower limb behind the less affected lower limb, forcing more weight through the more affected limb and the control group performed STS with feet placed symmetrically. Each group completed three programs of repeated STS training with three different angles of ankle dorsiflexion. Verbal and visual feedback were provided to the participants, symmetry and performance of normal components of STS were emphasized, however, cueing methods were not compared. They found significant improvements in weight-bearing on the more affected foot with improved symmetrical body weight distribution and standing balance as measured by a decrease in COP sway and Berg Balance Scale (BBS) scores pre-post training. Tung and colleagues (80) studied 32 chronic stroke patients who were randomly assigned to either a control group who received 30 minutes of general physiotherapy or an experimental group who received an extra 15 mins of additional STS training comprised of six different conditions designed according to the degrees of knee flexion and conditions of the floor (regular floor and medium hardness spongy floor) to complement standard care physiotherapy program three times a week for four weeks. Results of this study showed significant improvement in weight-bearing on the more affected side, improved static and dynamic standing balance as per maximal excursion and directional control (%) and BBS scores. In addition, the more affected hip and knee extensor muscle strength (hamstrings and quadriceps) improved as evaluated with a handheld dynamometer. Furthermore, in a study by Hesse et al. (56), therapists used the principles of NDT/Bobath to train post-stroke patients to distribute equal weight on both legs and to avoid lateral compensatory movements of the trunk during STS. Thirty-five subacute stroke patients participated in this four-week comprehensive program consisting of 16 sessions, four times a week for 45 minutes. NDT/Bobath techniques were used to promote STS during the session but not as a stand-alone treatment and number of repetitions was not documented. Although gains were seen in muscle strength (6% in the more affected lower limb as per the Motricity Index), spasticity as reduced 0.5 points (Modified Ashworth Scale) and motor function improved (Rivermead Mobility Index). Distribution of body weight between both lower limbs during STS did not change significantly as measured by displacement of the COM. In addition, gait cycle parameters: walking speed, cadence, and stride length did not significantly improve.

The aforementioned studies reinforce the concept of augmenting sensory awareness of the limb and improving weight-bearing symmetry, muscular strength and balance in patients post-stroke. As previously reported, more than 50% of patients have proprioceptive impairments post-stroke, therefore, increasing weight-bearing activities is a beneficial strategy to facilitate limb afferent and proprioceptive inputs to the neuromuscular system and ultimately improving proprioception in patients post-stroke (122-124).

Other research groups have examined the ‘critical ingredients’ for successful STS training among people with stroke. For example, Barreca et al. (125) showed that a daily standardized STS program should be implemented by physiotherapists, families, and rehabilitation staff for patients recovering from stroke. When a minimum range of repetitions per day (11-13.5/day) was met, significantly more stroke survivors were able to perform the STS task in a consistent, safe and independent manner from a surface height equivalent to that of a normal toilet (16”). Britton et al. (121) also endeavored to evaluate the amount of STS practice required to affect performance in 18 subacute stroke patients. In addition to usual rehabilitation, the experimental group (n=9) practiced STS and leg strengthening for 30 mins daily for two weeks with a physiotherapy support worker. Following the two-week trial, there was a mean increase of 50 extra STS performed daily in the experimental group, measured by an activity monitor (ActivPal) which was a significant change from the average 18 STS/day found in the control group. The training group also improved percentage of body weight distribution through the more affected limb as measured by a pressure mat.

Chair height has been shown to affect STS performance. To stand from a lower chair height requires more hip, knee and ankle flexion, therefore, more propulsive force to stand. Lee et al. (126) found that chair height and knee flexion resulted in significant differences in COP path length and peak pressure in the more affected limb. They found that employing a lower chair height and encouraging increased flexion of the knee resulted in more symmetrical pressure measured through the feet. Chair height is also an important consideration for the present study as the chair will be positioned higher or lower to challenge the participant. The methods described in this paragraph can be incorporated into physiotherapy sessions to progressively challenge STS competence in order to drive recovery.

Again, as previously noted, repetition and high dose of practice is a key factor in functional recovery. This evidence specifically identifies the importance of multiple repetitions for the STS task to produce a safe, independent STS post-stroke. Therefore, in the present study, attention to the number of repetitions that participants undergo should be carefully considered. What is becoming clearer in the body of research examining methods to retrain symmetrical STS post-stroke is that the optimal parameters (e.g. number of repetitions, type of feedback, alignment alterations) have not been identified. Therefore, it can be assumed that there may be a “best method” to retrain symmetry in STS. This study endeavours to compare manual cues and verbal cues with strict parameters to identify a “best method” to facilitate symmetry of STS.

1.10 Summary

Stroke-related disabilities creates an enormous burden for the affected individual and their care team/support network. Therefore, research must be focused on providing effective treatment methods to rehabilitate stroke-related disability and to optimize function in a timely manner. Improving STS interventions within rehabilitative therapy is an important area of focus since this complex movement strategy is the precursor to all locomotor tasks. This is important because if patients recovering from stroke are able to mobilize safely and efficiently, the burden of care will be reduced, and they will achieve a better quality of life.

Physiotherapy practice supports therapies that draw on principles of a number of different approaches, such as NDT/Bobath, Motor Relearning and task-specific practice for stroke recovery. Furthermore, when considering STS interventions more specifically, there is evidence that an STS trial should consider subacute stroke patients, repeated sessions with multiple repetitions, consideration of foot placement and chair height. Less is known about which cues (manual or verbal cues) are best to relearn STS symmetry in order to improve balance and walking recovery after stroke. Hence, the present study asks the question, "Does manual cueing promote symmetric weight-bearing posture in STS post-stroke more than verbal cueing?" By addressing these gaps in the literature, this study aims to contribute to the best practice guidelines supporting clinicians in order to optimize interventions that facilitate functional outcomes for patients who have suffered a stroke.

1.11 Objectives of thesis

The purpose of this thesis is to help address the main gaps identified in the literature comparing two methods of STS training (manual cues versus verbal cues) on movement symmetry, standing balance and walking in patients during the early phase (< 3 months) of stroke recovery. A randomized, outcome blinded intervention trial was conducted in the stroke unit of the province's tertiary rehabilitation facility.

1.12 Research Question and Hypothesis

Research question: When retraining STS in post-stroke rehabilitation do manual or verbal facilitation cues result in more symmetry?

Hypothesis: Manual facilitation cues will produce greater symmetry in STS than verbal cues.

Chapter 2: Manuscript

Chapter 2 is written in a manuscript style of the journal Physiotherapy Canada.

Co-Authorship Statement

This research was conducted under the supervision of Dr. Michelle Ploughman with the support of Drs. Jeannette Byrne, Jackie Vanderluit, and Jason McCarthy. Jennifer Shears was responsible for the design of the study, recruitment of participants, data collection, and analysis. Ms. Megan Kirkland, Mr. Augustine Joshua Devasahayam, and Mr. Beraki Abraha assisted with data collection. I wrote the original drafts of the manuscripts that constitute the chapters of this thesis. The manuscripts were revised based on comments from Drs. Michelle Ploughman, Jeannette Byrne, Jackie Vanderluit and Jason McCarthy, Katie Wadden and Ms. Marie Curtis and Mr. Matthew Downer.

2.1 Abstract

Introduction: Sit-to-stand (STS) is a prerequisite to walking and independent living. Following stroke, patients often perform STS asymmetrically. Physiotherapists use different techniques to help patients relearn symmetry in STS. The effects of two techniques, verbal and manual cueing on STS symmetry post-stroke were compared.

Methods: A randomized outcome-blinded intervention trial was conducted in a stroke rehabilitation unit. 10 participants were randomly assigned to a manual or verbal cue group. Participants completed 40 repetitions of STS daily for ten days. Sitting and standing symmetry, measures of lower limb mobility, balance and gait were assessed.

Results: Standing symmetry, balance and lower limb mobility significantly improved in both groups with no significant differences between groups. STS symmetry did not change following training.

Conclusion: Both verbal and manual cueing led to improved standing symmetry, however, STS remained asymmetrical. The improvements observed in both manual and verbal cueing techniques suggest that effective cueing combined with massed-practice of STS result in improved overall functional mobility.

2.2 Introduction

Stroke is the leading cause of brain damage in adults and is one of the leading causes of death and disability (6). Unilateral weakness, termed hemiparesis, is the most common impairment post-stroke and leads to compromised balance, increased risk of falls, and impaired ambulation and gait (3, 56).

One of the most fundamental activities of daily living is the ability to perform the transition movement of sit to stand. For many activities of daily living such as those requiring self-reliant, upright locomotion, STS is an important prerequisite (4). The inability to rise and stand without assistance influences the level of care required by others. Furthermore, movements that require a transition of the center of mass (COM) from one base of support to another, such as in STS, are particularly prone to falls. For example, Nyberg and Gustafson (78) found that 37% of falls post-stroke occurred during movement from one surface to another or from changing position from sitting to standing.

The STS transition is marked by four kinematic phases: (1) Flexion momentum: initiation of the movement by flexing the trunk over the hips using abdominals and hip flexor muscles (psoas and rectus femoris) ending just before buttocks lift from a surface. Lumbar paraspinal muscles co-contraction provide stability in extension of the trunk throughout the movement, (2) Momentum-transfer: buttocks are lifted using hip and knee extensor muscles (gluteals, quadriceps, and hamstrings) and ankles are fully dorsiflexed, (3) Extension: extension of hips and knees using gluteal, hamstrings and quadriceps, (4) Stabilization: hips and trunk extend and stabilize within the two-point base of support of standing (68).

Individuals learn to compensate early in their recovery post-stroke by spontaneously shifting their body weight to the unaffected, stronger side to achieve the standing position, albeit not as efficiently or as safely as a healthy individual (121). It is important to use the weaker limbs as early as possible after stroke in order to limit compensatory behaviour and "learned non-use" of the more-affected side (32). Learned non-use is a term coined by Edward Taub in the 1990's with respect to the upper limb. Animals and humans adapt to hemiparesis by relying on the stronger limbs at the expense of further recovery of the affected limbs (127). By encouraging/forcing a shift of body weight towards the more affected lower extremity, learned non-use can be minimized; promoting more appropriate limb proprioceptive inputs to the neuromuscular system and promote strengthening (118, 120, 123, 124).

Physiotherapists use a variety of methods to help patients activate weakened muscles and re-learn the task of STS in the early phase of rehabilitation. Many studies have found that STS training improved balance, weight distribution and lower limb function (76, 80, 110, 112, 118, 120, 128). Furthermore, incorporation of extra practice of STS that was task-specific, meaningful to the patients' function (i.e. ability to stand from a 16″ toilet), improved the efficiency of STS (decreased rise time) and functional outcomes such as standing balance and lower extremity mobility as measured by the Berg Balance Scale (BBS) and the Rivermead Mobility Index (RMI) (121, 125). Most studies have focused on modification of foot placement (posterior positioning or constraint on a step), knee and ankle range of motion (amount of knee and ankle dorsiflexion), height of the chair and incorporating tasks built into the protocols (reaching tasks or visual cues).

There are few studies that have focused on comparing the specific techniques that therapists use to provide feedback to patients in the subacute phase of stroke recovery during this training. Two types of feedback often used during rehabilitation are manual (tactile/hands-on cues on the agonist muscles) and verbal (verbal direction for appropriate movement patterns). Manual cues, involve the therapist touching the target muscles required for the movement, thus activating sensory afferents that result in rapid facilitation of the muscle contraction (129). Verbal correction by the therapist capitalizes on the cognitive aspects of the task. However, this approach may require more processing time, likely resulting in slower responses. Even though these methods are fairly entrenched in both Neurodevelopmental Treatment/Bobath (NDT) and motor learning approaches to stroke recovery (65, 130) their effectiveness in practice have yet to be sufficiently examined. In a study by Hesse et al. (56), therapists utilized manual cues, as per the NDT/Bobath concept to train post-stroke patients to distribute equal weight on both legs and to avoid lateral compensatory movements of the trunk during STS. Even though improvements were found in lower limb muscle strength, spasticity and gross function the authors did not find improvement in the distribution of body weight between the lower limbs during STS. Unfortunately, the Hesse et al. protocol included only 15 repetitions of STS training per session over 16 sessions for a total of 240 repetitions. This is substantially lower than the 400 repetitions recommended to change synaptic density as identified by Krakhauer et al. in an animal model (28). Liu et al. (120) used verbal prompting in their study, but to date verbal feedback has not been looked at as a main variable employed during training.

This study aimed to compare the effects of manual and verbal cueing methods on relearning symmetrical STS post-stroke using a randomized, outcome blinded intervention trial. Because the therapist was directly in contact with the patient, it was hypothesized that manual cueing would have a larger effect in promoting weight bearing symmetry between the more affected and less affected lower extremities during STS in the early phases of post-stroke recovery compared to verbal cueing.

2.3 Methods

2.3.1 Participants

Prospective subjects were required to meet the following inclusion criteria: (1). first ischemic or hemorrhagic stroke, (2). ≤ three months post-stroke (3). currently receiving inpatient rehabilitation, (4). able to sit independently, stand with minimal assistance and remain standing for five seconds after rising from sitting and (5). able to provide informed consent. Individuals were excluded if they presented with concurrent neurological diagnosis or had any lower extremity dysfunction (e.g. significant osteoarthritis or joint replacement). Given the relatively strict inclusion criteria and limited number of suitable patients on the rehabilitation unit (based on a 24-bed unit with 1-2 new patients admitted per week), convenience sampling was used. 18 patients were recruited from the stroke unit of the rehabilitation facility and 10 completed the study. This study received ethics approval the local Human Research Ethics Board and all participants completed the informed consent process prior to taking part in the study.

Physiotherapists and nurses in the rehabilitation unit used the inclusion criteria to identify potential subjects and obtain initial permission to be contacted by the researcher.

After the informed consent process was completed, participants were randomly assigned to either manual or verbal group using the opaque envelope method prepared by research assistants in the Recovery and Performance Laboratory. Participants were also randomly assigned to one of two intervention physiotherapists who both had twenty years of experience treating patients with stroke using the NDT/Bobath approach.

2.3.2 Procedures

Prior to the intervention, the age, gender and stroke-related information (type and location of stroke) of each participant was gathered from their health record. The Chedoke McMaster Stroke Assessment (CMSA) (131) and the Montreal Cognitive Assessment (MoCA) (132) scores were also collected. The CMSA measures the degree of recovery of the arm, hand, leg and foot and, postural control and the MoCA is a screening tool to detect cognitive impairment. The referring physiotherapist administered the CMSA (Appendix A). The CMSA and its postural control, arm, hand, leg and foot subscales were developed and validated for use with stroke patients from an inpatient and day hospital population (131). For each subscale, scores range from a low of 1 (no movement elicited) to 7 (full recovery of purposeful movements) at each joint of the limb (131). MOCA, a screening tool to detect mild cognitive dysfunction (132) (Appendix B) was completed by the referring occupational therapist or nursing staff on the rehabilitation unit.

For the intervention component, subjects received daily STS training using manual or verbal cueing depending on which group they were randomly assigned (Figure 2.1). Ten, one-hour training sessions took place within a two-week period. During the

STS training sessions, subjects were asked to perform 40 repetitions of STS (4 sets of 10 repetitions) from a height adjustable seat. Participants also received usual care, 1-2 hours per day, five days per week which was not altered in any way.

