Effects of Bilateral Task-Oriented Training on Arm Function After Stroke

Cecille Corsilles-Sy

A dissertation

submitted in partial fulfillment of the

requirements for the degree of

Doctor of Philosophy

University of Washington

2012

Reading Committee:

Janet M. Powell, Chair

Deborah Kartin

Brian Dudgeon

Program Authorized to Offer Degree:

Rehabilitation Science

University of Washington

Abstract

Effects of Bilateral Task-Oriented Training on Arm Function After Stroke

Cecille Corsilles-Sy

Chair of the Supervisory Committee:
Janet M. Powell, PhD
Department of Rehabilitation Medicine

Objectives: (1) To determine if the Bilateral Task-Oriented Training (BTOT) protocol results in improved motor performance in unilateral and bilateral upper limb activities following stroke. (2) To understand the participant's experience with the BTOT protocol and to identify barriers and facilitators that influence willingness to participate in this intervention approach.

Methods: This study used a mixed methods approach including a quantitative randomized blocked repeated measures design and qualitative description. For the quantitative study, 11 participants were recruited and randomized to a treatment (*N* = 6) or usual care group (*N*= 5). Both groups were tested before and after treatment using three instruments: (a) the Wolf Motor Function Test (WMFT) to assess performance time and functional ability in performing activities requiring single-limb function, (b) the Chedoke Arm and Hand Activity Inventory (CAHAI) to measure functional ability in performing activities requiring bilateral arm function, and (c) the Stroke Impact Scale to measure perceived level of difficulty in four domains (strength, activities of daily living, hand function, and social participation). For the qualitative study, two sets of interview questions were used before and after intervention. Coding and thematic analysis were carried out by the research team.

Results: In the quantitative study, the BTOT group showed improvements for the affected and less affected limb immediately after intervention on all measures including the WMFT performance time, functional ability in single limb, and grip and arm strength; and on the CAHAI functional ability of the affected limb in tasks requiring bimanual coordination. One month after intervention, gains were either continued or maintained in all measures except for functional ability in bilateral activities. In the qualitative study, an overarching theme of 'return to normal' emerged. Pre-intervention and post-intervention themes were also identified.

Conclusion: The BTOT program showed positive treatment effects in this preliminary study with potential to improve motor function in individuals with chronic stroke and mild to moderate upper limb impairment. Participants endorsed the program for increasing awareness of affected arm use and increasing use of affected arm in daily living activities. Further research is warranted.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Table Number Page

Chapter 1: Quantitative Study

Chapter 2: Qualitative Study

ACKNOWLEDGEMENT

I am thankful for the guidance, insightful feedback, and encouragement of my dissertation supervisory committee including Janet Powell (chair), Brian Dudgeon, Deborah Kartin, Valerie Kelly, Sarah Blanton, and Noel Chrisman.

I am deeply grateful for the cooperation and support of the Harborview Medical Center Department of Rehabilitation Medicine with special mention to Gaby Bell, who made it possible to juggle work and school.

A special thank you for the tireless work of the Bilateral Task-oriented Training research team including Krithika Rupnarayan, Carol Xiang, and Sarah Jacob.

And to my loving family who never wavered in their faith and devotion, and sustained me through this dissertation.

Introduction and Literature Review

One of the devastating sequelae of stroke is diminished upper limb function on one side of the body. Therapies to restore arm function following stroke have been in practice for over 60 years. Many of these are traditional treatments that have focused on regaining control over reflexive movement patterns using muscle activation techniques. However, these efforts have not resulted in favorable outcomes for regaining arm function. It was found that 50% of survivors experience hemiparesis six months post stroke (American Heart Association, 2008) . To maximize independence in self-care activities, it has become standard practice in occupational therapy to train patients with one-sided arm weakness to use compensatory techniques. This type of training which focuses on using only the less affected arm may be leading to further loss of arm function for the more affected limb (Takeuchi & Izumi, 2012; Taub, 1976).

Recent innovations in technology have allowed non-invasive examination of brain physiology leading to new theories on recovery of movement control and new ways to measure the effects of therapeutic interventions. Rehabilitation scientists are revisiting old models of movement control as new understanding of human motor performance become available. There is much evidence to support upper limb training using functional task practice (Higgins et al., 2006; McDonnell, Hillier, Miles, Thompson, & Ridding, 2007; Page, Levine, Leonard, Szaflarski, & Kissela, 2008; Page, Sisto, Levine, & McGrath, 2004; Wolf et al., 2006) potentially bringing new treatment interventions to clinical practice.

The Task Oriented Approach is based on the systems theory of motor control which considers normal movements to result from the interaction between the individual's abilities, the demands of the task, and the context in which the task was performed (Shumway-Cook &

Woollacott, 2001). Abnormal movements are said to result from impairment in one or more factors within this system. Furthermore, therapeutic interventions using this approach promote the use of goal directed task practice in training. This approach also assumes that motor learning can be achieved through active participation and problem-solving of the participant through repetitive attempts at accomplishing a functional task (Shumway-Cook & Woollacott, 2001). These training principles highlight the use of functional activities as a primary tool for training which can be used to create a comprehensive approach to restoring motor control.

One widely-studied clinical application of the task-oriented approach is Constraint-Induced Movement Therapy (CIMT). The classic CIMT protocol uses a combination of repetitive task-practice, behavioral strategies, and intensive single limb training with constraint to the less affected limb (D. Morris, Taub, & Mark, 2006). CIMT has been applied and tested in a variety of treatment intensities and different training schedules. Effects of CIMT have been studied in individuals with acute, subacute, and chronic stroke and in individuals with different severity of upper extremity motor impairment. A Cochrane review by Sirtori and colleagues (2009) examined 19 studies with 619 participants and concluded that CIMT resulted in "moderate reduction in disability," but that it was unclear if benefits persisted beyond six months. The same group of authors added four new randomized control trials (RCT) for a new Cochrane review in 2010 with a total of 674 participants (Corbetta, Sirtori, Moja, & Gatti, 2010). They concluded that CIMT resulted in "modest improvement in arm motor function" and that it has "no evidence of benefit on disability."

Constraint induced movement therapy was designed to address multiple factors that may be contributing to the lack of functional use of the affected limb. The application of the constraint is specific to forcing the use of the affected limb and to diminish the effects of learned nonuse, a phenomenon presumed to result from a combination of failed attempts at using the affected limb and compensatory strategies of using the less affected limb (Wolf, 2007). This training, therefore, could not provide opportunities for using both hands in task practice.

A majority of daily activities require bilateral limb coordination such as self-care activities of bathing and grooming and instrumental activities of daily living (IADL) of meal preparation and money management. As a principle of experience-dependent neural plasticity, specificity of training suggests that to restore bilateral arm function, it is necessary to use bilateral arm training (Kleim & Jones, 2008). In addition, motor patterns for bimanual manipulation acquired through years of bilateral hand use prior to the stroke may be best restored through bilateral training rather than unilateral training (McCombe Waller & Whitall, 2008).

The use of bilateral limb training as a restorative stroke therapy has also received ample research attention in the last decade. Although still lacking rigorous testing, there is extensive literature on bilateral training paradigms and their effect on cortical activation and motor recovery following stroke. For purposes of comparison, the three studies on bilateral training presented here have been chosen, at least in part, for their use of the principles associated with the task-oriented approach.

The first example is Bilateral Arm Training with Auditory Cuing (BATRAC). This training protocol used a device that required bilateral forward reaching and retrieving motions of the arms and a metronome to provide timing for the movements. A pilot study of the BATRAC (Whitall, McCombe Waller, Silver, & Macko, 2000) showed statistically significant improvements in motor impairments as measured by the Fugl-Meyer (FM) upper extremity motor assessment and the Wolf Motor Function Test (WMFT) in 14 participants. A RCT by Luft and his colleagues (2004) examined the effects of BATRAC compared to a dose-matched exercise intervention in 21 participants. They used fMRI to measure cortical changes following BATRAC and concluded that BATRAC induced contralesional cortical reorganization supporting the use of bilateral training as an upper extremity restorative therapy post stroke.

A second example of bilateral training was used in a pilot study on rhythmic Active-Passive Bimanual Training (APBT) (Stinear & Byblow, 2004). This training consisted of placing the hand in a device that fixed the proximal limb but allowed passive wrist flexion and extension of the affected hand, driven by the same, but active movements of the less affected hand through a manipulandum. This study showed improved motricity score on the FM motor assessment in five of nine participants. In addition, transcranial magnetic stimulation (TMS) showed decreased cortical map volume on the contralesional hemisphere associated with normalization of activation between the brain hemispheres and improved motricity of the affected limb.

A final example of bilateral training is a study by Mudie and Matyas (2000) where the researchers used real task objects for repetitive training. This study used a 12 single-case series with multiple-baseline design. Each participant practiced three different activities in random order per training session: (1) moving pegs, (2) moving blocks, (3) and simulated drinking from a cup. Baseline training consisted of using the affected limb alone, followed by training with the affected limb interlocked with the less affected limb, and then using Bilateral Isokinematic Training (BIT) with the two limbs moving simultaneously, but independently. The BIT was introduced in staggered timing to minimize training effects. Using observational kinematics, the authors found that BIT showed statistically significant improvement in movement patterns of the hemiparetic limb compared to other types of training used.

A Cochrane review found insufficient high quality evidence to support the use of simultaneous bilateral training in stroke rehabilitation (Coupar, Pollock, van Wijck, Morris, & Langhorne, 2010). However, systematic review of different bilateral training techniques concluded that there was “some evidence” that bilateral therapy improves function, but called for more RCTs (Latimer, Keeling, Lin, Henderson, & Hale, 2010).

Two of the three bilateral training techniques described above used rhythmic non-functional arm movements in their training protocols. While arm movements of moving cups, blocks, and pegs are included in one protocol, they were conducted in limited planes of motion which would not allow for training adaptations for increasing skilled practice. These techniques use the principle of interlimb coupling, interhemispheric inhibition (Luft et al., 2004; Whitall et al., 2000), and motor overflow (Mudie & Matyas, 2000; Stinear & Byblow, 2004), as rationale for training. Although these studies provided support for bimanual training, noted improvements have only been in diminishing motor impairments without addressing performance of functional activities.

While there are functional activities that require symmetrical arm movements, (i.e., moving a stack of plates), these are often part of a whole task requiring complex bimanual coordination (i.e., drying the dishes and stacking them on a counter top before putting them away). Most functional activities use bilateral coordination that require independent, but complementary, movements of the two limbs to accomplish a common goal (i.e., taking items out of a drawer, tying shoe laces, keyboarding, etc.). Reflexive and rhythmic movements as used in the bilateral training studies above facilitate stereotyped movement patterns generated primarily in the brain stem and spinal cord (Schmidt & Lee, 1999). It is fitting to examine bilateral movements which facilitate voluntary motor control generated in the motor cortex around where the majority of stroke infarcts occur. The use of non-functional, automatic, and rhythmic movements while a necessary step toward understanding bilateral motor control, may be limiting the potential benefits of task-specific bilateral training in restoring motor skills (J. H. Morris et al., 2008). Task-specific bilateral training can potentially activate cortical areas that are responsible for skilled functional movements and promote restoration of neural network that will lead to functional motor performance.

Two recent studies have used functional activities in their training protocol. Hayner, Gibson, and Giles (2010) examined the difference in treatment effects between CIMT and a control group using bilateral arm movements. Twelve participants were randomized to the two groups. Both groups used ADL as training activities and received the same frequency and total hours of training time. Both groups improved and no significant between-group differences in treatment effects were found. This supports the use of bilateral task-oriented training as a viable method to improve upper limb performance.

The second study was a RCT that used Bilateral Arm Training (BAT) in moving pegs, cups, blocks and wiping a table using symmetrical and alternating arm movements (Wu, Chuang, Lin, Chen & Tsay, (2011). This study compared three treatment approaches: (a) the BAT, (b) distributed CIMT (dCIMT) and (c) a combination of neurodevelopmental treatment (NDT) and compensatory training which served as a control group. All groups used essentially the same training schedule of two hours a day, five days a week for three weeks except for the dCIMT group which received six hours of additional constraint use outside the clinic. The authors concluded that the dCIMT was superior to the BAT, and both were superior to NDT in the measure of functional performance. This study provides further support for bilateral training using functional activities. However, the bilateral activities in this protocol used minimal skilled movements and practiced movements in limited planes which possibly have lessened the resulting treatment effects.

This paper presents the Bilateral Task-oriented Training (BTOT) protocol, an innovative training program designed to affect improvements in arm function following stroke. The Bilateral task-oriented training protocol is based on a contemporary motor control theory of task-oriented approach and uses current understanding in motor learning and neural plasticity. I hope to extend the benefits associated with the comprehensive model used in CIMT by eliminating the constraining mitt and to build upon early research in bilateral training by employing task-specific training using repetitive arm movements of symmetrical, asymmetrical, and complementary bilateral movements. As a task-oriented approach, the BTOT employs behavioral strategies used to maximize motor learning in enriched contextual environments. This dissertation research used a mixed methods approach of randomized control trial to explore the effect of the treatment protocol on arm function and qualitative description to explore the participant's experience in using the BTOT program. In the following chapters, I will present the results of quantitative and qualitative studies along with a full description of the treatment protocol.

References

American Heart Association. (2008). Heart Disease and Stroke Statistics 2009 Update [Electronic Version]. *Circulation*, e76. Retrieved 7/6/2010 from http://circ.ahajournals.org/cgi/reprint/CIRCULATIONAHA.108.191261v1.

Corbetta, D., Sirtori, V., Moja, L., & Gatti, R. (2010). Constraint-induced movement therapy in stroke patients: Systematic review and meta-analysis. *European Journal of Physical Rehabilitation and Medicine, 46*, 537-544.

Coupar, F., Pollock, A., van Wijck, F., Morris, J., & Langhorne, P. (2010). Simultaneous bilateral training for improving arm function after stroke. *Cochrane Database of Systematic Reviews, 4*, CD006432.

Hayner, K., Gibson, G., & Giles, G. M. (2010). Comparison of constraint-induced movement therapy and bilateral treatment of equal intensity in people with chronic upper-extremity dysfunction after cerebrovascular accident. *American Journal of Occupational Therapy, 64*, 528-539.

Higgins, J., Salbach, N. M., Wood-Dauphinee, S., Richards, C. L., Cote, R., & Mayo, N. E. (2006). The effect of a task-oriented intervention on arm function in people with stroke: A randomized controlled trial. *Clinical Rehabilitation, 20*, 296-310.

Kleim, J. A., & Jones, T. A. (2008). Principles of experience-dependent neural plasticity: Implications for rehabilitation after brain damage. *Journal of Speech Language Hearing Research, 51*(1), S225-239.

Latimer, C. P., Keeling, J., Lin, B., Henderson, M., & Hale, L. A. (2010). The impact of bilateral therapy on upper limb function after chronic stroke: A systematic review. *Disability and Rehabilitation, 32*, 1221-1231.

Luft, A. R., McCombe-Waller, S., Whitall, J., Forrester, L. W., Macko, R., Sorkin, J. D., … Hanley, D.F. (2004). Repetitive bilateral arm training and motor cortex activation in chronic stroke: A randomized controlled trial. *Journal of the American Medical Association*, *292*, 1853-1861.

McCombe Waller, S., & Whitall, J. (2008). Bilateral arm training: Why and who benefits? *NeuroRehabilitation, 23*, 29-41.

McDonnell, M. N., Hillier, S. L., Miles, T. S., Thompson, P. D., & Ridding, M. C. (2007). Influence of combined afferent stimulation and task-specific training following stroke: A pilot randomized controlled trial. *Neurorehabilitation and Neural Repair, 21*, 435-443.

Morris, D., Taub, E., & Mark, V. (2006). Constraint-induced movement therapy: Characterizing the intervention protocol. *Europa Medicophysica, 42*, 257-268.

Morris, J. H., van Wijck, F., Joice, S., Ogston, S. A., Cole, I., & MacWalter, R. S. (2008). A comparison of bilateral and unilateral upper-limb task training in early poststroke rehabilitation: A randomized controlled trial. *Archives of Physical Medicine and Rehabilitation, 89,* 1237-1245.

Mudie, M. H., & Matyas, T. A. (2000). Can simultaneous bilateral movement involve the undamaged hemisphere in reconstruction of neural networks damaged by stroke? *Disability and Rehabilitation*, *22*(1-2), 23-37.

Page, S. J., Levine, P., Leonard, A., Szaflarski, J. P., & Kissela, B. M. (2008). Modified constraint-induced therapy in chronic stroke: Results of a single-blinded randomized controlled trial. *Physical Therapy, 88*, 333-340.

Page, S. J., Sisto, S., Levine, P., & McGrath, R. E. (2004). Efficacy of modified constraint-induced movement therapy in chronic stroke: A single-blinded randomized controlled trial. *Archives of Physical Medicine and Rehabilitation, 85*(1), 14-18.

Schmidt, R. A., & Lee, T. D. (1999). *Motor Control and Learning: A Behavioral Emphasis*. Champaign, IL: Human Kinetics.

Shumway-Cook, A., & Woollacott, M. (2001). Theoretical Framework. In M. Biblis (Ed.), *Motor Control, Theory and Practical Applications* (2nd ed., pp. 1-127). Baltimore: Lippincott Williams & Wilkins.

Sirtori, V., Corbetta, D., Moja, L., & Gatti, R. (2009). Constraint-induced movement therapy for upper extremities in stroke patients. *Cochrane Database of Systematic Reviews* (4), CD004433.

Stinear, J. W., & Byblow, W. D. (2004). Rhythmic bilateral movement training modulates corticomotor excitability and enhances upper limb motricity poststroke: A pilot study. *Journal of Clinical Neurophysiology*, *21*, 124-131.

Takeuchi, N., & Izumi, S. (2012). Maladaptive plasticity for motor recovery after stroke: Mechanisms and approaches. *Neural Plasticity*, *2012*, 359728.

Taub, E. (1976). Movement in nonhuman primates deprived of somatosensory feedback. *Exercise and Sports Sciences Reviews*, *4*, 335-374.

Whitall, J., McCombe Waller, S., Silver, K. H., & Macko, R. F. (2000). Repetitive bilateral arm training with rhythmic auditory cueing improves motor function in chronic hemiparetic stroke. *Stroke, 31*, 2390-2395.

Wolf, S. L. (2007). Revisiting constraint-induced movement therapy: Are we too smitten with the mitten? Is all nonuse "learned"? and other quandaries. *Physical Therapy*, *87*, 1212-1223.

