

MODIFIED CONSTRAINT INDUCED MOVEMENT THERAPY TO IMPROVE
UPPER EXTREMITY FUNCTION POST-STROKE IN CANADIAN
NEUROLOGICAL REHABILITATION

by

Alana Bethany Fleet

Submitted in partial fulfilment of the requirements
for the degree of Master of Science

at

Dalhousie University
Halifax, Nova Scotia
August 2013

© Copyright by Alana Bethany Fleet, 2013

TABLE OF CONTENTS

LIST OF TABLES.....	vi
LIST OF FIGURES.....	vii
ABSTRACT.....	viii
LIST OF ABBREVIATIONS USED.....	ix
GLOSSARY.....	xi
ACKNOWLEDGEMENTS.....	xiii
CHAPTER 1 INTRODUCTION.....	1
CHAPTER 2 BACKGROUND.....	4
CHAPTER 3 RESEARCH OBJECTIVES AND HYPOTHESES.....	13
3.1 STUDY 1: CIMT SURVEY.....	13
3.2 STUDY 2: SYSTEMATIC REVIEW.....	14
3.3 STUDY 3: MCIMT TRIAL.....	14
3.4 SUMMARY TO CHAPTER 3 AND TRANSITION TO CHAPTER 4.....	15
CHAPTER 4 STUDY 1: CIMT SURVEY.....	17
4.1 INTRODUCTION.....	17
4.2 METHODOLOGY.....	19
4.2.1 Participants and Survey Distribution.....	19
4.2.2 Survey Development and Composition.....	20
4.2.3 Data Analysis.....	23
4.3 RESULTS.....	24
4.3.1 Participants.....	24
4.3.2 CIMT Usage.....	26
4.3.3 Therapist-Related Factors and CIMT Use.....	32
4.3.4 CIMT Effectiveness and Barriers to Use.....	32
4.4 DISCUSSION.....	33

4.4.1 CIMT Use and Parameters	34
4.4.2 Therapist-Related Factors and CIMT Use.....	35
4.4.3 Barriers to CIMT Use.....	37
4.5 CONCLUSION	39
4.6 KEY MESSAGES	40
4.6.1 What is Already Known on this Topic.....	40
4.6.2 What this Study Adds.....	40
4.7 SUMMARY TO CHAPTER 4 AND TRANSITION TO CHAPTER 5.....	41
CHAPTER 5 SYSTEMATIC REVIEW	43
5.1 INTRODUCTION	43
5.1.1 Description of the Condition	43
5.1.2 Description of the Intervention (mCIMT)	43
5.1.3 How the Intervention Might Work	46
5.1.4 Why it is Important to do this Review	48
5.1.5 Objectives.....	51
5.2 METHODOLOGY	51
5.2.1 Criteria for Selecting Studies for Review	51
5.2.2 Methods for Identification, Data Collection and Analysis of Studies.....	53
5.3 RESULTS.....	56
5.3.1 Levels of Evidence.....	56
5.3.2 Study Demographics.....	57
5.3.3 Intervention.....	61
5.3.4 Outcome Measures	66
5.4 DISCUSSION	71
5.4.1 Effectiveness Across the Stages of Recovery.....	72
5.4.2 Interpreting the Level of Evidence: Limitations.....	72
5.4.3 Incorporating mCIMT in Clinical Practice	74
5.4.4 Conclusion.....	74

5.5	SUMMARY TO CHAPTER 5 AND TRANSITION TO CHAPTER 6.....	75
CHAPTER 6	STUDY 3: mCIMT TRIAL.....	77
6.1	METHODOLOGY.....	77
6.1.1	Groups and Subjects.....	77
6.1.2	Assessments.....	79
6.1.3	Primary outcome measures	79
6.1.4	Secondary Outcome Measures.....	80
6.1.5	Analyses.....	82
6.1.6	Therapy	84
6.1.7	Thesis Work.....	86
6.1.8	Other Methodological Considerations.....	91
6.1.9	Case Description.....	91
6.2	RESULTS.....	97
6.2.1	Primary Outcomes	97
6.2.2	Secondary Outcomes.....	99
6.3	SUMMARY TO CHAPTER 6 AND TRANSITION TO CHAPTER 7.....	100
CHAPTER 7	DISCUSSION	102
7.1	CASE STUDY FINDINGS	102
7.1.2	Study Limitations.....	103
7.2	CHALLENGES AND BARRIERS TO mCIMT IMPLEMENTATION.....	104
7.2.1	Patient Challenges	104
7.3	CONCLUSION	113
REFERENCES	115
APPENDIX A	Copyright Permission Contract	124
APPENDIX B	Survey Description.....	125
APPENDIX C	Reported Components of CIMT.....	127
APPENDIX D	Search Phases	128

APPENDIX E	Search Strategy	133
APPENDIX F	Baseline Assessment Measures.....	135
APPENDIX G	Task Database.....	137

LIST OF TABLES

Table 1	Distribution of respondent characteristics relating to therapist- and therapy-specific factors.....	25
Table 2	Source of knowledge compared across respondents' reported levels of CIMT knowledge presented as frequencies.....	31
Table 3	Level of evidence hierarchy of a study based on research design.....	56
Table 4	Level of evidence hierarchy for a body of knowledge.....	56
Table 5	Methodological quality evaluated for each study.....	58
Table 6	Subject demographic information and study design employed for each study included in the review.....	59
Table 7	Descriptions of treatment delivery and outcomes for each study included in the review.....	62
Table 8	Scores for the case study on tests performed at screening.....	92
Table 9	Baseline clinical assessments collected as part of routine clinical care at the acute stroke unit and rehabilitation centre.....	94
Table 10	Scores on the ARAT, MAL and Accelerometry before and after treatment for the case study subject receiving mCIMT.....	98

LIST OF FIGURES

Figure 1	Flow diagram of survey framework.....	22
Figure 2	Frequency of respondents identifying key components of CIMT.	27
Figure 3	Total duration (weeks) of use of CIMT.	28
Figure 4	Parameters for use of traditional vs. non-traditional CIMT).....	29
Figure 5	Most selected barriers to CIMT use.....	33
Figure 6	Pretest to posttest change scores for the Action Research Arm Test.....	68
Figure 7	Pretest to posttest change scores for the Fugl-Meyer Assessment.....	69
Figure 8	Pretest to posttest change scores for the Motor Activity Log (AOU).....	70
Figure 9	Pretest to posttest change scores for the Motor Activity Log (QOM).....	71
Figure 10	Photo of a mitt worn by subjects receiving mCIMT.....	81
Figure 11	X-, Y- and Z-axes to describe movement direction.....	83
Figure 12	Treatment timeline.....	84
Figure 13	Amount of time as reported by the compliance device.....	100

ABSTRACT

Recovery of upper extremity (UE) function after stroke is often incomplete. Incorporating evidence-based treatments early in rehabilitation can promote better recovery. One intervention, constraint induced movement therapy (CIMT), has been shown to promote UE recovery after stroke better than usual care. While research has examined CIMT effectiveness, there are gaps in the literature regarding how the therapy is being used and implemented, as well as reviews summarizing the evidence in support of any one CIMT protocol. Also, there is a need to examine the feasibility and effectiveness of CIMT in the acute and subacute stage of stroke recovery in the context of the healthcare system in which it is intended to be delivered. To address these gaps, this research examines the clinical utilization of CIMT, derives the level of evidence in support of its use, and lastly examines, in a preliminary manner, the effectiveness and feasibility of CIMT acutely post-stroke.

While CIMT appears within the literature to be a viable treatment option, little is known about how therapists use it, nor what therapist characteristics predict who would use it. A national survey of therapists working in neurological rehabilitation identified CIMT parameters of treatment and barriers to use (including therapist lack of knowledge and a lack of institutional resources). Methods to overcome barriers to CIMT use are addressed in order to increase its clinical application.

A systematic review of the mCIMT literature, one of the most researched protocols that follows a distributed practice schedule, showed an intermediate level of evidence in support of its use. Specifically, mCIMT appears to be effective at improving UE function, reducing impairment and increasing activity. While these treatment effects were observed across all stages of recovery, most of the literature is based on chronic stroke populations. Summarizing a body of literature related to a treatment is important for clinicians as it helps evaluate the evidence in support of the therapy, aiding with treatment decisions.

Lastly, preliminary findings of the clinical trial (based on a case study) support the effectiveness of mCIMT to improve UE function acutely post-stroke. Post-treatment, the subject receiving mCIMT demonstrated clinically significant improvements in UE function and activity, and maintained these changes at the 6-month follow-up. While the results may be promising, a number of challenges (for patients and therapists) to mCIMT implementation are discussed along with possible mechanisms to overcome them.

Identifying barriers to mCIMT use is a first step to developing administrative-, education-, and intervention-based solutions to improve clinical utilization. Solutions may be to alter the personnel delivering treatment, providing resource materials to inform clinical practice, and to investigate the minimum required components of mCIMT. If shown that mCIMT is effective and feasible to use in Canada, we can increase its use, in turn improving the recovery of patients who have had a stroke.

LIST OF ABBREVIATIONS USED

ADL	Activity of daily living
ARAT	Action Research Arm test
AACPDM	American Academy of Cerebral Palsy Developmental Medicine
AOU	Amount of use
CAOT	Canadian Association of Occupational Therapy
CI	Confidence interval
CPA	Canadian Physiotherapy Association
CIMT	Constraint Induced Movement Therapy
FM	Fugl-Meyer Assessment
fMRI	Functional Magnetic Resonance Imaging
ICF	International Classification of Functioning, Disability and Health
mCIMT	Modified Constraint Induced Movement Therapy
LOE	Level of evidence
MAL	Motor Activity Log
M1	Primary motor cortex
OT	Occupational therapy
PT	Physical therapy
QOM	Quality of movement
RCT	Randomised control trial
ROM	Range of motion
RTP	Repetitive task practice
UE	Upper extremity

US	United States of America
VAS	Visual Analogue Scale
WMFT	Wolf Motor Function Test

GLOSSARY

Activity:	individual performance of an action or task
Behavioural training:	one of the main components of mCIMT that may include the use of short- and long-term goals, identifying and modifying tasks appropriately to meet those goals, applying shaping principles to the tasks so patients can be successful in their performance, problem solving sessions to address challenges to affected limb use in ADLs.
Body function:	body systems' physiological and psychological function
Body structure:	anatomical body part (and components)
Disability:	an umbrella term applied to describe the negative interaction between a person's health condition as well as environmental and personal factors. It includes impairments, activity limitations and participation restrictions.
Effectiveness:	ability of a treatment to lead to recovery (as assessed through particular outcome measures)
Feasibility:	the degree to which a treatment can be implemented realistically in a particular environment.
Functioning:	an umbrella term applied to describe the positive or neutral interaction between a person's health condition as well as environmental and personal factors. It includes body function, body structures, activities and participation.

Impairment:	loss or significant deviation in body function or structure
Learned nonuse:	learning phenomenon involving conditional suppression of movement and consequently, nonuse of a particular limb
Participation:	involvement in all areas of life, of a person as a member of society
Repetitive task practice:	one of the main components of CIMT; It involves the repetition of meaningful functional activities.
Shaping:	behavioural technique applied to repetitive task practice; shaping refers to approaching a task using small, measurable progressions (which typically increase in difficulty level) in order to eventually complete/achieve the task as a whole. During shaping, subjects receive positive feedback related to their task performance.

ACKNOWLEDGEMENTS

There are a number of people I would like to thank who helped me complete my graduate studies. Firstly, I would like to thank the greatest supervisor in the world, Dr. Shaun Boe, for dealing with my own special brand of crazy. He went above and beyond expectations to support me through my Master's work and I would not have been successful without him. Thank you to my committee members, Dr. Gail Eskes and Dr. Marilyn MacKay-Lyons for their input and guidance. Additionally, a special thanks is extended to the members of the Laboratory for Brain Recovery and Function, in particular Marion Che, Janet Green and Megan Freeman, for their assistance with various parts of my thesis projects. I would also like to thank my family and friends for ensuring my sanity over the past two years.

Included herein is a study published in Physiotherapy Canada, reprinted with permission from University of Toronto Press (www.utpjournals.com).

CHAPTER 1 INTRODUCTION

Stroke is the leading cause of neurologically related death and disability in North America, affecting approximately 50,000 Canadian adults every year.¹ This figure is likely to increase due to the aging population and the escalating percentage of individuals with risk factors for stroke.² Unfortunately, full recovery after stroke is elusive; of those who survive their stroke, approximately two-thirds will experience residual neurological deficits that impair daily function.³ Specifically, recovery of upper extremity (UE) function is a major challenge for survivors of stroke, with only 5% regaining full function.^{3,4} As healthcare delivery improves to more effectively treat stroke acutely, more Canadians are living with its long-term effects. Functional limitations resulting from UE deficits negatively impact on performance of daily activities, resulting in decreased levels of physical activity and participation, and increased risk of further health problems.⁵⁻⁷

People with post-stroke impairments most often receive rehabilitation therapy to address any loss of function. For instance, an occupational or physical therapist may work with a patient to improve balance and UE function, address deficits in strength, and engage in sensory and gait re-training. Specifically, treatments used to address UE functional deficits as part of usual clinical care include a task-oriented approach to functional activities (whereby the patient practices particular motor skills), active and passive range of motion (ROM) exercises, stretching and strength training.⁸ Treatments that are considered part of usual care help with UE recovery after a stroke, but they have limited effectiveness. The limited effectiveness of the current, usual care practice is evident in the high rates of disability, prevalence of secondary disease, and incomplete

functional recovery of the UE observed after stroke.^{9, 10} To improve UE function after stroke and reduce the long-term disability related to poor functional recovery, therapeutic interventions that are both evidence-based and clinically feasible are needed. Increased use of evidence-based therapies in rehabilitation can improve functional abilities post-stroke, decreasing health care costs and greatly improving overall quality of life.

Constraint induced movement therapy (CIMT) is a treatment that has been shown to facilitate UE functional recovery post-stroke, with numerous studies showing it to be better than usual care.^{11, 12} CIMT combines (1) repetitive task practice (RTP) in conjunction with shaping, during which patients engage in meaningful functional activities with measurable progressions for which they receive positive feedback as the activities become increasingly more difficult; (2) behavioural training to keep patients motivated and engaged throughout the therapy; and (3) restraint of the unaffected UE in order to promote use of affected UE.¹³⁻¹⁵ A number of different CIMT protocols have been developed and applied in post-stroke rehabilitation, including a ‘traditional’ or massed practice approach and a modified or distributed practice approach.^{11, 12, 16, 17} Regardless of the protocol, all CIMT interventions include the 3 components listed above.

Although much research has been performed examining the effectiveness of CIMT as an intervention to promote UE functional recovery post-stroke, there are gaps in the literature that relate to how the therapy is being implemented and used, and the potential barriers to its use. With regard to implementation and use, there is a lack of literature summarizing the evidence in support of any one CIMT protocol. Lastly, there is a need to examine the feasibility and effectiveness of CIMT in the acute stage of stroke

recovery in the context of the healthcare system in which it is intended to be delivered.

Thus the focus of this thesis is to take the first steps towards addressing these gaps, including examining the utilization of CIMT in clinical practice, summarizing the evidence in support of one form of CIMT, and lastly examining, in a preliminary manner via a case study, the effectiveness and feasibility of CIMT acutely post-stroke.

CHAPTER 2 BACKGROUND

Derived from basic studies in animals, CIMT is based on principles of behavioural psychology. In the initial studies that led to the development of CIMT, Taub and colleagues were interested in studying the role of sensory feedback in movement and motor learning. In these studies, the UEs of a group of monkeys were deafferented in order to abolish the sensory pathways while preserving the motor pathways, thereby disrupting sensorimotor integration.^{18, 19} Consequently, the animals exhibited poor UE function; when the monkeys attempted to use the deafferented limb, they encountered aversive effects (such as movement inaccuracy) and, as a result, stopped using the limb. This pattern of behaviour was deemed “learned nonuse.”^{18, 19} In subsequent studies, Taub et al. explored the behavioural consequences of UE motor impairment and found that over time, learned nonuse could be overcome by restraining the monkeys’ non-affected limbs.^{13, 18} Thus, by forcing the use of their deafferented (affected) UE, the monkeys engaged their deafferented limb in daily activities (eg. grooming, feeding, etc.). Over time, increased use of the deafferented or affected limb ultimately led to improved limb function.^{13, 18}

An additional behavioural technique used to overcome learned nonuse and induce use of the affected UE is training and practice. Thus, while restraint of the unaffected limb helps to overcome learned nonuse, the characteristics of the tasks utilized were also determined to be important elements. Nudo et al. demonstrated that along with functional UE improvements, animals repetitively engaging in novel motor tasks after experiencing an ischemic infarct experienced plastic changes in the brain characterized by a task-dependent reorganization of primary motor cortex.²⁰ Repetitive training

produced shifts in the movement representation in primary motor cortex (M1), that related to the acquisition of new motor skills. Motor skill acquisition was indicated by the development of new movement patterns and increased efficiency of the tasks. Cortical representations (for the affected UE) reorganized to reflect this skill acquisition.^{21, 22} Notably, the neurophysiological and functional changes were observed when animals engage in novel, rather than simple repetitive tasks. Related studies examining simple, repetitive movements, showed no task-related changes in cortical representation of M1 after training, compared to pre-training.²² In comparing these two groups (task oriented training vs. simple repetition), it appears that “repetitive motor activity alone does not produce functional reorganization of cortical maps... Motor skill acquisition, or motor learning is a prerequisite factor in driving representational plasticity in M1.”²² Researchers examining CIMT have applied this evidence to combat learned nonuse, and have employed conditioned-response techniques that allow animals to learn and practice different movements.^{13, 18} While some improvements in UE function were observed, these movements were not generalized to natural settings, prompting the application and use of an additional behavioural training technique.¹⁸

The third behavioural technique investigated by Taub et al. to overcome learned nonuse is termed ‘shaping’. Shaping is based on operant conditioning principles and approaches a particular behavioural goal in small, incremental steps to promote success.^{13, 23} When shaping principles were applied to UE task practice, animals learned to use their UE not only in training situations but also in their normal environment as well.^{24, 25}

Learned nonuse of a limb was upheld as a learning phenomenon involving the conditioned suppression of movement.¹³ Since the learned nonuse mechanism is essentially behavioural, Taub et al. reasoned that it should be independent of the source of injury and applicable to other conditions, so long as the appropriate reinforcements exist early after injury. This led to investigation into the appearance of learned nonuse in humans, and research into overcoming the phenomenon.^{13, 19, 26} Learned nonuse can be distinguished from poor recovery in humans by comparing a person's functional ability with their observed UE activity levels. If a person is able to perform a particular movement using their affected UE when directed, but chooses not to use that limb in practice during everyday activities, then learned nonuse is present.