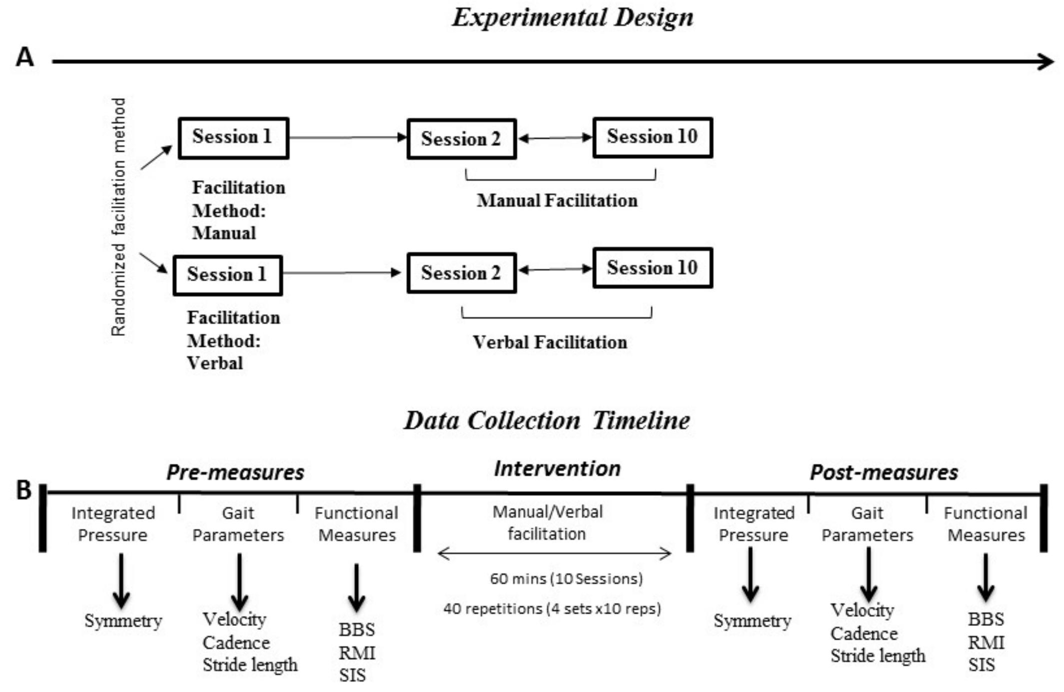


Figure 2.1**.** Experimental Design**.** (A) Randomization of manual and verbal groups. (B) Collection timeline: integral pressure (symmetry), gait parameters: velocity, cadence and stride length, outcome measures: balance (BBS; Berg Balance Scale), lower extremity mobility (RMI; Rivermead Mobility Index), perceived impact of stroke on everyday function (SIS; Stroke Impact Scale).

For all training sessions subjects sat on an armless height adjustable chair positioned on an instrumented walkway (Zeno Walkway, Protokinetics LLC Havertown, PA, USA). Chair height was adjusted to the length of the lower leg (distance from the most prominent point palpated on the lateral femoral condyle to the floor). Specifically, a third of thigh length (measured from the most prominent point palpated on the greater trochanter) was placed anterior to the edge of the seat. The feet were kept parallel; the distance between the lateral malleoli corresponded to the hip width and the ankles were at 10-15 degrees of dorsiflexion (76, 112). A standardized script was used to instruct the participants on the required task of standing from the height adjustable chair (Appendix G).

Both groups received a standardized verbal prompt (Appendix E and F). In the manual facilitation group, subjects were asked to sit tall, lean forward and stand up. As subjects shifted their weight forward and attempted to stand, the treating physiotherapist provided directional pressure cues to the knee muscles (quadriceps) and hip/trunk (gluteals/erector spinae) extensor muscles using their open palms, a technique commonly used by NDT therapists. In the verbal group, patients were asked to shift their weight evenly between both feet and stand up. For the verbal group only, a support bar was positioned next to the subject's less-affected side and they were encouraged to use it if they felt they required it to stand up. All STS training sessions were video-recorded, and the number of verbal or manual cues and number of times subjects used the support bar (for verbal cue group only) were counted by a trained research assistant once all training sessions were completed.

In both groups, the difficulty of the STS task was progressed at each session if the subject was able to perform it safely. These progressions/levels of difficulty included: adjusting seat height, (i.e. lower height to promote more concentric and eccentric muscle activation), foot position (i.e. more affected foot placed behind the less affected foot) to foster greater weight-bearing and positioning of a step or compliant surface under the less affected lower extremity to shift weight to the more affected side. Such progressions have been found to promote increased weight bearing on the more affected limb and to improve subsequent symmetry during STS (76, 112, 119, 120). The level of difficulty was determined by the intervention therapist at each session and recorded in a daily logbook.

2.3.3 Outcome Measures

2.3.3.1 Standing and STS Symmetry

STS symmetry was assessed using data collected from the Zeno Walkway (Protokinetics LLC Havertown, PA, USA; 16x2 feet; 576 pressure sensors per square foot; sampling rate 120 Hz; spatial resolution 0.5 by 0.5 inches). The walkway consists of an array of pressure sensors. Each sensor detects a pressure gradient and the mean pressure gradient from each of these sensors is summed by the Protokinetics Movement Analysis Software (PKMAS) to determine integrated pressure (IP) at each instant in time and under each foot **(Figure 2.2)**. The IP was processed automatically by the PKMAS software under each foot, beginning 2-3 seconds before subjects were asked to stand, 5 seconds of standing and ending when they returned to a seated position. A typical pressure reading during STS is presented in **Figure 2.3.** The integrated pressure readings from the mat were used to quantify symmetry using **Equation 1** adapted from Roy et al. (112).

Equation 1. Quantification of Symmetry

$$Symmetry = \left(\frac{(IP\ less\ affected) - \big(perfect\ symmetry(more\ affected + less\ affected)\big)}{(perfect\ symmetry)}\right) x\ 100\%$$

where $\boldsymbol{Perfect\ Symmetry} = \frac{\boldsymbol{total\ IP}}{\boldsymbol{2}}$

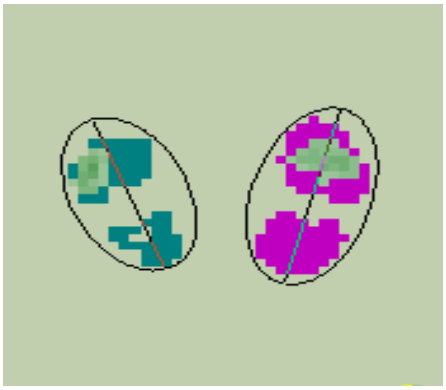


Figure 2.2. Activated pressure units under the more affected (left) and less affected (right) foot during STS. Representative data for one participant. Image generated by PKMAS (Darker areas indicate a higher number of pressure units activated under each foot).

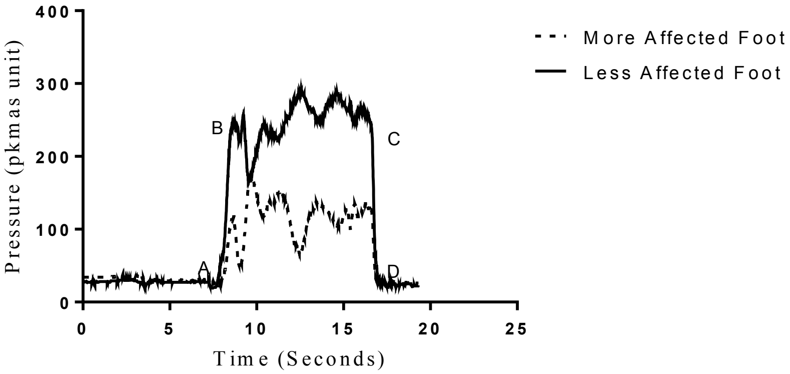


Figure 2.3. Representative pressure plot during STS task. (A): The subject initiates the STS; (B) Final_standing position with notably less pressure on the more-affected foot; (C) Begins to move from standing to sitting; (D) Completion of STS and has returned to seated position.

This symmetry ratio, therefore, indicates the extent to which the more affected or less affected leg moves away from perfect (symmetrical) weight bearing distribution. The ratio can range from -100% to +100% where 0% represents perfect symmetry between the lower limbs and -100% and +100% represent maximal asymmetry. A negative value indicates increased weight bearing on the more affected side and a positive value indicates greater loading on the less affected side.

Symmetry data was calculated from the following events identified using video data: (1). STS, (initiation of hip flexion to fully extended knees and hips) and (2). Standing, (standing from full extension of hips and knees and stable trunk motion to initiation of flexion of knees and hips; (Figures 2.2, 2.3).

2.3.3.2 Gait Assessment

All subjects, including those who required the use of an assistive device, were asked to walk at a self-selected pace along the 4.27m Zeno Walkway (Protokinetics LLC Havertown, PA, USA), step off the walkway, turn around and return. A standardized script was used (Appendix G) to give walking instructions. Data from the walkway was used to calculate gait velocity (cm/sec), cadence (step/min), step length (measured as the distance between heel strike of the same foot (cm) and step length ratio (more affected/ less affected) using PKMAS software.

2.3.3.3 Lower limb and Balance Function

In order to determine the effects of the intervention on stroke-related function the referring physiotherapist, who was blind to subject group allocation, administered the BBS (Appendix C) and the RMI (Appendix D) prior to the study and again at its completion. The BBS is a 14-item objective measure designed to assess function related to static balance and fall risk in adult populations. The BBS, which has been validated for stroke recovery, ranges from 0-56 with higher scores indicating better balance (133). The RMI is a 15-item objective measure designed to assess functional mobility following stroke (i.e. gait, balance, and transfers) was also administered. It ranges from 0-15 with higher scores indicating better mobility performance (134).

2.3.3.4 Perceived Impact of Stroke on Everyday Life

In addition to the RMI and BBS, the Stroke Impact Scale (SIS) (135) was administered by the investigator. This 59-item patient-reported questionnaire has eight domains (strength, hand function, ADL/IADL, mobility, communication, emotion, memory and thinking, participation/role function) which assess health status following stroke. Our study analyzed three of the eight domains: ADL/IADL, mobility and participation/role function, along with perceived percentage of recovery. Summative scores are generated for each domain with scores ranging from 0-100. Higher scores indicate the individual has an increased perceived functional outcome.

2.3.4 Statistical Analysis

A two-way repeated measures analysis of variance (ANOVA) was conducted to determine the main effect of TIME (Pre and Post intervention) and CUE (manual and verbal) as well as the interaction between TIME and CUE , on the two main outcome measures: (1). STS symmetry and (2). standing symmetry as well as the functional outcomes, BBS, RMI, and SIS. Level of significance was set at $p<0.05$. Effect sizes were calculated using partial eta squared (η^2) where 0.02 is considered a small effect size, 0.13

moderate and > 0.26 is large (136). Statistical analysis was performed using SPSS Version 23 (IBM Corporation, Armonk, NY, USA).

2.4 Results

2.4.1 Participant Characteristics

Details of participant recruitment are outlined in Figure 2.4. Eighteen participants initially agreed to participate, however, two then refused and withdrew before being assigned to their intervention group. Two other participants also withdrew, one due to illness and the second participant’s assessment session was interrupted by an unexpected event. Further, data from four participants was removed as a result of incomplete video data collection (2 from each group). Ten participants completed the entire study; five in each group. Seven of the 10 participants were able to walk at the beginning of the study. All participants were able to walk at the end of the study, with only one requiring a gait aid. Review of treatment session video data confirmed that both groups received a similar number of repetitions; 396 in verbal group and 405 in manual group.

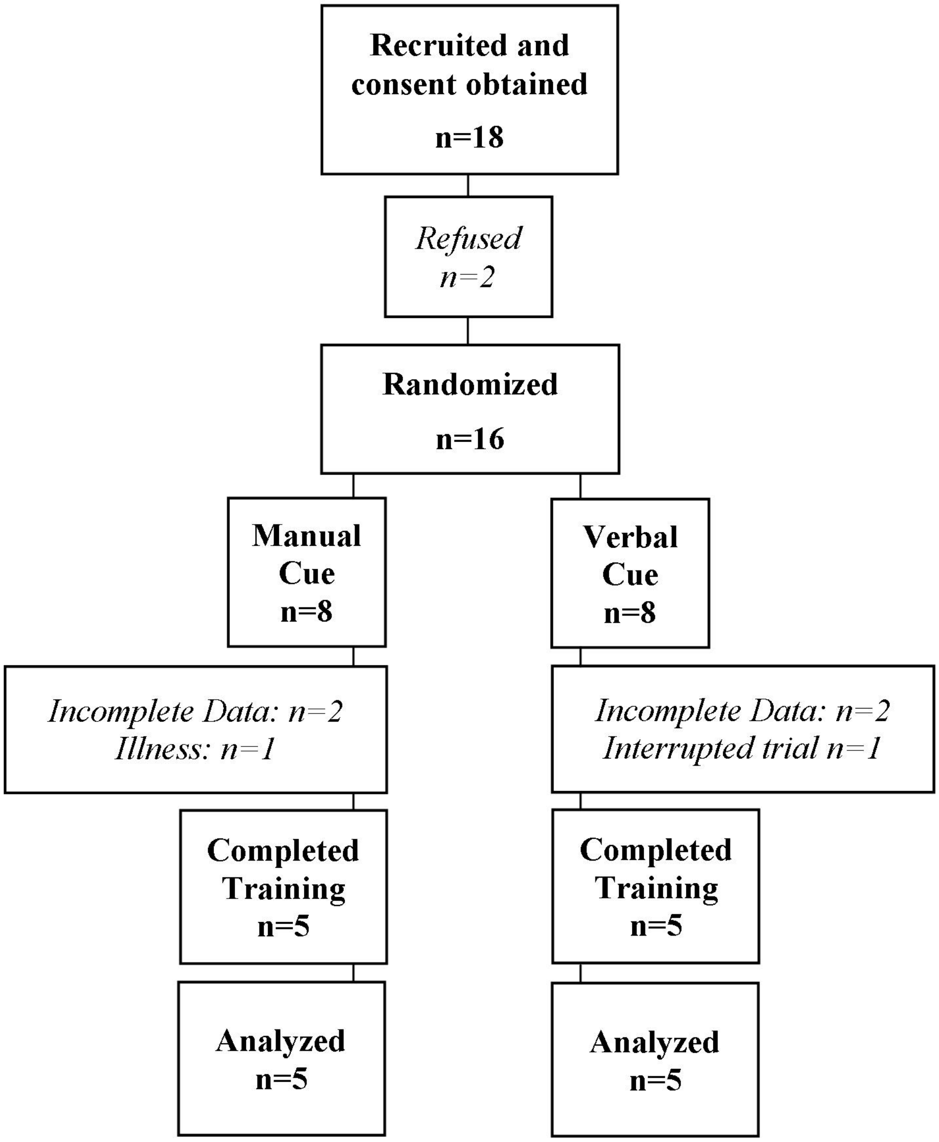


Figure 2.4 Consort diagram of participant recruitment.

Subject characteristics are outlined in **Table 2.1** All participants were male and were on average 63 (±15.00) years old and 36.5 (±18.93) days after stroke. There were no significant differences in the groups at baseline other than the manual group had a significantly faster cadence than the verbal group (Table 2.2).

Table 2.1. Baseline demographic characteristics of the manual and verbal experimental groups.