Wolf, S. L., Winstein, C. J., Miller, J. P., Taub, E., Uswatte, G., Morris, D., … Nichols-Larsen, D. (2006). Effect of constraint-induced movement therapy on upper extremity function 3 to 9 months after stroke: The EXCITE randomized clinical trial. *Journal of the American Medical Association*, *296*, 2095-2104.

Wu, C. Y., Chuang, L. L., Lin, K. C., Chen, H. C., & Tsay, P. K. (2011). Randomized trial of distributed constraint-induced therapy versus bilateral arm training for the rehabilitation of upper-limb motor control and function after stroke. *Neurorehabilitation and Neural Repair*, *25*, 130-139.

Chapter 1

Quantitative Study

Effect of Bilateral Task-Oriented Training on Arm Function After Stroke

University of Washington

Abstract

Effects of Bilateral Task-Oriented Training on Arm Function After Stroke

Cecille Corsilles-Sy

Chair of the Supervisory Committee:
Janet M. Powell, PhD
Department of Rehabilitation Medicine

Objective: To determine if the Bilateral Task-Oriented Training (BTOT) protocol results in improved motor performance in unilateral and bilateral activities following stroke.

Methods: This study used a randomized blocked repeated measures design. Eleven participants were recruited and randomized to a treatment (*N* = 6) or usual care group (*N*= 5). Both groups were tested before and after treatment using three instruments: (a) the Wolf Motor Function Test (WMFT) to assess performance time and functional ability in performing activities requiring single-limb function, (b) the Chedoke Arm and Hand Activity Inventory (CAHAI) to measure functional ability in performing activities requiring bilateral arm function, and (c) the Stroke Impact Scale to measure perceived level of difficulty on four domains: strength, activities of daily living, hand function, and social participation.

Results: The BTOT group showed improvements for the affected and less affected limb immediately after intervention in all measures including the WMFT performance time, functional ability in single limb, grip and arm strength and in the CAHAI functional ability of the affected limb in tasks requiring bimanual coordination. One month after intervention gains were either continued or maintained in all measures except for functional ability in bilateral activities.

Conclusion: The BTOT program showed positive treatment effects in this preliminary study with the potential to improve motor function in individuals with chronic stroke and mild to moderate upper limb impairment. Further research is warranted.

Background

Stroke is a leading cause of long-term disability among adults with 50% of survivors continuing to experience hemiparesis after six months (American Heart Association, 2008). Restorative therapies for improving upper extremity motor performance following stroke have been in practice for over 60 years; however, even in recovered stroke survivors, Lai et al. (2002) found persistent impairments in hand function. Innovation in technology which allows non-invasive examination of brain physiology has led to many new ways to measure the effectiveness of our therapeutic interventions and new understanding of the neural mechanisms behind recovery of upper extremity motor control following stroke.

The most widely studied intervention in recent years is Constraint-Induced Movement Therapy (CIMT). Morris, Taub, and Mark (2006) characterized CIMT as a family of intervention which includes the use of constraint, repetitive practice of discrete daily tasks, intensive therapies in the clinic (72 hours of intervention within 2 weeks) and an extensive home program, and the use of behavioral strategies designed to increase the patient's investment and participation in the therapy. There is much research evidence supporting the effectiveness of CIMT in improving upper extremity motor performance (Bonaiuti, Rebasti, & Sioli, 2007; Page, 2003; Page, Levine, Leonard, Szaflarski, & Kissela, 2008; Page, Sisto, Levine, & McGrath, 2004; Taub et al., 2006; Wittenberg et al., 2003; Wolf et al., 2006; Wu, Lin, Chen, Chen, & Hong, 2007). The most recent Cochrane review included 23 studies and 624 participants and concluded that CIMT resulted in "modest improvement in arm motor function" but "no evidence of benefit on disability," (Corbetta, Sirtori, Moja, & Gatti, 2010).

An emerging area of research is in bilateral arm training. . This approach has garnered more interest with the recognition that most daily activities require bilateral hand function.

Based on the principle of experience-dependent neuroplasticity (Kleim & Jones, 2008), it is necessary to use skilled training in bilateral arm use to regain motor control for bilateral activities. Furthermore, motor patterns for bimanual manipulation acquired through years of bilateral hand use prior to the stroke is best restored through bilateral training rather than unilateral training (McCombe Waller & Whitall, 2008).

Earlier studies on bilateral training techniques used training devices that limited movements to only parts of the arms and rhythmic movements in single joint and/or single planes of motion (Mudie & Matyas, 2000; Stinear & Byblow, 2004; Whitall, McCombe Waller, Silver, & Macko, 2000). There is evidence that these training techniques have resulted in cortical reorganization associated with improved motor function (Luft et al., 2004; Stinear & Byblow, 2004). Two recent studies on bilateral training used at least in part, some whole arm training. One study used group intervention of meal preparation as a comparison group for an equal dose of CIMT (Hayner, Gibson, & Giles, 2010) The authors attributed the gains made in this group to the intensity of intervention provided but did not explore other benefits bilateral training may have provided. A second study compared three different interventions: (a) distributed training of constraint induced therapy (dCIT), (b) bilateral simultaneous training, and (c) combined neurodevelopmental treatment and compensatory training which served as a control group (Wu, Chuang, Lin, Chen, & Tsay, 2011). The authors found that dCIT was superior to bilateral training and both were superior to the control group in kinematic measures and functional ability. Bilateral training was found to be superior to dCIT only in force generation

Two systematic reviews have been conducted to examine the effects of bilateral training. A Cochrane review found insufficient evidence to support this training technique (Coupar, Pollock, van Wijck, Morris, & Langhorne, 2010) while a second systematic review found "some evidence" that bilateral therapy improves function (Latimer, Keeling, Lin, Henderson, & Hale, 2010). Both set of authors called for more RCT in this area of research.

The present study examined an innovative therapeutic intervention, the Bilateral Task-Oriented Training (BTOT). It is based on contemporary motor control theory of task-oriented approach and uses current understanding in motor learning and neural plasticity. Based on the comprehensive model used in CIMT, it hopes to extend benefits associated with CIMT without the constraining mitt and build upon current knowledge on motor control in bilateral arm coordination.

Methods

Research Design

This study used a blocked randomized control repeated measures design. Participants were randomized to either the BTOT group or a Usual Care (UC) group. All participants were tested before randomization. After randomization, participants in the BTOT group received four weeks of intervention followed by two tests: (a) a post-test immediately after intervention and (b) a follow-up test four weeks later. The UC group was tested four weeks after the first test and was not tested beyond this time (Figure 1). No monetary compensation was offered for participation. During the study, all participants were asked not to begin any new activities directed at improving their hemiparetic limb function; however, they were allowed to continue existing health maintenance routines.

Randomization

Three researchers conducted telephone screens which determined general eligibility of participants. An occupational therapist performed the physical and cognitive screens and

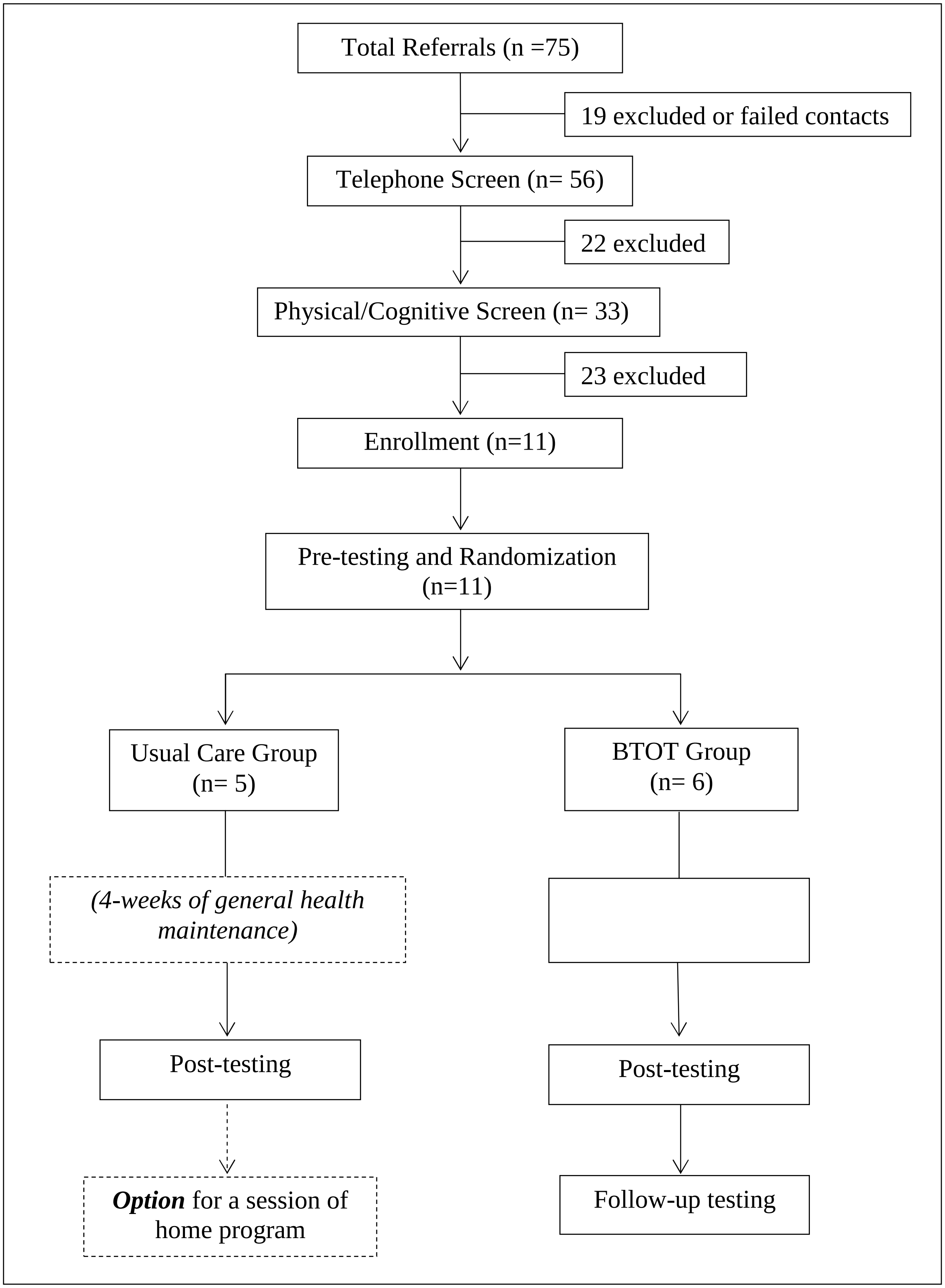

Figure 1. Randomization and flow of participants in the study.

administered all tests and intervention. A biostatistician established a blocked randomization which was concealed from other members of the research team. Group assignments were pre-determined and placed in sealed envelopes labeled and opened in sequence after pre-testing.

Training Protocol

The BTOT is a comprehensive program which combines repetitive task practice and behavioral strategies to maximize engagement in therapy, motor learning, and adherence to the home-based component of this training protocol. The BTOT uses a distributed practice schedule of two hours a day, three days a week for four weeks or a total of 24 hours of clinic-based intervention. In addition, participants engage in an individualized home program of at least 2 hours of daily bilateral arm use outside of the research clinic. The first 30-minutes of each session are used to review the journal for progress and challenges of the home program; and to assist the participant in problem-solving difficulties in practicing bilateral arm-use when not in the research clinic. This is also the time when new functional goals are established, and previous ones are adjusted as needed.

Repetitive task practice used *discrete (shaping) task practice* and *continuous task practice*. Discrete tasks practice used bilateral activities that were graded to challenge arm and hand function specific to components of movement that the participant was lacking (e.g.. grasp and release, alternating pronation and supination, combination of shoulder abduction and elbow extension, proximal stability above 90º shoulder flexion, etc.) (Figure 2) Repetitive bilateral movements of the upper limbs could be symmetrical, asymmetrical, or complementary movements where each hand performed two different movements to achieve a common goal. These tasks are performed repeatedly with increasing challenge for participants to increase the number of repetitions completed or keep the number of repetitions but attempt to complete them within a shorter period of time. Other options for discrete task-practice are detailed in Chapter 3.

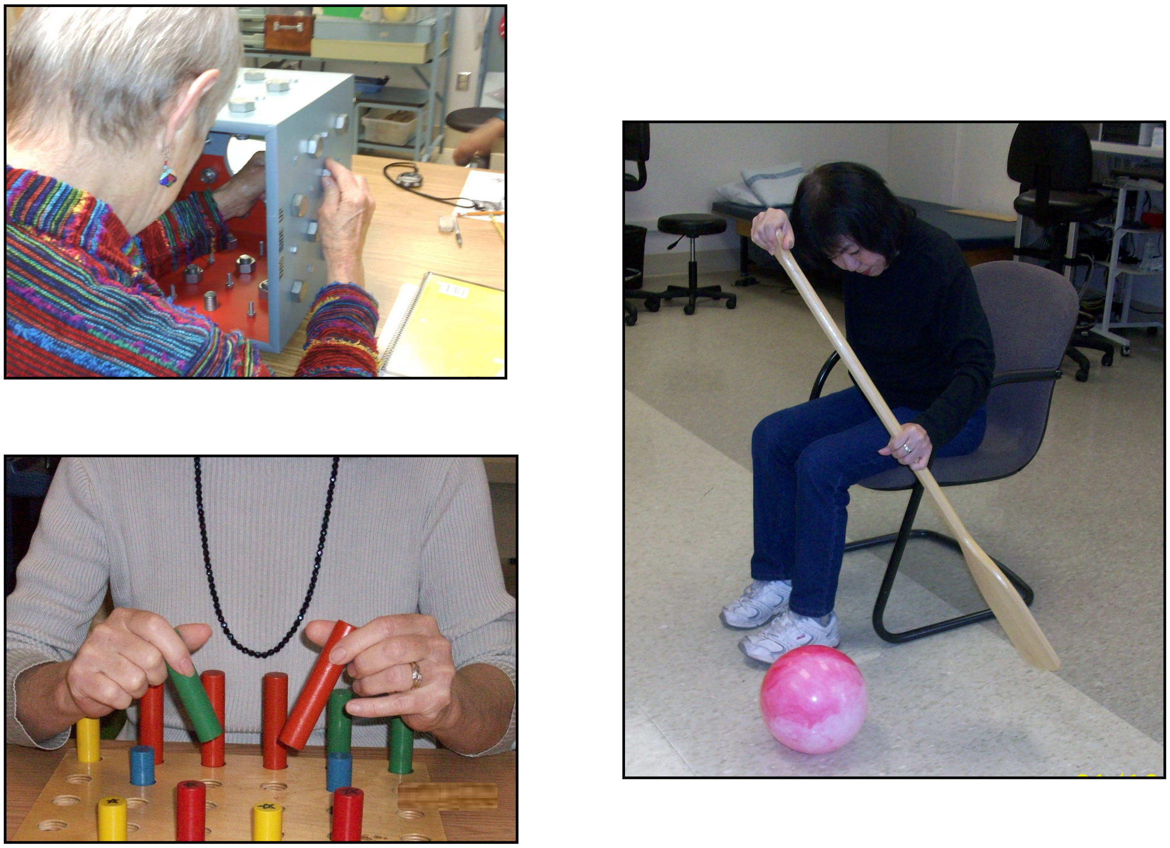

Figure 2. Discrete (*shaping*) task practice.

Continuous bilateral task practice used functional activities such as meal preparation, throwing and catching a ball, drumming, and typing (Figure 3). The home programs use continuous task practice exclusively, and attempt to incorporate bilateral arm use in the participant's daily routine such as showering, eating, folding clothes, washing and putting away dishes, and other functional activities relevant to the individual's life roles. These are also graded to allow progressive successes in practice. An example is setting a goal of using both hands in eating 25% of a meal and progressing to 50 % and 75% as bilateral hand function improves.

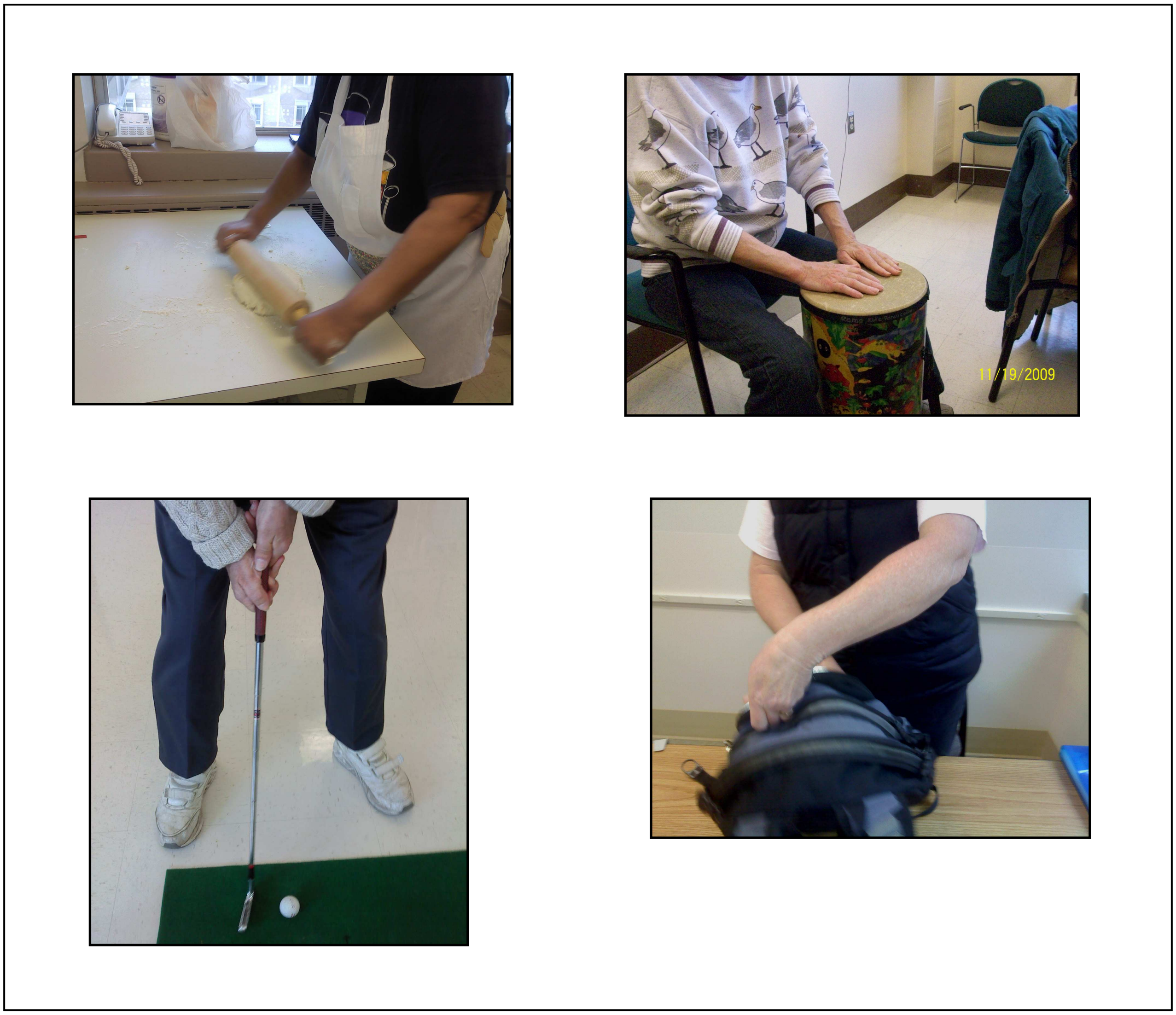

Figure 3. Continuous task practice.