Given the results observed in this series of animal-based studies, coupled with the observation of learned nonuse in individuals with UE functional deficits, Taub and colleagues applied the principles observed in the animal studies to a human population. The principles were applied primarily towards people with stroke-related UE functional deficits. Initially, studies investigated UE interventions involving restraint^{27, 28} and task training²⁹ separately. In 1993, Taub et al. combined restraint and task training³⁰; however, the goal of this particular study was to over train the affected UE so the tasks were given without any explicit training program (thus excluding any shaping principles). While subjects who received the restraint and training program experienced greater functional gains compared to a control group (receiving therapy to focus attention on the affected UE), Taub looked to maximize these improvements further. In animals, shaping and restraint had independently been used to overcome learned nonuse and improve motor function in a deafferented UE. Since restraint and task practice (without explicit

training) had been combined successfully, it was reasoned that adding shaping techniques could provide complementary, if not compounded, results.¹³ Thus, in addition to wearing a restraint on their unaffected UE, Taub and colleagues had subjects engage in RTP (including shaping) using their affected UE.¹² Shaping was established as a key principle that contributed to the functional gains observed in these human studies.^{13, 15} Together, restraint, RTP and behavioural techniques (including shaping) comprise CIMIT.

The original protocol for CIMIT was performed over a 2-week period and combined restraint of the unaffected limb for 90% of waking hours with functionally oriented RTP using the affected UE.^{11, 12} The task practice component (which applies shaping principles to task training) was performed 6 hours each weekday over the 2-week treatment period. Additionally, the therapy incorporated behavioural training techniques to help patients transfer any functional gains into real world activities.^{11, 31, 32} Behavioural training includes the application of shaping principles, as well as the use of a behavioural contract to promote therapy compliance, goal-setting setting, and problem-solving sessions to address challenges subjects may face in their ADLs. Many different studies have examined the original CIMIT protocol and support its effectiveness to improve UE functional outcomes post-stroke. A large randomized controlled trial (RCT), the EXCITE trial, followed 222 subjects 3-9 months post-stroke. Subjects who engaged in CIMIT demonstrated statistically and clinically significant improvements in UE function and use compared to the control group of usual care.¹¹ The control group received ‘usual and customary care’, ranging from no treatment to regular therapy [including the applications of orthotics, occupational (OT) and physical (PT) therapy home care, day treatments or hospital outpatient programs].³³ Specifically, subjects in the CIMIT group

demonstrated greater improvements compared to the control group pre-post on the Wolf Motor Function Test (WMFT), a laboratory based measure of UE motor ability (function). Importantly, subjects in the CIMT group also had greater gains in the amount of use of the affected UE compared to the control group, as measured using the Motor Activity Log (MAL), a measure of activity and subjective scale of real world limb use.¹¹

In addition to observing functional improvements in the affected UE, studies have demonstrated parallel neuroanatomical and neurophysiological changes in the brain post-CIMT treatment. Liepert et al. (2000), using transcranial magnetic stimulation, mapped the ‘hand area’ of primary motor cortex in subjects with chronic stroke before and after a 12-day CIMT intervention. Results of the study demonstrated that after CIMT, the representation of the hand area in primary motor cortex significantly increased in size.³⁴ Furthermore, cortical representation for the hand shifted to neighbouring regions in motor cortex, indicating a functional alteration in the somatotopic organization of motor cortex. The cortical changes paralleled increases in UE activity (tested using the MAL) observed after the CIMT intervention. This study provided evidence that CIMT can induce plastic anatomical and functional brain changes corresponding to improved UE movements.

Since Taub’s initial work, a number of different CIMT protocols have been developed and applied in post-stroke rehabilitation that differ from the ‘traditional’ or massed practice approach including a modified or distributed practice approach.^{11, 12, 16, 17} Other protocols have also been described that are variations of these two approaches (for example see ³⁵⁻³⁷). The most studied of these distributed practice approaches is termed ‘modified Constraint Induced Movement Therapy’ (mCIMT) whereby therapy sessions are performed for 30 minutes, 3 times per week over a 10-week schedule.^{17, 38, 39} Despite

differences in the frequency and overall duration of treatment, similar principles are utilized across the spectrum of these CIMIT protocols, including mCIMIT. The original CIMIT approach as developed by Taub offers a compressed, but intense treatment. While the original protocol has been demonstrated to be effective, anecdotal evidence suggests that it can be difficult to implement clinically due to its high resource demand (eg. time, availability of therapists, and equipment). Contrary to CIMIT, mCIMIT distributes therapy sessions over a longer duration with a considerable reduction in treatment time and thus a decreased use of resources. As highlighted above, treatment in mCIMIT is performed over 10 weeks and the UE is restrained for 5 hours/weekday (rather than 90% of waking hours under the original protocol).¹⁷

Despite the use of a distributed practice schedule and thus reduced intensity of the overall treatment, some evidence suggests that mCIMIT is better than usual care and as efficacious as CIMIT in promoting UE functional recovery post-stroke.^{16, 40-42} Page et al. (2008) demonstrated that mCIMIT was superior not only to a control group receiving no therapy but also to a dose-matched program of usual care in improving UE function in chronic stroke.¹⁷ The usual care group received a time-matched rehabilitation program consisting mostly of proprioceptive neuromuscular facilitation (PNF) techniques emphasizing functional tasks, as well as stretching and compensatory techniques when needed. The duration, frequency and content of usual care sessions were consistent with typical therapy provided to patients at the same stage of recovery.¹⁷ There were significant improvements for the mCIMIT group in both functional UE performance and amount of use, that mirrored changes observed with the original CIMIT protocol. Specifically, subjects in the mCIMIT group had greater improvements on the Action

Research Arm test (ARAT), an objective measure of UE function, and on the MAL.¹⁷ As with the traditional CIMT protocol, neuroanatomical and physiological changes have been demonstrated to underlie the clinical treatment effect observed with mCIMT. Szaflarski et al. (2006) used functional magnetic resonance imaging (fMRI) to demonstrate use-dependent cortical re-organization that occurred with mCIMT in subjects with chronic stroke.⁴⁰ Subjects who exhibited increases in affected UE function and use correspondingly demonstrated shifts in their brain activation patterns to the subcortical and cortical structures in the affected hemispheres. The neuroimaging results were positively correlated with the observed functional improvements in the affected UE.

Almost exclusively, mCIMT studies have applied the treatment to a sub-acute and chronic patient population. However, there is considerable evidence suggesting that initiating rehabilitation in the acute stage of recovery post-stroke is associated with greater functional outcomes.^{43,44} A large, multi-centre prospective study of stroke recovery in the United States (US) demonstrated that introducing rehabilitation early, including engaging patients in higher level activities such as UE functional tasks, was related to greater functional improvements and shorter length of stay in in-patient rehabilitation.⁴⁵ Page et al. performed one of the few studies examining the use of mCIMT in the acute stage of stroke recovery. The study demonstrated that mCIMT administered acutely (<14 days) post-stroke was associated with significantly greater improvements in UE function (observed with changes in ARAT scores) compared to a control group receiving dose-matched traditional UE therapy.¹⁶ Given the potential benefits of early intervention, a more in-depth investigation of acute mCIMT outcomes is warranted to confirm these findings in a larger and more diverse sample population.

Testing the effectiveness of mCIMT when initiated in the acute stage of stroke recovery can take advantage of the body's heightened responsiveness to treatment and further establish evidence in support of mCIMT.

To date, most of the evidence supporting the effectiveness of CIMT has been generated in the US, and as such it is not known how the treatment will translate into the publically (vs. privately in the US) Canadian healthcare system. Given limited resources within the publically funded Canadian healthcare system, implementing the original CIMT protocol may prove challenging.^{9, 10} mCIMT may be a more appropriate alternative to use clinically because the distributed practice schedule aligns better with the amount of therapy time allocated per patient; typically a patient receives one hour each of OT and PT per weekday with additional interdisciplinary therapies (eg, speech language pathology) as indicated.⁸ Since mCIMT has not been researched in Canada, it is not known if the treatment is being used clinically or if there are barriers associated with the treatment that prevent it from being implemented clinically. Given the lack of research about CIMT use in Canada, it is not understood to what degree CIMT is being implemented in Canada and if so, how often it is being used and in what form (eg. a traditional vs. modified protocol). Furthermore, it is not known if mCIMT is an effective and feasible treatment when implemented in an acute post-stroke patient population within the Canadian healthcare system. Thus, the purpose of my thesis is to investigate these research questions through a national survey of therapists, a systematic review of mCIMT, and preliminary findings of a clinical trial investigating mCIMT in an acute and sub-acute stroke rehabilitation setting. If mCIMT is shown to be effective and feasible to use in this patient population in Canada, we can increase its use and improve the recovery

of patients who have had a stroke. The overall personal, social and economic burden of stroke on Canadians can be minimized with improved rehabilitation and corresponding level of functional UE recovery.

CHAPTER 3 RESEARCH OBJECTIVES AND HYPOTHESES

Given the lack of studies examining mCIMT in Canadian healthcare, coupled with a lack of knowledge about CIMT utilization in rehabilitation, the focus of this research includes: 1) identifying utilization patterns and barriers related to CIMT use in Canadian neurological rehabilitation; 2) establishing the level of evidence (LOE) in support of mCIMT to promote UE recovery post-stroke; and 3) examining the effectiveness and feasibility of mCIMT to improve UE function of patients with stroke.

3.1 STUDY 1: CIMT SURVEY

Despite evidence of CIMT effectiveness, questions abound regarding its clinical feasibility.⁴⁶⁻⁴⁸ Prior articles have highlighted that despite CIMT being recommended as a treatment for UE hemi-paresis in national stroke care guidelines, it is not being implemented as standard practice for stroke care when appropriate.^{49, 50} Specifically, studies have identified several barriers to the implementation of CIMT, including resource intensity and therapist-/patient-related factors.

Given the lack of studies examining CIMT utilization, empirical knowledge is needed regarding clinicians' perceptions, actual application, and perceived barriers to its implementation. This knowledge would inform research regarding the clinical feasibility of CIMT and continuing education initiatives to facilitate its translation into clinical practice. Thus, the purpose of this component of my thesis work is to explore utilization patterns of CIMT amongst occupational and physical therapists practicing in adult neurological rehabilitation in terms of frequency of use, parameters of treatment and

barriers to use. Additionally, respondent characteristics are examined to identify factors related to CIMT utilization. Hypotheses related to study 1 include:

1. Despite evidence related to its effectiveness, CIMT is not routinely being used as a primary treatment for UE hemi-paresis by occupational and physical therapists practising in adult neurological rehabilitation
2. When CIMT is being employed clinically, it is not being delivered as outlined in the literature in terms of time of delivery and the key components of treatment.

3.2 STUDY 2: SYSTEMATIC REVIEW

The second component of this thesis evaluates the evidence in support of a specific CIMT protocol. Specifically, the goal is to establish the LOE for a modified version of the therapy (mCIMT). Performance of a systematic review such as this one is important as they summarize and evaluate the literature. Summarizing a body of literature related to a treatment is important for clinicians as it helps them to evaluate the evidence in support of the therapy, aiding with treatment decisions.⁵¹ Thus, the primary objective of the review is to investigate the LOE in support of mCIMT to promote UE recovery post-stroke. The data results generated by outcome measures that assess pre- to post-treatment changes in UE function, impairment and real-world use will be used to evaluate treatment effectiveness.

3.3 STUDY 3: MCIMT TRIAL

The last component of this thesis investigates, in a preliminary manner, the effectiveness and feasibility of a mCIMT protocol in an acute stroke population in

Canada. While much work has supported the effectiveness of various CIMT protocols in American healthcare settings, limited work has been done in Canada. Executing a clinical trial examining mCIMT will demonstrate if it is still effective when applied in a publically funded healthcare system given the constraints on resource availability and the capacity to deliver the treatment in its evidence-based form. Additionally, the trial examines if the therapy is feasible to implement into usual Canadian clinical practice. Specifically, the objectives of my thesis work within the trial focus on the development and execution of the mCIMT intervention. The purpose of my research work will be to explore initial findings based on a single case study. To this end I will identify and discuss key features and challenges of task development and mCIMT implementation by means of the case study. Additionally, I will investigate the preliminary results to identify potential trends relating to mCIMT's effectiveness and feasibility as a treatment option in Canada. The hypothesis for Study 3:

1. Subjects engaging in mCIMT therapy will demonstrate greater UE functional recovery compared to those in the dose-matched control group. These improvements will be observed in terms of UE function (Action Research Arm test), amount of use (accelerometry and Motor Activity Log) and quality of use (Motor Activity Log)

3.4 SUMMARY TO CHAPTER 3 AND TRANSITION TO CHAPTER 4

An important first step to evaluating mCIMT and to understanding its potential impact was to establish if it is being used in Canadian rehabilitation and if so, how it is being used and what the potential barriers to use are. To address this first step, the first

project was a national survey of therapists investigating current practices as they relate to CIMT use in Canada. This work, presented in the following chapter (4), has been accepted for publication and is currently 'in-press' (Appendix A). The manuscript presented in Chapter 4 has not gone through the entire editorial process at the time of this thesis completion. Thus, the official version of the article will be published in *Physiotherapy Canada* 2014; 66(1).

CHAPTER 4 STUDY 1: CIMT SURVEY

4.1 INTRODUCTION

Stroke is the leading cause of neurology-related disability and death in North America, affecting approximately 50,000 Canadian and 795,000 American adults each year.^{1, 52} Recovery of upper-extremity function is a major problem for survivors of stroke, with only 5% regaining full function.³

CIMT is one intervention that has been shown to facilitate UE functional recovery in a particular subset of patients after stroke. Derived from basic studies in animals, CIMT combines RTP with shaping¹³ during which participants engage in meaningful functional activities with measurable progressions for which they receive positive feedback as the activities become increasingly more difficult; behavioural training (e.g., behavioural contract, problem solving to address barriers to affected limb use); and restraint of the unaffected UE.^{13, 53} Several CIMT protocols have been developed, including a “traditional” or massed practice approach, a “non-traditional” or distributed practice approach,^{11, 13, 17, 41, 54} and variations on these two approaches.^{35, 37} Traditional CIMT involves 6 hours/day of RTP combined with restraint of the unaffected UE for 90% of waking hours over 10 consecutive weekdays (i.e., therapy sessions do not occur on weekends).^{11, 13} Conversely, modified CIMT, a non-traditional protocol, involves RTP for 30 minutes/day, 3 times/week, combined with 5 hours/day of unaffected UE restraint, over a 10-week period.^{17, 41} Regardless of the specific protocol used, the client is generally required to have a degree of movement in the affected UE that, at a minimum, includes 10° of active wrist extension with 10° extension of the thumb and at least two

fingers.^{11, 17} The need for this level of function and the corresponding capacity for active engagement in the treatment limits the number of people for whom CIMT is an appropriate intervention.⁵⁵

Despite evidence of CIMT's effectiveness for people who meet the criteria for treatment,^{11, 17, 56-58} questions abound regarding its clinical feasibility.⁴⁶⁻⁴⁸ Prior articles have highlighted the fact that, even though CIMT is recommended for treating UE hemiparesis in national stroke care guidelines,⁸ it is not being implemented as standard practice for stroke care.^{49, 50} The authors identify several barriers to the implementation of CIMT, including resource intensity and therapist- or patient-related factors. In a study examining therapists' opinions of CIMT, Page and colleagues reported that 74% of occupational and physical therapist respondents (n = 85) believed that their institutions lacked the resources necessary to provide traditional CIMT.⁴⁶ Our research team's observations suggest that CIMT is not routinely used in clinical practice and that when it is used, not all CIMT components are implemented.

Given the lack of studies examining use of CIMT, empirical knowledge is needed on clinicians' perceptions, actual application, and perceived barriers to implementation. This knowledge would inform research into the clinical feasibility of CIMT and educational initiatives to facilitate its translation into clinical practice. The purpose of this study, therefore, was to explore usage patterns of CIMT among occupational and physical therapists practising in adult neurological rehabilitation in terms of frequency of use, parameters of treatment and barriers to use. We also examined respondent characteristics to identify factors related to CIMT use.