Manual Group	**Gender**	**Age**	**Hemiplegic Side**	**Days post-stroke**	**Type of stroke**	**CMSA postural control score**
1	M	78	R	59	Ischemic	3
2	M	59	R	21	Ischemic	3
3	M	36	R	35	Ischemic	3
4	M	67	L	29	Ischemic	3
5	M	66	L	21	Hemorrhagic	3
Verbal Group						
1	M	69	L	76	Ischemic	3
2	M	54	L	23	Hemorrhagic	3
3	M	91	L	50	Hemorrhagic	3
4	M	56	R	23	Ischemic	3
5	M	54	L	28	Ischemic	3

Table 2.2. Baseline outcome measures for manual and verbal facilitation groups. * significant at $p<0.05$.

Baseline Measures	**Manual (SD)**	**Verbal (SD)**	**t-test**
STS Symmetry Ratio	15.14 (17.83)	14.63 (14.90)	$p=0.97$
Balance (BBS) (0-56)	38.4 (14.43)	27.4 (16.04)	$p=0.29$
RMI (0-16)	8.80 (4.76)	5.40 (1.52)	$p=0.17$
Walking Velocity (cm/sec)	61.14 (22.15)	25.7 (17.93)	$p=0.074$
Cadence (steps/min)	79.45 (10.42)	53.70 (15.04)	***$p=0.043$**
Step Length Ratio Affected/Non-Affected	1.01 ± .028	.90 ± .21	$p=0.33$

2.4.2 Effects of training on STS symmetry

Following the ten-day intervention trial, we found that there was no significant improvement in symmetry between the affected and less affected sides during STS, with no main effects of TIME ($F_{(1,9)} = 0.80$), $p = 0.40$, $\eta 2 = 0.10$) or CUE ($F_{(1,9)} = 0.001$, $p = 0.97$, $\eta 2 = 0.00182$), and no TIME X CUE interaction ($F_{(1,9)} = 0.036$, $p = 0.86$, $\eta 2 = 0.005$) (see **Table 2.3**).

2.4.3 Effects of training on standing symmetry

Standing symmetry results indicated a significant main effect of TIME ($F_{(1,9)} = 11.49$, **p = 0.012**, $\eta 2 = 0.62$), but no CUE ($F_{(1,9)} = 0.0010$, $p = 0.98$, $\eta 2 = 0.000099$) or TIME X CUE interaction effect ($F_{(1,9)} = 0.00027$, $p = 0.99$, $\eta 2 = 0.000038$) (**Table 2.3**).

Table 2.3. Mean values (standard deviation) of symmetry (see Equation 1 for details) for manual and verbal groups.

Outcome	Manual Pre	Manual Post	Verbal Pre	Verbal Post	Time	Cue	Time x Cue
Symmetry STS	15.14 (17.83)	10.59 (8.93)	14.63 (14.90)	11.67 (10.11)	F 0.80 p 0.40 η^2 0.10	F 0.0010 p 0.97 η^2 0.00182	F 0.036 p 0.86 η^2 0.005
Symmetry in stand	21.76 (17.53)	8.66 (18.71)	21.96 (10.22)	8.98 (14.08)	F 11.49 **p 0.012** η^2 0.62	F 0.0010 p 0.98 η^2 0.000099	F 0.00027 p 0.99 η^2 0.000038

2.4.4 Effects of training on balance

Balance (see **Figure 2.5**), as measured by the BBS, had a significant main effect of TIME (F $_{(1,9)}$ = 10.08, ***p* = 0.013** $\eta 2 = 0.56$), but there was no difference in CUE (F $_{(1,9)}$ = 1.84, *p* = 0.21, $\eta 2 = 0.19$), and no TIME X CUE interaction (F $_{(1,9)}$ = 0.36, *p* = 0.57, $\eta 2 = 0.043$).

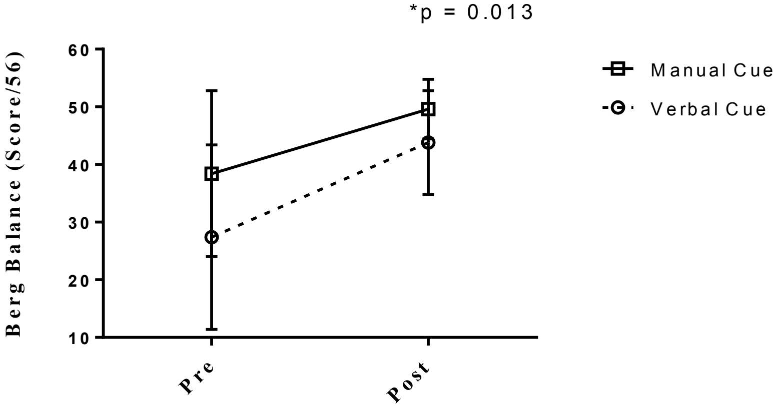


Figure 2.5**.** Effects of STS training on balance. Both groups significantly improved over 10 days. * significant main effect of time.

2.4.5 Effects of training on lower extremity functional mobility

Lower limb mobility (see **Figure 2.6**), measured using the RMI, significantly improved with a main effect of TIME (F $_{(1,9)}$ =17.05, ***p* = 0.003**, $\eta 2 = 0.68$) but no effect of CUE (F $_{(1.9)}$ = 2.75, *p* = 0.14, $\eta 2 = 0.26$) and no TIME X CUE interaction (F $_{(1,9)}$ = 0.21, *p* = 0.66, $\eta 2 == 0.026$).

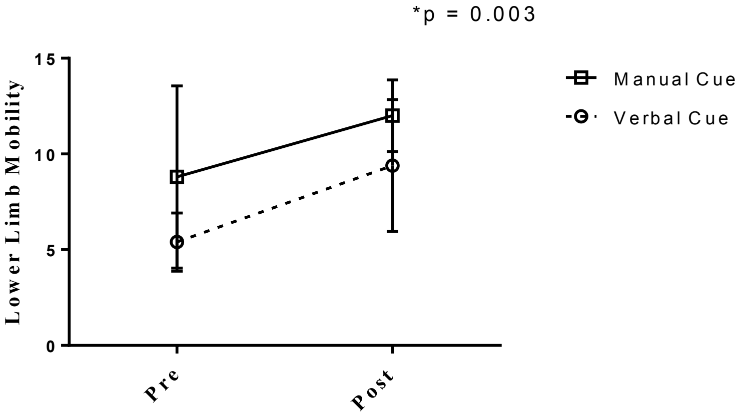


Figure 2.6. Effects of STS training on lower limb mobility. RMI values for the manual and verbal groups pre-post. *significant main effect of time**.**

2.4.6 Effects of training on gait

Three of the ten participants were not able to walk at the pre-assessment session so the gait assessment data is from seven participants only. Three spatiotemporal variables were analyzed; walking velocity, cadence and step length ratio (an indicator of step symmetry). There were no significant effects of TIME, CUE or TIME X CUE in any of the gait variables (**Table 2.4**).

Table 2.4. Mean values (standard deviation) of gait parameters for manual and verbal groups.

Outcome	ManualPre	Manual Post	Verbal Pre	Verbal Post	Time	Cue	Time x Cue
Walking Velocity (cm/s)	61.14 (22.15)	69.11 (22.58)	25.71 (17.93)	34.42 (14.98)	F 3.69 p 0.11 η^2 0.42	F 5.59 p 0.064 η^2 0.53	F 0.007 p 0.94 η^2 0.001
Cadence (steps/min)	79.45 (10.42)	81.93 (12.70)	53.70 (15.04)	72.00 (1.83)	F 5.80 p 0.061 η^2 0.54	F 5.71 p 0.062 η^2 0.53	F 3.36 p 0.13 η^2 0.40
Step Length Ratio (more affected/less affected)	1.01 (3.00)	0.98 (9.00)	0.90 (21.00)	1.00 (3.00)	F 0.26 p 0.63 η^2 0.049	F 0.74 p 0.43 η^2 0.13	F 1.09 p 0.34 η^2 0.18

2.4.7 Effects of training on the perceived impact of stroke

The 3 domains of the Stroke Impact Scale (SIS) that were analyzed were: (1). ADL/IADL, (2). Mobility, (3). Participation and Perceived percentage of recovery. Participants reported a significant improvement in mobility (significant effect of TIME; with no differences between cueing methods and no TIME X CUE interaction). There were no significant effects of TIME, CUE or TIME X CUE interaction in the other SIS domains; ADL/iADL, participation and perceived percentage of recovery (**Table 2.5**).

Table 2.5. Mean values (standard deviation) of Stroke Impact Scale scores for manual and verbal groups. (Note: higher values indicate improvement).

Outcome	Manual Pre	Manual Post	Verbal Pre	Verbal Post	TIME	CUE	TIME X CUE
ADL/ IADL	41.00 (23.34)	55.75 (16.74)	58.25 (26.92)	74.75 (27.28)	F 4.47 *p* 0.079 η^2 0.43	F 1.42 *p* 0.28 η^2 0.19	F 0.014 *p* 0.91 η^2 0.002
Mobility	46.75 (24.81)	87.00 (11.94)	43.00 (19.44)	74.25 (20.45)	F 20.72 ***p* 0.0040** η^2 0.78	F 0.51 *p* 0.50 η^2 0.079	F 0.33 *p* 0.59 η^2 0.052
Participation	37.5 (17.92)	44.50 (26.19)	41.00 (24.48)	53.25 (21.88)	F 2.69 *p* 0.15 η^2 0.31	F 0.17 *p* 0.70 η^2 0.027	F 0.20 *p* 0.67 η^2 0.032
Perceived % of Recovery	40.00 (14.14)	57.50 (9.57)	56.25 (34.00)	67.50 (22.17)	F 3.82 *p* 0.098 η^2 0.39	F 0.91 *p* 0.38 η^2 0.13	F 0.18 *p* 0.69 η^2 0.029

2.5 Discussion

We undertook this study to compare two methods of providing patient feedback during STS training. The key findings of the study were (1). STS symmetry did not improve, as a main effect of cueing result or interaction of time and cueing method, (2). Standing symmetry improved regardless of cueing method used, (3). Balance and lower extremity function improved for both groups with no significant differences between them, and (4). Participants reported improved mobility (SIS), however, there was no difference between the cueing groups. Therefore, the hypothesis for this study: manual cues will produce greater symmetry in STS than verbal cues is rejected.

2.5.1 Verbal or manual cueing: same or different?

Verbal cues are typically considered “extrinsic” and rely on efficient auditory processing and cognition while manual cues rely on the perception of touch and are therefore considered “intrinsic.” It would be reasonable to think that these stimuli would produce different effects on patient movement performance. However, we showed that 10 sessions of both manual and verbal cueing had similar benefits in improving standing balance symmetry, overall balance (BBS) and lower limb mobility (RMI). This is the first paper, to our knowledge, comparing the effects of either a manual cueing technique or verbal directional cueing technique to promote symmetry between more affected and less affected lower extremities during STS in patients during the subacute phase (≤ 3 months) of stroke recovery.

Both cueing methods had characteristics in common. For example, both cues provided focus on shifting more weight onto the more affected limb. Regardless of cue method, sessions also incorporated progressions of difficulty that had previously been shown to be effective among chronic stroke patients: manipulation of seat height to promote concentric muscle contraction to strengthen weakened muscles of the affected limb, manipulation of foot position and constraint of the less affected lower extremity (76, 111, 112, 126). Promotion of weight bearing with progressively challenging levels of difficulty may have contributed to improved standing symmetry outcomes for both manual and verbal groups. Furthermore, our participants were in the subacute phase < 3 months post-stroke when recovery is more rapid and amenable to rehabilitation-induced change. It may be that the quality of the practice rather than the type of cue that is the more ‘active’ ingredient at this stage of recovery. In fact, these cueing methods may have more similarities than differences and consequently provided equally beneficial and enriched daily therapeutic interventions.

2.5.2 Symmetry in standing without symmetry in STS

Following the ten-day intervention trial, we found that there was no effect of either training method on STS symmetry, however, standing symmetry significantly improved in both verbal and manual facilitation groups. The movement of STS remained asymmetrical regardless of training method suggesting that the task is more challenging than standing quietly (57, 64). It is conceivable that a much longer and intensive training period may be required to achieve symmetry in STS. For example, in a more recent study by Kim et al. (118), weight bearing distribution improved in chronic stroke patients who underwent a training protocol consisting of STS training five times a week for six weeks (30 sessions). The less affected lower limb was constrained on a step and participants were asked to perform 10 repetitions (increased to 15 repetitions in weeks 5-6) for each of 6 different tasks. A total of 1850 repetitions of STS were completed at the end of their study, substantially higher than our 400 repetitions. Furthermore, in a study by Barreca et al. (125) examining task-specific STS training among subacute stroke patients (12 sessions, 180 repetitions), they showed that a daily standardized STS program resulted in significantly more stroke survivors being able to perform a consistent, safe, independent STS. However, they did not examine kinetics or kinematics so the symmetry of the STS task was not considered. Our participants did not achieve STS symmetry, however, they did improve overall functional performance as indicated by significant improvement in standing symmetry, balance and lower extremity mobility, similar to outcomes found by Barreca et al. (125). There is likely a difference between STS independence and STS symmetry which begs the question whether symmetry is necessary for independence? In fact, patients can be independent yet asymmetrical during STS. Based on the participants in our study, all were independently mobile, however remained asymmetrical. Our findings, as well as the findings of others, suggest that STS symmetry is much more difficult to achieve compared to standing symmetry, likely due to the complexity of the STS task.

2.5.3 Asymmetry as evidence of early compensation

Participants began our study asymmetrical and remained asymmetrical in STS despite the fact that balance, lower limb function, and functional mobility improved overall. They were able to achieve improvement in function despite this asymmetry. Others have shown that STS training in the post-stroke population, improved balance, weight distribution, and lower limb function (58, 80, 111). Our result suggests that subjects may have developed compensatory strategies in order to achieve better function. Participants were likely adopting compensatory asymmetrical strategies to complete the STS task. The concept of “learned non-use” was first coined by Edward Taub (127) with regards to the hemiplegic upper extremity. It is possible that without focused symmetry training the level of learned non-use and further weakness of the lower extremity could have been worse. More research is required examining the independence versus symmetry paradox and which of these outcomes therapists should spend time focusing on. Like the work on “learned non-use” of the upper extremity, research in animal models of stroke may help to distinguish the effects of different approaches (symmetry versus function) on neuroplasticity.

2.5.4 Improved patient-reported mobility

Manual and verbal cueing methods to re-learn STS may also benefit aspects of quality of life. Notably, regardless of training method, participants in this study reported significant improvements in mobility but not ADLs, participation or recovery. Barreca et al. (125) also found that stroke survivors who were able to stand independently expressed greater satisfaction with their quality of life and physical mobility. Our result suggests that after only 10 days of STS training, mobility begins to improve, but as mentioned, compensatory strategies may be at play during this period. Patient-reported ADL/iADL, participation, and percentage of recovery improved over 10 days but not significantly. This suggests more time may be required to change these outcomes. Supporting this concept, a study which explored changes in SIS scores between 3 and 12 months post-stroke showed that participants rated their perception of recovery better at 12 months compared with 3 months post-stroke (137). This study also reported a lower perceived impact, indicating fewer problems in strength and emotional life at 12 months versus 3 months post-stroke (137). Because of the short duration of the current study, we were unable to replicate these findings.