Behavioral strategies used in the BTOT program includes a behavioral contract, daily journal writing, and augmented feedback during training designed to encourage full engagement in therapies, curb frustration level, and maximize motor learning. The BTOT intervention begins by establishing a behavioral contract that promotes the role of the participant as a partner in his/her recovery. The contract itemizes plans on how participants would use both hands as much as possible when not in the research clinic and identifies occasions when only the less affected limb would be used due to potential safety risks. The participant and researcher then generate a list of activities that the participant agrees to do as part of the home program. Participants are asked to keep a journal that documents their bilateral limb activities when at home and in the community and perceptions of their performance. The journal was used to increase participants' awareness of how they used their arms and to inform the researcher of difficulties in motor control that should be addressed in training.

Usual Care Activities

All participants in the UC group were offered and accepted one training session with the investigator to establish a home program after completion of the study. Once a week for four weeks, participants in the UC group were sent letters with recommendations for healthy living after stroke (American Stroke Association, 2011). These included information on nutrition, adherence to recommended medication regimen, benefits of physical activity, and controlling risk factors associated with stroke

Study Participants

To be included in the study, participants had to be community dwelling adults with self-reported one-sided ischemic or hemorrhagic stroke at least 6 months prior to enrollment in the study. Participants with more than one stroke were included if infarcts were in the same hemisphere. They had to have at least 10º of wrist extension and 10º of extension of the thumb and 2 fingers and score a 2 or below on the Modified Ashworth Scale for spasticity. They had to score ≥ 22 on the Montreal Cognitive Assessment (MoCA). Additionally, participants could not be taking part in other therapies directed at changing arm movement including rehabilitation therapies (i.e., occupational therapy [OT] and physical therapy [PT]) and Botox injections. Participants were excluded if they had pain in either upper limb that might be aggravated by intensive training or if they had uncontrolled medical conditions that might put them at risk due to the intensive training.

Recruitment

This study was approved by the University of Washington (UW) Institutional Review Board and all participants provided consent prior to enrollment. Participants were recruited from several metropolitan area hospitals, clinics, stroke support groups, and senior centers through flyers and presentations. In addition, medical records from two academic medical centers were pre-screened for patients diagnosed with stroke who had been discharged between 2009 and 2011. The study was also posted on five websites: (a) UW Rehabilitation Department, (b) UW Medicine Health Research, (c) UW Medicine at Valley Medical Center, (d) Washington Stroke Forum, and (e) Young Adult Stroke Survivors. Finally, pre-screening of medical records from Harborview Medical Center and University of Washington Medical Center was conducted for patients seen between 2009 and 20011 diagnosed with stroke and hemiparesis.

Outcome Measures

The primary outcome measure was the Wolf Motor Function Test (WMFT) which measured hemiparetic limb performance in unilateral activities. A secondary outcome was the Chedoke Arm and Hand Activity Inventory (CAHAI) which measured hemiparetic hand performance in bilateral activities. Both were video recorded during testing and were later scored by a rater blinded to group assignment and testing status of participants.

The WMFT measures motor skills based on performance time and functional ability in performing single limb activities. Functional ability is measured on a 6-point ordinal scale which rates the speed, fluidity, and precision of movements and the contribution of the affected limb in the completion of the task. The WMFT was found to have good construct validity and criterion validity for stroke patients (Wolf et al., 2001). It also had high inter-rater reliability, internal consistency, and test-retest reliability (D. M. Morris, Uswatte, Crago, Cook, & Taub, 2001).

The CAHAI uses an activity scale which rates the functional ability of the hemiparetic limb in the performance of 13 bilateral activities (Barreca et al., 2004). The CAHAI activity scale measures functional ability on a 7-point ordinal scale by rating the contribution of the hemiparetic limb in stabilization and a manipulation function during complementary bilateral hand activities. This instrument was found to have high inter-rater reliability and discriminant cross-sectional validity for patients with stroke (Barreca, Stratford, Lambert, Masters, & Streiner, 2005).

An occupational therapist other than the interventionist rated all WMFT and CAHAI videos to obtain functional ability scores. The rater did not engage in any other part of the study, and was blinded to the group assignment and testing status of the participants.

Additionally, the Stroke Impact Scale (SIS) Version 3.0 was used to measure self-reported level of difficulty in four domains: (a) Strength (4 items), (b) Activities of Daily Living (ADL) (10 items), (c) Hand Function (5 items), and (d) Social Participation (8 items). This instrument is an interviewer-administered measure that asked participants to compare their current status to their pre-stroke status and changes in quality of life after stroke. It has been found valid and reliable for the stroke population (Duncan, et al., 1999).

Data Analysis

Descriptive analysis was used to compare changes in scores in three time points (pre-test, post-test, and follow-up) for the intervention group and for two time points for the UC group. The Wilcoxon Signed Rank test was used to test the difference between the changed scores (pre-test to post-test) between the two groups. The Mann-Whitney U was used to test the difference in scores from pre-test to follow-up test within the BTOT group. As an exploratory study, no adjustments were made for multiple comparisons and values were used to examine the statistics that support the descriptive results rather than a statement of true significance.

Results

Recruitment

One thousand thirty-one medical records were pre-screened for eligibility and 105 letters were sent to potential participants resulting to 10 respondents (See Figure 4). There were a total of 65 respondents from all other recruitment methods. Fifty-six people completed the telephone screening and 33 completed the physical and cognitive screening. Eleven participants were enrolled with five randomized to the usual care group and six to the treatment group. Demographic characteristics of participants can be found in Table 1.

Randomization

Comparison of baseline characteristics for each group showed that the randomization resulted in an uneven distribution of participants characteristics as seen in Table 2. Participants who were more moderately impaired were randomized to the UC group compared to participants in the BTOT group. This is evidenced by mean scores on the 9-hole peg test which measures fine motor coordination and the number of participants who scored a 2 on the Modified

Ashworth Scale (MAS). Finally, the UC group scored lower on the baseline cognitive function represented by the mean MoCA screening score of 23.60 compared to 25.33 for the BTOT group (27.4=normal, 22.1=mild deficits)(Nasreddine, 2003).

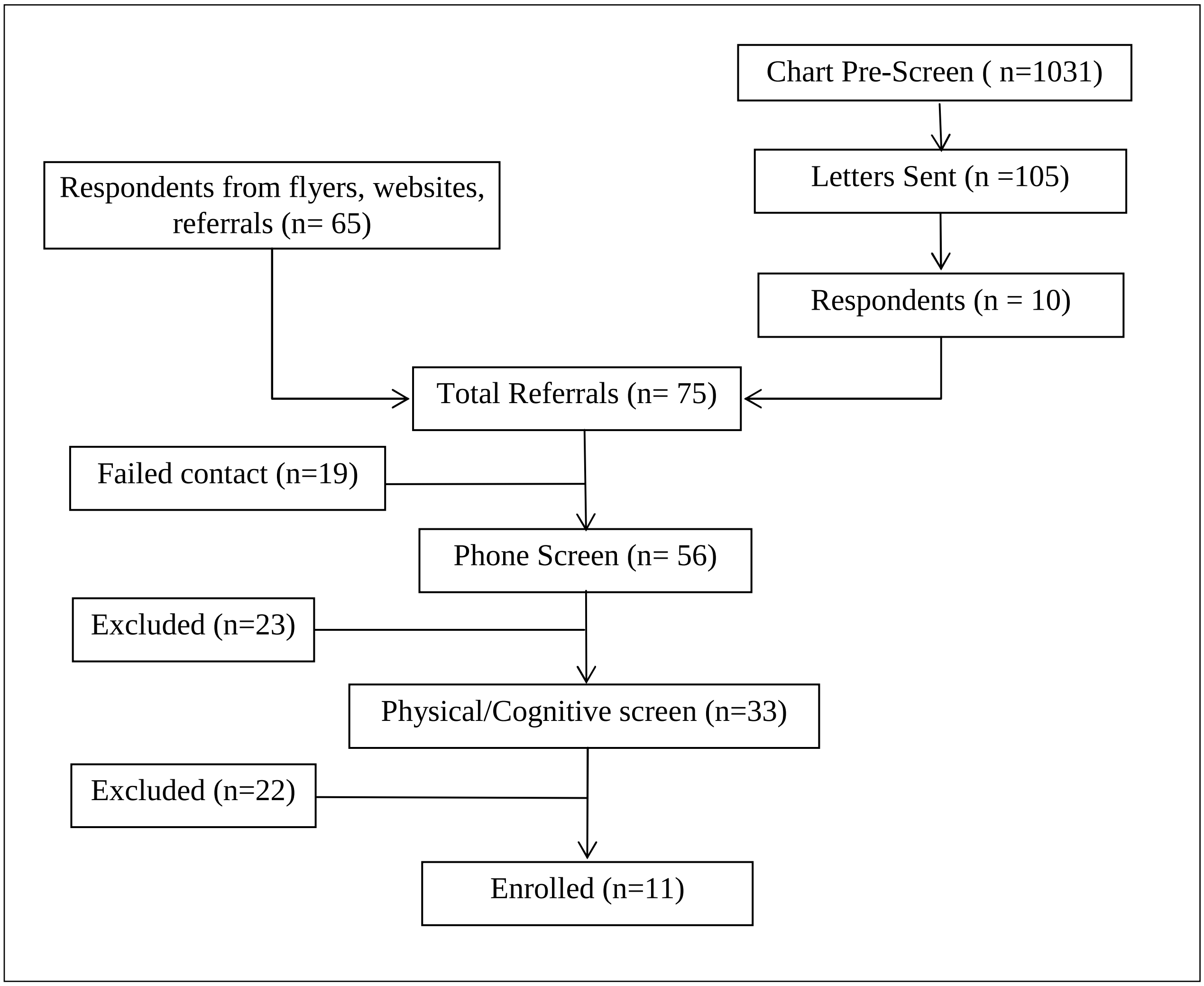

Figure 4. Recruitment results.

Usual Care Group Activities

Although the UC group did not receive formal intervention, they participated in a variety of activities that were part of their routine prior to study enrollment. Table 3 shows the range of activities which include no health maintenance activities to participation in an adult day program three days a week. One participant proceeded with pre-enrollment plans of decreased chore worker hours which increased her activities more than her normal routine.

Table 1. Participant Demographics

Characteristics	Usual Care (*n* = 5)	BTOT (*n* = 6)
Age range (Mean)	48-80 (61)	41-71 (57)
Male/Female	3/2	2/4
Right side Dominant, *n*	5 (100%)	5 (83%)
Paresis of pre-stroke dominant side	2 (40%)	2 (33%)
Side of brain lesions, (right/left)	3/2	3/3
Ischemic/hemorrhagic stroke (self-reported)	3/2	5/1
Mean years post stroke, (median)	13.6, (3)	7, (3)
History of >1 Stroke, *n*	0	2
Race		
White	3 (60%)	4 (66%)
Black	2 (40%)	1 (17 %)
Asian	0	1 (17 %)
Co-morbidities		
Heart/circulatory	4 (80%)	6 (100%)
Bone and joint	2 (40%)	3 (50%)
Respiratory	1 (20%)	4 (67%)
Diabetes	2 (40%)	1 (17%)

Table 2. Baseline Clinical Characteristics

	Usual Care	BTOT
9-hole peg test (mean)	107.6 s	84.0s
Score of 2 on MAS†	2/5 (40%)	0
MoCA*(mean)	23.6	25.33

†Modified Ashworth Scale, *MoCA- Montreal Cognitive Assessment

Descriptive Data

Comparing the percent changes (Table 4) and actual changes (Figure 5) between the pre-test to post test scores and pre-test to follow-up test scores within the BTOT group, all but one measure (functional ability on CAHAI) showed continued improvements four weeks after intervention. Comparing the pre-test to post test scores between the two groups, the BTOT group showed a change toward the positive direction for all outcomes while the UC group showed two measures toward negative direction (performance time and weight lifted on the WMFT) (Table 5 and Figures 6-8). However, there was variability in individual results for both groups. There were also greater magnitude of changes in the experimental compared to the UC group.

Table 3. Usual Care Participant Health Maintenance Activities

Usual Care Participant	Health Maintenance
1	None
2	Daily stretching, daily arm use in self-care
3	None (traveled)
4	Adult day program (3days/week)
5	Increased self-care activity (from decreased caregiver hours)

Table 4. Percent Change on Outcomes

Outcomes	UC	BTOT	
	Pre to Post (%)	Pre to Post (%)	Pre to Follow-up (%)
WMFT (Affected Limb)			
Performance time*	-11.5	-18.6	-34.7
Functional Ability	0.1	5.6	11.2
Grip Strength	13.0	19.1	32.5
Weight lifted	-33.9†	130.0	203.3
WMFT (Less Affected Limb)			
Performance time*	39.9†	-12.3	-10.0
Functional Ability	-0.1†	4.8	3.2
Grip Strength	3.6	5.9	12.6
Weight lifted	11.9	14.3	4.2
CAHAI (Functional Ability)	9.2	13.1	6.4
SIS Domains			
Strength	4.7	53	60.6
ADL	20.6	27.7	30.6
Hand	100	158	178.8
Participation	-34.2†	2.5	21.9

*negative score = faster (better), † decline in scores

The changes in the less affected limb were also measured for the WMFT. While the magnitude of change was smaller compared to the affected limb, a similar trend on the direction of change was found. All mean changes in the BTOT group were toward the positive direction while two scores on the UC group declined at post-test (Performance time and Functional Ability).

Participants reported increase in strength, ability to perform ADL, hand function and social participation after intervention and at follow-up testing as measured by the SIS. Of the four domains, hand function had the largest magnitude of change from pre to post-testing compared to the UC group.

Nonparametric Tests

The Wilcoxon Signed Rank test was used to compare within group differences in pre-test and follow-up test scores. Several comparisons reached statistical significance including the WMFT performance time (p = .028) (95% CI: -3.47 to -0.47), Functional Ability (p = .028) (95% CI: 17 – .60), grip strength (p = .028) (95% CI: 1.02 – 10.16), and weight lifted (p = .027) (95% CI: 2.50 – 7.00). The same was found for the SIS domain of Hand Function (p=.028) (95% CI: 22.5 – 57.50), and Participation (p=.028) (95% CI: 14.28 – 35.72). Within group comparisons were also tested for the less affected limb on the WMFT which showed statistical significance for performance time (p = .046) (95% CI: - 0.40 – .00) and weight lifted (p = .042) (95% CI: 0.50 – 8.00).

To test between group differences, mean changes between pre-test and post-test scores for the BTOT group were compared with the mean changes for the same period of time for the UC group using the Mann-Whitney U test. Two comparisons reached statistical significance, the WMFT functional ability (p = .010) (95% CI: -0.60 – -0.67), and the SIS Hand Function domain (p = .033) (95% CI: -0.45 – 0.00).

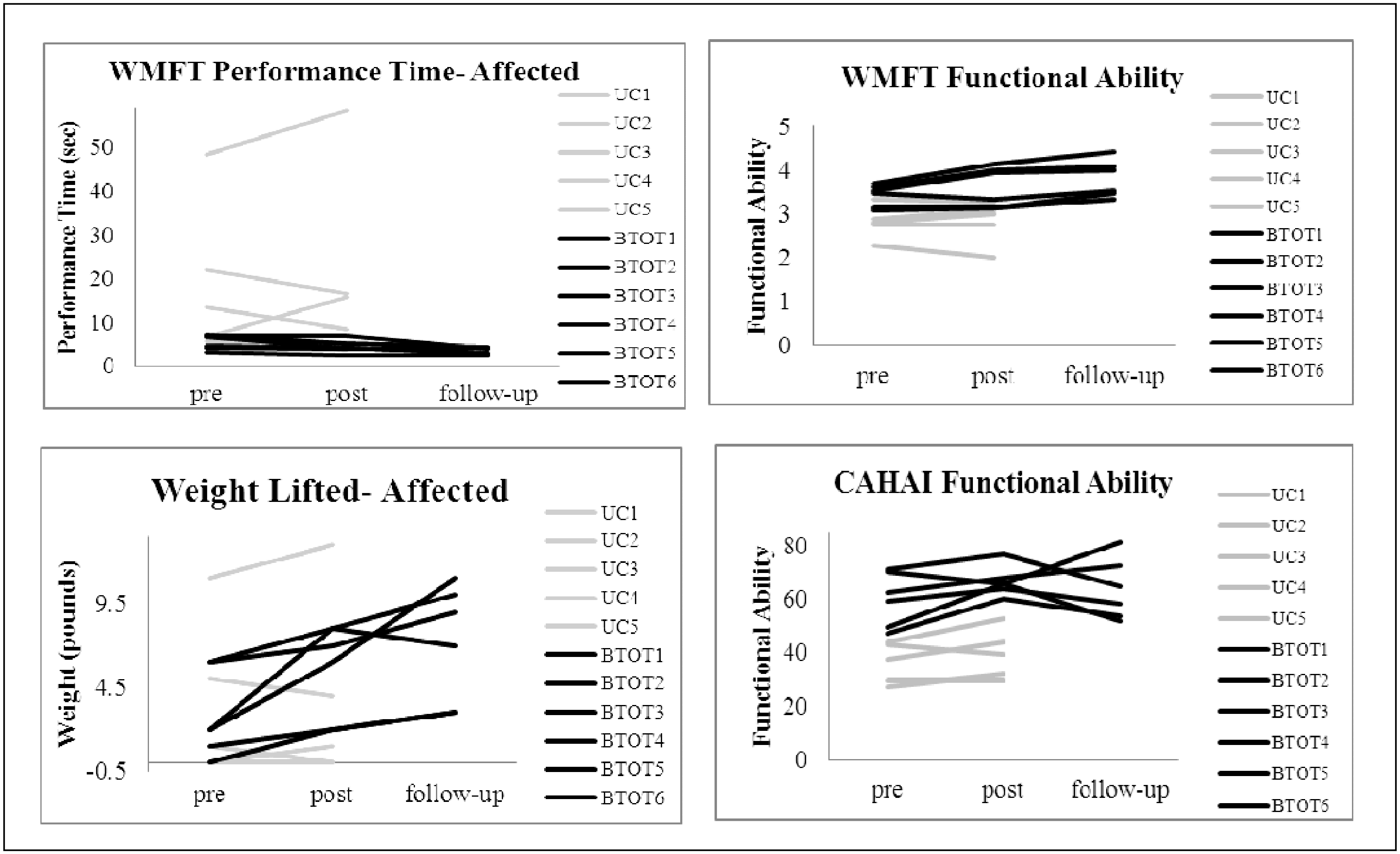

Figure 5. Results over three time points.