4.2 METHODOLOGY

Our study employed a non-experimental, quantitative research design using an online survey (Opinio version 6.5.1, ObjectPlanet Inc., Oslo, Norway). The study received approval from the Capital District Health Authority Research Ethics Board.

4.2.1 Participants and Survey Distribution

A total of 588 occupational therapists and 1968 physical therapists who are licensed to practise in Canada and who practise in adult neurological rehabilitation were invited to participate. *Neurological practice* was defined as engagement in treating people with stroke, traumatic or acquired brain injury, cerebral palsy, multiple sclerosis or dystonia. All participants were members of the Canadian Association of Occupational Therapists (CAOT) or the Canadian Physiotherapy Association (CPA).

We recruited occupational therapists directly via emails with a link to the online survey, using a list of email addresses, purchased from CAOT, for occupational therapists who self-identified as being involved in neurological practice and who had agreed to be contacted for research. Physical therapists were recruited through a national e-mail newsletter distributed by CPA to all its members (approximately 10,600), which included a brief description of the study and a link to the online survey, and invited participation from physical therapists who self-identified as practising in neurological rehabilitation. At the time of survey distribution, 1968 CPA members were actively involved in this area of practice. Follow-up reminders were sent to both occupational and physical therapists at 2 and 3 weeks after the initial invitation in the manner outlined above, and participants had 3 months to complete the survey. Respondents provided informed consent by completing and returning the survey.

4.2.2 Survey Development and Composition

Questions were related to two broad categories: respondent profile and CIMT usage pattern. Survey content complied with three criteria: (1) questions were relevant to the study's purpose; (2) the wording was not leading (i.e., did not provide the "correct" response for subsequent questions); and (3) completion time was <15 minutes.

Five "content experts" (3 occupational and 2 physical therapists) involved in neurological rehabilitation services in Canada, including CIMT, independently assessed the content and face validity of the penultimate draft of the survey. Their feedback was used to refine the final survey items.

The final version of the survey contained 48 questions. The majority were "close-ended", with a list of response choices; seven included "other, please specify" to allow for a written answer. Three questions relating to the respondents knowledge of CIMT, experience with CIMT, and perceived effectiveness of CIMT, used a 5-point Likert-type scale. For example, level of CIMT knowledge was coded as follows: 1 = not very knowledgeable, 2 = minimally knowledgeable, 3 = moderately knowledgeable, 4 = knowledgeable, and 5 = very knowledgeable). Ten questions required a typed response (e.g., "Based on your knowledge of CIMT, please list what the key components of CIMT are:"). For analysis of this question in particular, two researchers independently reviewed the responses and grouped them according to the themes that emerged (e.g., inclusion criteria, treatment duration and schedule, type of treatment). A third researcher resolved any discrepancies. The frequencies of responses per theme were tallied. Three categories described the components of CIMT: (1) restraint, (2) RTP, and (3) behaviour/shaping; a fourth category, "identified no components", was used for blank responses and those that

did not meet criteria for the three key component categories. Respondents also identified their practice location as “rural” or “urban”, and population size of practice location was determined from the first three digits of the postal code corresponding to the practice location. Finally, a free-response question at the end of the survey invited participants to comment on their clinical use of CIMT.

Depending on the responses to questions about CIMT usage patterns (e.g., “Are you aware of CIMT as a treatment option for upper limb hemi-paresis?”), participants branched into different arms of the survey (see Figure 1). This funnelling pattern screened participants so that responses to certain survey questions came from those who practiced in neurological rehabilitation and who had used CIMT clinically in the past two years. Participants who used CIMT were asked for characteristics of the protocol they employ. Responses from those participants who report not using CIMT were also collected in order to identify barriers to CIMT use in this group. The survey was structured in such a way that participants responded to a maximum of 37 questions. Further description of the survey is found in Appendix B.

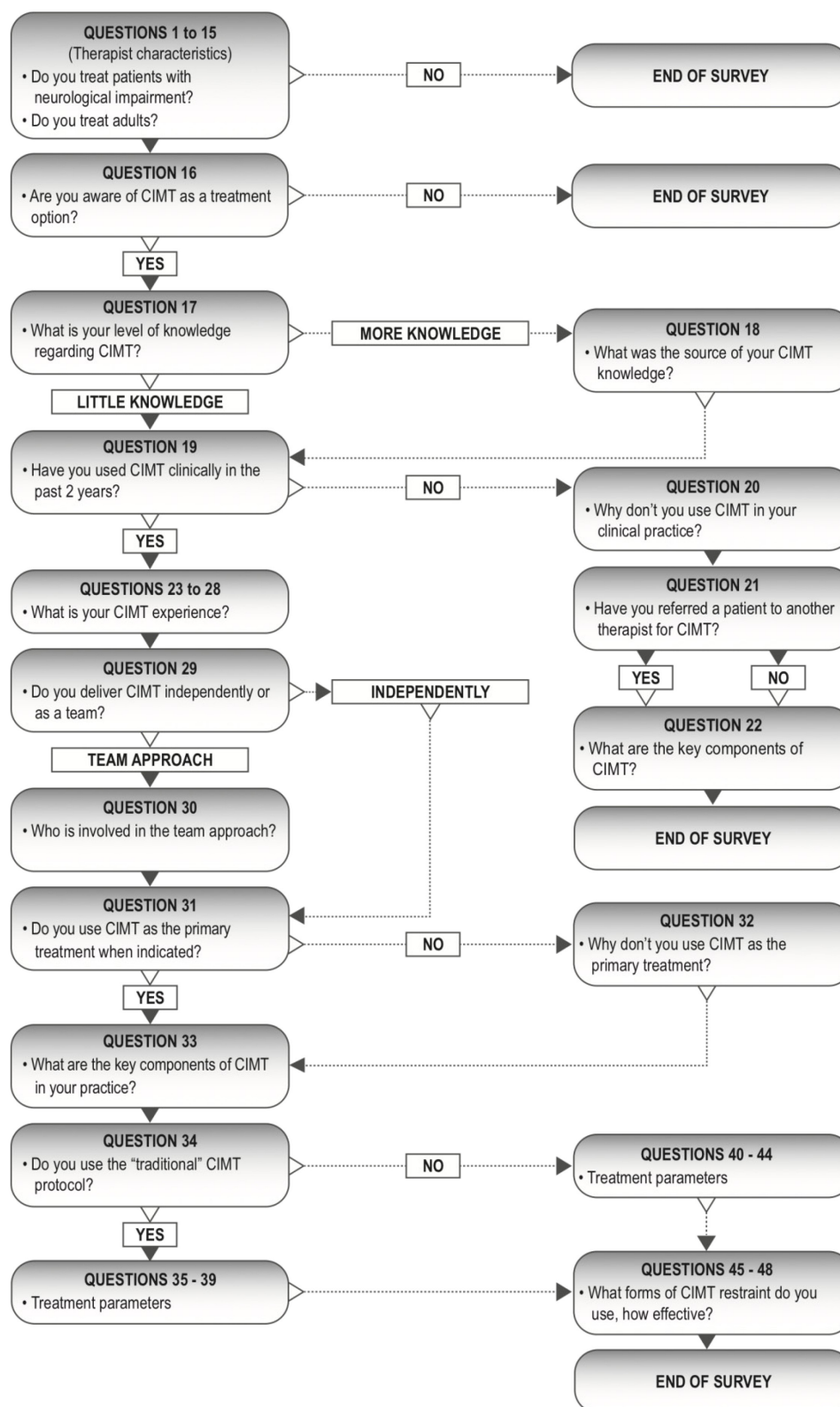


Figure 1 Flow diagram of survey framework designed to identify participants who met the inclusion criteria and had used CIMT clinically in the past two years and to further classify respondents according to their use of CIMT.

4.2.3 Data Analysis

Responses were treated as categorical variables. Because of the funnelling nature of the survey, the number of respondents was different for each question; we therefore report adjusted relative frequencies (%) and number of respondents who answered the question (*n*) throughout. For some questions, the adjusted relative frequencies do not sum to 100% because respondents could choose multiple responses. Throughout, we have grouped occupational and physical therapist responses for analysis. The rationale underlying this grouped approach is that, first, essential competencies for both professions include an expectation that therapists practice in an evidence-informed manner, including incorporating relevant and current knowledge into their practice;^{59, 60} and, second, that although differences exist between professions related to specific areas of practice, the assessment and treatment of UE dysfunction post-stroke is a shared area of practice.⁶¹⁻⁶³ The grouped approach is appropriate because it is reasonable to think that both occupational and physical therapist respondents have the potential to know about CIMT and the ability to use it in their practice.

To investigate practice setting size and CIMT use, we matched postal-code data to the corresponding geographic region using householder counts and map information available from Canada Post (<http://www.postescanada.ca/cpc2/addrm/hh/default-e.asp>); populations for these regions was then obtained from 2011 Statistics Canada data.⁶⁴

To investigate therapist-related factors and CIMT use, we applied a binary logistic regression using a forward stepwise (Wald) model (SPSS version 19, IBM Canada Ltd., Markham, ON). Number of years in practice, practice location, primary practice setting, and level of CIMT knowledge were chosen as predictor variables. The threshold for

statistical significance was set at $p < 0.05$. To examine variables that did not prove to be predictors of CIMT use through regression analysis, we cross-tabulated each variable against CIMT use. Using row percentages of the categories within each variable, we calculated the odds ratios and corresponding 95% CIs⁶⁵ of CIMT use between groups. For primary practice setting, we compared the odds of using CIMT for each setting category to the odds of using CIMT in an in-patient acute general setting. We defined the stages of stroke rehabilitation as follows: acute, 0-3 weeks; sub-acute, 3 weeks to 3 months; and chronic, >3 months post-stroke.

4.3 RESULTS

4.3.1 Participants

Our total response rate was 13.2% (338 responses out of a possible 2556). Of the 338 respondents, 39.9% (135/588, response rate of 23%) practiced as occupational therapists and the remaining 60.1% (229/1968, response rate of 10.3%) practiced as physical therapists. The therapists were 89.5% (229) women and represented all provinces and territories except the Northwest Territories and Nunavut; the majority (51.9%) practised in Ontario. Respondent characteristics are described in Table 1. Nearly two-thirds (65.9%, 208) reported a bachelor's degree as their highest level of education. While respondents worked in both in- and outpatient settings, the greatest number (22.1%, 208) reported working primarily in general out-patient rehabilitation. Of all neurological diagnoses, stroke was the most commonly treated (88.6%, 236). A majority of respondents (75%, 136) practiced in areas with a population greater than 55,000 people.

Table 1 Distribution of respondent characteristics relating to therapist- and therapy-specific factors.

	Absolute Frequency	Adjusted Relative Frequency (%)
Years Practicing (n = 225)		
0 – 5	25	11.1
6 – 10	31	13.8
11 – 15	27	12.0
16 – 20	45	20.0
21 – 25+	97	43.1
Practice Location (n = 213)		
Urban	170	79.8
Rural	43	20.2
Primary Practice Setting (n = 208)		
In-patient acute general	23	11.1
In-patient rehabilitation general	30	14.4
Out-patient rehabilitation general	46	22.1
Private practice	29	13.9
In-patient stroke unit (acute/rehabilitation)	30	14.4
Other*	50	24.0
Treatment Approach/Intervention for Upper Limb Hemi-paresis (n = 204)		
Stretching	181	88.7
Strengthening	175	85.8
Motor learning/repetitive task practice	166	81.4
Modalities [†]	158	77.5
Imagery/Mirror therapy	150	73.5

	Absolute Frequency	Adjusted Relative Frequency (%)
NDT/Bobath	141	69.1
Sensory Re-training	82	40.2
CIMT	78	38.2
Bilateral movement therapy	65	31.9
PNF	61	29.9
Other	15	7.4
Level of CIMT Knowledge (n = 185)		
1 – Not knowledgeable	10	5.4
2 – Minimally knowledgeable	38	20.5
3 – Moderately knowledgeable	72	38.9
4 – Knowledgeable	48	25.9
5 – Very knowledgeable	17	9.2
Level of CIMT Experience (n = 78)		
1 – Little experience	9	11.5
2 – Minimally experienced	22	28.2
3 – Moderately experienced	28	35.9
4 – Experienced	13	16.7
5 – Very experienced	6	7.7

* Includes skilled nursing/restorative care facility, community setting, home care and other.

†Includes biofeedback, neuromuscular electrical stimulation, virtual reality, robotics and serial casting

NDT = Neurodevelopmental Treatment; CIMT = Constraint-Induced Movement Therapy; PNF = Proprioceptive Neuromuscular Facilitation

4.3.2 CIMT Usage

Some 92% of respondents (202) were aware of CIMT as a treatment option for UE hemi-paresis; however, only 42.9% (182) said they had used CIMT in the last two

years, and only 19.4% (72) used CIMT as a primary treatment (when indicated) for UE hemi-paresis. CIMT was most commonly used in the chronic (74.0%, 77) and sub-acute (59.7%) stages of rehabilitation (vs. 7.8% in the acute stage) and was most often used for people with stroke (89.7%, 78). When asked to rate their level of experience with CIMT on a 5-point scale (1 = little experience, 5 = very experienced), a majority of therapists (35.9%, 78) chose 3 (see Table 1).

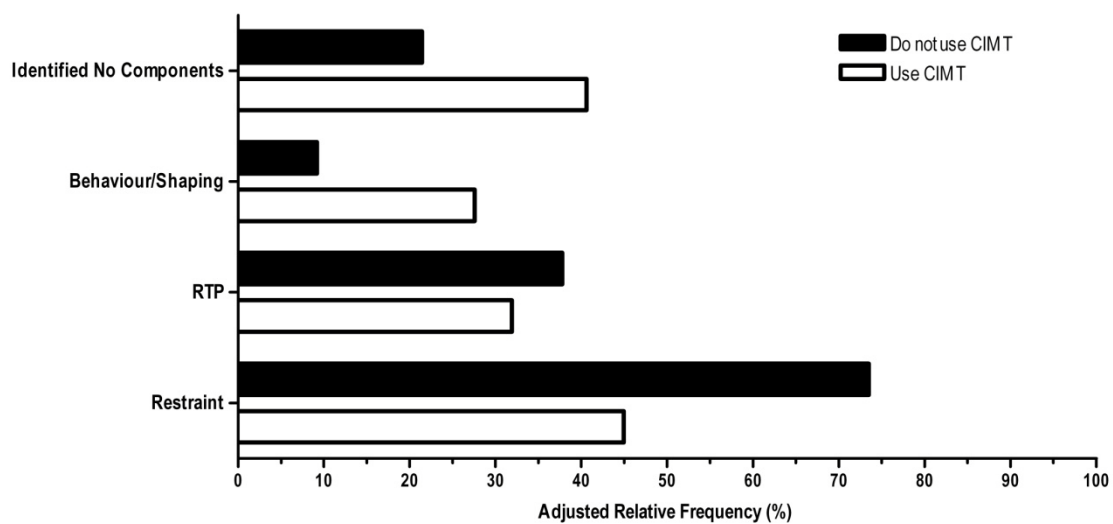


Figure 2 Frequency of respondents identifying key components of CIMT who do (n = 69) and do not (n = 98) use CIMT. ‘Identified no components’ refers to respondents who did not identify any of the key components of CIMT. RTP = Repetitive Task Practice

When asked to name the key components of CIMT, the majority of therapists using CIMT (88.4%, 69) did not name all three components (see Figure 2). Overall, however, this group did identify all three components more frequently than those who reported not using CIMT (11.6% of users vs. 9.2% of non-users). Surprisingly, 40.6% of CIMT users (vs. 21.4% of non-users) were unable to identify *any* of the key components. Common responses for CIMT components that were not categorized as

behaviour/shaping, RTP, or restraint included treatment duration and schedule (12 users, 27 non-users), inclusion criteria (5 users, 24 non-users), and type of treatment (7 users, 14 non-users). A complete list of responses is available in Appendix C.

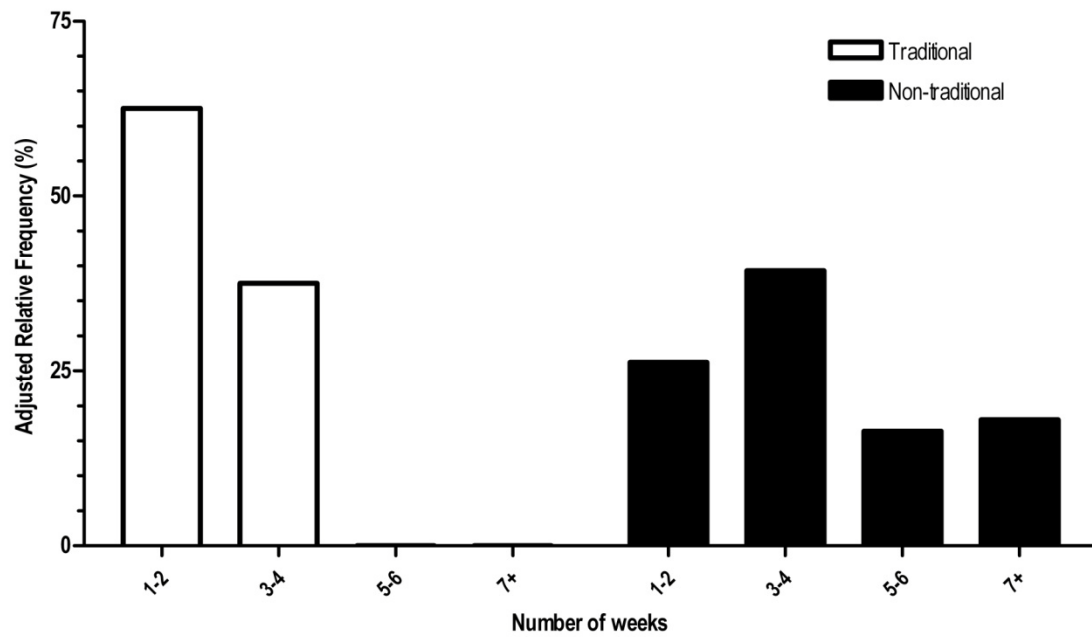


Figure 3 Total duration (weeks) of traditional (n = 8) vs. non-traditional (n = 61) use of CIMT.