2.6 Study Limitations

There are several limitations in this study. First of all, the small sample size and the lack of homogeneity resulted in variability in the participants (e.g location of stroke, type of stroke, sensory/proprioceptive impairment), which were not controlled for in our study. Over time people improve, therefore a larger sample consisting of a more heterogeneous group of post-stroke patients could still result in similar effects found in our study. Future studies may wish to increase the sample size while also attempting to recruit a more homogenous sample. This could potentially reduce the variability. Because of this limitation, we need to interpret our finding with caution as a larger, more homogenous sample could result in significance and larger effect size for the cueing method. Considering the fact that our rehabilitation facility has 24 beds dedicated to post-stroke patients, and the short duration allotted for this study to be carried out, a sample of convenience was utilized as was easily accessible to the researcher. As a result, we were only able to recruit 18 participants with only 10 completing the trial (5 per group) which points to the difficulty conducting trials during an inpatient stay. Recruitment was challenging on the stroke unit as there were drop outs as a result of illness and other unexpected interruptions. We also recruited stroke subjects with relatively high functional level to begin with who could complete STS. This made finding participants challenging as the stroke unit had several patients who did not meet our eligibility requirements. Participants were also 21 to 76 days post-stroke. It is believed that most recovery takes place within the first 90 days post-stroke (138), so a large proportion of patient's recovery may have already occurred. Future studies examining impairment-focused intervention should begin earlier; less than 2 weeks post-stroke. Another limitation is the lack of a true control group as both groups received typical rehabilitation in addition to participation in the study. This is a significant limitation, however in light of the convenience sample used in this study, and the short time line, a control group was not included. For future studies in this area, a control group should be considered to include post-stroke patients receiving regular care only. Also, our study did not track what rehabilitation patients received from PT and OT so we were unable to determine if there might have been differences. Typical care for post-stroke rehabilitation includes functional transfer practice, including STS, strengthening, ambulation and aerobic exercise. All participates would have received these treatment interventions. This being said, each of the treating physiotherapists would have had their own style of treatment. The effect of these differences on treatment outcome would have been very difficult to quantify.

2.7 Conclusion

Physiotherapists use many different treatment techniques to promote STS symmetry and functional improvement post-stroke: tactile cues (56), verbal, auditory and visual feedback cues (115) manipulation of chair height, (112) position of affected lower extremities to promote weight bearing, (119) task-specific practice (96, 102) and multiple repetition practice (125). We showed, in this small study, during inpatient stroke rehabilitation, that there was no difference between manual and verbal cues; both groups improved standing symmetry, balance, and lower limb mobility but not symmetry during STS. The STS task is challenging yet critical for performance of most ADL's (i.e. toileting, eating at a table) and likely takes longer to develop symmetry.

Acknowledgments

The study supported by an NL Centre of Applied Health Research Masters Grant and Neuroscience Scholarship Grant from the Physiotherapy Foundation of Canada. The research was supported by the Rehabilitation and Continuing Care Program, patients and staff Eastern Health Authority, the Canada Research Chairs Program (Dr. Michelle Ploughman).

Chapter 3: Discussion

Stroke is, unfortunately, a common condition and incidence of stroke is increasing with an aging population. Further, stroke is a principle cause of mortality and morbidity having major economic implications for society (6). On an individual level, a stroke changes a person's life and that of his or her family forever. Better emergency care and pharmaceutical interventions, such as tissue plasminogen activator, have resulted in more people surviving a stroke. However, these survivors now face a rise in disability severity which is a problem (139). In Canada, most people with disabling stroke are admitted to an acute hospital and once medically stable, are moved to a rehabilitation unit. Canadian rehabilitation practice guidelines state that patients should receive 3 or more hours of task-specific practice each day (i.e. 15 hours per week) in order to reach the threshold required to relearn a task (140). Even very simple tasks such as moving from sitting to standing (STS) can become challenging to a person in the early stages of stroke rehabilitation. With the assistance of skilled therapists, these so-called simple tasks are further broken down into manageable subtasks and patients pursue their practice in parts and as a whole. Patients often commit movement errors, for which therapists provide corrective feedback, with the aim to shape performance during the task re-learning process. The specifics of how this feedback is applied in subacute rehabilitation and how to optimize it within the re-learning process are two areas that have been rarely studied.

To our knowledge, the current study is the first attempt to examine the practice of feedback during inpatient rehabilitation. Our study aimed to examine two different feedback cues: (1) specific tactile feedback provided by the therapist's hand on the target muscle with the aim to promote symmetry in STS, and (2) focused verbal cues to move into a standing position. In our study, changes in STS symmetry were assessed as the primary outcome in people who had sustained a first disabling stroke and were within the first 3 months of their recovery. Secondary outcomes included standing symmetry, balance, lower extremity mobility and walking. Although manual feedback was hypothesized as being able to produce greater symmetry between the more and the less affected side in STS than verbal cues, our findings demonstrate no effect on STS symmetry when either of the feedback training methods was used. However, standing symmetry, balance, and lower extremity mobility, all significantly improved in both manual and verbal cueing groups. This suggests that both methods may improve standing balance and function, however, symmetry in STS was resistant to either intervention. The STS task requires a complex interplay of isometric, concentric and eccentric muscle control of all joints of the trunk and lower extremities; and as such, this transition movement is much more complex than standing and/or walking. The fact that the patients in the study achieved the ability to STS while remaining asymmetrical suggests they may have compensated by using the less affected side.

In this section, I will discuss the implications of these findings in the bigger field of ‘recovery versus compensation’ rehabilitation approaches and how these findings relate to the principles of motor learning. In addition, since conducting research during patient-therapist interactions is rare, discussion will follow regarding some of the logistical challenges of conducting this type of research in the real-world active patient care settings. In particular,the challenges of patient recruitment, attrition, therapist involvement, access to research support and technology and the importance of management support will be highlighted. Finally, I will end with limitations of our study, and suggestions for future research and clinical applications of the finding will be woven throughout the whole discussion.

3.1 Recovery versus compensation rehabilitation approaches

Typically, there are two approaches used by neurorehabilitation therapists. There are those that use treatment approaches aimed at facilitating recovery and those who will focus more on compensatory strategies. The ultimate goal is for the patient to regain as much function as is possible. According to Levin et al. (141), ‘recovery’ is defined as restoring the ability for patients to perform movements and functional tasks in the “manner it was prior to the injury.” These same authors define compensation as “performing an old movement in a new manner” and successfully accomplishing the task using the less affected limb. Performing the STS task is among the most common movements of daily living and is the precursor to all upright mobility tasks (4). Thus, achievement of a safe and efficient STS is a primary goal for patients and therapists in the rehabilitation of stroke.

Physiotherapists also use a variety of techniques to teach patients to relearn symmetry in STS. These techniques can include strategies such as the manipulation of chair height (112), variations in foot positioning (76, 112), and methods to constrain the less affected limb (119) to facilitate more proprioceptive/sensory input and concentric muscular contraction of the muscles of the affected limb. As these strategies are commonly used by physiotherapists specialized in stroke rehabilitation, they were incorporated into our study. There is little empirical evidence to support which method is best (91, 142).

The participants in our study did not achieve symmetrical STS performance, however, they did exhibit improvements in standing symmetry, balance, and lower limb mobility. The question remains whether or not these improvements were due to true recovery or compensation. Zeiler et al. (30) and Cirstea et al. (29), describe compensation in two ways. Firstly, they refer to compensation as the development of a new movement pattern often involving proximal and trunk muscles to achieve independence in a functional goal (e.g. walking), without achieving the precision of pre-stroke performance. Alternatively, they suggested that compensation may arise from the changes in underlying brain networks. Krakauer et al. (28) and Nudo (11) also underscored the importance of the “real-time” window of heightened neuroplasticity in the first 3 months post-stroke in which spontaneous biological recovery and cortical re-organization occur thereby changing the neural networks. The improvements detected in standing, lower limb function, and balance could be explained by improvements in overall strength and use of movement compensation and/or cortical reorganization. Although we gathered no empirical evidence to indicate that compensation occurred, these improvements would not be unexpected since all participants received a daily repetition of functional activities during regular therapy sessions as well as the progressively challenging STS training practice as per the study intervention protocol. Typical therapy sessions included specific strengthening exercises, task-specific practice such as transfers to and from different surfaces (hospital beds, toilets, physiotherapy gym plinths and wheelchairs), standing practice, balance activities and walking.

Furthermore, some of the improvement could also be explained by spontaneous biological recovery as described by Krakhauer et al. (2012) (<3 months post-stroke). As all the participants in our study were within this 3-month window it would be expected that they would all be experiencing some degree of naturally occurring neurological recovery. It could be argued that any active intervention could promote natural recovery and that the specifics of the intervention may not be as important as the encouragement to move (11, 28-30).

Given the results of the current study, it is impossible to conclude whether or not the improvement observed were due to compensation or recovery. In reality, both likely had contributed to improvement observed in participants in our study. As Krakhauer et al. (28) have indicated that recovery is never complete; there is always some degree of compensation along with true recovery.

3.2 Motor learning and importance of feedback

Irrespective of the mechanisms underlying motor improvement post-stroke neurorehabilitation therapists recognize the importance of motor learning and feedback when designing treatment plans. This being said, it is important to examine the results of this thesis from a motor learning and feedback lens. The concept of motor learning discussed earlier in this thesis, has been described as a set of processes associated with practice or experience leading to relatively permanent changes in the capability for producing skilled action and considers how humans acquire and modify movement (65). Knowledge of performance (KP) and knowledge of results (KR) are important forms of extrinsic (augmented) feedback (115, 143) that are directly related to motor learning.

Knowledge of performance, as described by Magill et al. (143), provides information regarding movement characteristics that resulted in the outcome of the movement. As an example, a therapist may tell patients that they need to bend forward over their knees in order to bear more weight on their legs. On the other hand, KR, as described by Magill et al. (144), is externally presented information about the outcome of performing a skill or the goal of a performance. For example, a patient may be told that they were able to transfer 50% of their body weight through their more affected leg using bathroom scales to measure the result. According to Van Vliet et al. (115), feedback inducing an external focus (KR) may be more effective than those with an internal focus (KP). Their research suggests that therapist feedback that encourages patients to have an external focus may help enhance motor learning post-stroke.

In clinical practice, motor learning and NDT techniques are commonly used in combination with each other. In the NDT approach, a decidedly internal focus is used, as tactile cues from therapists encourage patients to focus on muscle activation and movement of body segments. In the present study, both manual and verbal cues were used to provide facilitation during the task of STS. While feedback in the motor learning approach can be either internal or external, the nature of the verbal cues used (i.e. sit tall, lean forward, try to distribute equal weight between your feet) likely resulted in an internal focus. Our findings revealed that neither verbal nor manual cueing methods resulted in improved symmetry during STS. In light of the above discussion on motor learning and importance of external focus, one reason for the lack of improvement in STS symmetry may have been that both the verbal and manual cues used by the treating therapists encouraged an internal focus. Unfortunately, in designing this study we did not consider strategically employing internal focus versus external focus and in fact, the results may have been different if either of the cueing methods provided an external focus rather than the components of the movement of STS (internal focus). For example, it would have been interesting to see how results would have differed if both the manual and verbal cueing group were provided with visual/auditory feedback indicating lower limb weight distribution. This is an area worthy of more research.

3.3 Effects on balance, lower extremity function, mobility, and walking

In addition to the importance of STS in stroke recovery, a systematic review by Langhorne et al. (145) also highlighted the value of assessing and monitoring changes in standing balance, walking, lower extremity function and mobility. Our study participants demonstrated a significant improvement in balance and lower extremity function as revealed by scores on the BBS and RMI, regardless of cueing method. These findings are comparable to those of Liu et al. (120), Kim et al. (118), Britton et al. (121), all of whom found that STS training that featured greater loading of the more affected limb promoted increased joint compression, increased muscle strength, improved weight distribution, symmetry and balance which support the premise that STS training assists in the improvement of balance, weight distribution, lower limb and gross motor function.

Despite the improvements discussed above, our study also did not identify any significant improvement, as the main effect of time or cueing method used, in relation to spatiotemporal parameters of gait (velocity and cadence), however, three participants who were unable to walk independently at the onset did regain the ability to walk. Wade et al. (146) suggested that the ability to walk improves quickly following a stroke i.e. within the first five weeks. At the beginning of the study, only seven of ten participants were able to walk. At its conclusion, all participants were ambulatory, and only one required an ambulatory aid (e.g. walker). Participants regained the ability to walk without improvements in velocity and cadence suggesting that walking remained slow and asymmetrical. It is likely that the significant improvements in balance, lower extremity function and mobility found in our study may have contributed to walking ability, but not to the more subtle spatiotemporal parameters of gait.

3.4 Improved patient-reported health

The World Health Organization's Quality of Life Group (147) define quality of life as "individuals perceptions of their position in life in the context of culture and value system in which they live and in relation to their goals, standards and concerns" (p. 1570). Similarly, Oleson et al. (73) defined quality of life as the "subjective perception of happiness or satisfaction with life in domains of importance to an individual" (p.1570). This being said, quality of life may refer to a broad personal assessment of one's life (148). In our study, regardless of training method, participants reported significant improvements in their standing balance, and mobility but not in their ADLs, participation or perceived recovery measured by the Stroke Impact Scale (SIS). Barreca et al (2004) also found that stroke survivors who were able to stand independently expressed greater satisfaction with their quality of life and physical mobility. Our result suggests that after only 10 days of STS training, mobility begins to improve, but as mentioned, compensatory strategies may be at play during this period. Patient-reported ADL/iADL (Instrumental Activities of Daily Living), participation and percentage of recovery improved over 10 days but were not found to be statistically significant. This suggests more time may be required to demonstrate change in these outcomes. Guidetti and colleagues (137) explored changes in SIS scores between 3 and 12 months post-stroke, they found that participants rated their perception of recovery better at 12 months as compared to 3 months post-stroke. This study also reported a lower perceived impact on their life, indicating fewer problems in strength and emotional life at 12 months versus 3 months post-stroke (137). Our participants were in the subacute phase of recovery <3 months, therefore they were likely adjusting to the emotional and physical impairments associated with having a stroke and other confounding factors such as the social and financial implications that faced them. These issues are stressful and imposing upon being discharged home from formal rehabilitation and therefore may have overshadowed their perception of health at that point in time. If followed for a longer time, we may have detected improvements in the participant's perception of their health as they settled into a "new normal" post-stroke.

3.5 Conducting a trial within a real-world rehabilitation setting

There are several challenges associated with conducting research on an inpatient rehabilitation unit that should be considered when contemplating such an endeavor:

1. Reliance on busy staff. In order to determine whether patients met inclusion/exclusion criteria, the patient had to first be assessed by the staff therapist who then obtained initial permission to contact the researcher. The reality is that because of the demands of a busy patient caseload of 7-8 patients per day, the research project was of low priority for the therapists. To mitigate this challenge the researcher contacted each of the four staff physiotherapists almost daily. However, even with constant surveillance, it is likely that some potentially eligible participants may have been missed.

2. Requirement for existing trusted relationships. This study was conducted by a physiotherapist who had more than 20 years working on the same rehabilitation unit. Trusted relationships had already been built with therapists, physicians and nurses such that the rehabilitation staff felt secure that patients (study participants) were being managed in a way that aligned with existing policies and processes. It is unlikely that a researcher external to the rehabilitation unit could recruit and conduct an intervention trial with the cooperation of staff.

3. Coordinating elements of the research project with the patient's rehabilitation schedule. Research assessment and intervention in a busy 9-5, Monday to Friday environment is difficult to coordinate. Patients are scheduled for daily therapies, meetings, appointments with physicians and interventions outside of the hospital as well as visits by family and friends which often took precedence over the study. These factors may result in researchers often having to reschedule or return to try to coordinate assessment and intervention multiple times. Researchers need to have the flexibility of working outside of regular hours in order to accommodate patient schedules.