Black lines represent BTOT group scores and gray lines represent UC group scores. Lines going down in performance time indicate positive treatment effect (faster); lines going up indicate positive effects in all other outcome measures.

Table 5: Mean Scores Per Group

		WMFT (Performance Time in seconds)			WMFT (FA)*			CAHAI (FA)†		
		Mean	SD	Median	Mean	SD	Median	Mean	SD	Median
UC	Pre	19.2	17.6	13.5	2.8	.38	2.8	36.3	7.5	37.4
	Post	20.6	21.9	15.8	2.8	.49	3.0	39.6	9.4	39.6
BTOT	Pre	5.5	1.7	5.7	3.4	.25	3.5	60.1	10.2	61.0
	Post	4.4	1.5	4.1	3.6	.46	3.6	66.8	5.6	65.9
	Follow-up	3.4	.83	3.4	3.8	.42	3.8	63.7	11.5	61.5

*Functional Ability for Single Arm tasks

†Functional Ability for Bilateral Arm tasks

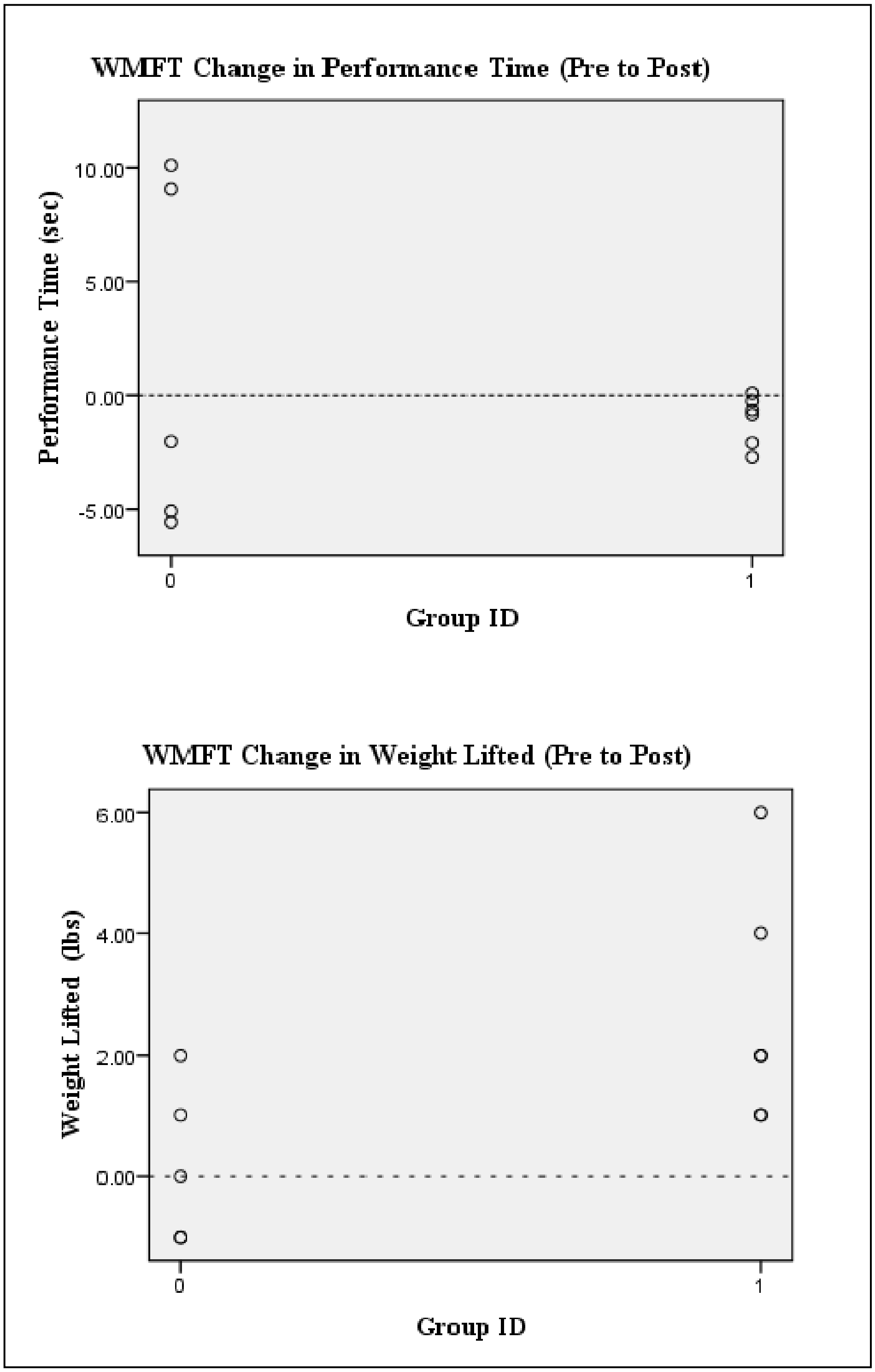

Figure: 6. Between-group comparisons of changes pre to post test scores on Wolf Motor Function Test.
UC group represented by 0 and BTOT group represented by 1.

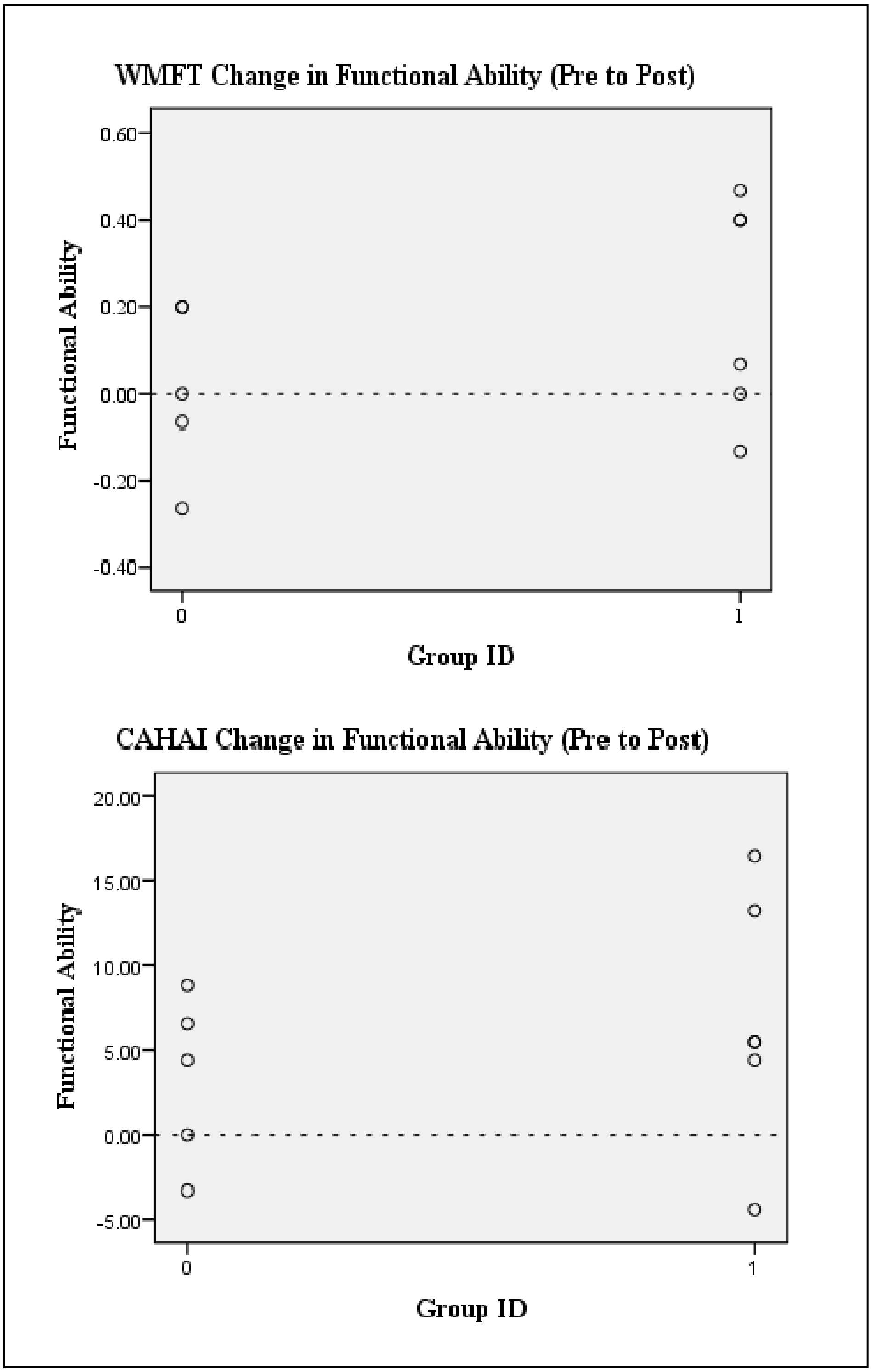

Figure: 7. Between-group comparisons of changes in functional ability pre to post test scores on Wolf Motor Function Test and Chedoke Arm and Hand Activity Inventory.

UC group represented by 0 and BTOT group represented by 1.

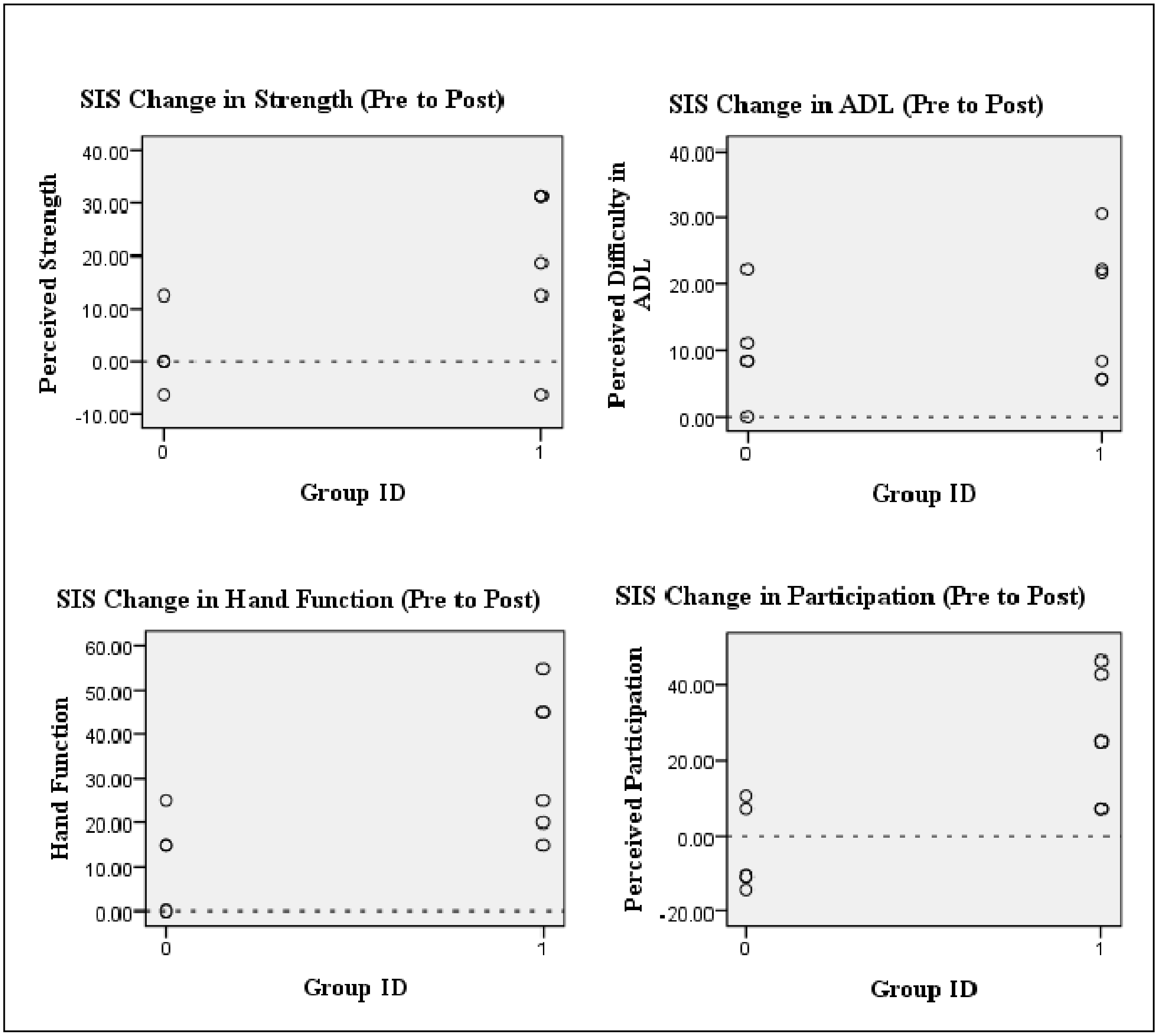

Figure: 8. Between-group comparisons of changes pre to post test scores on four domains of the Stroke Impact Scale.
UC group represented by 0 and BTOT group represented by 1. Darker circles indicate more than one data point.

Discussion

The aim of this pilot study was to explore the effects of Bilateral Task-Oriented Training in functional motor skills after stroke. Results suggest that the BTOT program has the potential to improve motor performance in individuals with mild to moderate impairment after chronic stroke. Findings also suggest that bilateral task-specific training when used in combination with behavioral strategies has the potential for lasting improvements in affected arm function; however, improvement in bilateral functional performance noted at post-intervention had limited lasting effects.

Measurable differences were found in the pre-test to follow-up test scores for the BTOT group with several outcomes noted to have continued improvements at follow-up testing. However, hypothesis testing comparing the UC and BTOT groups only showed significant differences in the WMFT less affected limb measure of FA and the SIS Hand domain. Potential reasons for progression at follow-up testing and limited between-group differences are explored.

Effects of Individualized Home Program

The primary mode of training used in the BTOT program was continuous practice of bilateral functional activities. This type of training was used in part of the research clinic training and in all task-practice for the home program. These training tools (ADL and instrumental activities of daily living [IADL]) were readily available for participants to utilize at home. The training time invested on establishing and reviewing individualized home programs at each session may have resulted in the participant's ability to continue on with their progress after completion of one-on-one training; resulting to continuing improvement four weeks after the intervention. The home programs consisted of providing structured practice in using both hands when not in the research clinic. After four weeks of training, the use of the affected arm at home and in the community was no longer a novel experience for the participants and may have eased the transition from supervised to non-supervised training. This may also be responsible for the measurable increase in health related quality of life measured by SIS.

Effects of Journal Writing

Keeping a journal was an essential component of the BTOT protocol. It served to track the participant's progress in using their affected arm in ADL and IADL, and provided a written record of the participant's successes and challenges in following their home programs. The process allowed the participants to practice careful observations of the amount of use and non-use of the affected limb. Some became skilled in self-monitoring their movements and level of frustration; leading to better choices of where and when they would attempt bilateral arm use (e.g. with pets, at social gatherings, in front of a loved one, etc.). Review of the journal at each session gave participants the practice of problem-solving with the researcher on how increase their frequency of arm use. This ranged from removing adaptations for one-handed techniques to creating a "safe" place at home to struggling with a new task and setting reasonable goals. It is possible that these skills in awareness of affected limb use and problem-solving allowed the participants to extend their training after clinic intervention were completed.

Neural Mechanisms of Bilateral Training

The BTOT program resulted in improvement in functional performance of the affected arm in single limb activities. This is consistent with other findings in bilateral simultaneous training paradigms (McCombe Waller & Whitall, 2008; Mudie & Matyas, 2000; Stinear & Byblow, 2004; Summers et al., 2007; Whitall et al., 2000). Several of these authors suggested the role of interlimb coupling in initiating and maintaining improvements in the affected limb. A study which examined three groups that used three different types of bilateral training methods (symmetrical, asymmetrical, and independent movements of the limbs) found improvements at post-testing to be less rapid for the group which used independent arm movements (Mudie & Matyas, 2000). The authors suggested that the neural network behind specific movements that were intact in the non-stroke hemisphere, were used as a template for cortical reorganization in the stroke hemisphere through a central control mechanism over the two hemispheres. They further suggested that, because two independent movements of the limbs use different motor maps, it was not recommended for training that would lead to immediate improvement in motor control of the affected limb. They also suggested that the complexity of movements in this method required longer training time to learn, but may be responsible for the continued improvements they noted after training had ceased.

Bilateral symmetrical movements were used in the BTOT protocol and may have played some role in the observed improvement. However, a larger part of training used bilateral independent and complementary movements. The results of the present study do not support the model of cortical re-organization described above. Despite the use of bilateral independent and complementary arm movements, improvements were noted in the affected limb in the performance of both single and bilateral limb movements. It is, however, true in this study that improvements were less rapid immediately after intervention compared to improvements noted in single limb motor skills four weeks after intervention. Longer training periods may be considered if complexity of movement is taken into account as an important function of motor learning and cortical re-organization. More complex movements are likely to have more complex neural pathways and may recruit larger neuronal network which can require higher intensity of training to re-establish. Furthermore, complex movements of the affected limb have shown increased activity (as measured by PET and fMRI) on several areas of the non-stroke hemisphere which has been associated with improved motor performance in the affected limb (Butefisch, Wessling, Netz, Seitz, & Homberg, 2008; Cramer & Bastings, 2000).