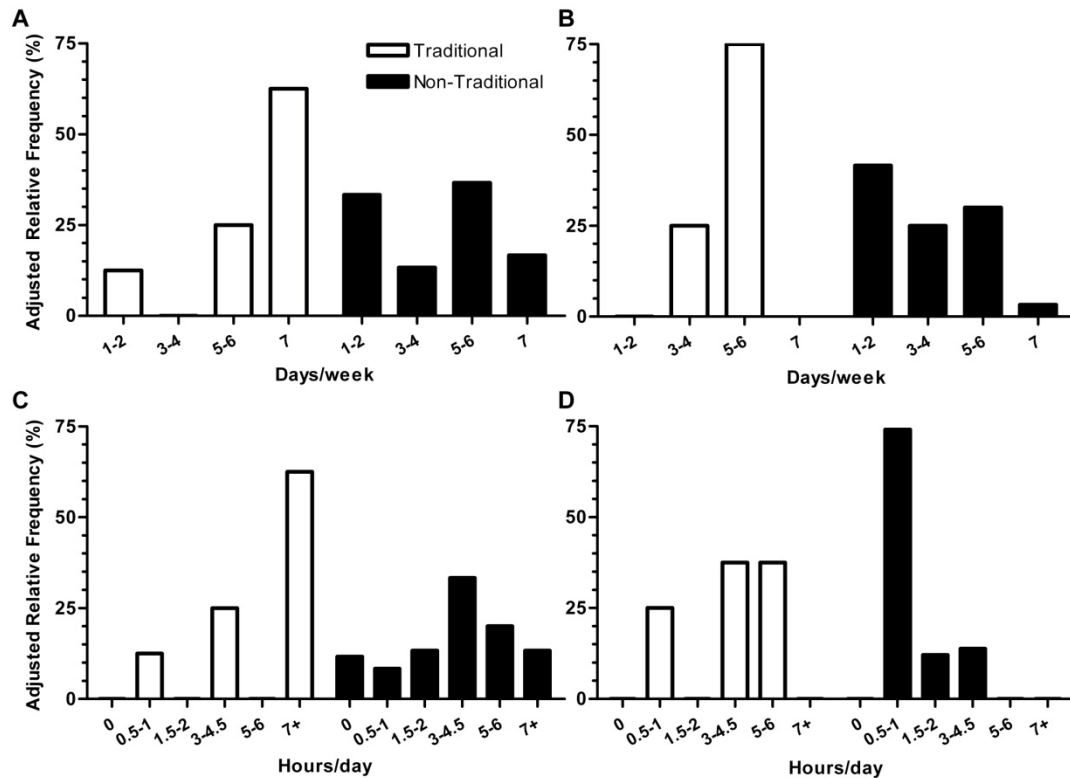


Figure 4 Parameters for use of traditional vs. non-traditional CIMT respectively, including: (A) days/week of restraint (n = 8, n = 60); (B) days/week of RTP/shaping (n = 8, n = 60); (C) hours/day of restraint (n = 8, n = 60); (D) hours/day of RTP/shaping (n = 8, n = 58). RTP = Repetitive Task Practice

The majority of CIMT users reported using a non-traditional approach (88.4%, 69) rather than a traditional approach (11.6%, 69) (see Figures 3 and 4). The most commonly reported approach involved using CIMT for fewer hours per day over a longer duration than the traditional approach (see Figures 3 and 4B). There was considerable variability in the parameters reported for the delivery of non-traditional CIMT; for instance, hours of restraint per day varied from 0 to >7 (see Figure 3C), while days of RTP/shaping per week ranged from 1 to 7 (see Figure 4B).

When asked about their level of knowledge related to CIMT, 38.9% of respondents (185) said they were moderately knowledgeable (rating of 3 on a 5-point

Likert-type scale). More than half (60.7%, 173) reported obtaining their knowledge from research publications; other sources of knowledge are outlined in Table 2.

Table 2 Source of knowledge compared across respondents' reported levels of CIMT knowledge presented as frequencies (respondents with a knowledge level of '1' were not asked to complete this question)

Level of Knowledge	Total # Respondents	University education	Colleagues	Conferences	In-service	Courses/Seminars	Workshops	Newspaper/news channel/magazines	Professional organization publication	Research publications	Best practice guidelines/evidence based reviews	Stroke survivor/family member	Publically accessible resources†
2	36	10 (27.8)	12 (33.3)	7 (19.4)	12 (33.3)	12 (33.3)	4 (11.1)	5 (13.9)	13 (36.1)	12 (33.3)	6 (16.7)	1 (2.8)	4 (11.1)
3	70	26 (37.1)	36 (51.4)	32 (45.7)	32 (45.7)	22 (31.4)	13 (18.6)	3 (4.3)	29 (41.4)	44 (62.9)	27 (38.6)	6 (8.6)	22 (31.4)
4	48	9 (18.8)	28 (58.3)	28 (58.3)	26 (54.2)	24 (50)	19 (39.6)	2 (4.2)	24 (50)	34 (70.8)	28 (58.3)	1 (2.1)	14 (29.2)
5	17	5 (29.4)	10 (58.8)	9 (52.9)	7 (41.2)	12 (70.6)	8 (47.1)	1 (5.9)	7 (41.2)	15 (88.2)	13 (76.5)	1 (5.9)	6 (35.3)
Total # Responses		50	86	76	77	70	44	11	73	105	74	9	46

* Examples of publically accessible resources include StrokeEngine (<http://strokengine.ca>)

4.3.3 Therapist-Related Factors and CIMT Use

Self-reported level of CIMT knowledge predicted CIMT use (Wald = 27.2, $p \leq 0.001$). A rating of 2 (minimally knowledgeable) or 3 (moderately knowledgeable) predicted less CIMT use (18.5, $p \leq 0.001$, and 7.9, $p = 0.005$, respectively) relative to a rating of 5 (very knowledgeable). The odds of using CIMT were 31.3 (95% CI, 6.5–14.3) times as high for a very knowledgeable respondent as for a minimally knowledgeable respondent, and 6.9 (95% CI, 1.8–26.3) times as high as for a respondent with moderate knowledge. CIMT use did not differ between respondents with knowledge self-ratings of 4 and 5, however. Respondents with very little knowledge of CIMT (rating of 1) were non-users of CIMT, as they did not report using it in the past two years.

We compared the odds of CIMT use within each non-significant variable from the regression analysis and found that primary practice setting influenced the odds of a therapist's using CIMT. Compared to an in-patient acute general setting, the odds of using CIMT increased by 4.9 (95% CI, 1.2–21.0) times for respondents working in in-patient general rehabilitation; 6.1 (95% CI, 1.5–25.9) times for those in a dedicated stroke unit (acute or rehabilitation); and 8.0 (95% CI, 2.0–31.4) times for those working in out-patient general rehabilitation; all increases are statistically significant ($p < 0.05$). The odds of using CIMT were not significantly higher for those working in private practice.

4.3.4 CIMT Effectiveness and Barriers to Use

The majority of respondents (51.2%, 59) believed CIMT to be a moderately effective (3) or effective (4) UE therapy for people with stroke. Respondents identified various patient-, therapist-, and resource-related barriers to CIMT use (see Figure 5).

Non-users of CIMT most commonly identified lack of knowledge as a barrier to use (42.3%, 104), while for CIMT users the most commonly reported barrier (17.2%, 58) was a belief that their patients had cognitive challenges that might prohibit CIMT. Importantly, these data demonstrate differences in perceived barriers to use between those who use CIMT and those who do not; CIMT users primarily identified patient- or resource-related barriers, including lack of time, while non-users reported therapist-related factors, including lack of knowledge of and confidence related to CIMT treatment.

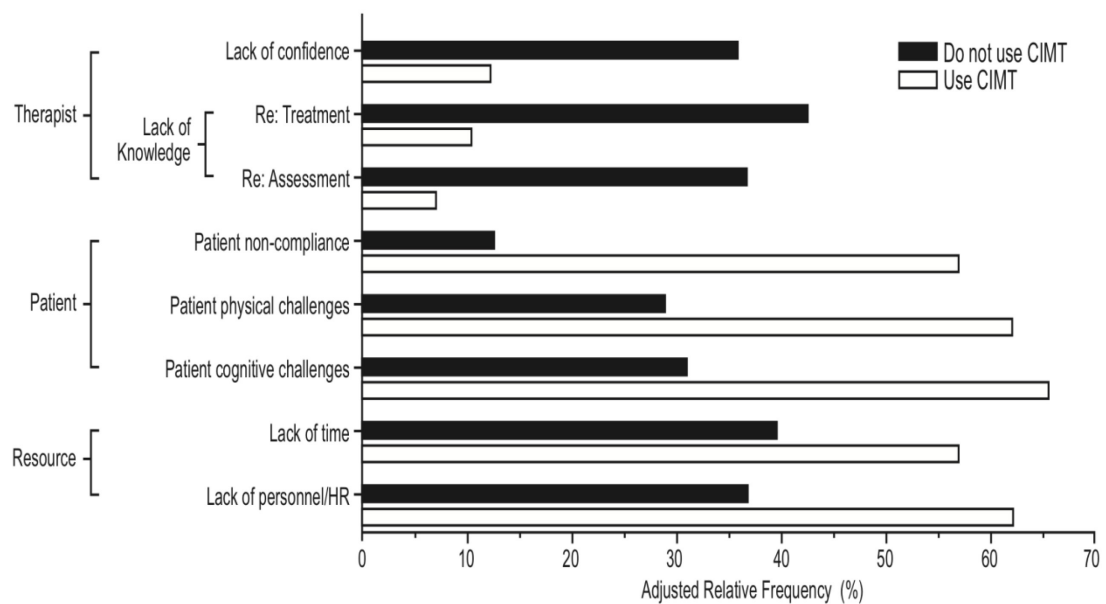


Figure 5 Most selected barriers to CIMT use (users of CIMT, n = 58; non-users of CIMT, n = 104). HR = Human Resources

4.4 DISCUSSION

Although evidence shows CIMT to be an effective therapy for UE hemi-paresis in patients who meet the criteria for treatment, and although the majority of respondents know about CIMT, less than half reported using it. Based on our findings, discrepancies between awareness of CIMT and clinical use of this therapy suggest that both lack of knowledge and lack of resources are barriers to the implementation and use of CIMT in clinical practice.

4.4.1 CIMT Use and Parameters

Respondents most often reported using CIMT for fewer hours/day for a longer duration (i.e., using a non-traditional protocol), which suggests that more intense (i.e., traditional) protocols may be perceived as less clinically feasible. The treatment parameters reported by therapists who use non-traditional CIMT (see Figures 3 and 4) indicate variability in its delivery, which may reflect the integration of studies examining CIMT across the continuum from traditional to non-traditional protocols, resulting in limited consensus as to the most effective and feasible protocol.^{56, 57, 66} While useful in determining overall effectiveness, this approach becomes problematic when therapists try to implement a specific CIMT protocol clinically. The variability we observed suggests that many therapists opt to develop their own method by integrating different evidence-based protocols. The discrepancy between CIMT treatment parameters reported in the research literature and those noted in our study suggests a problem in translating CIMT knowledge from research to clinical practice, although this conclusion should be considered in the context of the current sample. In light of these results, we must also consider the notion that CIMT protocols, in their current form, do not reflect the constraints of clinical practice and that these constraints should be taken into account as

protocols are further studied and modified – that is, that clinical practice should drive research.

To assess respondents' knowledge about CIMT, we asked them to list its key components. Predictably, non-users of CIMT could not list all three components; more unexpectedly, however, the majority of CIMT users were also unable to identify all three components – for instance, less than 32% were able to identify the RTP and shaping/behavioural components of CIMT. Shaping in conjunction with RTP is considered one of the core components of treatment, and consequently a critical part of any CIMT protocol.^{15, 32} Thus, when CIMT is used clinically, therapists may not be implementing the treatment components that have been shown empirically to be effective including the use of shaping (e.g.,^{11, 13, 17, 53}). This inability to identify CIMT's fundamental components implies a lack of crucial knowledge of the therapy, at least among respondents to our current study. This finding reveals knowledge barriers not only among therapists who do not use CIMT but also among those who do. Continuing clinical education may be a means to target and reduce knowledge-related barriers for both users and non-users, with the goal of delivering CIMT protocols in their evidence-based form.

4.4.2 Therapist-Related Factors and CIMT Use

4.4.2.1 Level of Knowledge

Among respondents in our study, level of CIMT knowledge was a significant predictor of its use. Therapists who reported being very knowledgeable about CIMT had greater odds of using it in their clinical practice than those who reported minimal or moderate knowledge. The inability to distinguish CIMT use between very knowledgeable

and knowledgeable therapists supports our conclusion that having only *some* knowledge of CIMT (i.e., minimal or moderate knowledge) is not sufficient to implement CIMT in clinical practice, at least within this sample of respondents. Notably, a majority of respondents (59.4%, 130) reported having only some knowledge about CIMT, which may explain the discrepancy between the number of people who *know about* CIMT and the number who *actually use it clinically*. As highlighted below and in Figure 5, non-users of CIMT reported lack of knowledge as the primary barrier to CIMT use. Interestingly, while a similar number of respondents across all knowledge levels identified non-empirical sources of knowledge, a higher percentage of “very knowledgeable or knowledgeable” respondents than of those with minimal or moderate knowledge identified more research-based sources of knowledge (Table 2). The latter group tended to rely more on their entry-level education or on non-empirical sources of information. While these findings are specific to our small sample of therapists, they parallel prior observations on barriers to CIMT use and therapists’ knowledge.^{49, 50, 67}

4.4.2.2 Practice Setting

Our findings show that therapists in our sample rarely use CIMT for their clients with acute stroke. Rather, they most often employ CIMT in out- and in-patient rehabilitation settings, likely because their clients in these settings are in the sub-acute to chronic stage of rehabilitation – the predominant patient groups in which CIMT’s effectiveness has been examined in the literature.^{11, 39, 41} Moreover, there is a tendency for patients in the acute stage of recovery to be excluded from treatment because they do not meet the criteria for CIMT. Excluding these patients also helps to explain our findings: if fewer patients are eligible for treatment, therapists may be less likely to focus

on CIMT, instead investing their time in interventions more appropriate to the acute stage of stroke recovery. While there is evidence that some forms of CIMT are effective in the acute phase, Brunner and colleagues suggest that CIMT not be used before 4 weeks post-stroke, since rapid improvement appears to occur during the first month of standard rehabilitation.⁵⁵

4.4.3 Barriers to CIMT Use

Therapists who use CIMT and those who do not reported different types of barriers to CIMT use: non-users more frequently identified therapist-related barriers (see Figure 5), while CIMT users more frequently identified barriers related to their patients (e.g., physical/cognitive challenges) and institutions (e.g., lack of resources). Given their lack of experience using CIMT, one might expect that non-users would be unaware of patient barriers and thus would not report them; the finding that non-users identified therapist-related factors as barriers to CIMT use supports the notion that increasing CIMT knowledge through training and education may increase clinical use of CIMT. Conversely, the fact that users of CIMT tended not to report barriers related to themselves (knowledge and confidence), and instead cited external barriers (related to their patients and institutional resources), suggests that in the absence of increased funding for in- and out-patient stroke rehabilitation, CIMT protocols may need further adaptation within the constraints of clinical practice.⁶⁸ Specifically, researchers need to engage clinicians in conversations about evidence-based treatments to better align research with what is feasible in a clinical setting.

With respect to patient and institutional barriers, our findings indicate not only that a lack of resources can prevent CIMT use but also that patient non-compliance and

physical and cognitive characteristics may be major barriers to implementing CIMT (see Figure 5, patient-related factors). Similarly, Page and colleagues have suggested that when offered the traditional CIMT protocol, many patients with stroke do not participate, preferring a less intensive CIMT protocol.⁴⁶ It is important to note that in identifying barriers to use of CIMT, we did not distinguish between traditional and non-traditional protocols; our conclusions on the feasibility of traditional CIMT are drawn from the frequency with which therapists report using it relative to non-traditional CIMT. Therapists who report patient and institutional barriers to CIMT use may be doing so in the context of either a traditional or a non-traditional approach. Regardless of the protocol, the fact that CIMT users identified patient and institutional barriers suggests a need to further develop a CIMT protocol that is both effective and clinically feasible. It should also be noted that if therapists primarily treat people who do not meet the criteria for CIMT, they will not report using it, even though they may be knowledgeable and able to implement it.

Given regional differences in delivery of health care (e.g., publicly vs. privately funded services), barriers to CIMT use, and specifically patient and institutional barriers (e.g., patient populations and resources available to therapists), may vary from those identified in our study. Irrespective of these differences, however, previous articles commenting on barriers to CIMT implementation in multiple countries^{47, 49, 50} have consistently identified therapist knowledge as a barrier to CIMT use. The results obtained from our sample of therapists reinforce prior observations that increasing therapists' knowledge of CIMT can contribute to more frequent use in clinical practice.