4. Participant fatigue/motivation. Many patients are too fatigued or lack the motivation to participate in anything extra (149) outside of their structured rehabilitation sessions. Also, many stroke patients have not been physically active prior to their stroke and lack motivation to change their exercise behaviours post-stroke (8). Therefore, asking them to participate in an intensive program requiring extra time doing exercise outside of scheduled therapy time was not appealing to some and was perceived as an added burden.

5. Unexpected events. There are many unexpected situations that can arise in a rehabilitative environment such as patients becoming ill and having to drop out of a research project, unexpected discharge from rehabilitation and participants refusing to continue the project for a variety of reasons such as not enjoying it or finding it too difficult. Also, researchers have no control over when appropriate participants will be available on the rehabilitation unit. This can result in long delays between recruitment of participants that can prolong research completion.

6. Requirement for in-house technology and research support. Having access to appropriate technology and research support required for a study is a key factor. We were fortunate to have the technology (Protokinetics Walkway, Havertown, PA.) that was used to collect the data for our study at our rehabilitation facility. The proximity of our Recovery and Performance Laboratory enabled researchers to transport study participants for assessment and intervention in an efficient and timely manner without leaving the facility. In addition, research assistants were available to randomize study participants, assist in data collection and schedule lab time for researchers to conduct the study assessments and intervention. Not all clinicians conducting clinical research have access to on-site technology or research assistants. Having access to the technology and research assistants made conducting this project possible for this researcher. Without this support the research would not have been possible.

7. Support from hospital management. Support from physicians, nurses and management is imperative for inpatient rehabilitation research to be conducted and for it to be successful. Researchers having access to patient records, being an extra presence on a busy unit asking questions about patients, ensuring staff are aware when patients are removed from the unit, requires patience and support by the busy team of physicians, nurses and therapists. Management support is also required as research needs to be aligned with policies of the rehabilitation program and sanctioned by them. Management must also be supportive of the fact that the clinical researcher may require a portion of their paid workday to be devoted to the research project and not to regular job-related activities. Furthermore, management need to authorize the presence of researchers in the facility after hours if necessary. Considering all of these factors, it is not surprising that this type of research has been difficult to execute by busy clinicians.

3.6 Limitations of the study

There are several limitations in this study. The main limiting factor is the small sample size, a factor that points to the challenges of conducting trials during the inpatient rehabilitation stay and an important reality of conducting a study on a busy inpatient stroke unit as previously discussed. As a result, our study sample was a sample of convenience. It is possible, that with a larger sample size, significant differences may have existed between the cueing methods. The small sample size and resultant small effect size may have been due to the lack of homogeneity of the subjects in the sample (e.g. location of stroke, type of stroke, sensory impairment). Over time post-stroke patients improve, therefore a larger sample consisting of a more heterogeneous group of post-stroke patients could still result in similar effects found in our study. Future studies may wish to increase the sample size while also attempting to recruit a more homogenous. This could potentially reduce the variability. Because of this limitation, we need to interpret our finding with caution as a larger, more homogenous sample could result in significance and larger effect size for the cueing method. We also recruited stroke subjects with a relatively high functional level to ensure they could perform an STS. As a result, individuals recruited for the study were 21-76 days post-stroke. It is believed that most recovery takes place within the first 90 days post-stroke (138), and therefore a large proportion of the recovery process may have already occurred in our sample. In addition, it is possible that the 10-day intervention period was too short to produce STS symmetry. The 400 repetitions used in the current study was based upon a previous study using the rodent model that found changes in synaptic density in the primary cortex occurred after 400 repetitions (28). It is possible that motor learning in humans requires a longer intervention with more practice.

Another limitation is the lack of a control group in our study; both groups received typical, standard rehabilitation care as an inpatient. Having a control group which excluded STS practice would not be ethical considering the importance of this activity in stroke recovery, which has already been highlighted in the literature.

3.7 Future Directions

Future studies in this area should endeavour to recruit a more homogenous sample of post-stroke patients to minimize variability. This is difficult to do in a busy clinical environment as the number and type of post-stroke patients in any given facility is inconsistent. It will be very difficult to recruit a homogenous cohort of post-stroke patients, however, maybe a smaller sample size will have to be employed as a starting point. Also, future studies examining impairment-focused intervention should begin earlier; less than two weeks post-stroke and should possibly stratify across the recovery continuum, from acute through to chronic phases. Most importantly, in order to determine the effects of treatment, future research should include a control group that involves only the standard care intervention typically offered on the rehabilitation unit. This being said, there will always be barriers to performing research in a clinical setting as there will always be variables that cannot be fully controlled. However, if the optimal climate presents itself it should be capitalized upon.

3.8 Conclusions

Our study did not find that manual, hands on, cueing was superior to verbal cueing to promote symmetry of STS post-stroke. Subjects entered our study presenting with an asymmetrical weight bearing distribution in STS and remained asymmetrical at its conclusion. However, regardless of the training method used to teach participants the STS movement, subjects did improve in standing balance and lower extremity mobility outcomes. This resulted in a significant difference in their perceived health-related quality of life for mobility at the conclusion of our study. Based on the results of the present thesis, we can conclude that there is not a “best method” to facilitate symmetry in STS. We are left questioning whether the effectiveness of these techniques rests in the combination of methods, including both manual and verbal cueing, or should we abandon the therapeutic aim of achieving symmetry and focus on the capacity to perform a safe, effective, independent STS.

Compensatory adaptations begin very early post-stroke, with the less affected side used more than the more affected side resulting in less loading and perhaps even non-use of the more affected lower limb (4). As a result of these compensatory adaptations, early in the rehabilitation process following a stroke, therapists endeavour to re-educate optimal symmetrical movements to maximize motor recovery and minimize impairments. However, as patients improve functionally over the course of inpatient rehabilitation admission, the focus on the ability to perform a perfectly symmetrical STS shifts towards their capacity to perform an independent, safe and consistent STS in order to be discharged home. It is expected that the practice towards achieving symmetrical movement earlier on has enhanced their performance. However, this discussion leaves us to wonder how important achieving perfect symmetry during STS really is. Studies have identified that even healthy individuals have a component of asymmetry between lower extremities during STS, (56) thus perfect symmetry in all movement strategies may not be an achievable or realistic goal post-stroke.

Although an element of compensation will always exist post-stroke, most neurorehabilitation therapists would likely agree that compensation should not be the end goal but instead be a strategy of last resort. As Krakauer and colleagues (28) report, some degree of recovery is always possible. However, time spent in a formal rehabilitation setting is precious – time when the brain is most amenable to change, and the resources are in place to foster behaviourally driven plasticity. The most effective strategies to promote recovery need to be identified early in the recovery phase and then readily incorporated into daily therapies. Ploughman et al. (39) identified that shortened lengths of stay on rehabilitation units is a problem, and optimizing therapeutic time in the rehabilitation environment is vital to maximizing outcomes. The task-specific goal of symmetrical STS with massed-practice introduced in our study intervention protocol is an example of how therapeutic time can be optimized.

It is important for post-stroke patients to have the opportunity to avail of intensive task-specific intervention, where a high level of repetition of a movement or activity is practiced optimizing motor recovery, mobility, and quality of life outcomes. These outcomes are vital to maximizing patient independence, reducing the burden of care on families, and minimizing the fiscal drain on an already taxed health care system.

Perhaps our participants were able to distribute their weight more effectively through the lower extremities during STS with the manual and verbal cues during the intervention protocol sessions, however, this ability was not transferred effectively to the task-relearning process without the constant feedback from the treating therapist. Could it mean that more time is required to re-learn more symmetrical distribution between the more affected and less affected lower extremities or is it even possible to attenuate the compensatory strategies learned early in the recovery phase to achieve function? More carefully designed task-specific research will be required to answer this question.

References

1. Ontario Stroke Network [Internet]. Toronto: CorHealth Ontario; [cited 2018 Jan 08]. Stroke Stats and Facts; [1 screen]. 2018 [Available from: http://ontariostrokenetwork.ca/information-about-stroke/stroke-stats-and-facts/.
2. Hendricks HT, van Limbeek J, Geurts AC, Zwarts MJ. Motor recovery after stroke: a systematic review of the literature. Archives of Physical Medicine and Rehabilitation. 2002;83(11):1629-37.
3. O' Sullivan SB, Schmitz TJ. Physical rehabilitation. 5th ed. Philadelphia: FA Davis; 2007.
4. Lee MY, Wong MK, Tang FT, Cheng PT, Lin PS. Comparison of balance responses and motor patterns during sit-to-stand task with functional mobility in stroke patients. American Journal of Physical Medicine & Rehabilitation. 1997;76(5):401-10.
5. Lai S-M, Studenski S, Duncan PW, Perera S. Persisting consequences of stroke measured by the Stroke Impact Scale. Stroke. 2002;33(7):1840-4.
6. Public Health Agency of Canada. (2009). Tracking Heart Disease and Stroke in Canada, 2009. [Available from: https://www.canada.ca/content/dam/phac-aspc/migration/phac-aspc/publicat/2009/cvd-avc/pdf/cvd-avs-2009-eng.pdf.
7. Feigin VL, Forouzanfar MH, Krishnamurthi R, Mensah GA, Connor M, Bennett DA, et al. Global and regional burden of stroke during 1990-2010: findings from the Global Burden of Disease Study 2010. Lancet (London, England). 2014;383(9913):245-54.
8. Shaughnessy M, Resnick BM, Macko RF. Testing a model of post-stroke exercise behavior. Rehabilitation Nursing. 2006;31(1):15-21.
9. Blumenfeld H. Neuroanatomy through Clinical Cases. 2nd ed. Massachusetts: Sunderland, Mass. : Sinauer Associates; 2010.
10. Kandel ER, Schwartz JH, Jessell TM, Siegelbaum SA, Hudspeth AJ. Principles of Neural Science. 4th ed: McGraw-hill New York; 2000.
11. Nudo RJ. Recovery after brain injury: mechanisms and principles. Frontiers in Human Neuroscience. 2013;7:887.
12. Mercier L, Audet T, Hébert R, Rochette A, Dubois M-F. Impact of motor, cognitive, and perceptual disorders on ability to perform activities of daily living after stroke. Stroke. 2001;32(11):2602-8.
13. Hirano Y, Hayashi T, Nitta O, Takahashi H, Nishio D, Minakawa T, et al. Prediction of independent walking ability for severely hemiplegic stroke patients at discharge from a rehabilitation hospital. Journal of Stroke and Cerebrovascular Diseases. 2016;25(8):1878-81.
14. Bogousslavsky J, Van Melle G, Regli F. The Lausanne Stroke Registry: analysis of 1,000 consecutive patients with first stroke. Stroke. 1988;19(9):1083-92.
15. Davidoff RA. The pyramidal tract. Neurology. 1990;40(2):332-9.
16. Smith DL, Akhtar AJ, Garraway WM. Proprioception and spatial neglect after stroke. Age and Ageing. 1983;12(1):63-9.

17. Palmer I. On the injuries to the ligaments of the knee joint: a clinical study. Acta Chirurgica Scandinavica. 1938;81(53):1-282.

18. Hasan Z, Stuart D. Animal solutions to problems of movement control: the role of proprioceptors. Annual Review of Neuroscience. 1988;11(1):199-223.

19. Kenzie JM, Semrau JA, Findlater SE, Herter TM, Hill MD, Scott SH, et al. Anatomical correlates of proprioceptive impairments following acute stroke: A case series. Journal of the Neurological Sciences. 2014;342(1–2):52-61.

20. Torre K, Hammami N, Metrot J, van Dokkum L, Coroian F, Mottet D, et al. Somatosensory-related limitations for bimanual coordination after stroke. Neurorehabilitation and Neural Repair. 2013;27(6):507-15.

21. Prescott R, Garraway W, Akhtar A. Predicting functional outcome following acute stroke using a standard clinical examination. Stroke. 1982;13(5):641-7.

22. Tyson SF, Hanley M, Chillala J, Selley AB, Tallis RC. Sensory loss in hospital-admitted people with stroke: characteristics, associated factors, and relationship with function. Neurorehabilitation and Neural Repair. 2008;22(2):166-72.

23. Burke D. Spasticity as an adaptation to pyramidal tract injury. Advances in Neurology. 1988;47:401.

24. Hufschmidt A, Mauritz K. Chronic transformation of muscle in spasticity: a peripheral contribution to increased tone. Journal of Neurology, Neurosurgery & Psychiatry. 1985;48(7):676-85.

25. Bobath B. Abnormal Postural Reflex Activity Caused by Brain Lesions. 3rd ed. ed: Aspen Publishers; 1985.

26. Brunnstrom S. Associated reactions of the upper extremity in adult patients with hemiplegia; an approach to training. The Physical Therapy Review. 1956;36(4):225.

27. Jones TA. Motor compensation and its effects on neural reorganization after stroke. Nature Reviews Neuroscience. 2017;18(5):267-80.

28. Krakauer JW, Carmichael ST, Corbett D, Wittenberg GF. Getting neurorehabilitation right what can be learned from animal models? Neurorehabilitation and Neural Repair. 2012;26(8):923-31.

29. Cirstea M, Levin MF. Compensatory strategies for reaching in stroke. Brain. 2000;123(5):940-53.

30. Zeiler SR, Krakauer JW. The interaction between training and plasticity in the poststroke brain. Current Opinion in Neurology. 2013;26(6):609-16.

31. Wahl A-S, Schwab ME. Finding an optimal rehabilitation paradigm after stroke: enhancing fiber growth and training of the brain at the right moment. Frontiers in Human Neuroscience. 2014 06/27
08/30/received
05/14/accepted;8:381. PubMed PMID: PMC4072965.

32. Murphy TH, Corbett D. Plasticity during stroke recovery: from synapse to behaviour. Nature Reviews Neuroscience. 2009;10(12):861-72.

33. Capaday C, Ethier C, Van Vreeswijk C, Darling WG. On the functional organization and operational principles of the motor cortex. Front Neural Circuits. 2013;7:66. PubMed PMID: 23616749. PMCID: Pmc3629310. Epub 2013/04/26. eng.

34. Jackson A, Mavoori J, Fetz EE. Long-term motor cortex plasticity induced by an electronic neural implant. Nature. 2006;444(7115):56-60.

35. Jones TA, Chu CJ, Grande LA, Gregory AD. Motor skills training enhances lesion-induced structural plasticity in the motor cortex of adult rats. Journal of Neuroscience. 1999;19(22):10153-63.

36. Karni A, Meyer G, Rey-Hipolito C, Jezzard P, Adams MM, Turner R, et al. The acquisition of skilled motor performance: fast and slow experience-driven changes in primary motor cortex. Proceedings of the National Academy of Sciences of the United States of America. 1998;95(3):861-8.

37. Kleim JA, Barbay S, Nudo RJ. Functional reorganization of the rat motor cortex following motor skill learning. Journal of Neurophysiology. 1998;80(6):3321-5.

38. Nudo RJ, Milliken GW, Jenkins WM, Merzenich MM. Use-dependent alterations of movement representations in primary motor cortex of adult squirrel monkeys. Journal of Neuroscience. 1996;16(2):785-807.

39. Ploughman M, Kelly LP. Four birds with one stone? Reparative, neuroplastic, cardiorespiratory, and metabolic benefits of aerobic exercise poststroke. Current Opinion in Neurology. 2016;29(6):684-92.