Most studies in bimanual training measure its effects on the affected limb in performing tasks requiring single limb coordination. The present study is the first to measure the contributions of the affected limb in tasks requiring bilateral coordination after intervention. Participants in the study showed improvements in single limb function beyond the training time; however, gains in bilateral limb performance were not maintained. A possible explanation may be in the role of interhemispheric inhibition (IHI), a process in which each hemisphere can limit communication between the two hemispheres to prevent interference on control of movements (Fling & Seidler, 2012). It is still unclear how IHI relates to motor recovery, but many agree that it is modulated by the demands of the task (Nudo, 2006). Unilateral task results in high IHI to prevent mirror movements in the opposite limb; however, bilateral movements require a higher coordination of the hemisphere resulting in a decrease in IHI in normal individuals (Fling & Seidler, 2012). As suggested by Mudie and Matyas (2000), it may be necessary to provide more training time to achieve lasting effects for bilateral arm use in functional activities.

These comparisons with previous studies in bilateral training may be limited by several factors. A large majority of existing bilateral arm training used only symmetrical and asymmetrical movement patterns. The few that used independent arm movements did not use coordinated movements of the two limbs to complete a common functional goal which is the primary type of repetitive bilateral movements used in the BTOT protocol. In addition, much of the previous studies used training devices that stabilized the pelvis and trunk in sitting and restricted the participant’s movements to arm motions. The present study is the first to examine bilateral training using whole-arm and trunk movements in enriched environments of an outpatient clinic, and extended training at home and the community.

Cognitive Demands of Tasks Requiring Bilateral Coordination

Despite initial rapid increases in the measure of functional ability in bilateral activities (i.e. the CAHAI), participants in the present study were unable to maintain these gains four weeks after intervention. It is of interest that, at the same time point, the same group demonstrated continued improvements in single-limb activities on the WMFT. This may be explained by the different attentional demands of bilateral activities. The WMFT used such tasks as picking up a pencil, bringing a can of soda to the mouth, and turning a key which allowed participants to give their full attention to the use of their affected limb to complete the task. However, on the CAHAI the affected limb is rated on its contribution to completing such tasks as opening a coffee jar, buttoning, drawing a line with a pencil and ruler, and pouring a glass of water. It is possible that the goal of completing the task takes priority over how the task is done whether with full or less engagement of the affected limb. The decreased score at follow-up testing may be indicative of this challenge.

Uneven Results of Randomization

Hypothesis testing did not show measurable differences between the BTOT and the UC groups except for the WMFT less affected arm measure of FA and the Hand Functional domain of the SIS. This may be associated, in part, to the uneven results of randomization. The treatment group included participants who had milder motor deficits or higher scores at baseline. Improvements in this group may have been less measurable than those in the UC group which included participants with more moderate impairments. Smaller gains in this group may have translated to larger changes in post-test scores.

Limitations

Generalizability of results is limited due to the small sample size. The challenges of recruitment in the stroke population for rehabilitation intervention studies have been well documented (Blanton et al., 2006). In recognition of these challenges, the inclusion criteria were relaxed (compared to the original CIMT study) to include individuals with less motor abilities (10 degrees of wrist extension), those who have had more than one stroke on the same hemisphere, and no upper limit on the chronicity of stroke. Despite this, and the use of a variety of recruitment strategies, the sample size was still limited. A larger sample size would likely reduce the chances of uneven baseline abilities between the groups which may have affected the results.

Although the rater was blinded to the group assignments and testing status to evaluate test videos, this blinding was only used in two of the three outcome measures. The occupational therapist who served as the interventionist also gave all the assessments which may have added some bias to the results. In addition, the absence of follow-up testing for the control group did not allow for between group analyses on the lasting effect of the BTOT program.

Conclusion

The BTOT protocol resulted in positive treatment effects in individuals with chronic stroke and mild to moderate motor impairments. It has the potential to improve functional performance of the affected arm in activities requiring unilateral and bilateral limb coordination. Results of the study warrants further investigation of the BTOT protocol with a larger sample size.

References

American Heart Association. (2008). Heart Disease and Stroke Statistics 2009 Update [Electronic Version]. *Circulation*, e76. Retrieved 7/6/2010 from http://circ.ahajournals.org/cgi/reprint/CIRCULATIONAHA.108.191261v1.

American Stroke Association. (2011, August 3, 2011). Healthy Living After Stroke. from www.strokeassociation.org/STROKEORG/LifeAfterStroke/HealthyLivingAfterStroke/Healthy-Living-After-Stroke_UCM_308568_SubHomePage.jsp

Barreca, S., Gowland, C., Stratford, P., Huijbregts, M., Griffiths, J., Torresin, W…. Masters, L. (2004). Development of the Chedoke Arm and Hand Activity Inventory: Theoretical constructs, item generation, and selection. *Topics in Stroke Rehabilitation, 11*, 31-42.

Barreca, S., Stratford, P., Lambert, C., Masters, L., & Streiner, D. (2005). Test-retest reliability, validity, and sensitivity of the Chedoke arm and hand activity inventory: A new measure of upper-limb function for survivors of stroke. *Archives of Physical Medicine and Rehabilitation, 86*, 1616-1622.

Blanton, S., Morris, D. M., Prettyman, M. G., McCulloch, K., Redmond, S., Light, K. E., & Wolf, S.L. (2006). Lessons learned in participant recruitment and retention: The EXCITE trial. *Physical Therapy, 86*, 1520-1533.

Bonaiuti, D., Rebasti, L., & Sioli, P. (2007). The constraint induced movement therapy: A systematic review of randomised controlled trials on the adult stroke patients. *Europa Medicophysica, 43*, 139-146.

Butefisch, C. M., Wessling, M., Netz, J., Seitz, R. J., & Homberg, V. (2008). Relationship between interhemispheric inhibition and motor cortex excitability in subacute stroke patients. *Neurorehabil Neural Repair, 22*, 4-21.

Corbetta, D., Sirtori, V., Moja, L., & Gatti, R. (2010). Constraint-induced movement therapy in stroke patients: systematic review and meta-analysis. *European Journal of Physical Rehabilitation and Medicine, 46*, 537-544.

Coupar, F., Pollock, A., van Wijck, F., Morris, J., & Langhorne, P. (2010). Simultaneous bilateral training for improving arm function after stroke. *Cochrane Database of Systematic Reviews, 4*, CD006432.

Cramer, S. C., & Bastings, E. P. (2000). Mapping clinically relevant plasticity after stroke. *Neuropharmacology, 39*, 842-851.

Fling, B. W., & Seidler, R. D. (2012). Task-dependent effects of interhemispheric inhibition on motor control. *Behavioural Brain Research, 226*, 211-217.

Hayner, K., Gibson, G., & Giles, G. M. (2010). Comparison of constraint-induced movement therapy and bilateral treatment of equal intensity in people with chronic upper-extremity dysfunction after cerebrovascular accident. *American Journal of Occupational Therapy, 64*, 528-539.

Kleim, J. A., & Jones, T. A. (2008). Principles of experience-dependent neural plasticity: Implications for rehabilitation after brain damage. *Journal of Speech Language Hearing Research, 51*, S225-239.

Lai, S. M., Studenski, S., Duncan, P. W., & Perera, S. (2002). Persisting consequences of stroke measured by the Stroke Impact Scale. *Stroke, 33*, 1840-1844.

Latimer, C. P., Keeling, J., Lin, B., Henderson, M., & Hale, L. A. (2010). The impact of bilateral therapy on upper limb function after chronic stroke: A systematic review. *Disability and Rehabilitation, 32*, 1221-1231.

Luft, A. R., McCombe-Waller, S., Whitall, J., Forrester, L. W., Macko, R., Sorkin, J. D. …Handley D.F. (2004). Repetitive bilateral arm training and motor cortex activation in chronic stroke: A randomized controlled trial. *Journal of the American Medical Association*, *292*, 1853-1861.

McCombe Waller, S., & Whitall, J. (2008). Bilateral arm training: Why and who benefits? *NeuroRehabilitation, 23*, 29-41.

Morris, D., Taub, E., & Mark, V. (2006). Constraint-induced movement therapy: Characterizing the intervention protocol. *Europa Medicophysica, 42*, 257-268.

Morris, D. M., Uswatte, G., Crago, J. E., Cook, E. W., & Taub, E. (2001). The reliability of the wolf motor function test for assessing upper extremity function after stroke. *Archives of Physical Medicine and Rehabilitation*, *82*, 750-755.

Mudie, M. H., & Matyas, T. A. (2000). Can simultaneous bilateral movement involve the undamaged hemisphere in reconstruction of neural networks damaged by stroke? *Disability and Rehabilitation*, *22*, 23-37.

Nasreddine, Z. (2003, January 5, 2011). The Montreal Cognitive Assessment. from http://www.mocatest.org/

Nudo, R. J. (2006). Mechanisms for recovery of motor function following cortical damage. *Current Opinion in Neurobiology, 16*, 638-644.

Page, S. J. (2003). Intensity versus task-specificity after stroke: How important is intensity? *American Journal of Physical Medicine and Rehabilitation, 82*, 730-732.

Page, S. J., Levine, P., Leonard, A., Szaflarski, J. P., & Kissela, B. M. (2008). Modified constraint-induced therapy in chronic stroke: Results of a single-blinded randomized controlled trial. *Physical Therapy*, *88*, 333-340.

Page, S. J., Sisto, S., Levine, P., & McGrath, R. E. (2004). Efficacy of modified constraint-induced movement therapy in chronic stroke: A single-blinded randomized controlled trial. *Archives of Physical Medicine and Rehabilitation, 85*, 14-18.

Stinear, J. W., & Byblow, W. D. (2004). Rhythmic bilateral movement training modulates corticomotor excitability and enhances upper limb motricity poststroke: A pilot study. *Journal of Clinical Neurophysiology, 21*, 124-131.

Summers, J. J., Kagerer, F. A., Garry, M. I., Hiraga, C. Y., Loftus, A., & Cauraugh, J. H. (2007). Bilateral and unilateral movement training on upper limb function in chronic stroke patients: A TMS study. *Journal of Neurological Sciences, 252*, 76-82.

Taub, E., Uswatte, G., King, D. K., Morris, D., Crago, J. E., & Chatterjee, A. (2006). A placebo-controlled trial of constraint-induced movement therapy for upper extremity after stroke. *Stroke, 37*, 1045-1049.

Whitall, J., McCombe Waller, S., Silver, K. H., & Macko, R. F. (2000). Repetitive bilateral arm training with rhythmic auditory cueing improves motor function in chronic hemiparetic stroke. *Stroke, 31*, 2390-2395.

Wittenberg, G. F., Chen, R., Ishii, K., Bushara, K. O., Eckloff, S., Croarkin, E.…Cohen. L.G. (2003). Constraint-induced therapy in stroke: Magnetic-stimulation motor maps and cerebral activation. *Neurorehabilitation and Neural Repair, 17*(1), 48-57.

Wolf, S. L., Catlin, P. A., Ellis, M., Archer, A. L., Morgan, B., & Piacentino, A. (2001). Assessing Wolf motor function test as outcome measure for research in patients after stroke. *Stroke, 32*, 1635-1639.

Wolf, S. L., Winstein, C. J., Miller, J. P., Taub, E., Uswatte, G., Morris, D.,…Nichols-Larsen, D. (2006). Effect of constraint-induced movement therapy on upper extremity function 3 to

9 months after stroke: The EXCITE randomized clinical trial. *Journal of the American Medical Association, 296*, 2095-2104.

Wu, C. Y., Chuang, L. L., Lin, K. C., Chen, H. C., & Tsay, P. K. (2011). Randomized trial of distributed constraint-induced therapy versus bilateral arm training for the rehabilitation of upper-limb motor control and function after stroke. *Neurorehabilitation and Neural Repair, 25*, 130-139.

Wu, C. Y., Lin, K. C., Chen, H. C., Chen, I. H., & Hong, W. H. (2007). Effects of modified constraint-induced movement therapy on movement kinematics and daily function in patients with stroke: A kinematic study of motor control mechanisms. *Neurorehabilitation and Neural Repair, 21*, 460-466.

CHAPTER 2

Qualitative Study

Participant Experience of Bilateral Task-Oriented Training After Stroke

University of Washington

Abstract

Participant Experience of Bilateral Task-Oriented Training After Stroke

Cecille Corsilles-Sy

Chair of the Supervisory Committee:
Janet M. Powell, PhD
Department of Rehabilitation Medicine

Objective: The aim of this study was to understand the participant's experience with Bilateral Task-Oriented Training (BTOT) and to identify barriers and facilitators that influence willingness to participate in this intervention approach.

Design and Setting: As part of a mixed methods approach on using the BTOT protocol, a qualitative study was conducted in an outpatient academic medical center in an urban setting.

Participants: Six participants randomized to the treatment group of the BTOT program. All participants had a stroke at least 6 months prior to study enrollment, had mild to moderate upper limb motor impairment, and scored ≥ 22 on the Montreal Cognitive Assessment.

Methods: Participants engaged in two sets of semi-structured interviews prior to and immediately following a 4-week intervention using the BTOT protocol. The interviews were audio recorded and transcribed verbatim. Coding and thematic analysis were carried out by a research team.

Results: A desire to "return to normal" was expressed in both pre- and post-intervention interviews. At pre-testing, "cautious optimism" and a desire for "learning new things" emerged as major themes. Upon experiencing the BTOT program participants identified having a "new awareness" of their affected hand and a "return to daily living activities using both hands."

“Challenges and rewards” with study participation, and encouraging (supportive) “responses from family and friends” were also recognized.

Conclusions: Participants found the BTOT program challenging to take on and follow, but useful in increasing awareness of how they were using their affected hand as an important change, and a starting point for increasing the use of their affected limb. Participants expressed direct effects of the program in the way they used their hands in daily activities, and found validation from family and friends of the changes they experienced.

Background

Stroke is a leading cause of serious long-term disability among adults with 50% of survivors continuing to experience hemiparesis after six months (American Heart Association, 2008). In the last 20 years, research in stroke rehabilitation has highlighted the positive effects of Task-oriented Approach in improving upper limb motor control (Higgins et al., 2006; National Stroke Foundation, 2005). This approach is based on a systems model of motor control which considers motor behaviors as a result of the interaction among the individual, the task and the environment and context in which the task was performed (Shumway-Cook & Woollacott, 2001).

In a systematic review by Timmermans, Spooren, Kingma and Seelen (2010) the authors operationalized the Task-oriented Approach by examining the different components of upper limb treatment that had been used in stroke research under the name of *task-oriented intervention,* and were associated with the largest positive treatment effects. Among the most commonly used training techniques found were functional task training, clear activity of daily living (ADL) goals, real object manipulation, total skill practice, frequent repetitions, and feedback on motor performance. These training techniques can require high engagement of stroke survivors in the intervention. Therefore, it is important to understand the how these training methods are received by stroke survivors.

This article presents the results of a qualitative study that aimed to understand the participants' experience of a novel stroke intervention, the Bilateral Task-Oriented Training (BTOT) program, and to identify barriers and facilitators that influence the willingness of stroke survivors to participate in such an intervention approach. This study used a mixed methods approach with randomized block repeated measures design and qualitative description. The quantitative study aimed to gather preliminary evidence for the effectiveness of the BTOT protocol designed to improve upper extremity function in individuals with chronic stroke and is fully described in Chapters 1 and 3.

Qualitative Description

Qualitative description is described by Sandelowski (2000) as a method that can offer a comprehensive summary of observations using language that is easily understood. By deliberate departure from conceptualization and philosophical abstraction, this method provides observations closer to the data without heavy interpretation. The BTOT protocol uses daily living activities in its treatment and relies on the reports of participants on their experiences outside the research clinic as a means to grade progression in training. Qualitative description provided a methodological framework that allowed presentation of data that highlighted the real experiences as reported by participants.

Methods

Research Design

This study is the qualitative section of a larger study that used a mixed methods approach. Two sets of interview questions were used to gather information from study participants who received the BTOT protocol. Narratives from the interview were used in a data analysis. The quantitative section of this research used a randomized control repeated measures design with one group receiving the experimental protocol (BTOT group) and the other receiving no formal intervention, but allowed to continue on their existing maintenance therapy program (Usual Care group [UC]). This intensive training was conducted in an outpatient clinic in an academic medical center.

BTOT Protocol

Bilateral task-oriented training used intensive training of repetitive bilateral upper limb movements. It included two types of motor skills training: (1) discrete tasks graded to approximate the participant's skill level and (2) continuous tasks such as with daily living activities salient to the participants. The protocol used individualized home therapy programs and behavioral strategies designed to increase the participant engagement in their recovery. The BTOT group worked one-on-one with an occupational therapist two hours a day, three days a week for four weeks.

The first treatment session was devoted to understanding the participant's specific goals, establishing plans for daily journaling on bilateral hand use, and creating a behavioral contract. Contained within the contract was a list of activities generated with the help of the participant, to represent his/her typical daily routine. By signing this contract participants agreed to incorporate re-learned bilateral arm use at home and in the community as often as possible. The contract was reviewed and updated periodically throughout the four weeks of intervention.

Each two-hour treatment session began with 30 minutes of reviewing the journal entries on bilateral activities performed when not in the clinic. Participants were encouraged to write comments on their experiences regarding the tasks they completed at home. This was used as a starting point of discussion on their progress, challenges, problem-solving for solutions, and exploration of options to increase opportunities for bilateral arm use when not in the clinic.

The remaining hour and a half of intervention was used for repetitive practice in bilateral arm-use. The two types of training used were: (a) discrete task practice (shaping) which included such things as moving blocks of wood, and moving weighted cane above shoulder level and (b) continuous task practice which included activities such as meal preparation, typing, and other functional tasks identified by the participant.

Participants

This study received approval from the University of Washington Institutional Review Board. The quantitative study recruited 11 participants. Six were randomized to the BTOT group and participated in this qualitative study, (see Table 1: for Participant Characteristics). Eligibility for study participation included mild to moderate upper limb impairment, at least 6 months post stroke and a score of ≥ 22 on the Montreal Cognitive Assessment which represents no more than mild cognitive deficits. Other inclusion and exclusion criteria have been fully described in Chapter 1.

The eligibility process began with a telephone screening followed by an in-person screening which tested the participant's level of motor impairment and cognitive skills. The consenting process included full disclosure of the intensity of training including the time commitment both in the clinic and away from the clinic. No compensation was provided for participation in the study and each participant was responsible for securing transportation to and from the research site.

Data Collection and Analysis

Methods for data collection and analysis used in this study were based on procedures described by King and Horrocks (2010). Two sets of semi-structured interviews were used. The first interview was conducted prior to quantitative testing and randomization, and asked about the participant's prior therapy experiences, and their expectations and concerns regarding their participation in the study. The second interview was conducted after intervention, but before

Table 1. Participant Characteristics

Participant	Gender	Race	Hemiparesis	Number of Years since last stroke
P1	Female	Asian	Left	24 months
P2	Female	White	Right	17 months
P3	Female	Black	Left	13 months
P4	Male	White	Right	18 years
P5	Female	White	Right	24 months
P6	Male	White	Right	26 months

quantitative post-testing to avoid influencing participant responses based on their perceived level of success in post-testing. The second set of interview questions asked about the participant's experiences of the BTOT program and the relative ease and difficulties with any part of the protocol. Researchers other than the interventionist conducted the second interview to allow candid responses to the questions. All interviews were audio recorded and transcribed verbatim.