Our study has several limitations. First, the size of our sample resulted in low statistical power and potential for bias in the data. Although 338 therapists responded, not all completed every question. The lower number of respondents was problematic for questions near the end of the survey (due in part to the funnelling nature of the survey) and those with multiple levels. Further, because we specifically targeted therapists practising in neurological rehabilitation, our sample may not be representative of the Canadian occupational therapy/physical therapy population as a whole. Our results and subsequent discussion should therefore be framed in the context of our sample. For instance, relatively wide CIs reflect the possible variability of the results, which should be taken into consideration when interpreting the applicability of the findings to the larger OT/PT population. Furthermore, the low response rate suggests a possible self-selection bias. Finally, because so few respondents ($n = 8$) reported using traditional CIMT, we were unable to investigate whether certain factors could predict the type of CIMT protocol used.

4.5 CONCLUSION

Although research has shown CIMT to be an effective therapy for UE hemiparesis post-stroke for patients who meet the criteria for treatment, a discrepancy exists between the high level of awareness of CIMT and its low clinical use in our sample of occupational and physical therapists. Our findings regarding lack of knowledge about CIMT among practising therapists in our sample underscore the need for continuing education. Of equal importance, the number of therapists reporting patient and institutional barriers suggests a need to further modify current CIMT protocols to ensure

that they fit with clinical practice while remaining effective. Therapists' perceptions of CIMT can inform recommendations for educational initiatives and the development of clinical guidelines. Furthermore, these results can guide future research, which should focus on achieving a balance between the clinical feasibility of CIMT and its effectiveness. This objective may be accomplished by investigating treatment dosage to find a quantity that is clinically feasible while eliciting optimal rehabilitation outcomes.

4.6 KEY MESSAGES

4.6.1 What is Already Known on this Topic

Many people experience UE impairment following a stroke, and few regain full function. There is evidence that CIMT is effective in improving UE function after stroke; however, it is not known whether and how CIMT is being implemented in stroke rehabilitation. Although a few studies subjectively report barriers to CIMT use,^{46, 49, 50} no empirical studies have examined CIMT use, specifically clinicians' perceptions, actual clinical use, and perceived barriers to implementation.

4.6.2 What this Study Adds

This study is the first to report data from practicing therapists relating to their use and perception of CIMT in clinical practice. Although awareness of CIMT was high amongst the sample of therapists, many do not use it clinically. Lack of knowledge about CIMT was the most commonly reported barrier to its implementation amongst therapists who do not use CIMT. Institutional resources and patient barriers were frequently cited by all respondents, but particularly by therapists who report using CIMT. These data

underscore the need for 1) educational initiatives to improve knowledge related to CIMT; and 2) increased consultation between researchers and clinicians to optimize CIMT protocols for clinical practice. Both of these initiatives have the potential to improve the clinical use of CIMT.

4.7 SUMMARY TO CHAPTER 4 AND TRANSITION TO CHAPTER 5

A survey investigated CIMT use in Canadian neurological occupational and physical therapy in terms of participant practices, perceptions and opinions related to their use of CIMT in their clinical practice. While many therapists knew of the therapy, less than half reported using it. Additionally, those who did use CIMT most often employed a non-traditional or distributed protocol. A number of barriers to CIMT use were identified, including lack of knowledge about the treatment and institutional resources to support its use.

While the lack of institutional resources is important, for the purposes of my thesis I am focusing on the amount of knowledge regarding the therapy as a barrier to use of CIMT. In identifying knowledge as a barrier to use, a logical next step is to determine how to address it and to direct efforts to overcome it. The survey study presented in Chapter 4 identified the need for educational initiatives to improve therapist knowledge. Importantly, therapist respondents that were most knowledgeable about CIMT tended to acquire their information from research publications and best practice guidelines. Thus, these are resources that can be targeted to address this knowledge barrier by describing the treatment and outlining the evidence that supports its use. Specifically, systematic reviews are important tools for clinicians because they summarize and evaluate the literature, allowing clinicians to make evidence-informed treatment decisions. The

following chapter reports a systematic review of the literature whose purpose is to establish the LOE in support of mCIMT.

CHAPTER 5 SYSTEMATIC REVIEW

5.1 INTRODUCTION

5.1.1 Description of the Condition

Stroke is the leading cause of neurological related death and disability in North America, affecting approximately 50,000 Canadian and 795,000 American adults every year.¹ This figure is likely to increase due to the aging population and the escalating percentage of individuals with risk factors for stroke.² Unfortunately, full recovery after stroke is elusive; of those who survive their stroke, approximately two-thirds will experience residual neurological deficits that impair daily function. Specifically, recovery of UE function is a major challenge for survivors of stroke, with only approximately 5% regaining full function.³ As healthcare improves to more effectively treat stroke acutely (e.g., through improvements to thrombolytic drugs), more North Americans are living with its effects. Functional limitations resulting from UE deficits negatively impact on performance of daily activities, resulting in decreased levels of participation and physical activity, and increased risk of further health problems.^{5, 7}

5.1.2 Description of the Intervention (mCIMT)

Post-stroke, patients often receive rehabilitation therapy to address functional deficits. For instance, an occupational or physical therapist may work with a patient to improve balance and motor function, address deficits in strength, and engage in sensory and gait re-training. Specifically, treatments used to address UE functional deficits as part of usual clinical care can include a task-oriented approach to functional activities, active and passive range of motion (ROM) exercises, stretching and strength training.⁸

Treatments that are considered part of usual care help with UE recovery but have limited effectiveness, evident in the high rates of disability, prevalence of secondary disease, and incomplete functional recovery of the UE observed after stroke.^{9, 10} To improve UE function after stroke and reduce the long-term disability related to poor functional recovery, effective, evidence-based therapeutic interventions are needed. Increased use of evidence-based therapies in rehabilitation can improve functional abilities post-stroke, decreasing health care costs and greatly improving overall quality of life.

Constraint induced movement therapy (CIMT) is a treatment that has been shown to promote UE recovery post-stroke in a particular subset of patients, with numerous studies showing it to be more effective than usual care.^{11, 17, 57} CIMT combines RTP training, behavioural training techniques, and restraint of the unaffected UE.^{11, 69} In CIMT, RTP is delivered in conjunction with shaping, during which patients engage in meaningful functional activities with measurable progressions for which they receive positive feedback as the activities become increasingly more difficult.¹³ Generally patients are required to have some movement in the affected UE, which at a minimum includes 10 degrees of active wrist extension, with 10 degrees extension of the thumb and at least 2 fingers. The need for this level of function and corresponding ability to actively engage in the treatment limits the number of patients for which CIMT is an appropriate intervention.

As developed by Taub et al., the traditional form of CIMT follows a massed practice schedule, and is performed over a 2-week period.^{11, 12} During this 2-week treatment period, restraint of the unaffected limb for 90% of waking hours is combined

with 6 hours of functionally oriented RTP using the affected UE each weekday.

Behavioural training techniques are also employed to help patients transfer functional gains into real world activities.

Numerous studies have examined this traditional CIMT protocol and support its effectiveness at improving UE function post-stroke. For instance, the EXCITE trial, a large RCT, followed 222 subjects 3-9 months post-stroke.^{11, 33} Subjects randomised to the CIMT group demonstrated statistically and clinically significant improvements in UE function and use compared to a usual care control group. Specifically, subjects in the CIMT group demonstrated greater improvements pre-post treatment on the WMFT, a laboratory based measure of UE function. Importantly, subjects in the CIMT group also had greater gains in the amount of use of the affected UE compared to the control group, as measured using the MAL, a subjective scale of real world limb use.

Since the initial description of the traditional CIMT protocol, a number of different CIMT protocols have been developed and applied in post-stroke rehabilitation, including those that more closely resemble the traditional or massed practice approach, as well as those using a modified or distributed practice approach.^{11, 12, 16, 17} Other protocols have also been described that are variations of these two approaches (^{for example see 35-37}). Importantly, the CIMT protocols developed to date comprise the same 3 key components: restraint, repetitive task practice, and the application of behavioural techniques including shaping.

The most studied of the distributed practice approaches, developed by Page and colleagues, is termed mCIMT. In mCIMT, therapy sessions are performed for 30 minutes, 3 times per week over a 10-week schedule.^{16, 17} Despite the use of a distributed

practice schedule and thus a reduction in the overall treatment time, evidence suggests that mCIMT is as efficacious as CIMT in promoting UE functional recovery post-stroke. Page et al. demonstrated that mCIMT was superior to a dose-matched program of usual care in improving UE function in chronic stroke.¹⁷ Significant improvements were observed for the mCIMT group in both functional UE performance and amount of use. Specifically, subjects in the mCIMT group had greater improvements on the ARAT, an objective measure of UE function, and increased affected arm use as measured by the MAL.

Despite differences in the frequency and overall duration of treatment, similar principles are utilized across the spectrum of these CIMT protocols, including mCIMT. The traditional CIMT approach as developed by Taub offers a compressed, but time-intensive treatment. While the traditional protocol has been demonstrated to be effective, evidence suggests that it can be difficult to implement clinically due to its high resource demand (eg. time, availability of therapists, and equipment).^{46, 49, 70} Contrary to CIMT, mCIMT distributes therapy sessions over a longer duration with a considerable reduction in treatment time and thus a decreased use of resources, making the treatment easier to manage clinically.⁷¹ As highlighted above, treatment in mCIMT is performed over 10 weeks and the UE is restrained for 5 hours/weekday (rather than 90% of waking hours under the traditional protocol).

5.1.3 How the Intervention Might Work

Derived from basic studies in monkey's, Taub and colleagues observed a pattern of behaviour they termed "learned nonuse"^{18, 19}; that is, removal of sensory feedback

from the UE resulted in the animals encountering aversive effects when using it and, as a result, stopped using the limb.

In subsequent studies, it was found that learned nonuse could be overcome by restraining the monkeys' non-affected limb thereby forcing use of the deafferented limb in daily activities (e.g., grooming, feeding). Over time, increased use of the deafferented limb ultimately led to improved limb function.^{13, 18} Given the results observed in this series of animal-based studies, coupled with the observation of learned nonuse in individuals with UE functional deficits, Taub and colleagues applied the principles observed in the animal studies to rehabilitation of individuals post-stroke.^{13, 19, 26}

The treatment components of CIMT are grounded in sound neurophysiological evidence. It is generally accepted that the basis for functional recovery post-stroke is the repetitive practice of novel, skilled movements. Research in animals has clearly demonstrated that repetitively engaging in novel motor tasks after an ischemic infarct results in plastic changes in the brain, characterized by a task-dependent reorganization of primary motor cortex.^{20, 22, 34, 72} Similar observations have been made in humans post-stroke, with evidence from neuroimaging studies repeatedly demonstrating task-dependent changes in the brain that correlate with UE functional recovery.^{27, 6132} Thus, in addition to wearing a restraint on their unaffected UE, subjects in CIMT engage in RTP using their affected UE. Task selection is believed to be an important aspect of the therapy, such that tasks utilized should be of value and interest to the subjects. Lastly, shaping and other behavioural techniques have been established as key principles that contribute to the functional gains observed in human studies.^{13, 32, 47}

5.1.4 Why it is Important to do this Review

Owing to the number of studies examining CIMT in recent years, systematic reviews have evaluated the effectiveness of the treatment in promoting UE recovery post-stroke.^{57, 58, 66, 73-77} While useful in gauging the overall effectiveness of CIMT protocols collectively, there are 2 major issues with the current reviews that limit their ability to portray the evidence in support of CIMT. These issues include: (1) they only focus on RCTs; and (2) they group treatment protocols of different durations.

5.1.4.1 Focus on RCTs

Although RCTs are valuable in that they provide the strongest LOE to support causality (i.e., a given outcome is related to the experimental treatment or intervention), the number of large RCTs ($N \geq 100$) examining any of the CIMT protocols is small in number, and as such the majority of systematic reviews draw conclusions regarding treatment efficacy based on smaller ($N < 100$) RCTs. Of note, inclusion of the EXCITE trial, the largest RCT examining CIMT, may well introduce bias into meta-analyses with potential for skewed data resulting from overemphasizing the effects of CIMT compared to a control group. The therapy received by the control group was not consistent, with subjects receiving no therapy throughout the study. As the number of studies examining the efficacy of the various CIMT protocols increase, systematic reviews have become more specific to include only those with dose-matched treatment groups. For instance, Stevenson et al. (2012) performed a meta-analysis comparing CIMT to dose-matched interventions, showing CIMT to be superior to usual care or standard treatment. Owing to the use of a comparator group which for the most part did not receive any treatment, the EXCITE trial is most often excluded from these types of reviews. Overall, inclusion of

RCTs only in systematic reviews disregards a large body of literature that provides evidence with regard to the efficacy of CIMT in promoting UE functional recovery post-stroke. There is support for systematic reviews that are based on the comprehensive body of literature including various study designs.⁷⁸ Inclusion of non-RCT study designs would provide a comprehensive picture of the evidence for or against the use of CIMT post-stroke.

5.1.4.1 Grouping of Different Treatment Protocols

As highlighted previously there is considerable variability in the duration and schedule of treatment sessions along the continuum of CIMT protocols. Accordingly, there is a large body of literature reporting on the effectiveness of these different treatment protocols, which has led to the publication of numerous systematic reviews summarizing their findings.^{58, 73, 74, 76} While these systematic reviews have proved useful to measure the effectiveness of CIMT in broad terms, it is difficult to draw conclusions regarding the effectiveness of a specific CIMT protocol, as the different protocols are grouped and examined collectively (eg.^{57, 75-77}). Owing to the differences relating to both the duration of treatment sessions and the overall treatment schedule (i.e., massed vs. distributed practice), it may be more appropriate to perform a systematic review and subsequently assign a LOE to a 'body of literature' that relates to a specific CIMT protocol. Performing a systematic review of the literature relating to a single CIMT protocol would allow a clinician to make decisions about implementing a therapy based on the evidence in support of a specific protocol (not a number of protocols grouped together), with consideration of how that protocol suits their clinical practice.

Data from a recent study (survey study – Chapter 4) examining utilization patterns of CIMT by practicing occupational and physical therapists supports the notion that clinicians do not relate a particular treatment schedule/session duration with a given CIMT protocol.⁷⁰ For instance, amongst therapists who report using a ‘non-traditional’ CIMT protocol (i.e., distributed practice greater than 2 weeks in duration), there was considerable variability in both the treatment schedule (number of therapy sessions/week) and session duration (therapy time/day). These results suggest that clinicians within this sample appear not to be following the treatment parameters of any one CIMT protocol as it is reported in the literature. While it is understood that variations in the delivery of a given CIMT protocol may be made to facilitate its clinical use, it is not known how deviations from its ‘evidence-based form’ will impact on its effectiveness. Furthermore, results of the study showed that no one protocol was being used with greater frequency compared to others. As suggested by Mulrow, systematic reviews are an important tool for clinicians to keep up-to-date on the current literature and to make informed decisions regarding evidence-based practice.⁵¹ Prior studies have reported that a large proportion of therapists obtain knowledge related to interventions from research publications. Thus, the grouping of protocols within the systematic review literature may be a factor related to the variability observed in the delivery of CIMT in the clinical setting.

An alternative to grouping CIMT protocols with distinct treatment parameters would be to focus on a single protocol in order to establish its LOE with regard to promoting UE recovery. Coupling a LOE with a clearly defined treatment protocol would better facilitate its translation to clinical practice in the form in which the evidence supporting its use was generated. One of the more frequently examined CIMT protocols

is the modified version developed by Page and colleagues (mCIMT: 3 times/week for 10 weeks as described previously).^{16, 17, 38} Owing to the distributed nature of its treatment schedule, mCIMT offers considerable promise in terms of its clinical feasibility and ease of implementation for clinicians, particularly in comparison to traditional protocols. Establishing the LOE with regard to mCIMT independent of massed practice protocols would allow one to discern its effectiveness at promoting UE recovery post-stroke.

5.1.5 Objectives

The primary objective of this review was to investigate the LOE in support of mCIMT (i.e., a CIMT protocol with a distributed practice schedule of 3 sessions/weekday for 10 weeks) to promote UE recovery post-stroke. Effectiveness was determined based on outcome measures that assess pre-post treatment changes in UE function, impairment and activity.

5.2 METHODOLOGY

5.2.1 Criteria for Selecting Studies for Review

All study designs were eligible for inclusion. For a study to be included it must have included adult subjects (≥ 18 years) with a clinical diagnosis of stroke and who had experienced UE impairment.

The experimental intervention employed in the selected studies followed a distributed therapy schedule and in most instances reflected the mCIMT protocol of Page et al.^{16, 17, 38} Therapy had to be performed 3 times per week over a 10-week period. The amount of therapy time per session and amount of restraint per day could vary. Because

there was no restriction with regard to study design, the comparator interventions vary across studies (eg. usual care control, no treatment control, no comparator group).

The outcome measures used to assess treatment effectiveness were not part of the inclusion criteria for the study review. Measures of interest included UE function (the anatomical and physiological parts of the body's systems), as assessed by the ARAT; UE impairment (the loss or significant deviation from full functioning body systems), as assessed by the Fugl-Meyer Assessment of Motor Recovery After Stroke (FM); and UE activity (the performance of an action at the level of an individual), as assessed by the MAL.