40. Bernhardt J, Dewey H, Thrift A, Donnan G. Inactive and alone: physical activity within the first 14 days of acute stroke unit care. Stroke. 2004;35(4):1005-9.

41. Glasgow Augmented Physiotherapy Study Group. Can augmented physiotherapy input enhance recovery of mobility after stroke? A randomized controlled trial. Clinical Rehabilitation. 2004;18(5):529.

42. Dobkin BH. Rehabilitation after stroke. New England Journal of Medicine. 2005;352(16):1677-84.

43. Biernaskie J, Corbett D. Enriched rehabilitative training promotes improved forelimb motor function and enhanced dendritic growth after focal ischemic injury. The Journal of Neuroscience 2001;21(14):5272-80.

44. Johansson BB, Ohlsson A-L. Environment, Social Interaction, and Physical Activity as Determinants of Functional Outcome after Cerebral Infarction in the Rat. Experimental Neurology. 1996;139(2):322-7.

45. Kolb B, Forgie M, Gibb R, Gorny G, Rowntree S. Age, Experience and the Changing Brain. Neuroscience & Biobehavioral Reviews. 1998;22(2):143-59.

46. Sjöholm A, Skarin M, Churilov L, Nilsson M, Bernhardt J, Lindén T. Sedentary behaviour and physical activity of people with stroke in rehabilitation hospitals. Stroke Research and Treatment. 2014 Mar 19; 2014.

47. Salbach N, Mayo N, Wood-Dauphinee S, Hanley J, Richards C, Cote R. A task-orientated intervention enhances walking distance and speed in the first year post stroke: a randomized controlled trial. Clinical Rehabilitation. 2004;18(5):509-19.

48. Salbach NM, Mayo NE, Robichaud-Ekstrand S, Hanley JA, Richards CL, Wood-Dauphinee S. The effect of a task-oriented walking intervention on improving balance self-efficacy poststroke: A randomized, controlled trial. Journal of the American Geriatrics Society. 2005;53(4):576-82.

49. Horak FB. Clinical measurement of postural control in adults. Physical Therapy. 1987;67(12):1881-5.

50. Murray M, Seireg A, Scholz R. Center of gravity, center of pressure, and supportive forces during human activities. Journal of Applied Physiology. 1967;23(6):831-8.

51. Pai YC, Patton J. Center of mass velocity-position predictions for balance control. Journal of Biomechanics. 1997;30(4):347-54.
52. Goldie PA, Matyas TA, Evans OM, Galea M, Bach TM. Maximum voluntary weight-bearing by the affected and unaffected legs in standing following stroke. Clinical Biomechanics 1996;11(6):333-42.
53. Bohannon RW, Barreca SR, Shove ME, Lambert C, Masters LM, Sigouin CS. Documentation of daily sit-to-stands performed by community-dwelling adults. Physiotherapy Theory and Practice. 2008;24(6):437-42.
54. Engardt M, Olsson E. Body weight-bearing while rising and sitting down in patients with stroke. Scandinavian Journal of Rehabilitation Medicine. 1992;24(2):67-74.
55. Cheng PT, Liaw MY, Wong MK, Tang FT, Lee MY, Lin PS. The sit-to-stand movement in stroke patients and its correlation with falling. Archives of Physical Medicine and Rehabilitation. 1998;79(9):1043-6.
56. Hesse S, Schauer M, Petersen M, Jahnke M. Sit-to-stand manoeuvre in hemiparetic patients before and after a 4-week rehabilitation programme. Scandinavian Journal of Rehabilitation Medicine. 1998;30(2):81-6.
57. Lomaglio MJ, Eng JJ. Muscle strength and weight-bearing symmetry relate to sit-to-stand performance in individuals with stroke. Gait & Posture. 2005;22(2):126-31.
58. Turnbull GI, Charteris J, Wall JC. Deficiencies in standing weight shifts by ambulant hemiplegic subjects. Archives of Physical Medicine and Rehabilitation. 1996;77(4):356-62.
59. Sackley CM. Falls, sway, and symmetry of weight-bearing after stroke. International Disability Studies. 1991;13(1):1-4.
60. Chou SW, Wong AM, Leong CP, Hong WS, Tang FT, Lin TH. Postural control during sit-to stand and gait in stroke patients. American Journal of Physical Medicine & Rehabilitation / Association of Academic Physiatrists. 2003;82(1):42-7.
61. Galli M, Cimolin V, Crivellini M, Campanini I. Quantitative analysis of sit to stand movement: experimental set-up definition and application to healthy and hemiplegic adults. Gait & Posture. 2008;28(1):80-5.
62. Etnyre B, Thomas DQ. Event standardization of sit-to-stand movements. Physical Therapy. 2007;87(12):1651-66.
63. Janssen WG, Bussmann HB, Stam HJ. Determinants of the sit-to-stand movement: a review. Physical Therapy. 2002;82(9):866-79.
64. Berger RA, Riley PO, Mann RW, WA. H. Total Body Dynamics in ascending stairs and rising from a chair following total knee arthroplasty. Trans Ortho Res Soc. 1988;13:542.
65. Shumway-Cook A. Motor Control Theory and Practical Application. 2nd ed. Baltimore, MA: Lippincott Williams and Wilkins; 1995.
66. Roebroeck ME, Doorenbosch CAM, Harlaar J, Jacobs R, Lankhorst GJ. Biomechanics and muscular activity during sit-to-stand transfer. Clinical Biomechanics. 1994;9(4):235-44.
67. Vander Linden DW, Brunt D, McCulloch MU. Variant and invariant characteristics of the sit-to-stand task in healthy elderly adults. Archives of Physical Medicine and Rehabilitation. 1994;75(6):653-60.

68. Schenkman M, Berger RA, Riley PO, Mann RW, Hodge WA. Whole-body movements during rising to standing from sitting. Physical Therapy. 1990;70(10):638-48; discussion 48-51.

69. Gahery Y. Associated movements, postural adjustments and synergies: some comments about the history and significance of three motor concepts. Archives Italiennes de Biologie. 1987;125(4):345-60.

70. Goulart FR, Valls-Solé J. Patterned electromyographic activity in the sit-to-stand movement. Clinical Neurophysiology. 1999;110(9):1634-40.

71. Hirschfeld H, Thorsteinsdottir M, Olsson E. Coordinated ground forces exerted by buttocks and feet are adequately programmed for weight transfer during sit-to-stand. Journal of Neurophysiology. 1999;82(6):3021-9.

72. Caruthers EJ, Thompson JA, Chaudhari AMW, Schmitt LC, Best TM, Saul K, et al. Individual Muscle Forces during Sit to Stand Transfer. Prepared for the 2014 Hayes Graduate Research Forum: The Ohio State University April 15, 2014.

73. Gollhofer A, Horstmann G, Berger W, Dietz V. Compensation of translational and rotational perturbations in human posture: stabilization of the centre of gravity. Neuroscience Letters. 1989;105(1):73-8.

74. Kasai T, Kawai K. Quantitative EMG analysis of analysis of anticipatory postural adjustments of voluntary contraction of leg muscles in standing man. Electroencephalography and Clinical Neurophysiology/Evoked Potentials Section. 1994;93(3):184-7.

75. Prudente C, Rodrigues-de-Paula F, Faria CD. Lower limb muscle activation during the sit-to-stand task in subjects who have had a stroke. American Journal of Physical Medicine & Rehabilitation / Association of Academic Physiatrists. 2013;92(8):666-75.

76. Lecours J, Nadeau S, Gravel D, Teixera-Salmela L. Interactions between foot placement, trunk frontal position, weight-bearing and knee moment asymmetry at seat-off during rising from a chair in healthy controls and persons with hemiparesis. Journal of Rehabilitation Medicine. 2008;40(3):200-7.

77. Canning CG, Shepherd RB, Carr JH, Alison JA, Wade L, White A. A randomized controlled trial of the effects of intensive sit-to-stand training after recent traumatic brain injury on sit-to-stand performance. Clinical Rehabilitation. 2003;17(4):355-62.

78. Nyberg L, Gustafson Y. Patient falls in stroke rehabilitation. A challenge to rehabilitation strategies. Stroke. 1995;26(5):838-42.

79. Gryfe C, Amies A, Ashley M. A longitudinal study of falls in an elderly population: I. Incidence and morbidity. Age and Ageing. 1977;6(4):201-10.

80. Tung FL, Yang YR, Lee CC, Wang RY. Balance outcomes after additional sit-to-stand training in subjects with stroke: a randomized controlled trial. Clinical Rehabilitation. 2010;24(6):533-42.

81. Canadian Physiotherapy Association [Internet]. Toronto: The Association; [cited 2017 Dec 01]. About Physiotherapy; [1 screen]. [Available from: https://physiotherapy.ca/about-physiotherapy.

82. Brooks VB. The neural basis of motor control: Oxford University Press; 1986.

83. Langhorne P, Bernhardt J, Kwakkel G. Stroke rehabilitation. The Lancet. 2011;377(9778):1693-702.

84. Bobath B. Adult Hemiplegia: Evaluation and Treatment. 3rd ed. ed: Elsevier Health Sciences; 1990.

85. Gordon J. Assumptions underlying physical therapy intervention: Theoretical and historical perspectives. In: Movement Science: Foundations for Physical Therapy in Rehabilitation. 1987:1-30.

86. Neuro-Developmental Treatment Association. Definition of Neuro-Developmental Treatment. Accessed on 04 Dec 2017 [Available from: http://www.ndta.org/whatisndt.php].

87. Sober SJ, Sabes PN. Flexible strategies for sensory integration during motor planning. Nature Neuroscience. 2005;8(4):490-7.

88. Neuro-Developmental Treatment Association. Definition of Neuro-Developmental treatment. Accessed on 04 Dec 2017 [Available from: http://www.ndta.org/whatisndt.php].

89. Cayo C, Diamond M, Bovre T, Mullens P, Ward P, Haynes M, et al. The NDT/Bobath (Neuro-Developmental Treatment/Bobath) Approach. NDTA Network. 2015;22(2):1.

90. Paterson M. The Senses of Touch: Haptics, Affects and Technologies. New York: Berg; 2007.

91. Lennon S, Ashburn A, Baxter D. Gait outcome following outpatient physiotherapy based on the Bobath concept in people post stroke. Disabil Rehabil. 2006;28(13-14):873-81.

92. Pollock A, Baer G, Langhorne P, Pomeroy V. Physiotherapy treatment approaches for the recovery of postural control and lower limb function following stroke: a systematic review. Clinical Rehabilitation. 2007;21(5):395-410.

93. Newell KM. Motor skill acquisition. Annual Review of Psychology. 1991;42(1):213-37.

94. Stein J. Stroke recovery and rehabilitation. Stein J, editor. New York: New York : Demos Medical; 2009.

95. National Stroke Foundation. Clinical Guidelines for Stroke Rehabilitation and Recovery. Melbourne 2005.

96. French B, Leathley M, Sutton C, McAdam J, Thomas L, Forster A, et al. A systematic review of repetitive functional task practice with modelling of resource use, costs and effectiveness. Health Technology Assessment 2008;12(30):1-117.

97. Winstein CJ, Gardner ER, McNeal DR, Barto PS, Nicholson DE. Standing balance training: effect on balance and locomotion in hemiparetic adults. Archives of Physical Medicine and Rehabilitation. 1989;70(10):755-62.

98. Nielsen JB, Willerslev-Olsen M, Christiansen L, Lundbye-Jensen J, Lorentzen J. Science-based neurorehabilitation: recommendations for neurorehabilitation from basic science. Journal of Motor Behavior. 2015;47(1):7-17.

99. Oleson M. Subjectively perceived quality of life. Journal of Nursing Scholarship. 1990;22(3):187-90.

100. Rossi F, Gianola S, Corvetti L. Regulation of intrinsic neuronal properties for axon growth and regeneration. Progress in Neurobiology. 2007;81(1):1-28.

101. Van Peppen RP, Kwakkel G, Wood-Dauphinee S, Hendriks HJ, Van der Wees PJ, Dekker J. The impact of physical therapy on functional outcomes after stroke: what's the evidence? Clinical Rehabilitation. 2004;18(8):833-62.

102. Hubbard. The Conventional care of therapists as acute stroke specialists: a case study. International Journal of Therapy and Rehabilitation. 2007;14:357-62.

103. Kwakkel G, Kollen B, Lindeman E. Understanding the pattern of functional recovery after stroke: facts and theories. Restorative Neurology and Neuroscience. 2004;22(3-5):281-99.

104. van der Lee JH. Constraint-induced therapy for stroke: more of the same or something completely different? Current Opinion in Neurology. 2001;14(6):741-4.

105. Lang CE, MacDonald JR, Reisman DS, Boyd L, Kimberley TJ, Schindler-Ivens SM, et al. Observation of amounts of movement practice provided during stroke rehabilitation. Archives of Physical Medicine and Rehabilitation. 2009;90(10):1692-8.

106. Luke LM, Allred RP, Jones TA. Unilateral ischemic sensorimotor cortical damage induces contralesional synaptogenesis and enhances skilled reaching with the ipsilateral forelimb in adult male rats. Synapse. 2004;54(4):187-99.

107. Remple MS, Bruneau RM, VandenBerg PM, Goertzen C, Kleim JA. Sensitivity of cortical movement representations to motor experience: evidence that skill learning but not strength training induces cortical reorganization. Behavioural Brain Research. 2001;123(2):133-41.

108. Thorndike EL. The law of effect. The American Journal of Psychology. 1927;39(1/4):212-22.

109. Farqalit R, Shahnawaz A. Effect of foot position during sit to stand training on balance and upright mobility in patients with chronic stroke. Hong Kong Physiotherapy Journal. 2013;31(2):75-80.

110. de Haart M, Geurts AC, Dault MC, Nienhuis B, Duysens J. Restoration of weight-shifting capacity in patients with postacute stroke: a rehabilitation cohort study. Archives of Physical Medicine and Rehabilitation. 2005;86(4):755-62.

111. Farqalit R, Shahnawaz A. Effect of foot position during sit-to-stand training on balance and upright mobility in patients with chronic stroke. Hong Kong Physiotherapy Journal. 2013;31(2):75-80.

112. Roy G, Nadeau S, Gravel D, Malouin F, McFadyen BJ, Piotte F. 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. 2006;21(6):585-93.

113. Stanton R, Ada L, Dean CM, Preston E. Feedback Received While Practicing Everyday Activities During Rehabilitation After Stroke: An Observational Study. Physiotherapy Research International : The Journal for Researchers and Clinicians in Physical Therapy. 2015;20(3):166-73.

114. Subramanian SK, Massie CL, Malcolm MP, Levin MF. Does provision of extrinsic feedback result in improved motor learning in the upper limb poststroke? A systematic review of the evidence. Neurorehabilitation and Neural Repair. 2010;24(2):113-24.

115. van Vliet PM, Wulf G. Extrinsic feedback for motor learning after stroke: what is the evidence? Disability and Rehabilitation. 2006;28(13-14):831-40.

116. Mak MK, Hui-Chan CW. Audiovisual cues can enhance sit-to-stand in patients with Parkinson's disease. Movement Disorders. 2004;19(9):1012-9.

117. Ploughman M, Shears J, Quinton S, Flight C, O'Brien M, MacCallum P, et al. Therapists' cues influence lower limb muscle activation and kinematics during gait training in subacute stroke. Disability and Rehabilitation. 2017:1-8.