Transcriptions were reviewed by two researchers for accuracy then read several times to develop familiarity before codes were identified. General codes were developed from the semi-structured interview questions and additional codes were identified in process of reading through transcriptions. Overall, 14 codes were identified with being 5 applied with the pre-intervention interviews and 9 with the post-intervention interviews. The coders initially worked separately and later met to establish agreements in the coded transcripts. A third researcher was brought in to assist in a few instances when consensus was not readily achieved.

Results

Based on the content analysis of the transcribed data from the pre and post intervention interviews, several themes emerged that will subsequently be presented. An overarching theme that was found in both the pre and post intervention interviews will be presented followed by pre-intervention themes, and concluding with post-intervention themes and sub-themes.

Return to Normal

The overarching theme which emerged in both pre and post intervention interviews was the participant's statements related to returning to normal. There was a preponderance of statements using the word *normal* in the transcripts. It was used to describe the changes in the way the participant used their affected limb in activities requiring bilateral limb coordination after the intervention, "So I had been putting on my clothes in a more normal way," (P1); "…put my sock over my foot and pull it on in a normal way," (P5). It described the importance of how loved ones perceived a participant, "…my partner has noticed that and she says that I am looking more like a normal person when I am putting on my shirts,"(P5). Positive emotions were associated with the use of both hands, "I was using my both hands in a sort of a natural way…and I liked that feeling very much. It made me feel like I was returning to normal," (P5). Participants related bilateral hand function with normal motor behavior prior to the stroke and many described returning to their normal in the way they described their return to using their affected arm, "…eating a meal … the old the old way," (P6), "…it's going back towards pretty much where it was before," (P2), and "…try to work it towards being more dominant again," (P6).

One participant decided to enroll in the study after she felt strong urging from family to continue working toward recovery. This reveals that the desire for returning to normal to be shared by family and friends of stroke survivors. “It looked interesting and… I had a lot of pressure from my husband,” (P2).

Normal was also used to describe activities in the home program that participants were able to return to as part of their daily routine.

> “…what I liked about the home program, was that it was practical, it was things that I would normally do, and, and it didn’t take a lot of time. You know, because that is one thing that I don’t have much—time.”(P1)

However, the same word was used to describe the challenge of creating a journal of daily arm use to be outside of their typical day and further highlights the desire for returning to normal routine.

> “I couldn’t remember those details. So I felt like I always had to stop what I was going to do, to do the logging… that was a little disruptive in my life, but it’s such a small disruption… it wasn’t difficult but it was just a little intrusive to have to stop …normal flow of activities in order to log…I think that probably was good for my brain.” (P2)

Cautious Optimism

A pre-intervention theme emerged from questions regarding expectations from their participation in the study. Many responded with hopefulness and cautious optimism, “…to get a little more use of this hand… that would be the biggest thing,” (P3); “I would really like for it to be a hundred percent back, what I am hoping is that I will improve” (P1); and “I’d like to get as close as I could to parity with my right hand.”(P5).

Some expressed more neutral expectations, “I mean I am not doing it with the hope that I am gonna become like normal again, but I think I will be better” (P2) and “Just my hand gets better. That’s about it; no expectations … I’ll just take what comes,” (P6).

All the participants reported engagement in various therapies within the first two years following their stroke including rehabilitation therapies in inpatient, outpatient, and skilled nursing facilities. Three participants also continued therapies through community programs such as health clubs, community day programs, and working with a personal trainer.

Participants’ descriptions of their previous therapies highlighted their expansive knowledge of therapeutic interventions and acquired expertise regarding the timeliness of the therapies they received. Consequently, participants reported that they would not have done so well with the BTOT program if it was offered early in their recovery when they had no movement in their arms. “I think in the hospital it was mostly they taught me to use my left hand because you know; the right arm …...it wasn’t ready to start working at all,” (P2) and “…the one for my hand, it was deep work but it just, my hand just would not respond to it.” (P3).

Learning New Things

Related to the expansive knowledge of participants regarding therapies to improve arm function, a second pre-intervention theme was found. Several participants expressed continuing efforts to find new therapies as a reason they decided to participate in the study, “…looking for new therapies,” (P1) “Because I thought I’d learn something new,” (P4). It was noted that one person came to be involved in the study with support from friends.

> “.a friend of mine… he was telling me about one of the books to read …which talks about constraint induced therapy and it talks about brain plasticity,” (P1).

New Awareness

The BTOT program included several intervention techniques designed to increase awareness of how stroke survivors use (or do not use) their affected limb (e.g., behavioral contract, daily journal, explicit feedback, increasing knowledge of performance). This resulted in many comments regarding new insight to motor abilities and awareness of previous arm use which has emerged as the first post-intervention theme; “Aha! I really do have firing in here. That made it a new insight,” (P4); “I was able to do things that I didn’t realize I could do…I have also been more conscious of what my left hand can do,” (P1); and “It’s helping me to learn how to use my left hand in different ways than I used to… I have to use it more, because I was not using it, hardly at all,” (P3). On participants describe an even deeper sense of awareness.

> “I became aware of a new feeling and I couldn’t rightfully describe what this was but just as I was using my hands I had a sort of an awareness - a new awareness that I was orchestrating things, that I was using both hands in sort of a natural way,” (P5).

Awareness of movements is an important starting point for changing motor behavior, “[the program] …has given me all kinds of new ideas and new perspective … that I didn’t have before,” (P4). This self-awareness was expressed by two people who used ‘self-talk’ to process the changes they experienced, “I am keyed into it now… I taught myself to start reaching with my left hand instead of starting with my right hand,” (P5) and “[asking herself]…could you have done this with your left hand? … I could not, before the study,” (P2).

Return to Daily Living Tasks Using Both Hands

The largest part of on-task training in the BTOT program was the practice of continuous task using daily living activities. In addition to the clinic training, the individualized home program used focused task-practice of at least two hours daily and an attempt by participants to use both hands as often as possible without compromising their safety. The participant's reflections on their experiences were filled with examples of how they changed the way they used their arms in daily living activities and is the second post-intervention theme (Table 2).

Table 2. Return to Daily Living Activities Using Affected Limb

Participant	Statements
P3	"…put my hair up. (My son was doing it for me before), take my shower using my left hand as much as I can and tie my shoes."
P1	"Previous to the study I did all my typing with my left hand" "…now it is really easy for me to button my coats,"
P2	"…doing the countertops with my right hand"
P4	[putting away dishes] "Now, I take two hands, and I don't have to go back and forth as much."
P6	"… I do a lot more with cooking…and just simple things like petting my cat. "I used to be all left handed with the [computer] mouse, now it's just grab with the right hand."
P5	"I can reach out and get the bowl… I can reach up and grab the cereal."

Challenges and Rewards of the BTOT Protocol

The third post-intervention theme emerged from question exploring barrier and facilitators of participation in the BTOT protocol. To maintain participant motivation throughout the training, the BTOT program used carefully graded activities to challenge motor skills while ensuring a measure of success at every level. Participants' reports showed that these motor training principles were at work, "There was no easy [tasks], I think everything was difficult to start with but some of the things became easier over time," (P2); "I think the more I did them, I got better. And that was really exciting for me… to see how I got better," (P1), and "I would say anything manipulating with the fingers was probably the most difficult but probably the most satisfying too, you know because by the end of it I could do it," (P2).

Activities were also chosen based on what is important and relevant to the participant. This motivational factor expressed by participants may have kept them working with their best effort, "I liked that it was very practical," (P5); and "…the time she got the paddle with the balls (because she knows that I dragon boat), that was so fun for me… and I really, I really appreciated that," (P1).

Participants reported role changes at home resulting from improvements in hand function and increased participation in activities, "Like… put my hair up, my son was doing it for me before… [He] doesn't have to as much for me as he was before," (P3) and "I hadn't cooked at all previous to the study…so; I am going to cook a little more now," (P1).

Thoughts on repetitive tasks. A post intervention sub-theme related information specific to repetitive task practice. Most participants did not mind the repetitive practice, but many found the discrete tasks challenging; "I respond well to that kind of tasks. And I didn't mind that they were repetitive," (P5), "My number of repetitions in the time period would go up and so I think it was good," (P2); "Yes, but now sometimes, like with these nuts and bolts… I couldn't do that. It was very frustrating for me," (P4); and "All the turning that I had to do with my left hand…that was the most difficult," (P6).

However, the most emphatic comments were associated with continuous task-practice based on their previous leisure pursuits, "Yes! Oh the drumming. Yes! Yes! Yes! Yes!" (P2) and, "I enjoyed the Tai-Chi and I really enjoyed the ball games…throwing the tennis balls, those were fun," (P5);

> "[Re: golf] Swing it gives the strength…but the right hand is for aiming. I had to really work hard … to forget about that left hand and concentrate on the right hand…and doing that, I got three holes in a row," (P4).

One participant summarized her positive experience with discrete and continuous task practice:

> "What I have liked about the study is that we have really done tasks. Because I felt like doing those things was helping me. It's not a complex direction. It's very linear and specific and it has a specific goal," (P5).

Thoughts on journaling. The use of journals received mixed comments and emerged as the second post-intervention sub-theme. Designed to increase awareness of arm use and accountability in their home program, participants were asked to write brief notes on when and how they used their hands and to provide some comments on their experiences. Some participants felt that journaling was very valuable, "…it's good for me to write down everything that I do…kinda keeps me focused on what I need to do," (P3) and "…the log showed me … made me aware of the use of my hands," (P5).

Participants were encouraged to write in their journal at least at mid-day and at the end of the day. However, some participants with memory deficits found this a challenge, "Sometimes that was hard, I would like, go to bed and I'd forget to do it so then the next morning… I would not remember," (P1); "I couldn't remember those details. So I felt like I always had to stop what I was doing to do the logging," (P5), and "Keeping the journal, that was probably the biggest task for me to do at home," (P2). One participant also felt that the 30-minutes in the beginning of each two-hour session devoted to reviewing the log and updating home programs would have been better used for on-task training."…the log …kinda cut into some of the exercise time," (P6).

Just as journaling has high cognitive and language demands (i.e., memory and attention to details) making it particularly challenging to some participants, some explicit visual and verbal feedback were difficult for one participant with more profound spatial deficits,

> "I don't seem to be able to hold it in my mind…if the directions are complex; I don't seem to be able to see an example and then to reproduce it on my own. So that was difficult…," (P5).

Responses from Family and Friends

The final post-intervention theme was derived from reports on comments by family and friends. Two participants lived alone and four lived with at least one family member. Many provided positive comments on how family and friends thought of their study participation, "I am now able to do this that I wasn't able to do before. And so they are really really excited for me… they were all really happy, (P3); "He said it's moving much better than it was before," (P2); "My partner says that she notices quite a lot of differences," (P5); and "She just noticed it and kinda nodded, subtle but noticeable," (P6). These comments validated what the participants reported about their progress and served to motivate them for continuing effort toward bilateral hand use after the study, "I plan to work on more at home cause I really do want my hand back," (P2), and "I think it will improve if I keep trying to do what I have to do," (P3).

Discussion

Results from qualitative description and analysis showed that participants and their family have the desire to return to normal in their arm function and their daily routine. Participants enrolled in the study to learn new things and were hopeful for improvements in arm function. The reported experience of participants with the BTOT protocol was positive with new awareness of their changing arm function and return to performing daily living activities using both hands. Participants found repetitive practice of both discrete and continuous tasks to be rewarding while journaling was reported to be valuable but challenging. Family and friends of participants were generally supportive of study participation and provided validation of the participant's changing arm function.

Content and thematic analysis revealed the potential difficulties of people with cognitive deficits to document bilateral arm function, experience of increased awareness of affected arm-use, reported increase in bilateral arm function for ADL, and positive experiences with repetitive task practice. Although there was a specific interview question regarding concerns in study participation, there was a general lack of concerns from study participants. Each of these participant experiences will be discussed in its effect on participant engagement in the BTOT protocol. Potential adaptations to maximize the benefits of the protocol for participants with varying impairments are also discussed.

Although journal writing was most often cited by participants as the reason for their increased awareness of arm function, it was also cited as the most challenging part of the BTOT protocol. As a new task, journal writing was not part of a daily routine and required new habituation. It also presented additional challenge for participants with memory and language deficits.

Awareness of affected arm-use may not be critically necessary for improvement in motor impairments, however; it is essential for planning and carrying out activities that could lead to positive changes in motor behaviors. For example, repetitive training set up by a therapist can result in improvements in performance time. However, the repetition needed to affect functional changes requires practice of the same movements in multiple contexts and environments

Shummway-Cook & Woollacott, 2001). Plans for carrying out such tasks require participant awareness of affected limb used and follow-though with plans in the absence of cues from a therapist. Therefore, alternatives to written journals to minimize the challenges of this task should be considered in future studies. Using a written checklist, computer-generated picture list, a video log, and audio recorders are potential options.

The use of activities of daily living (ADL) in the individualized home programs was well received and was effective in increasing the amount of time for bilateral hand training outside of the research clinic. There was a reported increase in using both hands in daily living activities which may be associated with the task-practice performed in the daily home program.

Repetitive task-practice was used for all discrete tasks and some continuous task-practice. The shaping process gave participants the opportunity to observe improvements in their skills and was reported to be a rewarding experience. The use of leisure activities salient to the participants may have provided additional motivation for full effort during the repetitive practice.

There were a limited number of concerns regarding study participation that were voiced by participants during pre-intervention interview. This was not surprising given that participants went through strict eligibility screening prior to enrollment in the study and therefore, were more likely to meet the demands of study participation. Many potential participants who could not commit to the time, endurance, and transportation demands of the study had chosen not to enroll. The low number of expressed concerns may also reflect the effectiveness of the consenting process used prior to study enrollment.

The study participants were highly motivated individuals. All completed different types and several sets of therapies prior to this study; however, they remained hopeful seekers of new therapies that may provide them with even small means of improvements. Many have made significant changes in their work and home schedules, and called-on their social support systems, for the opportunity to continue in their recovery. This level of motivation and desire for improvements is an important factor in their perceived success in the study.

Conclusion

Participants expressed a desire to return to normal in the way they used their arms. They described the BTOT program as challenging but rewarding. They found the activities used in training as practical and relevant which allowed some ease of follow through with their customized home programs There was a growing awareness of their capacity to use their affected limb through the training and journal writing, however, the latter was found to be the most challenging aspect of the treatment program. The BTOT program allowed for adaptation of instructions to be useful with individuals with mild cognitive deficits. Participants and their family noted improvements in the way participants used their affected limb in performing daily living activities.

References

American Heart Association. (2008). Heart Disease and Stroke Statistics 2009 Update [Electronic Version]. *Circulation*, e76. Retrieved 7/6/2010 from http://circ.ahajournals.org/cgi/reprint/CIRCULATIONAHA.108.191261v1.

Higgins, J., Salbach, N. M., Wood-Dauphinee, S., Richards, C. L., Cote, R., & Mayo, N. E. (2006). The effect of a task-oriented intervention on arm function in people with stroke: A randomized controlled trial. *Clinical Rehabilitation, 20*, 296-310.

King, N., & Horrocks, C. (2010). *Interviews in Qualitative Research*. Thousand Oaks, CA: SAGE Publications.

National Stroke Foundation: Clinical Guidelines for Stroke Rehabilitation and Recovery 2005. [Electronic Version]. Retrieved July 4, 2012 from http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/cp105.pdf.

Sandelowski, M. (2000). Whatever happened to qualitative description? *Research in Nursing and Health*, *23*(4), 334-340.

Shumway-Cook, A., & Woollacott, M. (2001). Theoretical Framework. In M. Biblis (Ed.), *Motor Control, Theory and Practical Applications* (2nd ed., pp. 1-127). Baltimore: Lippincott Williams & Wilkins.

Timmermans, A. A., Spooren, A. I., Kingma, H., & Seelen, H. A. (2010). Influence of Task-Oriented Training Content on Skilled Arm-Hand Performance in Stroke: A Systematic Review. *Neurorehabilitation and Neural Repair*.

CHAPTER 3

Bilateral Task-Oriented Training Protocol

Therapist Training and Patient Intervention	Rationale, Clinical Reasoning, and Clinical Decision Making

***Prior to using this training protocol, the therapist must have demonstrated general stroke competency which includes knowledge of the different mechanisms and types of stroke, medical and surgical management, co-morbidities, lateralization of brain function and related impairments, typical presentation of dysfunctions, parameters for training, precautions associated with severity and chronicity of stroke, risk factors, and your (the therapist's) institution's emergency medical procedures.*

Comprehensive Evaluation	
Medical History • Perform medical record screen and intake interview, determine location, size, and number of stroke(s), baseline function, co-morbidities, and potential barriers to recovery • Review general parameters for training: ▪ BP: systolic: 120-190 mmHg, diastolic: 50-105 mmHg ▪ SaO2: 92% or greater ▪ Max HR=(220-age)x .75 • Review risk factors and warning signs and know your institution's emergency medical procedures	• Knowledge of location and size of infarct or bleed will help identify associated impairments and direct more focused assessments • Co-morbidities can limit participation and may include precautions for intensive training • BTOT will involve physical exertion and can be stressful; maintain vital signs within parameters to avoid risk of injury, MD may give more conservative parameters for some patients • Previous stroke is a risk factor for repeat stroke
Social History • Determine strengths and potential barriers to adherence to intervention and progress towards goals; include education, work history, substance abuse history, health insurance/ funding source, and availability of social support	• BTOT uses activities that are salient to the patient and that build upon their experiences and interests. This method brings the patient's expertise into the therapeutic process and may increase engagement and investment into his/her recovery

BILATERAL TASK-ORIENTED TRAINING PROTOCOL

Therapist Training and Patient Intervention	Rationale, Clinical Reasoning, and Clinical Decision Making
Cognitive-Communication skill • Review relevant notes from speech language pathology and results of neuropsychological evaluation when available. Also review notes for recommended adaptations or compensation for cognitive dysfunction. Request consults if necessary. • Review presentation and management of fluent and non-fluent aphasia, auditory comprehension, speed of information processing, attention, memory, impulse control, and executive cognitive skills	• Complexity of instructions will be adapted depending on ability to attend, recall, comprehend, initiate, execute, and problem-solve • The BTOT protocol uses verbal communication as the primary mode of instruction. Providing feedback to increase patient knowledge of their performance (KP) is necessary for increasing awareness, and improving techniques. Encouragement for sustained effort during training are all provided through verbal means. Written expression is essential for the home program and creating and maintaining a journal. Assessment should, therefore, identify communication methods that will result to best comprehension and adherence to the protocol. Adaptations (e.g. audio recorder, video logs, checklist, and picture list) that will allow maximal participation for those with mild to moderate communication deficits should also be considered.
Sensory – Perceptual skills • Review consults notes from ophthalmology, optometry, audiology, neuropsychological evaluations if available. • If indicated perform visual screen (test for visual acuity, binocular vision, field of vision, and depth perception) • Test for pain and temperature sensation for upper limbs	• Object manipulation is highly dependent on perception of task objects, task demands, and the environment. Increasing challenge will need to match the patients' skills. • Visual, auditory, and tactile input influence motor response • Relearning bilateral techniques require understanding orientation, posture, and joint positions. • Adapt training within the motor learning capacity of individual.