The ARAT is an evaluative measure for use in individuals with hemi-paresis resulting from stroke to assess UE function.⁷⁹ The measure includes 19 items grouped into four sub-scales including grasp, grip, pinch and gross movement.⁸⁰ Each sub-scale item is graded on a four point ordinal scale (0 = cannot perform any part of the test, 1 = performs test partially, 2 = completes test, but in abnormally long time, and 3 = performs the test normally) for a total possible score of 0-57. The UE portion of the FM is a performance-based assessment of UE motor impairment.^{81, 82} A total score of 66 points can be obtained as each item is scored on an ordinal scale of 0 (cannot perform) to 2 (can perform fully). The FM uses direct observation to assess a series of voluntary limb movements (at times using a variety of small objects). The MAL assesses people with moderate-mild hemiparesis resulting from stroke and their affected UE activity.^{83, 84} It is a semi-structured interview that measures the amount of use (AOU) and quality of movement (QOM) of a patient using the UE to complete 14 ADLs. Responses are scored

along a 6-point scale and can range from 0 (did not use affected UE) to 5 (use affected UE the same as pre-stroke).

5.2.2 Methods for Identification, Data Collection and Analysis of Studies

Identification, selection and initial analysis of the studies to be included in the review were performed in 3 phases by two independent reviewers (including myself). A multi-phase approach ensured identification of all relevant sources and allowed the review to begin with a broad, comprehensive literature search, followed by identification and selection of articles that matched the reviews specific inclusion criteria (outlined below and in Appendix D). The initial search was conducted on June 20, 2011 by one of the study authors and a reference librarian who specializes in evidence-based searching, and included electronic databases for empirical research studies and the grey literature.

Electronic databases searched included PubMed, CINAHL, Embase, the Cochrane Library, Web of Science, ProQuest and OpenGrey from inception to present. The search followed a multi-step process and initially included key words and medical subject headings (MeSH; e.g., cerebrovascular disease; upper extremity; exercise therapy), exploded to include related terms (Appendix E). Limiters (Humans; English; and Adults) were then added to the search to filter results to match the reviews inclusion criteria. Individual citations were then exported to a reference manager database (EndNote X4; Thomson Reuters, New York, NY) for each database searched and duplicates were removed. The full text version of each citation was then retrieved and added to the reference manager database. The comprehensive search of electronic

databases culminated in the identification of 486 articles. Thirteen of the citations obtained following the literature search were removed before the first phase of article selection because the full text was not accessible in print or electronic copy.

5.2.2.1 Phase 1 – Refining the Literature

The two independent reviewers received the reference manager database that included all 473 citations and the PDF full text of the article. An Excel spreadsheet was used to record information related to the selected studies including the first author, date of publication, journal, and reason for exclusion (if excluded). Article selection in this phase was based on information gathered from the title and abstract; criteria for inclusion was the presence of content related in any way to CIMT, or the use of alternate terms (e.g., forced use; constraint induced therapy). Any disagreement between the two reviewers related to inclusion of specific articles was resolved by an additional reviewer. Following phase 1, 151 articles were identified for further review.

5.2.2.2 Phase 2 – Identifying Articles Examining mCIMT

Articles identified in phase 1 were subjected to further review to select those that utilized the mCIMT (distributed CIMT) protocol. Article selection was based on review of the abstract and full text. A standard checklist form was used to evaluate the studies and record the pertinent data (study design, population, intervention studied, target of intervention, comparator intervention, and primary outcome measures). Studies were selected based on the following inclusion criteria: (1) mCIMT intervention following a distributed practice schedule (3 times/weekday for 10 weeks); (2) adult subjects (≥ 18 yrs); (3) clinical diagnosis of stroke (ischemic or hemorrhagic); and (4) the UE was the target of the intervention. As in phase 1, any disagreement with regard to article inclusion

was resolved by an additional reviewer. Fifteen studies were identified after the second phase.

5.2.2.3 Phase 3 – Assessing and Assigning the Level of Evidence

The articles selected for review following phase 2 were categorized based on study design for analysis. Both assessors reviewed the identified articles and assessed the LOE of each single study. The LOE was based on the American Academy of Cerebral Palsy Developmental Medicine (AACPDM) methodology to develop systematic reviews of treatment intervention.⁸⁵ A standardized form was used to extract information related to the subjects (mean age, time since stroke, number of subjects in intervention or control groups) and a basic description of the intervention. Conduct questions on the data collection form were used to assess the risk of bias and methodological quality. Collectively the studies were reviewed to assess and assign the LOE to the body of knowledge on mCIMT.

To examine the body of evidence related to mCIMT in this systematic review, all study designs were included. Thus, the LOE assigned to single studies was based on research design and categorized levels 1 through 5. As shown in Table 3, in descending order the study designs are decreasingly able to demonstrate causality, that is, that the intervention was responsible for UE improvements. The LOE for the body of knowledge looks at all the included studies and can be labelled A to D (Table 4).

Table 3 Level of evidence hierarchy of a study based on research design

Level of evidence	Intervention Studies	Causality
I	Large RCT (n>100)	Most definitive
II	Smaller RCT (n<100)	
III	Cohort studies (concurrent control group)	
IV	Case series; Cohort studies (not concurrent control; Case-control	
V	Case study; Expert opinion	Only the possibility

Table 4 Level of evidence hierarchy for a body of knowledge

Level of Evidence	Support	Types of Studies
A	Very strong	Consistent level I studies
B	Strong	Consistent level II or III studies, or extrapolations from level I studies
C	Intermediate	Level IV studies, or extrapolations from level II or III
D	Weak	Level V evidence or troubling inconsistent or inconclusive studies at any level

5.3 RESULTS

5.3.1 Levels of Evidence

All 15 studies included in the review showed the 10-week mCIMT protocol to be effective at promoting UE recovery post-stroke. Of the included studies, 7 had a LOE of II (RCT < 100 subjects), 5 were level IV (case-based or cohort studies), and 3 were level V (case study). While the largest proportion of studies had a LOE of II, the presence of level IV and V studies led to an overall LOE of C (intermediate) for the body of literature

reviewed. Table 5 describes the methodological quality, including the level of evidence for each study.

5.3.2 Study Demographics

The studies included subjects with ages ranging from 37 – 83 years with the intervention occurring in different stages of stroke recovery; ten of the studies treated patients in the chronic stage of recovery (>12 months post-stroke); 4 treated patients in the sub-acute stage of recovery (4 weeks-6 months post-stroke)^{38, 41, 42, 71, 86}, while 1 took place in the acute stage of stroke recovery (< 14 days post-stroke)¹⁶. Within the chronic stroke studies, the time since stroke ranged from 13 to 156 months. The subacute and acute studies followed patients from 2-6 months and 2-9 days post-stroke, respectively. Demographic information is summarized in Table 6, including the mean ages and time since stroke for each study population.

Table 5 Methodological quality evaluated for each study.

Authors	Year	Level of Evidence	Inclusion/Exclusion criteria described & followed?	Intervention described & adhered to?	Described, valid & reliable measures?	Blinded assessors?	Proper statistics evaluation and power calculation?	<20% dropout/loss? Equal for all groups?	Control confounding variables and limit bias?
Atteya, A	2004	2	YES	NO	YES	NO	NO	YES	NO
Page, S	2001	2	YES	NO	YES	YES	NO	YES	YES
Page, S	2002a	2	YES	YES	YES	YES	NO	YES	YES
Page, S	2002b	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Page, S	2002c	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Page, S	2003	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Page, S	2004	2	YES	YES	YES	YES	YES	YES	YES
Page, S	2005	2	YES	YES	YES	YES	NO	YES	YES
Page, S	2006	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Page, S	2007a	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Page, S	2007b	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Page, S	2007c	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Page, S	2008	2	YES	YES	YES	YES	NO	YES	YES
Page, S	2009	2	YES	YES	YES	YES	NO	YES	YES
Szaflarski, J	2006	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 6 Subject demographic information and study design employed for each study included in the review.

Authors	Year	Sample Size Total (int/control)	Number of Men	Age (mean; range)	Time since stroke (mean; range)	Stroke Population	Study Design
Atteya, A	2004	6 (2/2/2)	3	53.5; 45-67	4.7 mo.; 2.3-5.8 mo	Subacute	Case series
Page, S	2001	6 (2/2/2)	3	55.8; 44-77	4.6 mo.; 2-5.5 mo.	Subacute	Case series
Page, S	2002a	14 (4/5/5)	9	64.8; 45-83	4.4 mo.; 4-6 mo	Subacute	RCT - prospective multiple baseline, pretest-posttest
Page, S	2002b	1 (1/0)	1	67	2 years, 4 months	Chronic	Case study
Page, S	2002c	1 (1/0)	0	68	5 months	Subacute	Case report - multiple baseline, pretest-posttest
Page, S	2003	1 (1/0)		44	14 months	Chronic	Case study
Page, S	2004	17 (7/4/6)	14	59.2; 37-76	32.3 mo.; 14-74 mo	Chronic	RCT - single blinded multiple baseline pretest- posttest
Page, S	2005	10 (5/5)	8	60.4; 46-72	4.4 days; 2-9 days	Acute	RCT - pilot multiple baseline, pretest-posttest
Page, S	2006	6 (6/0)	2	62.8; 54-75	62.8 mo.; 29-131 mo.	Chronic	Case series - single- blinded pretest-posttest
Page, S	2007a	4 (4/0)	3	62.5; 49-73	32 mo.; 14-63 mo	Chronic	Case series - single- blinded pretest-posttest
Page, S	2007b	4 (4/0)	3	59.75; 55-73	69.25; 13-156 mo.	Chronic	Case series - single- blinded pretest-posttest
Page, S	2007c	4 (4/0)	4	60.25; 53-67	37.5 mo; \pm 23.2 mo.	Chronic	Case series - single blinded multiple-baseline, pretest-

Authors	Year	Sample Size Total (int/control)	Number of Men	Age (mean; range)	Time since stroke (mean; range)	Stroke Population	Study Design
Page, S	2008	35 (13/12/10)	22	57.9; 47-76	39.8 mo.; 20-60 mo.	Chronic	posttest RCT - single-blinded, multiple baseline, pretest- posttest
Page, S	2009	10 (5/5)*	7	61.4; 48-79	28.5 mo.; 13-42 mo.	Chronic	RCT - single-blinded, multiple baseline pretest- posttest
Szaflarski, J	2006	14 (4/10)†	7	59.25; 54-68	72.5 mo.; 22-178 mo.	Chronic	Case series - pretest- posttest

*comparison group not control

†10 control only for MRI

5.3.3 Intervention

Consistent with the stated inclusion criteria, all of the studies followed a distributed practice schedule with treatment sessions occurring 3 times/week for 10-weeks. The majority of the studies (10/15) employed thirty-minute therapy sessions, while the remainder of the studies employed sixty minute therapy sessions (30 minutes each of OT and PT). Each study performed mCIMT, including the 3 key components that are consistently described in the literature and across the different CIMT protocols (restraint, RTP and behavioural techniques including shaping). In many instances (6/15 studies), the mCIMT intervention was compared to a control group, which consisted of either usual care (e.g., proprioceptive neuromuscular facilitation techniques focusing on functional tasks, stretching and compensatory techniques using the less affected UE as needed)¹⁷ or no therapy. Of the six studies that used a control group, all compared mCIMT to a dose-matched control group receiving usual care therapy, with five of those studies also comparing mCIMT to a no therapy control group. While all 15 studies included performed pre- and post-treatment assessments (baseline and at 10 weeks), 3 studies also included a 3-month follow-up assessment.^{39, 87, 88} Information about the treatment delivered in each study is summarized in Tables 7.

Table 7 Descriptions of treatment delivery and outcomes for each study included in the review.

Authors	Year	Outcome Measures	Interventions	Training time	Restraint time	Control group	Outcomes	Follow-up
Atteya, A	2004	FM ARAT WMFT MAL	mCIMT	1 hour total (0.5 hour each with OT & PT)	5 days/week for 5 hours (UE and lower extremity)	(1) traditional therapy (2) no therapy	mCIMT: substantial increases on all measures Traditional/no therapy: few improvements	
Page, S	2001	FM ARAT WMFT MAL	mCIMT	1 hour total (0.5 hour each with OT & PT)	5 hrs/weekday	(1) traditional therapy (2) no therapy	mCIMT: substantial increases on all measures Traditional/no therapy: no improvements	
Page, S	2002a	FM ARAT MAL	mCIMT	1 hour total (0.5 hour each with OT & PT)	5 hrs/weekday	(1) traditional therapy (2) no therapy	mCIMT: substantial increases on all measures Traditional/no therapy: few improvements	
Page, S	2002b	FM ARAT MAL	mCIMT	1 hour total (0.5 hour each with OT & PT)	5 hrs/weekday	none	Increases on all measures Activity monitor data	3 months post-intervention

Authors	Year	Outcome Measures	Interventions	Training time	Restraint time	Control group	Outcomes	Follow-up
		actigraphy					corroborated MAL AOU improvements.	
Page, S	2002c	FM ARAT WMFT MAL	mCIMT	1 hour total (0.5 hour each with OT & PT)	5 days/week for 5 hours	none	Substantial improvements on all measures	
Page, S	2003	FM ARAT MAL	mCIMT + chemodenervation (botulinum toxin A)	1 hour total (0.5 hour each with OT & PT)	5 hrs/weekday	none	Substantial increases on all measures	After botox (2 weeks post-mCIMT treatment)
Page, S	2004	FM ARAT MAL	mCIMT	0.5 hours	5 days/week for 5 hours	(1) traditional therapy (2) no therapy	mCIMT: significantly greater increases in FM and ARAT vs. control groups; improvements on MAL Traditional: some increases on FM and ARAT; no change on MAL No therapy: no change on any measure	
Page, S	2005	FM ARAT MAL	mCIMT	0.5 hours	5 days/week for 5 hours	(1) traditional therapy	mCIMT: significant increases in FM and ARAT; increases in	

Authors	Year	Outcome Measures	Interventions	Training time	Restraint time	Control group	Outcomes	Follow-up
							MAL	
							Traditional: modest increases in FM and ARAT; nominal increases in MAL	
Page, S	2006	FM ARAT goniometry	mCIMT (preceded by Electromyography -triggered stimulation)	0.5 hours	5 hrs/weekday	none	Increases on all measures; Reported new ability to perform valued activities	
Page, S	2007a	FM ARAT	mCIMT (preceded by mental practice)	0.5 hours	5 hrs/weekday	none	Increases on all measures; Reported new ability to perform valued activities	3 months post-intervention
Page, S	2007b	MAL WMFT	Remotely based mCIT Extension (mCITE) program	0.5 hours	5 hrs/weekday	none	Increases on all measures; Reported new ability to perform valued ADLs; Informal interviews post-testing saw high satisfaction with mCITE	
Page, S	2007c	FM ARAT	mCIMT	0.5 hours	5 hrs/weekday	none	Increases on all measures	

Authors	Year	Outcome Measures	Interventions	Training time	Restraint time	Control group	Outcomes	Follow-up
Page, S	2008	MAL FM ARAT MAL	mCIMT	0.5 hours	5 hrs/weekday	(1) traditional therapy (2) no therapy	mCIMT: significant increases on ARAT and MAL; Treatment effect across all 3 groups for ARAT traditional therapy: few improvements on ARAT and FM No therapy: no change	
Page, S	2009	FM ARAT	mCIMT	0.5 hours	5 hrs/weekday	Comparison group: mCIMT and 30 min mental practice sessions	Increases on all measures for both groups	3 months post-intervention
Szaflarski, J	2006	FM ARAT MAL - AOU fMRI at 4T	mCIMT	0.5 hours	5 days/week for 5 hours	Volunteers provided data re: typical activation patterns for fMRI	For 3 subjects, substantial increases on ARAT and MAL; modest increases on FM; Reported new ability to perform valued ADLs; fMRI data suggests cortical reorganisation 4 th subject saw minimal changes on any measures	

A number of studies incorporated additional elements beyond the standard mCIMT protocol. When this was the case, the studies utilized scores reported for assessments performed pre-post mCIMT, independent from any other treatment. For instance, mCIMT was combined with another therapy in 3 studies. Two of these studies involved combining mCIMT with mental practice. Page et al. had all subjects receive mCIMT, however one group also received 30 minutes of mental practice following each mCIMT session.⁸⁶ This differed from a 2007 study that began delivering mCIMT a week after the mental practice therapy post-testing.¹⁷ A case study performed in 2003 by Page et al. followed mCIMT with chemodenervation, using botulinum toxin A.⁸⁷

5.3.4 Outcome Measures

To identify the directionality of the LOE we looked to evaluate the effectiveness of mCIMT to improve UE function, impairment and use post-stroke. Across the fifteen studies, common assessment tools used included the ARAT, FM, and MAL. While both measure motor changes, the ARAT measures UE function while the FM measures changes in UE impairment. The MAL evaluates participation through two subscales that measure the amount of use, and quality of movement. Since the MAL is a self-report tool and vulnerable to subject bias, the MAL can also be administered to the primary caregiver.⁸⁴ This was done in 4 of the included studies. In addition to the clinical outcome measures, 2 studies incorporated other means to quantify treatment-related changes. Szaflarski et al. used functional magnetic resonance imaging (fMRI) to examine cortical reorganization resulting from treatment (patients receiving mCIMT were compared to 10 non-disabled subjects who demonstrated the typical brain activation

patterns in response to a finger-tapping task)⁴⁰ while Page et al. used activity monitors to assess changes in UE use, and to corroborate data obtained via the MAL.³⁹

The outcome measures outlined above are often evaluated in terms of a change score; change scores for the ARAT, FM and MAL for each study are depicted in Figures 6-9. Considering the different populations and range in time since stroke, the studies are arranged based on the stage of rehabilitation [chronic (A), sub-acute (B), and acute (C)]. As shown in Figure 6, the change in ARAT scores for those receiving mCIMT varied across studies, but regardless of the stage of recovery, all scores were greater than the minimal clinically important difference (MCID). The MCID is the smallest change in an outcome measure that needs to be observed to be relevant clinically. The MCID used for the outcome measures in this review are based on literature looking at CIMT in stroke populations. The MCID is derived somewhat arbitrarily, largely based on clinical experience; that is the change score that represents a clinically important difference is derived based on clinical experience. In addition to clinical experience, the MCID is often expressed as being 10% of the score ranges for the outcome measure of interest. For the outcome measures discussed presently, the MCIDs for the ARAT and FM also correspond to Bland-Altman limits of agreement, close to but falling outside of the limits of agreement.⁸² The MCIDs (noted in each figure as the horizontal dashed line) are 6, 7 and 0.5 for the ARAT, FM and MAL, respectively^{82, 83, 89}. In addition to those receiving mCIMT, the figures also show results amongst usual care or no therapy control groups (when employed). In general, subjects receiving usual care or no therapy show small improvements across the 3 outcome measures of interest; however, most are below the MCID for the respective measure.