118. Kim K, Kim YM, Kang DY. Repetitive sit-to-stand training with the step-foot position on the non-paretic side, and its effects on the balance and foot pressure of chronic stroke subjects. Journal of Physical Therapy Science. 2015;27(8):2621-4.

119. Rocha A, Knabben RJ, Michaelsen SM. Non-paretic lower limb constraint with a step decreases the asymmetry of vertical forces during sit-to-stand at two seat heights in subjects with hemiparesis. Gait & Posture. 2010;32(4):457-63.

120. Liu M, Chen J, Fan W, Mu J, Zhang J, Wang L, et al. Effects of modified sit-to-stand training on balance control in hemiplegic stroke patients: a randomized controlled trial. Clinical Rehabilitation. 2016;30(7):627-36.

121. Britton E, Harris N, Turton A. An exploratory randomized controlled trial of assisted practice for improving sit-to-stand in stroke patients in the hospital setting. Clinical Rehabilitation. 2008;22(5):458-68.

122. Davies PM. Steps to Follow A Guide to the Treatment of Adult Hemiplegia. 7th ed. Germany: Springer-Verlag; 1985.

123. Gruber M, Gollhofer A. Impact of sensorimotor training on the rate of force development and neural activation. European Journal of Applied Physiology. 2004;92(1-2):98-105.

124. Jung K, Kim Y, Chung Y, Hwang S. Weight-shift training improves trunk control, proprioception, and balance in patients with chronic hemiparetic stroke. The Tohoku Journal of Experimental Medicine. 2014;232(3):195-9.

125. Barreca S, Sigouin CS, Lambert C, Ansley B. Effects of Extra Training on the Ability of Stroke Survivors to Perform an Independent Sit-to-Stand: A Randomized Controlled Trial. Journal of Geriatric Physical Therapy. 2004;27(2):59-64.

126. Lee MY, Lee HY. Analysis for Sit-to-Stand Performance According to the Angle of Knee Flexion in Individuals with Hemiparesis. Journal of Physical Therapy Science. 2013;25(12):1583-5.

127. Taub E, Wolf SL. Constraint Induced Movement Techniques To Facilitate Upper Extremity Use in Stroke Patients. Topics in Stroke Rehabilitation. 1997;3(4):38-61.

128. Lee H, Kim H, Ahn M, You Y. Effects of proprioception training with exercise imagery on balance ability of stroke patients. Journal of Physical Therapy Science. 2015;27(1):1-4.

129. Abraira VE, Ginty DD. The sensory neurons of touch. Neuron. 2013;79(4):618-39.

130. Howle JM. Neuro-Developmental Treatment Approach: Theoretical Foundations and Principles of Clinical Practice. Laguna Beach, CA: NeuroDevelopmental Treatment Association; 2002.

131. Gowland C, Stratford P, Ward M, Moreland J, Torresin W, Van Hullenaar S, et al. Measuring physical impairment and disability with the Chedoke-McMaster Stroke Assessment. Stroke. 1993;24(1):58-63.

132. Dong Y, Sharma VK, Chan BP-L, Venketasubramanian N, Teoh HL, Seet RCS, et al. The Montreal Cognitive Assessment (MoCA) is superior to the Mini-Mental State Examination (MMSE) for the detection of vascular cognitive impairment after acute stroke. Journal of the Neurological Sciences. 2010;299(1):15-8.
133. Berg KO, Wood-Dauphinee SL, Williams JI, Maki B. Measuring balance in the elderly: validation of an instrument. Canadian Journal of Public Health. 1992;83:Suppl 2: 7-11.
134. Collen FM, Wade DT, Robb G, Bradshaw C. The Rivermead mobility index: a further development of the Rivermead motor assessment. International Disability Studies. 1991;13(2):50-4.
135. Duncan PW, Wallace D, Lai SM, Johnson D, Embretson S, Laster LJ. The stroke impact scale version 2.0. Stroke. 1999;30(10):2131-40.
136. Bakeman R. Recommended effect size statistics for repeated measures designs. Behavior Research Methods. 2005;37(3):379-84.
137. Guidetti S, Ytterberg C, Ekstam L, Johansson U, Eriksson G. Changes in the impact of stroke between 3 and 12 months post-stroke, assessed with the Stroke Impact Scale. Journal of Rehabilitation Medicine. 2014;46(10):963-8.
138. Jorgensen HS, Nakayama H, Raaschou HO, Olsen TS. Recovery of walking function in stroke patients: the Copenhagen Stroke Study. Archives of Physical Medicine and Rehabilitation. 1995;76(1):27-32.
139. Caplan LR. Tissue plasminogen activator for acute ischemic stroke. N Engl J Med. 1999;341(16):1240-1.
140. Hebert D, Lindsay MP, McIntyre A, Kirton A, Rumney PG, Bagg S, et al. Canadian stroke best practice recommendations: Stroke rehabilitation practice guidelines, update 2015. International Journal of Stroke. 2016;11(4):459-84.
141. Levin MF, Kleim JA, Wolf SL. What do motor “recovery” and “compensation” mean in patients following stroke? Neurorehabilitation and Neural Repair. 2009;23(4):313-9.
142. Pollock A, Gray C, Culham E, Durward BR, Langhorne P. Interventions for improving sit-to-stand ability following stroke. The Cochrane Database of Systematic Reviews. 2014;5:CD007232.
143. Magill RA. Motor Learning and Control: Concepts and Applications. 8 ed: McGraw-Hill; 2007.
144. Magill RA, Anderson DI. Motor Learning and Control: Concepts and Applications: McGraw-Hill New York; 2007.
145. Langhorne P, Coupar F, Pollock A. Motor recovery after stroke: a systematic review. The Lancet Neurology. 2009;8(8):741-54.
146. Wade DT. Functional abilities after stroke: measurement, natural history and prognosis. Impact Commentaries: BMJ Publishing Group Ltd; 2012.
147. Group TW. The World Health Organization quality of life assessment (WHOQOL): development and general psychometric properties. Social science & medicine. 1998;46(12):1569-85.
148. McDougall J, Wright, Virginia, Rosenbaum, Peter. The ICF model of functioning and disability: incorporating quality of life and human development. Developmental Neurorehabilitation. 2010;13(3):204-11.

149. Annoni J-M, Staub F, Bogousslavsky J, Brioschi A. Frequency, characterisation and therapies of fatigue after stroke. Neurological Sciences. 2008;29:244-6.

Appendix

Appendix A – Chedoke McMaster Stroke Assessment (Postural Control)

IMPAIRMENT INVENTORY – STAGE OF POSTURAL CONTROL
Score Form Page 1

Standard Starting Position: No shoes and socks. No standard position. Encourage good sitting posture (ie. with hips and knees at 90°) during testing when indicated. Start the assessment at Stage 4.

STAGE 1

Unable to demonstrate at least two of the Stage 2 tasks

STAGE 2

Task 1: **Facilitated log roll to side lying**
Position: Supine.
Instruction: "Roll onto your strong side."
Method: Facilitate rolling at head, shoulders or pelvis.
Required: Some active movement (either log or segmental rolling is acceptable).

Task 2: **Resistance to trunk rotation**
Position: Side lying on the strong side.
Instruction: "Let me move your trunk."
Method: Place one hand on the shoulder girdle and the other over the hip. Passively move shoulder girdle and hip in opposite directions with sufficient speed of passive movement to elicit a stretch reflex. Feel for resistance to trunk rotation.

Task 3: **Static righting with facilitation**
Position: Sitting unsupported on the side of the bed, hands on lap, feet on floor
Instruction: "Sit without holding on."
Method: Facilitate static righting in sitting.
Required: Some active response, without falling.
Don't accept: Holding on for support.

STAGE 3

Task 1: **Log roll to side lying**
Position: Supine.
Instruction: "Roll onto your strong side without pulling on the bed."
Required: Unassisted rolling onto side. Segmental rolling is acceptable.
Don't accept: Using hands to pull self over.

IMPAIRMENT INVENTORY – STAGE OF POSTURAL CONTROL
Score Form Page 1

Task 2: **Move forward and backward**
Position: Sitting unsupported on the side of the bed, hands on lap, feet on floor
Instruction: "Lean forwards and backwards, and return to the centre."
Required: Independent righting forward and backward within base of support. Head and shoulders should be aligned over the pelvis to complete the task.
Don't accept: Holding on for support, eg. knees.

Task 3: **Remain upright for 5 seconds**
Position: Standing unsupported.
Instruction: "Stand for 5 seconds."
Method: Time standing position for 5 seconds. You can help the person into standing. Uneven weight bearing is allowed.
Don't accept: Leaning against plinth or chair.

STAGE 4

Task 1: **Segmental rolling to side lying**
Position: Supine
Instruction: "Roll onto your strong side without pulling on the bed."
Required: Independent rolling onto strong side. Either the pelvis and legs or the head and shoulders can lead.
Don't accept: Using hands to pull over.

Task 2: **Righting within the base of support**
Position: Sitting unsupported on the side of the bed, hands on lap, feet on floor
Instruction: "Move your weight from one hip to the other while keeping your bottom on the bed and return to the center."
Required: Independent weight shift from side to side with return to midline, within the base of support. Head and shoulders should be aligned to complete the task.
Don't accept: Holding on for support.
Allowed: Unequal weightbearing through the hips.

Task 3: **Standing Up**

Position: Sitting unsupported on the side of the bed, hands on lap, feet on floor
Instruction: "Stand up."
Required: Safe independent rising from sitting to standing, can push off with hands. Some weight bearing through affected limb.
Allowed: Uneven weight bearing.
Don't accept: Pushing legs against the bed or chair to stand, or standing by bracing against the bed or chair.

IMPAIRMENT INVENTORY – STAGE OF POSTURAL CONTROL
Score Form Page 1

STAGE 5

Task 1: **Dynamic righting side to side, feet on floor**
Position: Sitting unsupported on the side of the bed, hands on lap, feet on floor
Instruction: “Shift your weight from one hip to the other, lifting your buttocks off the mat as you move and return to the centre."
Method: Weight shifting from one hip to the other. The client must maintain balance when centre of gravity falls outside base of support. Head, trunk and pelvis must be aligned on completion of task.
Required: Some shortening and elongation of trunk while weight shifting. Buttocks need to come off the mat.
Don't accept: To use hands for support.

Task 2: **Standup with equal weight bearing**

Position: Sitting unsupported on the side of the bed, hands on lap, feet on floor
Instruction: "Stand up, making sure to take the same amount of weight through both legs."
Required: Independent standing with equal weight bearing during transition from sit to stand.
Don’t accept: Use of hands.

Task 3: **Step forward onto weak leg, transfer weight**
Position: Standing unsupported taking equal weight through both legs.
Instruction: "Take a step forward with your weak leg, and then with your stronger one."
Required: Smooth weight shifting forward onto the weak leg while maintaining control of hip and knee extension of the weak leg during the stance phase.

STAGE 6

Task 1: **Dynamic righting backward or sideways with displacement, feet off floor**
Position: Sitting unsupported on the side of the bed, hands on lap, feet off floor
Instruction: Choose a) or b)
a) "Shift your weight from one hip onto the other without stopping."
b) “Shift your weight forwards and backwards without stopping.”
Method: Place your hand lightly on client's shoulders and attempt to push client off balance when client is beyond base of support.
Required: Balance and equilibrium reactions adequate to maintain balance even when displaced beyond base of support.
Don't accept: Holding on for support or the loss of one’s balance.

IMPAIRMENT INVENTORY – STAGE OF POSTURAL CONTROL
Score Form Page 1

Task 2:	**On weak leg 5 seconds**
Position:	Standing unsupported, arms at side.
Instruction:	"Stand only on your weak leg as long as you can."
Method:	Time unipedal stance and record results in box provided.
Required:	Independent unipedal stance for at least 5 seconds.
Allowed:	Arm, leg, and trunk movements that permit the person to accomplish the task.

Task 3:	**Sideways braiding for 2 meters**
Position:	Standing unsupported.
Instruction:	"Walk sideways to the left, keep crossing your right foot in front of the left foot for a distance of 2 meters, then reverse for 2 meters with your left foot crossing in front of your right foot. Keep your hips and feet facing forward and keep your feet on the line."
Method:	Use a 2 meter (2 yard) line on the floor. The client may stop to change directions.
Required:	The trunk, pelvis, and feet must remain facing forward, and the feet must stay on the line.

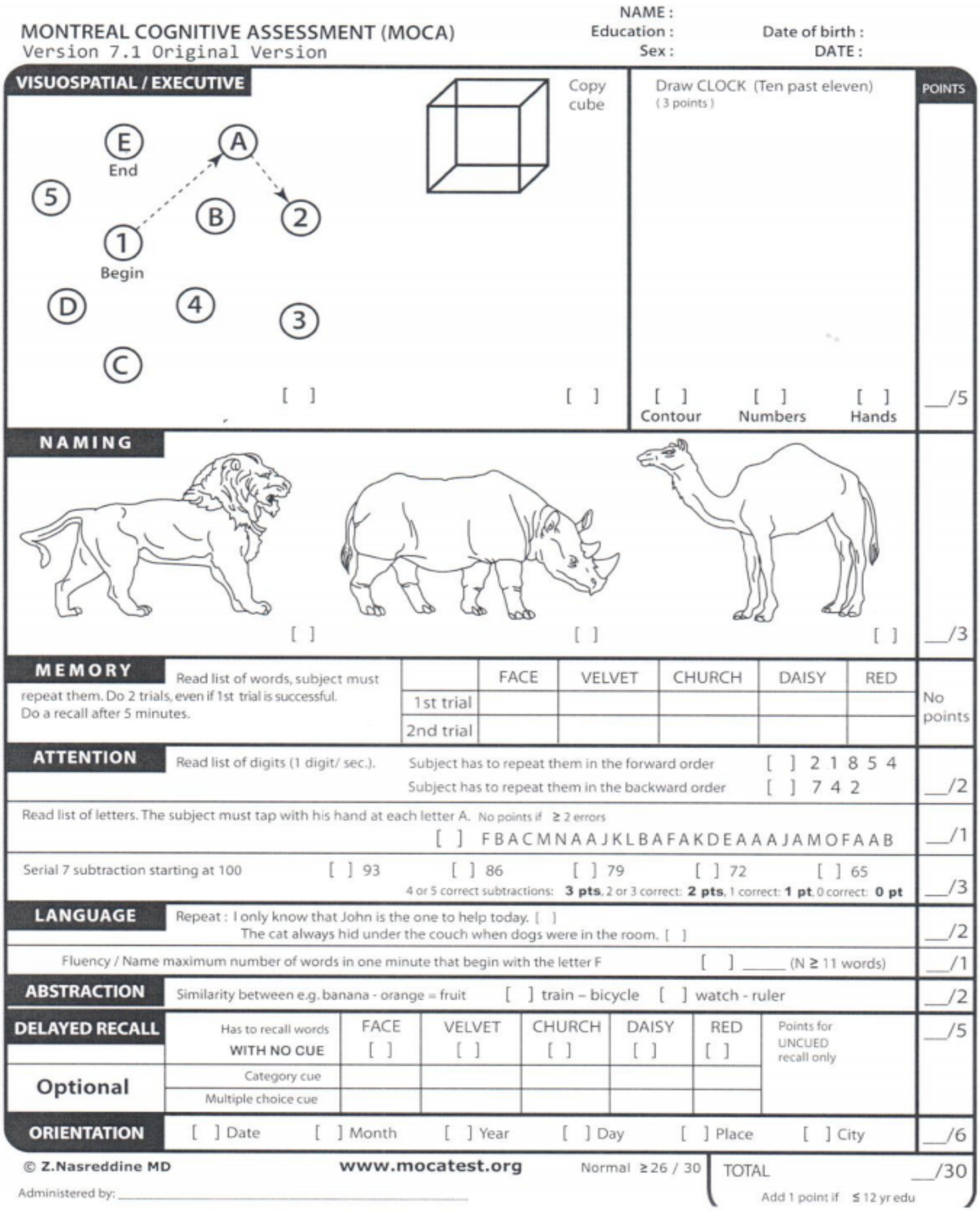
STAGE 7

Task 1:	**Abduction of strong leg**
Position:	Standing unsupported.
Instruction:	"Lift your strong leg out to the side while keeping your weak leg straight.
Required:	Abduction of strong leg beyond neutral, maintaining pelvic alignment.
Don't accept:	Trendelenburg.