BILATERAL TASK-ORIENTED TRAINING PROTOCOL

Therapist Training and Patient Intervention	Rationale, Clinical Reasoning, and Clinical Decision Making
Motor skills • Assess UE A/PROM, strength, coordination (single and bilateral-hand function), tone, joint integrity, postural alignment, pain, edema, synergistic vs. isolated movements, and symmetry of limb movements (Left/Right to determine “normal” movement). • Check for stability and flexibility of the trunk in sitting and ambulation, determine best mobility aid if needed, review physical therapy notes, request consultation if necessary • Note signs of complex regional pain syndrome (CRPS), shoulder impingement, subluxation, carpal tunnel syndrome (CTS) on both upper limbs.	• Graded training will begin at a level where patient will be successful; slow increase in complexity and challenge is dependent on baseline function • Identify specific motor skill areas to be addressed including foundational motor skills that need to be in place (postural control, proximal vs. distal control, limitations in endurance, and strength within specific range of motion • Training will need to be adapted to avoid aggravation of pain conditions; BTOT may be contraindicated for those with severe pain conditions, and conditions where repetitive movement training should be avoided (e.g. CTS, severe arthritis, etc.).
Psychosocial skills • New onset or baseline mood disorder including depression and anxiety; differentiate from disinhibited crying /laughing • Observe affect, level of motivation, frustration tolerance	• BTOT is an intensive training program that can cause frustration. Training leads to increased awareness of limitations in frequency of hand use and hand function (to promote behavior change). Adjust intensity of training based on motivation, emotional stability, and level of support available. Refer patient to rehabilitation psychology when necessary
Functional Assessment • Determine baseline vs. new level of functional skills in ADL, IADL, functional mobility, leisure, educational, vocational pursuits	• Identify functional goals that will direct choices of activities and environment that will be included in the training program • Identify if there are environmental and equipment adaptations that my be reinforcing one-hand arm use

Therapist Training and Patient Intervention	Rationale, Clinical Reasoning, and Clinical Decision Making

Background on Bilateral Task-Oriented Training (BTOT):

• BTOT is a restorative therapy specifically designed to improve upper limb motor performance following stroke. This training technique could be considered for restoring upper limb function following focal brain injury resulting in hemiparesis	
• Based on the constraint-induced movement therapy (CIMT), the BTOT protocol combines task-oriented approach, repetitive movement training, and behavioral strategies. It however, differs from CIMT that all training uses activities requiring bilateral hand coordination.	• Morris, et al., (2006) Characterization of CIMT
• Using the International Classification of Functioning, Disability & Health (ICF), the BTOT addresses improvements in *Body Functions & Structure* and *Activity* performance. Intervention can also address *Participation*, if training is specifically designed for upper limb use in the engagement of life roles at school, vocational, avocational, and/or leisure pursuits.	• Read: Ustun, Chatterji, Bickenbach, Kostanjsek, & Schneider (2003). The International Classification of functioning, Disability and Health: a new tool for understanding disability and health. *Disability and Rehabilitation*, *25*(11-12) 565-571. • Reference: World Health Organization, (2001). *International Classification of Functioning, Disability and Health.* Geneva: World Health Organization
• It is critical that this protocol be implemented under the framework of the Task-Oriented Approach and address goals toward performance of life roles (more to follow on Task-oriented approach below)	• BTOT is **not** a collection of bilateral activities that can be prescribed to any individual. It needs to be tailored to the individual's motor skills and functional needs. If implemented without an overarching framework for practice, intervention may lead to learning 'splinter skills' and not to functional improvements relevant to the individual.

BILATERAL TASK-ORIENTED TRAINING PROTOCOL

Therapist Training and Patient Intervention	Rationale, Clinical Reasoning, and Clinical Decision Making
• Minimum motor requirement: Some ability to generate movements is necessary to implement this protocol. The affected hand should have some beginning ability to stabilize objects for bilateral hand manipulation. • Depending on progression of recovery, the BTOT can be implemented in inpatient rehabilitation, home therapy, outpatient therapy, and community-based programs • BTOT is also not recommended for individuals with significant soft tissue shortening (contracture), spasticity, and severely limited endurance	• In the acute stages of recovery (up to 8-12 weeks), motor function may be severely limited, therefore, BTOT is *not* recommended at this stage. • However, acute training can include inclusion of affected hand by keeping it visible during all activities and allowing stabilization function as soon as possible • If one-handed training and adaptive equipment is necessary, create a treatment plan that will include progressive training to include both hands and progressive withdrawal of one-handed adaptive equipment. (One-handed training is necessary when there is persistent paralysis and significant dependence in basic ADL) • Severe spasticity and contracture limit all voluntary movements and therefore, should first be managed by other means before attempting BTOT

BILATERAL TASK-ORIENTED TRAINING PROTOCOL

Therapist Training and Patient Intervention	Rationale, Clinical Reasoning, and Clinical Decision Making
• Treatment time available for each patient varies depending on level of patient acuity, health insurance therapy coverage, and ability of the patient to engage in therapy. BTOT is best used in high-intensity training. The following treatment schedule is recommended (clinic + home program): ▪ Inpatient rehab: 1 hour 2x/day, 4 days/week and 1-hour group therapy 2x/week (until discharge) ▪ Home therapy: 1 hour 2x/week and 2-hour home program 4 days/week (for 6 weeks) ▪ Outpatient therapy: 1 hour 3x/week and group therapy 1-2 hour 2days per week (for 4-6 weeks) ▪ Community-based programs (community center/adult day health): group therapy 1-2 hours 5days/week, 2-hour home program 5 days/week • BTOT should be *integrated* in all interventions including training in eating, grooming, showering, dressing, toileting, cooking, cleaning, clothing care, handwriting, etc; if within the capacity of the individual (see Task Practice below).	• High-intensity training increases practice time, associated with increased motor performance. Increasing intensity of intervention can be achieved by collaborating with the patient in developing an extensive home program and participation in group therapy. • Recommendations are based on current reimbursement schedule for each service area. It also takes into account the time necessary to address other therapy goals often addressed within each service areas. • Although *massed* practice schedule is recommended, *distributed* practice has been found effective. Recommended reading: Page, S. J., Sisto, S., Levine, P., & McGrath, R. E. (2004). Efficacy of modified constraint-induced movement therapy in chronic stroke: a single-blinded randomized controlled trial. *Archives of Physical Medicine and Rehabilitation*, *85*(1), 14-18; Wu, C. Y., Chuang, L. L., Lin, K. C., Chen, H. C., & Tsay, P. K. (2011). Randomized trial of distributed constraint-induced therapy versus bilateral arm training for the rehabilitation of upper-limb motor control and function after stroke. *Neurorehabilitation and Neural Repair*, *25*(2), 130-139 • Community-based programs with a regular therapist can implement the BTOT in a group setting with assistance from aides. Programs that could not provide regular skilled evaluation by a licensed therapist should not attempt BTOT due to high risk of injury to patient.

BILATERAL TASK-ORIENTED TRAINING PROTOCOL

Therapist Training and Patient Intervention	Rationale, Clinical Reasoning, and Clinical Decision Making

The BTOT Protocol uses the principles of:

- ❶ ***Task-oriented Approach***
- ❷ ***Repetitive Bilateral Training***
- ❸ ***Behavioral Strategies***

❶ **Task-oriented Approach**	
• Based on *systems theory* of motor control • Defines motor behavior to result from the interaction of the individual's capacity, the task demand, and the context in which the task is performed	• Read: Shumway-Cook, A., & Woollacott, M. (2001). Theoretical Framework. In M. Biblis (Ed.), *Motor Control, Theory and Practical Applications* (2nd ed., pp. 1-127). Baltimore, MD: Lippincott Williams & Wilkins.
• <u>General assumption</u>: functional tasks help organize motor behaviors • Allow individuals to discover the most efficient movement patterns through repeated trials and feedback on motor performance as needed	• Read: Bass-Haugen, J., Mathiowetz, V., & Flinn, N. (2002). Optimizing Motor Behavior using the Occupational Therapy Task-Oriented Approach. In C. A. Trombly & M. V. Radomski (Eds.), *Occupational Therapy for Physical Dysfunction* (5th ed., pp. 481-499).

Therapist Training and Patient Intervention	**Rationale, Clinical Reasoning, and Clinical Decision Making**
• <u>Key components and principles of training</u>: ▪ *Motor Control principles:* based on the *systems theory*, the approach attributes the individual's actions to his motor capacity and cognitive-perceptual skills (i.e. attention, interpretation of objects and environments, motivation for action, etc.) ▪ Training is directed toward functional goals, use real objects, and as much as possible, should be conducted in real environment ▪ Training is highly individualized to reflect the unique goals and perspectives of the individual; and the capacity for skilled movements ▪ Repetitive training uses a series of discrete and continuous tasks practice, part and whole-task practice; and using simple and complex movement patterns ▪ Graded progression of training is designed to increase capacity for movements and/or refinement of movements while ensuring success in trials	• Read: Timmermans, A. A., Spooren, A. I., Kingma, H., & Seelen, H. A. (2010). Influence of Task-Oriented Training Content on Skilled Arm-Hand Performance in Stroke: A Systematic Review. *Neurorehabilitation and Neural Repair*

BILATERAL TASK-ORIENTED TRAINING PROTOCOL

Therapist Training and Patient Intervention	Rationale, Clinical Reasoning, and Clinical Decision Making
▪ *Motor Learning principles:* provide specific feedback in performance for ***explicit*** learning at early stages of learning; ensure level of success for each practice, train in various contexts using a random practice schedule. ▪ Once improved skill is noted (i.e. increased speed, precision and consistency in efficient techniques), move toward decreasing feedback for ***implicit*** learning. ▪ Adapt teaching techniques (explicit vs. implicit, verbal cues vs. visual or tactile cues, amount of cues, complexity of demonstration, etc.) depending on location of brain lesion(s) and associated deficits it language, spatial skill, vision, planning, attention to detail, and memory. ▪ Uses feedback on performance to direct behavior change, increase awareness of affected arm use, and provide feedback to encourage practice of most efficient techniques	• Read: Schmidt, R. A., & Lee, T. D. (1999). Motor Learning In *Motor Control and Learning: A Behavioral Emphasis* (pp. 301-460). Champaign, IL: Human Kinetics. • Rad: Halsband & Lange (2006) Motor learning in man: A review of functional and clinical studies. *Journal of Physiology, Paris, 99 (4-6), 414-424.*

Therapist Training and Patient Intervention	Rationale, Clinical Reasoning, and Clinical Decision Making

❷ **Repetitive bilateral arm training**	
• *<u>Consider the task</u>* ▪ Task analysis is critical to the use of the BTOT. Each task used for training should be analyzed to address improvement of impairment (i.e. increase shoulder abduction and ext. rotation), functional goal (safety and efficiency in meal preparation) and participation goal (serve meals Sunday night dinner for family)	• The use of real tasks is the primary tool of the BTOT intervention. The ability of the therapist to choose the right task is essential to facilitate motor behavior change
▪ Match the individual's capacity for movements with tasks that will provide *challenge* toward increasing bimanual coordination ▪ Training specificity- a principle of experience-dependent neuroplasticity indicate bilateral training should improve bilateral hand function ▪ Increasing challenge will drive experience-dependent neuroplasticity associated with cortical re-organization	• Read: Kleim, J. A., & Jones, T. A. (2008). Principles of experience-dependent neural plasticity: implications for rehabilitation after brain damage. *Journal of Speech Language Hearing Research*, *51*(1), S225-239
▪ Use task with increasing # of steps ◆ ***Discrete (Shaping) Task-practice***- use of short <u>discrete</u> tasks that are components of a continuous task. Discrete task has a definite beginning and end. Examples: putting away cans of food from counter to nearby cupboard/shelf	• Breaking down longer tasks to smaller steps accommodates for lower strength and endurance. It also allows for skilled practice in simpler tasks before increased skills training in component movements that are more complex • Discrete tasks also provide end points during training that allows a patient to receive feedback regarding performance • Shorter tasks allow progressive tolerance for activity (for those with limited endurance) and present less cognitive demands

Therapist Training and Patient Intervention	Rationale, Clinical Reasoning, and Clinical Decision Making
◆ ***Continuous Task-practice-*** practice of <u>continuous</u> tasks requiring a sequence of movements not typically repetitive (e.g. making a sandwich, folding clothes, and practice of Tai Chi). Some continuous task inherently include repetitive motion without need for additional set-up (e.g. playing catch in baseball, playing a drum and other percussion instruments)	• Use of continuous tasks are more challenging due to delayed feedback on results, less opportunity to receive feedback on performance and the need to sequence a series of successfully completed steps • Continuous task presents higher cognitive demands as functional activities have inherent goals (fold T-shirt, deal cards, etc.) which can be "distracting" for individuals who need to focus on using their affected limb. • Motor learning studies have found that practice of the *whole task* is necessary for transfer of learning (Schmidt & Lee, 1999)
▪ Analyze tasks and determine task demands. Complexity of movement includes not just the *index of difficulty* for the motor system, but also for sensory, cognitive, perceptual and psychological systems. The general progression for *difficulty* of movements is as follows: ◆ symmetrical ⟶ asymmetrical *reach*	• Knowledge of movement complexity is necessary when grading the task to make it easier or more difficult • Symmetrical bimanual movements create same target and timing for movements for both limbs, presenting less challenge than bimanual movements with incongruent targets. Symmetrical movement also taps into central representation of movement patterns, *interlimb coupling*, and strong *temporal coupling.* Symmetrical reach can be used to help *initiate* movements of hemiparetic limb • Read: Schmidt, R. A., & Lee, T. D. (1999). Coordination. In *Motor Control and Learning: A Behavioral Emphasis* (pp. 243-270). Champaign, IL: Human Kinetics

BILATERAL TASK-ORIENTED TRAINING PROTOCOL

Therapist Training and Patient Intervention	Rationale, Clinical Reasoning, and Clinical Decision Making
◆ asymmetrical reach → simultaneous incongruent targets	• Simultaneous movement to incongruent targets in functional task is a skilled movement requiring complementary movements of the hands. Example: opening a pill box requires hands to move simultaneously, but perform different functions to complete a unified goal
◆ rhythmic → variable speed	• Rhythm adds predictability to movements while variable speed requires more flexibility in initiation, maintenance and termination of muscle activation. Variability also adds challenge to attentional skills. Rhythmic bilateral movements should be considered for severe motor deficits when there is only limited generation of movements. Example: catching a ball rolling with random timing on a table surface is more difficult than stopping a rolling dowel with both hands
◆ single plane → multiple planes	• Movements in multiple planes require more proximal control of the trunk and limbs. Example: moving an object on the surface of a table vs. moving the object behind the patient and slightly above his shoulder level. These also increase demands on anticipatory movements of the trunk

Therapist Training and Patient Intervention	Rationale, Clinical Reasoning, and Clinical Decision Making
◆ single joint ⟶ composite joints	• The greater the number of joints to be controlled, the more difficult the task. Example: moving a therapy cone on a table with elbow supported on the table is easier than moving the same cone with an unsupported elbow • ADLs are complex tasks involving gross and fine coordination of multiple joints. Based on principle of neuroplasticity, specific training in ADL is necessary to increase skill in ADL performance. For severe motor deficits, consider slow graded combination of single limb motion and composite limb movements within functional tasks
Important ▪ The use of symmetrical, asymmetrical and simultaneous-incongruent hand movements should be practiced in random order while increasing time/practice on more complex movements	• Motor learning theory supports random practice trials for better transfer of learning. Complexity of movements is identified to allow the therapist to offer a variety of tasks that will challenge the patient while allowing successful trials. It is not meant to be used as a strict protocol for progression of training
▪ Increasing the number of repetitions of shaping tasks changes the task. Longer practice time pushes for more efficient movements. Increasing repetition can be done in combination with or in addition to changing the complexity of movements (above)	• Movements that are particularly subject to low repetitions are ones that challenge strength (anti-gravity movements), alternating movements, and movements requiring fine control. When better quality of movements is observed, slowly increase repetition to increase practice time. Improved quality of movements include increased symmetry, precision, accuracy, speed and control; with less postural compensation
▪ Increase the number of repetitions in some structured increments. Recommendation: increase by 15 % -20 % of last set	• The recommended % increase is used to provide structured/predictable increase in movements rather than a strict formula in this protocol

BILATERAL TASK-ORIENTED TRAINING PROTOCOL

Therapist Training and Patient Intervention	Rationale, Clinical Reasoning, and Clinical Decision Making
▪ Although some decline in quality of movement may be observed with increasing repetitions, make sure that this decline is temporary. If decline in quality of movement persist, decrease # of repetitions or add other tasks that practice similar movements	• Any change in the task demand (including # of repetitions) will affect quality of movement. The goal is multiple practice of efficient movements. This can be expected with increasing practices, hence, the need to increase repetitions
▪ Use task that will provide sufficient practice for weaker hand to serve as *stabilizer* and as *manipulator*. Both these functions are necessary to perform bilateral functional activities	• Depending on the task and the hand dominance of the individual, ADL often require bilateral hand coordination with each hand working simultaneously while performing different parts of the task. Example: cutting paper with a pair of scissors-one hand stabilized the paper, the other manipulates the tool
▪ Change weight and texture of materials to add challenge in modulating amount of grip/pinch to maintain object in hand ▪ Change size of objects- larger objects require larger hand opening, smaller objects require finer pinch	• Object affordance directs motor response. Changing the characteristic of the objects increases variability of responses necessary for motor learning
▪ Decrease the time to complete the task or use smaller targets to increase the demand for more precise movements	• There is a trade off between speed and accuracy (Fitts's Law). Adjust one or the other depending on the functional goal
• <u>*Consider the Repetition*</u> ▪ Repetitive training in bilateral hand function	• Motor learning studies have shown that practice improves performance • Increasing # of repetitions increases opportunities for 'problem-solving' of the nervous system to find efficient movement, increasing practice of muscle recruitment in specific firing patterns