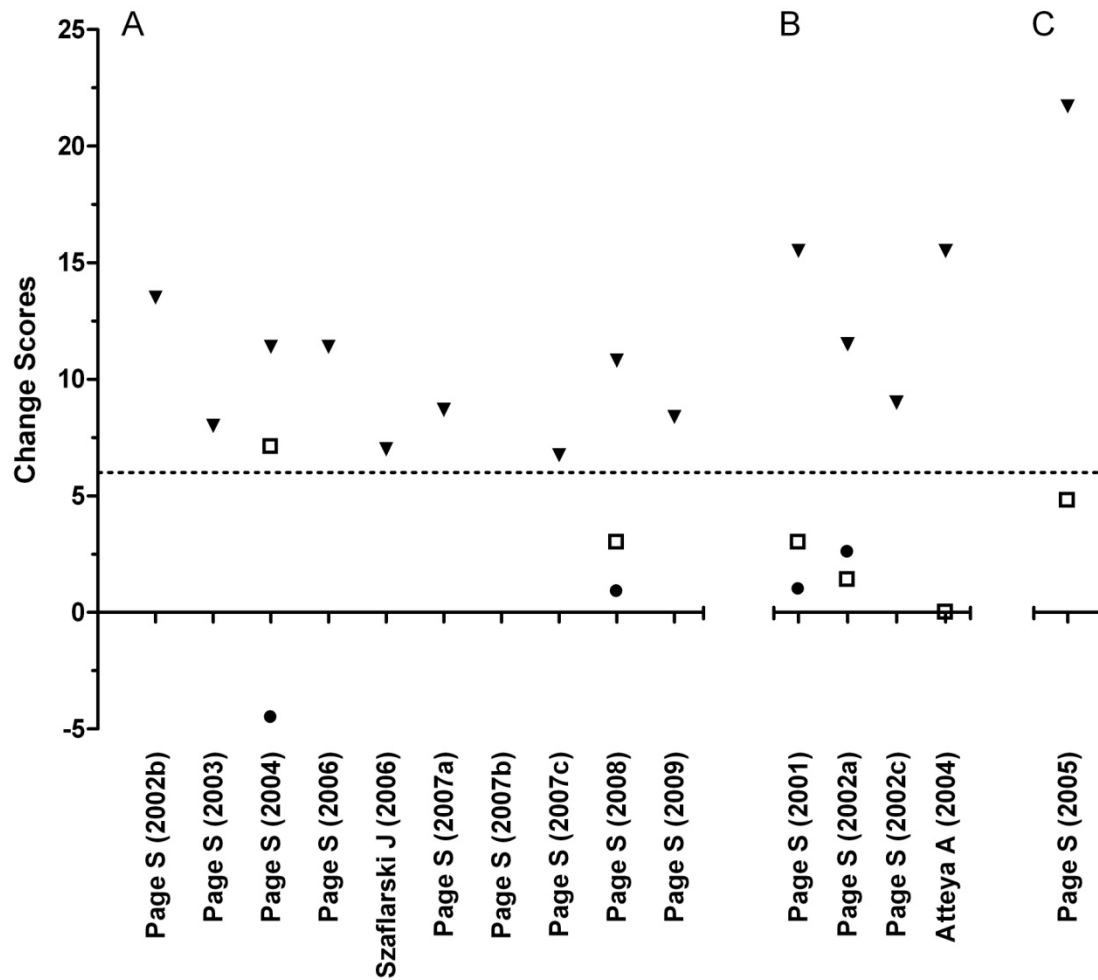


Figure 6 Pretest to posttest change scores for the Action Research Arm Test (ARAT) with a dashed line to represent the minimal clinically important difference. Atteya (2004) also has a ‘no therapy’ group, but does not report the scores. A – chronic, B – subacute, C – acute; inverted triangle – mCIMT, square – traditional therapy, circle – no therapy.

A similar trend is observed for the FM and MAL scores (Figures 7-9) in that the mCIMT group in most studies improved more than the MCID, while the usual care and no therapy control groups did not surpass the MCID. However, the FM results differ in that the mCIMT group scores fall below the MCID in 3 studies investigating a chronic stroke population. For the MAL (AOU) scores, the studies examining patients in the

sub-acute stage of recovery had varied results. Two of the 4 studies included usual care and no therapy control groups whose improvement in affected limb amount of use improved more than the MCID.^{38, 42} Additionally, Page found the MAL (QOM) scores for subjects receiving traditional therapy were greater than the MCID³⁸ (Figure 9b).

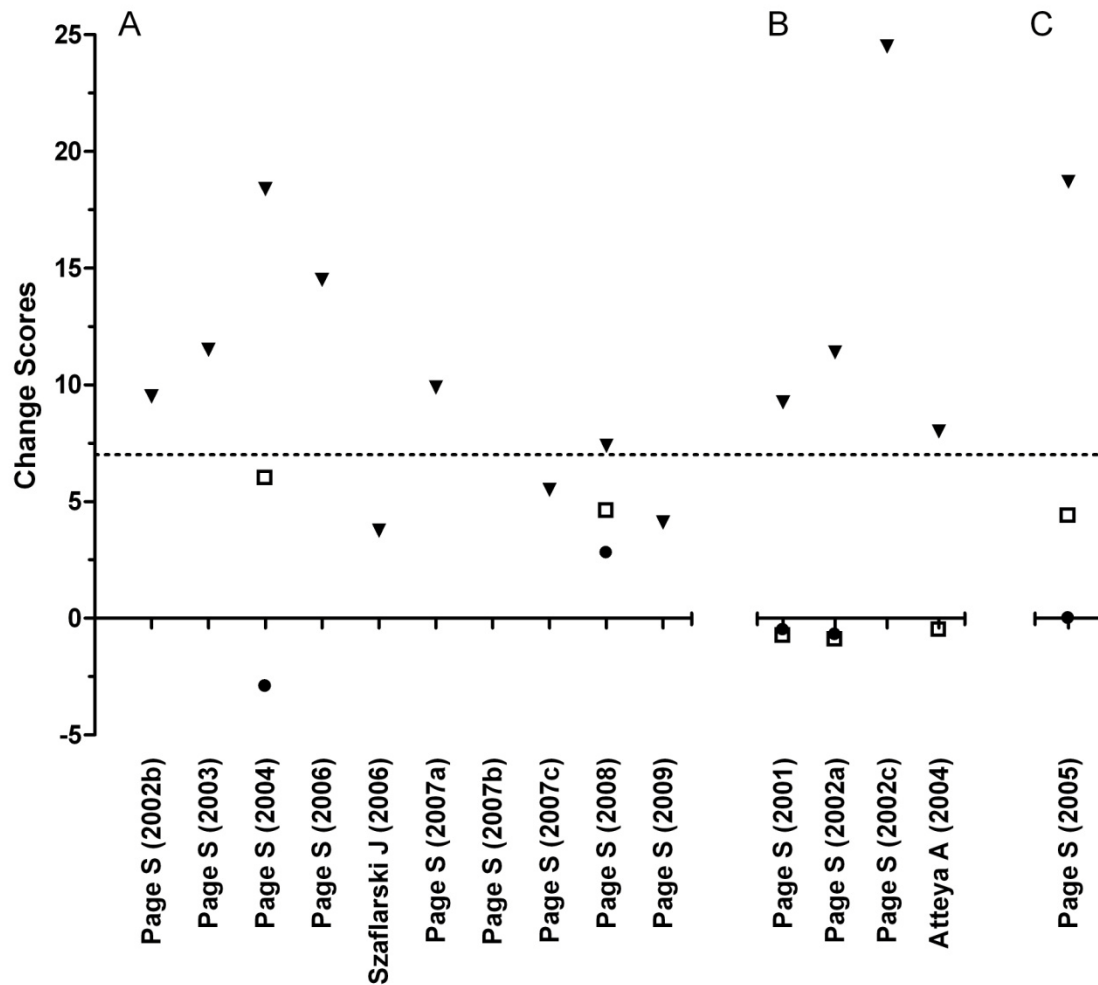


Figure 7 Pretest to posttest change scores for the Fugl-Meyer Assessment (FM) with a dashed line to represent the minimal clinically important difference. Atteya (2004) also has a ‘no therapy’ group, but does not report the scores. A – chronic, B – subacute, C – acute; inverted triangle – mCIMT, square – traditional therapy, circle – no therapy.

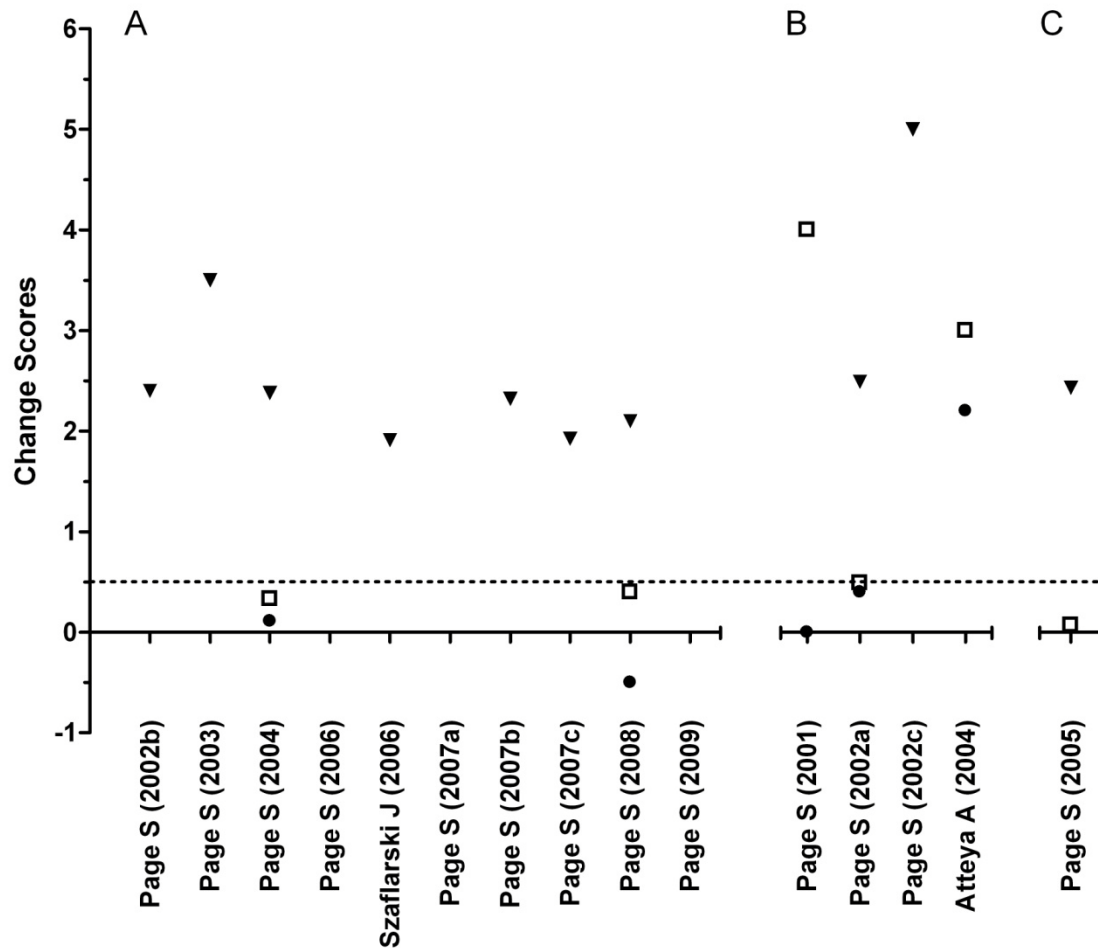


Figure 8 Pretest to posttest change scores for the Motor Activity Log – Amount of Use (MAL - AOU) with a dashed line to represent the minimal clinically important difference. Atteya (2004) does not report the scores for the mCIMT group. A – chronic, B – subacute, C – acute; inverted triangle – mCIMT, square – traditional therapy, circle – no therapy.

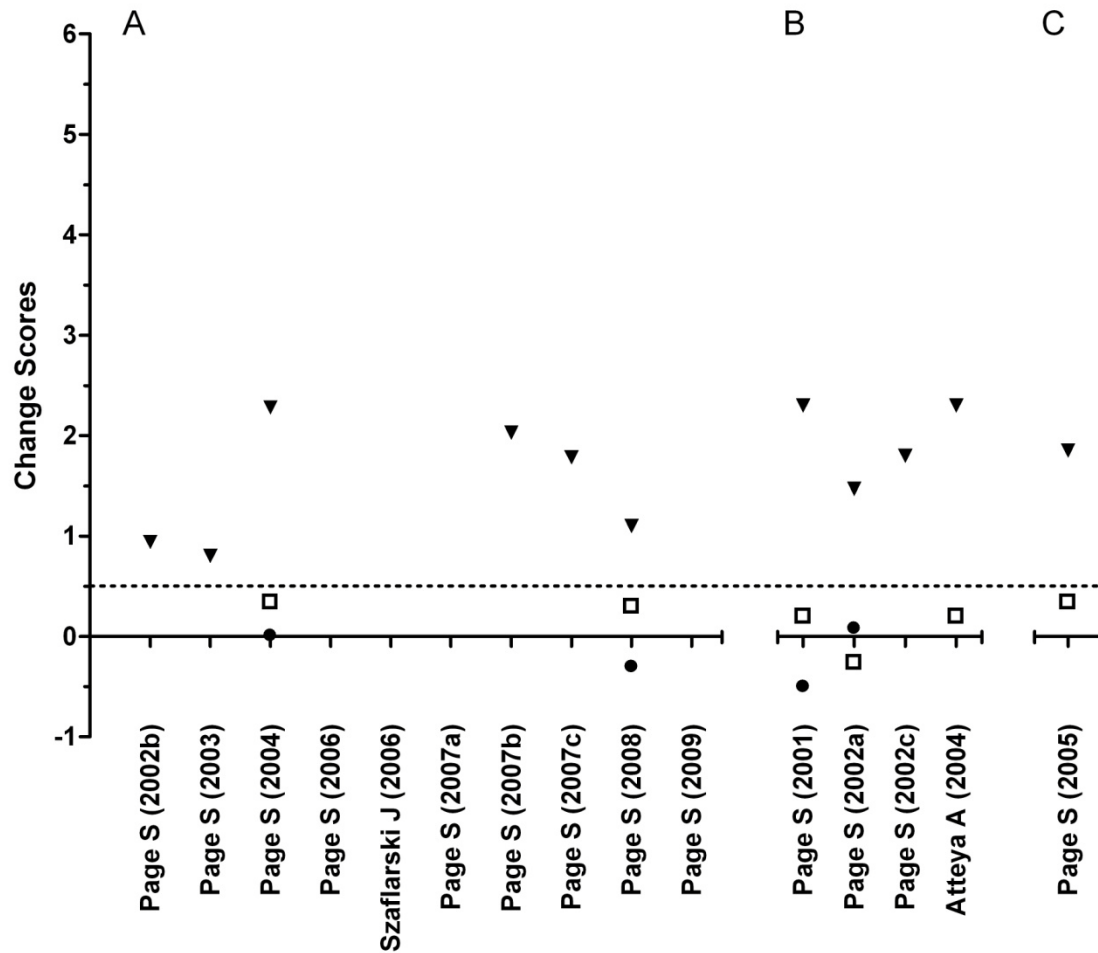


Figure 9 Pretest to posttest change scores for the Motor Activity Log – Quality of Movement (MAL - QOM) with a dashed line to represent the minimal clinically important difference.
A – chronic, B – subacute, C – acute; inverted triangle – mCIMT, square – traditional therapy, circle – no therapy.

5.4 DISCUSSION

A review of the literature examining the 10-week mCIMT protocol shows it to be an effective treatment promoting UE recovery post-stroke. Owing to the inclusion of a number of level IV and V studies, an intermediate LOE (Level C) was established for the body of literature supporting the effectiveness of mCIMT. The outcome measures for all

studies demonstrated a positive improvement for subjects who received mCIMT with regard to UE function, impairment and use (Figures 1-4). Importantly, in most of the studies the degree of change was greater than the MCID. Thus, those receiving mCIMT observed a degree of UE recovery that is clinically meaningful. This differs from subjects in the control groups who may have experienced some change in outcome measure scores; however these changes generally were not clinically meaningful.