Task 2:	**Tandem walking 2 meters in 5 seconds**
Position:	Standing unsupported.
Instruction:	"Touching heel to toe, walk along this straight line as quickly as possible."
Method:	Time 2 meters (2 yards) tandem walking. Record the number of seconds in the box provided. Use tape to make a 2 meter (2 yard) line on the floor.
Don't Accept:	Any loss of balance. (ie: falling off the line) or not touching heels to toes.

Task 3:	**Walk on toes 2 meters**
Position:	Standing unsupported.
Instructions:	"Walk on your tip toes without stopping."
Method:	Use tape to make a 2 meter (2 yard) line on the floor.
Required:	Bilateral equal plantar flexion and weight bearing.

Appendix B – Montreal Cognitive Assessment



MONTREAL COGNITIVE ASSESSMENT (MOCA)
Version 7.1 Original Version

NAME :
Education :
Sex :
Date of birth :
DATE :

VISUOSPATIAL / EXECUTIVE

Copy cube

Draw CLOCK (Ten past eleven) (3 points)

[ ] [ ] [ ] Contour [ ] Numbers [ ] Hands

POINTS ___/5

NAMING

[ ] [ ] [ ] ___/3

MEMORY Read list of words, subject must repeat them. Do 2 trials, even if 1st trial is successful. Do a recall after 5 minutes.

	FACE	VELVET	CHURCH	DAISY	RED
1st trial					
2nd trial					

No points

ATTENTION Read list of digits (1 digit/ sec.).

Subject has to repeat them in the forward order [ ] 2 1 8 5 4
Subject has to repeat them in the backward order [ ] 7 4 2
___/2

Read list of letters. The subject must tap with his hand at each letter A. No points if ≥ 2 errors
[ ] F B A C M N A A J K L B A F A K D E A A A J A M O F A A B ___/1

Serial 7 subtraction starting at 100 [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65
4 or 5 correct subtractions: **3 pts**, 2 or 3 correct: **2 pts**, 1 correct: **1 pt**, 0 correct: **0 pt** ___/3

LANGUAGE Repeat : I only know that John is the one to help today. [ ]
The cat always hid under the couch when dogs were in the room. [ ] ___/2

Fluency / Name maximum number of words in one minute that begin with the letter F [ ] _____ (N ≥ 11 words) ___/1

ABSTRACTION Similarity between e.g. banana - orange = fruit [ ] train – bicycle [ ] watch - ruler ___/2

DELAYED RECALL

	FACE	VELVET	CHURCH	DAISY	RED	
Has to recall words WITH NO CUE	[ ]	[ ]	[ ]	[ ]	[ ]	Points for UNCUED recall only
Optional Category cue						
Multiple choice cue						

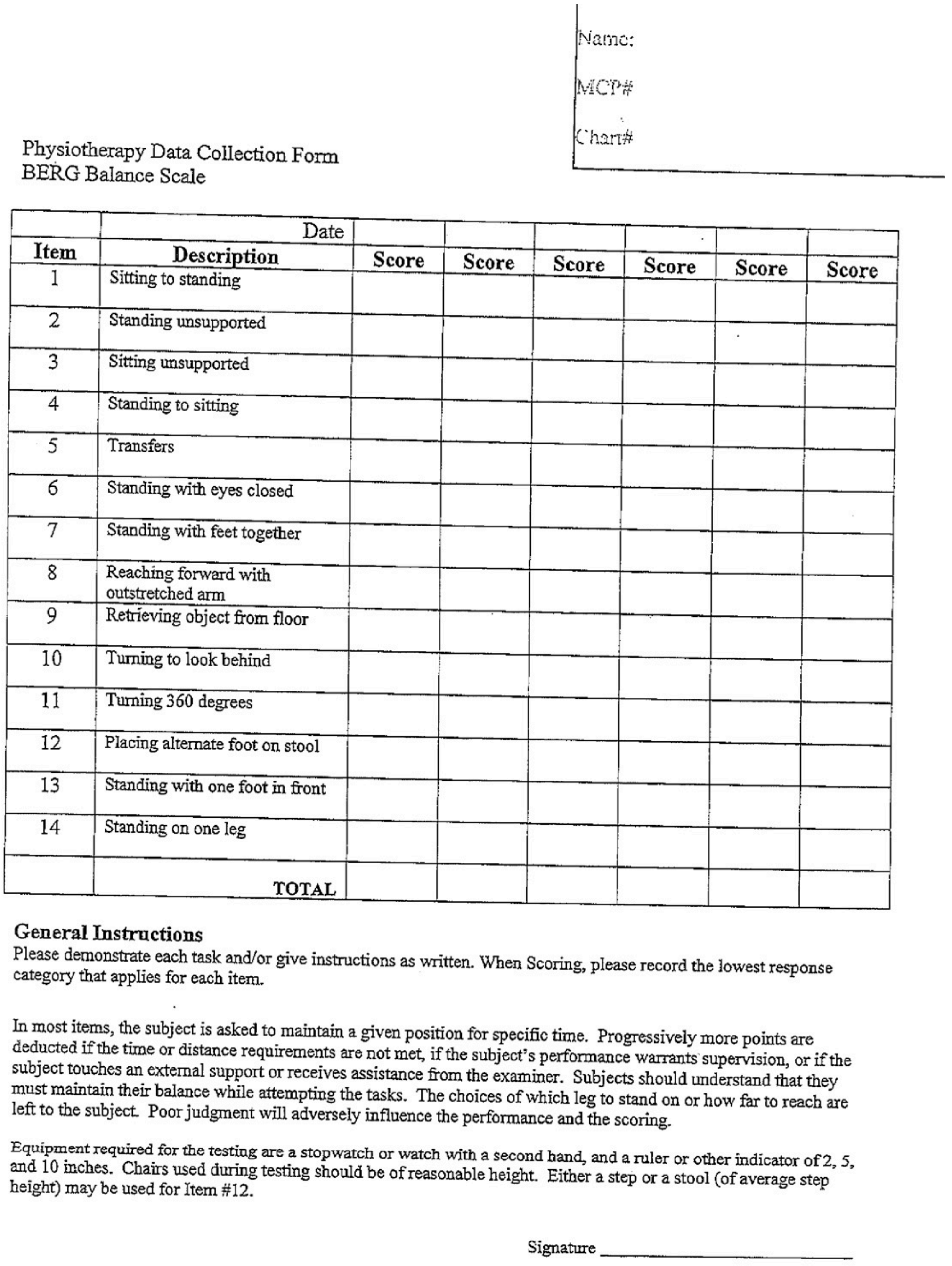
___/5

ORIENTATION [ ] Date [ ] Month [ ] Year [ ] Day [ ] Place [ ] City ___/6

© Z.Nasreddine MD www.mocatest.org Normal ≥26 / 30 TOTAL ___/30
Add 1 point if ≤ 12 yr edu

Administered by: ______________________

Appendix C -Berg Balance Scale



Name:
MCP#
Chart#

Physiotherapy Data Collection Form
BERG Balance Scale

	Date						
Item	**Description**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**
1	Sitting to standing						
2	Standing unsupported						
3	Sitting unsupported						
4	Standing to sitting						
5	Transfers						
6	Standing with eyes closed						
7	Standing with feet together						
8	Reaching forward with outstretched arm						
9	Retrieving object from floor						
10	Turning to look behind						
11	Turning 360 degrees						
12	Placing alternate foot on stool						
13	Standing with one foot in front						
14	Standing on one leg						
	TOTAL						

General Instructions

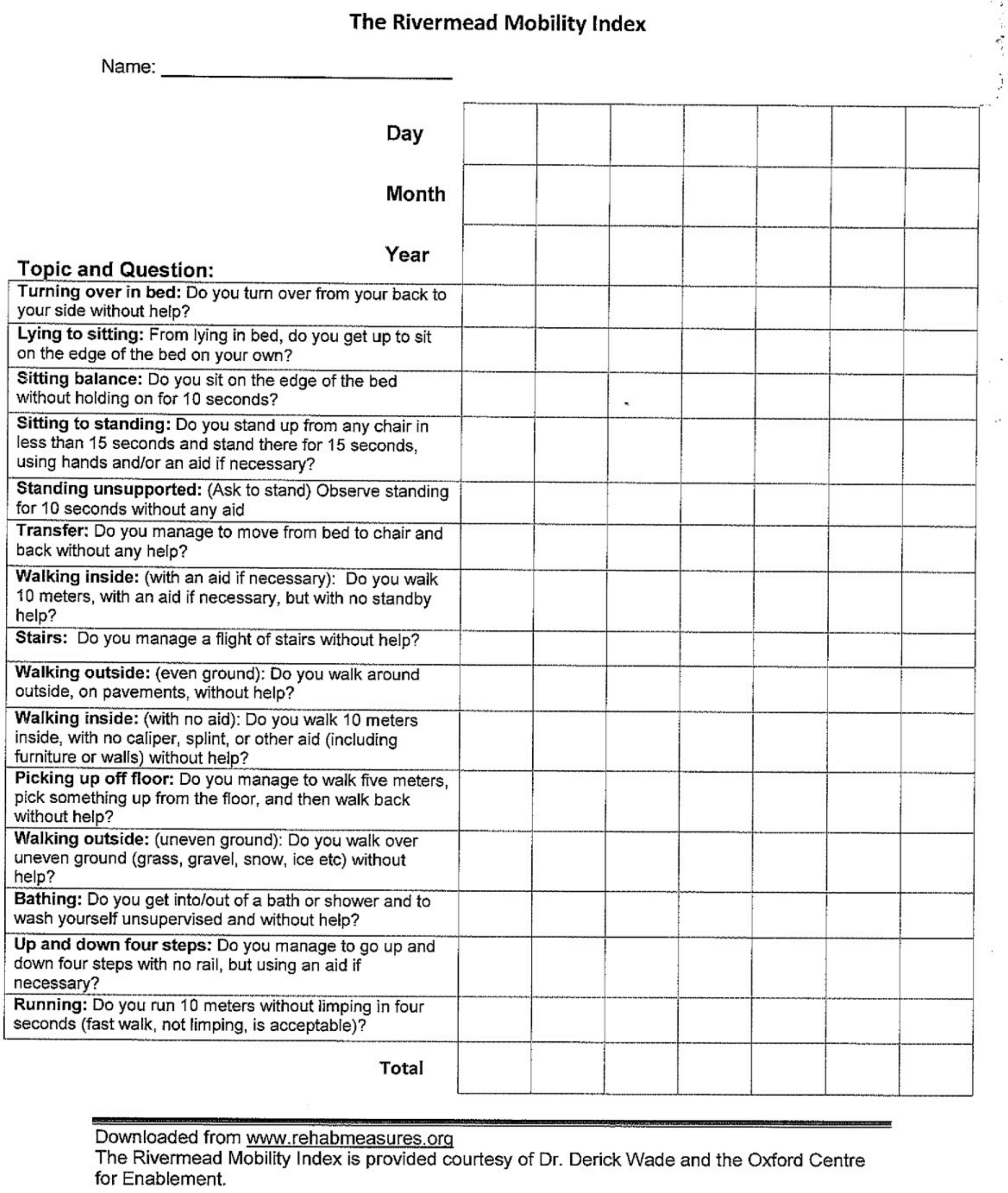
Please demonstrate each task and/or give instructions as written. When Scoring, please record the lowest response category that applies for each item.

In most items, the subject is asked to maintain a given position for specific time. Progressively more points are deducted if the time or distance requirements are not met, if the subject's performance warrants supervision, or if the subject touches an external support or receives assistance from the examiner. Subjects should understand that they must maintain their balance while attempting the tasks. The choices of which leg to stand on or how far to reach are left to the subject. Poor judgment will adversely influence the performance and the scoring.

Equipment required for the testing are a stopwatch or watch with a second hand, and a ruler or other indicator of 2, 5, and 10 inches. Chairs used during testing should be of reasonable height. Either a step or a stool (of average step height) may be used for Item #12.

Signature ____________________________

Appendix D- Rivermead Mobility Index



The Rivermead Mobility Index

Name: ______________________

Day							
Month							
Year							
Topic and Question:							
Turning over in bed: Do you turn over from your back to your side without help?							
Lying to sitting: From lying in bed, do you get up to sit on the edge of the bed on your own?							
Sitting balance: Do you sit on the edge of the bed without holding on for 10 seconds?							
Sitting to standing: Do you stand up from any chair in less than 15 seconds and stand there for 15 seconds, using hands and/or an aid if necessary?							
Standing unsupported: (Ask to stand) Observe standing for 10 seconds without any aid							
Transfer: Do you manage to move from bed to chair and back without any help?							
Walking inside: (with an aid if necessary): Do you walk 10 meters, with an aid if necessary, but with no standby help?							
Stairs: Do you manage a flight of stairs without help?							
Walking outside: (even ground): Do you walk around outside, on pavements, without help?							
Walking inside: (with no aid): Do you walk 10 meters inside, with no caliper, splint, or other aid (including furniture or walls) without help?							
Picking up off floor: Do you manage to walk five meters, pick something up from the floor, and then walk back without help?							
Walking outside: (uneven ground): Do you walk over uneven ground (grass, gravel, snow, ice etc) without help?							
Bathing: Do you get into/out of a bath or shower and to wash yourself unsupervised and without help?							
Up and down four steps: Do you manage to go up and down four steps with no rail, but using an aid if necessary?							
Running: Do you run 10 meters without limping in four seconds (fast walk, not limping, is acceptable)?							
Total							

The Rivermead Mobility Index is provided courtesy of Dr. Derick Wade and the Oxford Centre for Enablement.

Appendix E – Script for Manual Group

- Sit as tall as you can
- Lean your body forward and stand up

Appendix F – Script for Verbal Group

- Sit as tall as you can
- There is a bar next to you to help you stand if you need it
- Lean your body forward, make sure you put equal weight through both of your feet
  and stand up

Appendix G – Scripts for STS and Walking

For the STS (manual group):

- When you see the light I would like for you to stand from where you are sitting
- Stand for 5 seconds, I'll count out loud for you
- When 5 seconds is up to you many sit back down

For the STS (verbal group):

- When you see the light I would like for you to stand from where you are sitting
- You can use the bar if you need to
- Stand for 5 seconds, I'll count out loud for you
- When 5 seconds is up you may sit back down

For the walking:

- Start at the far end and walk down
- Walk off the mat until you reach the wall, turn around, and walk back to the start
- You may go when you see the yellow light
- Please stay to the outside of the black line (demonstrate this to the participant)