BILATERAL TASK-ORIENTED TRAINING PROTOCOL

Therapist Training and Patient Intervention	Rationale, Clinical Reasoning, and Clinical Decision Making
▪ Count the maximum # of repetitions pt. can perform within a set period of time at initial trial ▪ Calculate 80% of the maximum # repetitions to get the beginning maximum repetitions for practice. ▪ Example: if at baseline the patient transfers 16 cans of juice [8 by each hand] from a low to a high surface; within 30 second, practice of this task will begin at 6 repetitions (8 max reps x 80%) within 30s	• There are no studies to show that repetitive training to improve motor control requires the use of "1 rep max" typically used in resistance training. It is used here only to provide a clear structure for grading task challenge and for progression of training. It is also used as a strong motivator for improving performance (see comments under behavioral strategies)
▪ Perform 3-5 sets for each practice adjusting to the patient's level of impairment. Use the quality of movements (symmetry, precision, fluidity and speed of movements) as criteria to decide total # of sets on baseline trial. Consistently use this set # for future trials	• Similar to # of repetitions, counting the # of sets is a way to provide clear progression of training. However, fatigue will result in degradation of the quality of movement and should be avoided. Allow practice of normal patterns of movement. Repetitive practice in synergistic movements can lead to increased fatigue and associated condition such as nerve impingement
▪ Use *massed practice* schedule for shaping tasks, so that for every 60 s practice set, give 30s to 40s of rest periods between sets	• Rest periods have been found to help in performance during practice when skills are in acquisition phase. In the case of stroke, restorative training is working to re-acquire previously learned movements but using different patterns of activation or possibly even using different parts of the brain to regulate movements • Recommended Reading: Schmidt, R. A., & Lee, T. D. (1999). Motor Control. In *Motor Control and Learning: A Behavioral Emphasis* (pp. 125-300). Champaign, IL: Human Kinetics

Therapist Training and Patient Intervention	Rationale, Clinical Reasoning, and Clinical Decision Making
▪ Continuous task-practice performed within the context of functional goals has inherent rest periods and therefore, a schedule of rest breaks is not necessary. However, observe patient for signs of fatigue or decreased quality of movement and give rest breaks when necessary	• Since there are no scheduled rest periods, monitor patient closely for fatigue as this can degrade performance and decrease transfer of learning, and/or motivation for intensive training
▪ Allow sufficient trials for patient to discover (problem-solve for) best movement option that will achieve functional goals with least energy consumption ▪ Provide explicit feedback necessary to assist patient in finding most effective and efficient movements	• Cognitive, sensory, and perceptual deficits may limit some patients from receiving intrinsic feedback during practice. Provide extrinsic feedback regarding *result* and *performance* during practice. Provide feedback between sets, adjusting the amount of information provided to patient's comprehension skills. Provide demonstration of movements for patients with language deficits
• *Consider the environment and context* ▪ Perform tasks in a high-stimulus environment to challenge attention skills (if typical for task)	• Principles of motor learning indicate need for practice of tasks in variable settings/context for transfer of learning • Performing tasks in its real environment provide contextual demands not available if the same task is performed in a simulated environment. Example: meal preparation in a kitchen)

BILATERAL TASK-ORIENTED TRAINING PROTOCOL

Therapist Training and Patient Intervention	Rationale, Clinical Reasoning, and Clinical Decision Making
▪ Use tasks that are meaningful to the patient ▪ Use tasks that are age appropriate	• Choosing tasks that are salient increases patient effort during training. This is particularly important when choosing tasks practice for home programs where little or no supervision is available. Example: (1) a musician will respond to task-practice which uses a musical instrument different than one that uses a carpentry tool; (2) although using different size balls are readily available in a clinic, an elderly woman may not have been working with this in recent years and may not respond with her best effort
▪ Practice the same movements in different context	• Application of similar movements in different environment increases variability of experience and will increase generalization to other environment. Example: alternating pronation-supination can be practiced in a card game on a table top as well as flipping pancakes in the kitchen
▪ Perform shaping tasks in the context of competition against time, or against the individual's previous 'score' (repetitions or sets) to vary motivational demands	• A sense of competition provides an environment that pushes for excellence in performance, but ensure a level of success

Therapist Training and Patient Intervention	Rationale, Clinical Reasoning, and Clinical Decision Making
❸ **Behavioral Strategies**	
▪ Designed to support patient in their effort, create a structure for continued use of the affected limb, and establish a new routine that will promote bilateral hand use outside therapies	• Sustained engagement of patients and dedication to changing routine is difficult especially in light of sometimes discouraging experiences of limited arm movements. These strategies are specific to targeting motivational components of motor behaviors
• *Create a Behavioral Contract* ▪ Formalize the role of the patient in their recovery process ▪ Establish functional goals with patient input ▪ Establish expectation from patient and therapist ▪ Establish the need for intensity of training ▪ Recognize the difficulty of changing routines	• It is necessary to change the typical patient-therapist relationship so that the patient is an equal partner in their recovery. The patient input is essential in choosing salient functional goals, continuing problem solving for increasing challenge in training, and to maintain intensity of intervention when not in the clinic
▪ Assist patient in creating a schedule of activities they can follow to establish a new routine of arm use	• This is especially important for patients with difficulty in executive cognitive skills. Listing options for activities help in planning, organizing and executing home program
▪ Identify which adaptations will be removed and which ones will be maintained	• One-handed tools (i.e. rocker knife, button hook, card-holders, etc.) should be removed from daily use with patient agreement • Examine/review environment for adaptations such as use of open shelves vs. drawers to store clothing, use of 'door knob converter' to create lever arm, etc. Remove those that will not present safety concerns

BILATERAL TASK-ORIENTED TRAINING PROTOCOL

Therapist Training and Patient Intervention	Rationale, Clinical Reasoning, and Clinical Decision Making
▪ Identify specific activities that will CONTINUE to require ONE-HANDED limb use	• Due to possible deficits in judgment, and for clarity it is best to identify activities that will require continued use of the stronger arm alone for safety reasons (i.e. lifting an infant, cooking at high temperatures, driving, etc.)
• *Create daily journal* ▪ Patient will document activities that he participated in at least once a day. Encourage writing down notes (or use of other recording device) on the full experience such as difficulties in performing the task, if he's moving better or faster, if the task is too frustrating, level of fatigue, pain, comments from family, etc.	• Documentation increases awareness to otherwise unnoticed behaviors. This will also serve as a means to provide feedback to therapist which is particularly difficult for patients with deficits in memory • Documentation also increase awareness of consistency in practice outside of clinic
• *Establish/ formalize support systems (when possible)* ▪ Increasing the intensity of bilateral arm use is created by extending training at home and in social situations. This can lead to a temporary increase in time for completing ADL, increase frustration; possible shame/embarrassment is using the weaker arm in front of others	• Recognizing the role of family/friends in the support they can provide increases chances of continuing bilateral hand use outside the clinic • Use of the limb at home and in social situations potentially embarrassing to patient and difficult for family to observe. Preparing the patient and their family that the struggle is a necessary and important part of training can help in transitioning to a routine of bilateral hand use
▪ Change in routine is often difficult. Establish ways to provide patients with feedback regarding progress in consistently using both hands in daily activities. Some patients may choose to have their family give them feedback immediately after observing 1-handed performance, while others may choose to receive feedback no more that 3x/day	• Although there is intent to use the hemiparetic limb, it is common for patients to revert back to using the less affected limb without their awareness. Family and friends are formally asked to provide the patient this feedback, with agreement from patient on how and how often this feedback is delivered, minimizing the potential for strain in relationship

BILATERAL TASK-ORIENTED TRAINING PROTOCOL

Therapist Training and Patient Intervention	Rationale, Clinical Reasoning, and Clinical Decision Making
• *Review progress and goals regularly* ▪ Create an environment of collaboration, mutual respect and trust ▪ Graph progression on repetition, sets, speed, or resistance when appropriate. This is particularly helpful for patients who benefit from visual feedback	• Providing 'progress reports' keep both patient and therapist on track toward established functional goals • Increasing accountability of patient for their training outside the clinic • Feedback on progress may increase patient awareness of 'how far' they have progressed and motivate for continued training • Visual feedback is a strong motivator for continuing effort in training

Summary

In 2010, the estimated stroke related costs in the US including health care services, medications, and missed days of work totaled 53.9 billion (Center for Disease Control, 2012). The cost associated with outpatient rehabilitation services 12 months after discharge from inpatient rehabilitation was estimated at $11,689 per person (Godwin, Wasserman, & Ostwald, 2011). While it remains to be seen how the Patient Protection and Affordable Care Act and the changing US healthcare system will affect service utilization of stroke survivors, the rising cost of health care services and the potential increased access to health services calls for the continued pursuit of better outcomes in stroke rehabilitation and, more specifically, better outcomes in restorative stroke therapies.

To affect outcomes in rehabilitation services means, among other things, using evidence-based interventions and interventions that will be accepted by patients and their support systems. The present study used a mixed methods approach to examine both the effects of the Bilateral Task-Oriented Training (BTOT) protocol as well as explore the experience of participants who received this intervention. To summarize the findings of this pilot study, the BTOT program was found to have the potential to improve hemiparetic arm function in individuals with chronic stroke and mild to moderate motor impairments. The participants endorsed the program for its role in helping them return to more “normal” arm use in activities of daily living (ADL) and for the use of “practical” goal-oriented activities that they were able to follow at home. This study brought new understanding of participant experience of the BTOT program and the effectiveness of bilateral arm training that uses a task-oriented approach.

Results of this study have led to more questions that can inform future research in bilateral training. The use of mixed methods research, the need for new outcome tools to measure changes in bilateral functional skills, and thoughts on future studies in training to improve bilateral motor control will be presented.

Value of Mixed Methods Approach

Associated with the increasing cost of healthcare is the shift of service provision from the hospitals and clinics to home and community-based programs. With this shift is an increase in expectations for a more collaborative relationship between patients and their therapists to move the patient towards functional recovery. This may include expectations for patients to follow through on therapy recommendations such as home programs. It is therefore important to examine how shared responsibility for intervention can be effectively managed by patients (and families of patients) with neurologic disorders. Mixed methods research may have an important place in rehabilitation research to achieve such collaboration (Kroll, Neri, & Miller, 2005).

Participants in the BTOT study were highly motivated individuals, and this may have contributed to positive responses to the intensive training schedule and goal-oriented task-practice associated with the protocol. On the other hand, this study also highlighted components of the program that were challenging for the participants (e.g., journal writing). Examining participant's perception of new therapies should be considered if we are to expect full engagement of participants in the interventions. It is recommended that new intervention techniques that rely heavily on patient adherence to the treatment protocol include an effort to understand how this therapy will be received by future patients. This understanding could permit adjustments to the protocol and potentially increase its successful translation to clinical practice.

Need for Instruments to Measure Bilateral Arm Function

There is a need for instruments that can measure changes in functional performance in bilateral activities. The Chedoke Arm and Hand Activity Inventory (CAHAI) used in this study, while validated for the stroke population (Barreca, Stratford, Lambert, Masters, & Streiner, 2005), was primarily designed as a clinical assessment (Barreca, Gowland et al., 2004). For this reason, the rating system was closely paired with the well-known clinical measure of functional independence, the Functional Independence Measure (FIM). This may have facilitated more intuitive use of the CAHAI rating system for clinicians who are familiar with the FIM, however, it created some challenges in scoring for research in motor control. The CAHAI uses a 7-point rating system where the score of 1 to 4 closely examined the contribution of the hemiparetic arm in performing bilateral functional activities including identification of key movements for object stabilization and manipulations which is extremely useful in measuring functional ability (Barreca, Stratford et al., 2004). However, the 7-point rating scale also includes a score of 5 when supervision is necessary due to safety concerns or when cues are provided due to impairments in cognition, and a score of 6 when adaptive equipment is necessary. A score of 7 is provided when the affected limb performs normal movements (without cues or adaptations). In this regard, the CAHAI aligns well with the FIM rating of 5 (supervision or cues required) and 6 adaptive equipment required). While these scores provide important clinical information regarding a patient's level of independence in completing a task, they do not provide additional information regarding recovery of motor control. In the present study, this rating system resulted in a bigger challenge in scoring 'improvements' from a score of 4 to a 7 and a reciprocal ease in scoring 'decline' from 7 to 4. An adaptation of the CAHAI that will rate only the functional ability of the arm may be more useful in research on motor control.

There is also a need to develop an outcome tool that can measure coordinated bilateral arm movements. An instrument that measures bilateral movement in symmetrical, asymmetrical, alternating, simultaneous, rhythmic, variable speeds, independent, and complementary movement patterns would be useful especially when each movement can be embedded in functional activities. Such an outcome measure may provide additional information for progression of bilateral training.

Future Studies

The field of study on neural mechanisms behind bilateral motor control has been in development since the 1960s. Recent innovations in neural imaging and recording techniques have resulted in an accumulation of new and pertinent neural models of bilateral motor control.

There are several investigations on the role of interhemispheric inhibition (IHI) and interlimb coupling in bilateral movements; however, our understanding of these mechanisms remains unclear. There is increasing consensus that bilateral movements should be considered as the primary mode of training in restoring bilateral and unilateral coordination (Mudie & Matyas, 2000; Stoykov & Stinear, 2010) as bilateral training affects both unimanual and bimanual coordination. There is also an impetus to understand the differences in the corticomotor processes behind symmetrical, asymmetrical, single and multi-frequency, and independent complementary bilateral movements (Daffertshofer, Peper, & Beek, 2005) as this could inform better progression and choice of training to maximize recovery. On specificity of training, there are new theories on lateralization of motor control suggesting that the left hemisphere may be responsible for multi-joint coordination and the right hemisphere for accuracy of end position of the less affected hand (Schaefer, Haaland, & Sainburg, 2009). Developments in these areas of research could help refine bilateral training protocol including the BTOT.

The application of task-oriented training is limited to individuals with sufficiently recovered motor control and may be considered as soon sufficient motor control is available. Based on the studies above, it seems that much *un-learning* of compensatory movement is necessary to build efficient motor maps through repetitive task-oriented training (unilateral or bilateral). Perhaps less repetition would be needed if new, but inefficient movements were more controlled in their development. Clinical trials using new theories on bilateral motor control should also be examined earlier during inpatient rehabilitation. Primate studies have found that brain develops adaptive connections to restore arm function during early recovery from brain lesions (Nudo, 2007); therefore, early in recovery may be the best time to create efficient neural connections that could serve as better foundation for later bilateral functional skills. Bilateral motor control studies in early stroke can lead to better outcomes for all other interventions applied for more chronic stroke, including the BTOT.

The results of this study indicate further investigation on the effects of the BTOT protocol in arm function after stroke. Future studies with larger sample size are necessary to better understand the applications of the protocol. There is a need to measure outcomes up to a year post-intervention to provide information on the long-term effects of the BTOT protocol. Studies that use neuroimaging techniques such as fMRI may help determine and measure if the protocol leads to changes in cortical activation patterns and could add to the increasing knowledge on neural mechanisms behind bilateral movement control.

This pilot study of the BTOT protocol provided support for using functional activities for bilateral training and for using individualized home programs to affect improvements in upper limb functional performance. The BTOT has the potential to offer meaningful interventions that can be made available through outpatient clinics and community-based health programs. The BTOT offers chronic stroke survivors hope for increased functional use of their arms and improved health-related quality of life.

References

Barreca, S., Gowland, C., Stratford, P., Huijbregts, M., Griffiths, J., Torresin, W., …Masters, L. (2004). Development of the Chedoke Arm and Hand Activity Inventory: Theoretical constructs, item generation, and selection. *Topics in Stroke Rehabilitation, 11,* 31-42.

Barreca, S., Stratford, P., Lambert, C., Masters, L., & Streiner, D. (2005). Test-retest reliability, validity, and sensitivity of the Chedoke arm and hand activity inventory: A new measure of upper-limb function for survivors of stroke. *Archives of Physical Medicine and Rehabilitation, 86*, 1616-1622.

Barreca, S., Stratford, P., Masters, L., Gowland, C., Lambert, C., Griffiths, J., … Torresin, W. (2004). Chedoke Arm and Hand Activity Inventory administration guidelines version 2. 2010, from http://www.cahai.ca/layout/content/CAHAI-Manual-English-v2.pdf

Center for Disease Control. (2012). Stroke Facts: Burden of Stroke. Retrieved August 3, 2012, from http://www.cdc.gov/stroke/facts.htm

Daffertshofer, A., Peper, C. L., & Beek, P. J. (2005). Stabilization of bimanual coordination due to active interhemispheric inhibition: A dynamical account. *Biological Cybernetics, 92*(2), 101-109.

Godwin, K. M., Wasserman, J., & Ostwald, S. K. (2011). Cost associated with stroke: Outpatient rehabilitative services and medication. *Top Stroke Rehabilitation, 18 Suppl 1*, 676-684.

Kroll, T., Neri, M. T., & Miller, K. (2005). Using mixed methods in disability and rehabilitation research. *Rehabilitation Nursing, 30*, 106-113; discussion 113.

Mudie, M. H., & Matyas, T. A. (2000). Can simultaneous bilateral movement involve the undamaged hemisphere in reconstruction of neural networks damaged by stroke? *Disability and Rehabilitation, 22*, 23-37.

Nudo, R. J. (2007). Postinfarct cortical plasticity and behavioral recovery. *Stroke*, *38*(2 Suppl), 840-845.

Schaefer, S. Y., Haaland, K. Y., & Sainburg, R. L. (2009). Hemispheric specialization and functional impact of ipsilesional deficits in movement coordination and accuracy. *Neuropsychologia*, *47*, 2953-2966.

Stoykov, M. E., & Stinear, J. W. (2010). Active-passive bilateral therapy as a priming mechanism for individuals in the subacute phase of post-stroke recovery: A feasibility study. *American Journal of Physical Medicine and Rehabilitation, 89*, 873-878.

VITA

Cecille Corsilles-Sy received her Bachelor of Science in Occupational Therapy from the University of Washington in 1992. She has practiced as an occupational therapist for 20 years with clinical expertise in neurorehabilitation. In 2012 she graduated with a Doctor in Philosophy in Rehabilitation Science from the University of Washington. Her focused studies were in three cognates: (a) Motor Learning and Motor Control (b) Teaching and Learning (c) Health, Culture and Community.