5.4.1 Effectiveness Across the Stages of Recovery

The improvements noted for subjects receiving mCIMT were observed across all stages of recovery, indicating a 10-week mCIMT intervention can be applied effectively amongst acute, sub-acute or chronic patients who have had a stroke. While this evidence suggests that mCIMT can be beneficial for patients across the recovery continuum, it is important to consider that the bulk of evidence comes from a chronic stroke population. The changes observed amongst the acute stroke population¹⁶, while significantly different between the mCIMT and usual care therapy groups, should be considered cautiously since the study only engaged 8 subjects.

5.4.2 Interpreting the Level of Evidence: Limitations

While the 10-week mCIMT intervention appears to be an effective tool for rehabilitation of the UE post-stroke, the lack of large RCTs (≥ 100) or greater number of small RCTs reduce its overall LOE (i.e., for the body of literature). Additionally, it is difficult to run a comprehensive statistical or meta-analysis on the data from the current collection of studies as they differ in methodology. The inability to perform a meta-analysis is a necessary trade-off that allows for a comprehensive review of the mCIMT

literature and the assignment of a LOE to a specific CIMT protocol. Similarly, there are challenges comparing studies with patient populations ranging across the stages of rehabilitation. To circumvent this to some degree, we sub-divided the data into chronic, sub-acute and acute populations. Sub-dividing the data in this manner allows clinicians to determine the effectiveness of the mCIMT intervention in relation to the number and quality of the studies examining a given stage of recovery. While we applied a consistent MCID for the respective outcome measures across all stages of recovery, research suggests that the MCID can change depending on the stage of recovery. In particular the degree of change would be larger in more acute stages of recovery. For instance Lang et al. estimate the MCID for the ARAT in acute stroke populations to vary between 12 and 17 points, depending if the affected UE is dominant or non-dominant, respectively.⁹⁰ Importantly, these values were determined from a study that applied the original 2-week CIMT protocol. The post-treatment assessment was conducted an average of 25.9 days post-stroke. Comparatively, Page et al. also recruited subjects within 14 days of stroke but applied a 10-week mCIMT protocol.¹⁶ Thus, post-stroke assessments ranged from 10-12 weeks (70-84 days) post-stroke. Considering the much shorter post-stroke assessment time period, the MCID values suggested by Lang et al. may not be appropriate for the purposes of this review.

The outcome measures and their generalizability can also prove challenging for researchers. While both the ARAT and FM assess similar movements, they include differing features. The FM tends to focus less on the skills performed and practiced during mCIMT. This differs from the ARAT which tests movements that more closely resemble those practiced in mCIMT. Hence, the ARAT tends to have greater

responsiveness (more sensitive to change) for UE improvements compared to the FM in patients post-stroke.^{82, 91} The ARAT may be a better tool (relative to the FM) to measure changes in UE function for subjects receiving mCIMT. This can help to explain the discrepancies between the two measures, as depicted in Figures 1 and 2. Since the ARAT is more likely to find changes in subjects who received mCIMT, it is not surprising that the mCIMT group across all of the included studies had ARAT changes scores greater than the MCID. The less responsive FM, however, had variable changes scores; most, though not all, studies were above the MCID.

5.4.3 Incorporating mCIMT in Clinical Practice

It is important for therapists and clinicians to know the LOE of specific therapy protocols, in this instance mCIMT, in order to make informed decisions about using it in their clinical practice. The majority of mCIMT evidence focuses on chronic stroke populations and supports mCIMT use at this stage of recovery. Studies examining patients in the subacute stage of recovery, though fewer in number, also support mCIMT as an effective intervention for the UE post-stroke. Although it appears promising, the evidence is limited to support mCIMT for people with acute stroke. Clinicians should consider their patients' stage of recovery, if they meet CIMT criteria, and which protocol is reasonable to implement for their particular practice setting, in the context of the evidence supporting a given CIMT protocol.

5.4.4 Conclusion

Overall there is an intermediate LOE in support of mCIMT as an effective treatment for UE hemi-paresis post-stroke. Future research including large RCTs would

strengthen the LOE for mCIMT. Additional investigation into the effectiveness of mCIMT in acute and sub-acute stroke populations is warranted. A specific MCID should also be established for each stage of rehabilitation. In-turn, a stronger LOE for mCIMT can provide additional support for its inclusion in best practice guidelines for stroke care, further promoting its use in clinical practice. Publications outlining in detail the way in which a particular therapy is delivered can augment systematic reviews summarizing the evidence for a given protocol. For instance, Page et al. provide a detailed account of the ‘ingredients’ necessary for implementing mCIMT in clinical practice.⁵⁴ Such methods-based papers can act as a valuable resource for therapists. By improving clinical use of mCIMT we can improve the rehabilitation outcomes for people who have experienced a stroke.

5.5 SUMMARY TO CHAPTER 5 AND TRANSITION TO CHAPTER 6

As outlined previously, mCIMT is a 10-week protocol that can be used as a treatment option for the hemiparetic UE post-stroke. Overall there is an intermediate LOE in support of mCIMT as an effective UE treatment. Specifically, subjects receiving mCIMT most often see UE recovery in terms of improved function, reduced impairment and increased activity. While a number of studies have been performed using mCIMT, they primarily include case series and small RCTs examining its effectiveness in the chronic stage of post-stroke rehabilitation. A number of studies however have emerged evaluating mCIMT amongst sub-acute and acute post-stroke populations. Importantly, subjects receiving mCIMT saw greater UE functional recovery compared to usual care and no therapy groups across all stages of recovery.

Through examination of the current literature and understanding how researchers have investigated mCIMT, we can evaluate the evidence in support of the therapy. One question that arises based on this review is whether mCIMT would be clinically feasible and effective to implement in Canada. This question represents the focus of the final component of this thesis, which was completed as part of a clinical trial examining the application of mCIMT in acute stroke.

CHAPTER 6 STUDY 3: mCIMENT TRIAL

The effectiveness and feasibility of mCIMENT was investigated through a clinical trial that implements a mCIMENT protocol within an acute and sub-acute post-stroke rehabilitation setting. This trial was a pilot, single centre, randomized single-blinded parallel group study. The following sections describe the methodology of the trial as a whole; however, as this thesis includes a single case study of a subject that has completed the trial, subsequent sections will outline methodology specific to this case and my role in the delivery of mCIMENT. Subsequent sections will discuss challenges to the implementation of mCIMENT as well as a discussion of its feasibility and effectiveness (in a preliminary manner) based on the results of a case study.

6.1 METHODOLOGY

6.1.1 Groups and Subjects

The study compared rehabilitation outcomes of an experimental group to a control group. All subjects received usual care as part of their normal therapy sessions, as designated by their healthcare team. The experimental group was enrolled in a mCIMENT intervention that was additional to usual care. The control group received additional usual care as part of the research study that was dose-matched to the mCIMENT therapy received by the experimental group. Matching the dose of therapy between groups ensured the same exposure to therapy throughout the treatment phase of the study.

Subjects were selected from admissions to the acute stroke service at the Queen Elizabeth Health Sciences Centre (QEII). To participate, subjects must have experienced their first symptomatic stroke (ischemic or hemorrhagic) resulting in UE hemi-paresis

within 2 weeks of recruitment. Additional inclusion criteria were: (1) ability to perform a two-step command, (2) \geq 18 years old, (3) resided within a 75km radius of the QEII, (4) met standard mCIMT criteria^{16, 17, 40} including (i) $\geq 10^\circ$ of active wrist extension (ii) $\geq 10^\circ$ of active thumb abduction/extension (iii) $\geq 10^\circ$ of active extension in two additional digits (iv) ability to perform the movements 3 times in 1 minute. Exclusion criteria were: (1) excessive pain in the affected UE, defined as > 4 on a 10 cm visual analogue scale (VAS), (2) orientation score of < 6 , (3) diagnosis of pre-stroke dementia, (4) diagnosis of terminal illness, life-threatening co-morbidity, or concomitant neurological or psychiatric illness, (5) excessive tone in the upper limb, > 3 on the modified Ashworth Scale (MAS), (6) MAL score > 2.5 on the amount of use sub-scale. The VAS is a 10 cm line anchored by 0 (far left) and 10 (far right) whereby subjects were able to mark the severity of pain in their UE ranging from no pain (equivalent to 0) to pain equal to the worst pain they have experienced (equivalent to 10). The MAS provides a means of quantifying hypertonicity. To perform the MAS, the extremity being examined was moved passively through the joint ROM, with the degree of tone assigned a score along a 6-point scale ranging from 0 (no increase in tone) to 4 (rigid in flexion and extension).⁹²

Subjects were randomized into the experimental or control groups following consent and the pre-treatment assessment. Subjects were stratified by pre-treatment ARAT scores [≤ 24 (lower UE function) or $>$ than 24 (higher UE function)] and subject age (≤ 60 or > 60 years)], into one of four groups including (1) younger with lower UE function; (2) younger with higher UE function; (3) older with lower UE function; and (4) older with higher UE function.

6.1.2 Assessments

Within 2 weeks of admission to the acute stroke service, subjects agreeing to enrol and who provided written, informed consent underwent baseline measures (only collected once and described in Appendix F). Assessments were performed at 4 time points: (1) pre-treatment (T=0); (2) immediately post-treatment (T=10 weeks); (3) at 6 months from the last treatment session (T=36 weeks); and (4) at 12 months from the last treatment session (T=62 weeks). Outcome measures were assessed at all time points for both experimental and control subjects to facilitate comparison between the two groups. The assessor was blinded to group assignment throughout the trial.

6.1.3 Primary outcome measures

The ARAT is a functional test used to assess UE movement. Changes in ARAT scores over time can assess UE functional recovery. Particularly, the measure is used to assess UE functional changes in individuals post-stroke with hemiparesis.⁷⁹ The test contains 19 items that are grouped to test different qualities of UE function by the following 4 sub-scales: grasp, grip, pinch and gross movement. Each subscale is graded on a 4 point scale where '0' = cannot perform any part of the movement; 1 = performs the test partially; 2 = completes the test, but in an abnormally long time; and 3 = performs the test normally. Thus, there is a total possible score of 57 points, with a score of 57 indicative of good UE function. The ARAT is commonly used in studies examining UE recovery and function because it requires less than 10 minutes to complete and has been shown to be a valid and reliable measure of UE function for individuals recovering from stroke.^{80, 93} It is sensitive and responsive to change resulting from treatment in the stroke population.^{91, 94, 95} On the ARAT, a change of 6 points identifies the MCID.^{82, 89}

Amount of use and quality of use of the affected UE were assessed using the MAL and through accelerometry. The MAL is a 14-item questionnaire used for patients with mild-moderate hemiparesis to measure ‘real world’ use of the affected UE (‘activity’ as per the ICF).^{83, 84} Fourteen ADLs are assessed based on AOU and QOU subscales to ascertain how much and how well the affected UE is used. Each activity is evaluated on a 6 point scale whereby 0 = ‘did not use my weaker arm’ and 5 = ‘used my weaker arm as often as before the stroke.’ The MAL has been used extensively to evaluate stroke rehabilitation treatments because of a large responsiveness ratio (>3) and sensitivity to changes pre-post CIMT.⁸³ A change of 0.5 points indicates 10% of the scale’s total range and is often used to identify a clinical difference.^{83, 84} Accelerometry (Gulf Coast Data Concepts, LLC) was used to quantitatively measure the amount of use of the UEs during a 3-day period prior to each assessment (thus 4 times in total). The equipment is a small (10 x 2.5 x 2.5 cm; 55g), 3-axis unit that acquires and stores time-stamped acceleration data. The units are placed inside custom-made bands that are worn on each wrist. The devices capture daily use of the affected and unaffected UEs with the memory and battery capacity to record and store data for 3 days. It provides a valid, quantitative measure of functional UE recovery post-stroke among the subjects.^{83, 96, 97}

6.1.4 Secondary Outcome Measures

Feasibility of the mCIMT intervention was assessed by patient compliance to the regimen. Compliance was measured in the following ways: 1) the percentage of patients enrolled in the experimental group who complete all therapy sessions; and 2) the percentage of prescribed time that patients wear the restraint, as quantified by a compliance device. The second method of measuring compliance assigns a quantitative

value to restraint use and is a more accurate measure of treatment compliance. Subjects in the mCIMT group used a protective mitt as the restraint for the unaffected UE (see Figure 10). The compliance device was a custom-made unit placed inside the mitt consisting of a simple electrical circuit with one AAA battery, two small magnets (one on each side of the mitt restraint, palmer and dorsal) and a small voltage data logger (11 x 2 cm; 57 g; Omega Engineering Inc.). The device sampled a voltage that corresponds to whether a subject was wearing the mitt restraint. When the mitt was not being worn, the electrical circuit was closed, resulting in a steady output of 0.5V. When the mitt was being worn, there was a break in the circuit and thus a voltage of 0V. The amount and time of day the mitt was worn can be determined, as the voltage output level was sampled 20 times/hour. This resulted in a measurement error of $\pm 1.7\%$; over a 6-hour period there was a measurement error of ± 6 minutes. Data were downloaded after the 10-week intervention period.



Figure 10 Photo of a mitt worn by subjects receiving mCIMT. The compliance device is located within the mitt, under the palm.

6.1.5 Analyses

For the purpose of my thesis, only data based on a preliminary subset of subjects was investigated. Given the number of subjects enrolled, and the number randomized to the experimental (mCIMT) group, subsequent sections report methods and data as they relate to a single subject. Information regarding individual subject data is presented to characterize the subject (e.g., demographic data, type of stroke experienced, and baseline measures). Changes in UE function and activity were assessed using accelerometry, MAL and ARAT scores. Custom software applied to the accelerometry data quantified UE movement as a composite score using parameters equivalent to those previously reported.⁹⁸ Specifically, time-stamped accelerometer data were examined in 2-second epochs (equivalent to 20 samples) for each of the X, Y and Z-axes. The resultant 2-second epochs were then examined to determine the number of epochs that exceed an absolute threshold value of 2, which is representative of a movement in that particular axis. The resulting composite score was the sum of the number of 2-second epochs, expressed in seconds, which exceed the threshold value. For instance, if 2000 epochs were found to exceed the threshold value, the resultant composite score would be 4000 seconds (i.e., for that axis, movement was detected during the data collection period for 4000 seconds). Movement along the x-axis (moving front-to-back as shown in Figure 11) is reported and used for analysis as it has been shown to be most reflective of movement.⁹⁸ Where appropriate, comparisons were made within the same UE from pre to post-treatment, and between the unaffected and affected UE at baseline and at post-treatment. As outlined previously, the MAL is a quantitative, but subjective, report of

affected UE use post-stroke. MAL scores pre- and post-treatment were compared to examine any changes in UE amount or quality of use. The MAL and accelerometry findings were compared to identify potential discrepancies between subjective and objective reports of UE use.³⁹ Additionally, ARAT scores for the affected UE were compared pre-treatment and post-treatment (at 10 weeks) to examine changes in function.

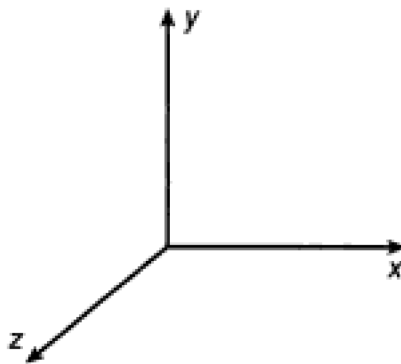


Figure 11 X-, Y- and Z-axes to describe movement direction. To describe gross movements, the xyz system is attached to the centre of mass of the body.⁹⁹ Movement along the x-axis goes front-to-back. Movement along the y- and z-axes moves head-to-toe and side-to-side, respectively.

To examine feasibility of the mCIMT treatment, compliance with the treatment was examined for subjects in the experimental group. Subjects in the control group were not required to perform any independent therapy outside of the structured therapy sessions and thus compliance was not needed to be examined for this group. Data obtained using the compliance device were analyzed to calculate the amount of time each subject wore the restraint over the treatment period to facilitate comparison between actual and prescribed use. Compliance with the restraint device was plotted graphically as a function of voltage by time and visually interpreted.

6.1.6 Therapy

As highlighted above, subjects were enrolled within 2 weeks of admission and treatment continued for 10 consecutive weeks. Thus, treatment spans from acute inpatient care at the QEII to in- or out-patient rehabilitation at the Nova Scotia Rehabilitation Centre (NSRC) (see Figure 12 for a detailed timeline). The same occupational or physical therapist administered treatment for subjects in the experimental and control groups. The team members received training in mCIMT at a workshop performed prior to the onset of the study.

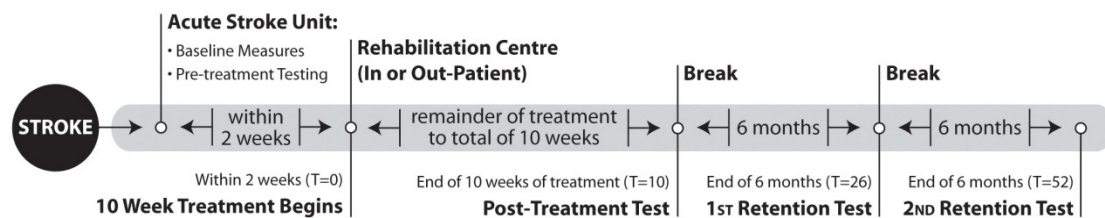


Figure 12 Treatment timeline. Patients meeting the inclusion criteria and who are willing to provide informed consent will be assessed [baseline measures and pre-treatment testing (T=0)] and then randomized within two weeks of admission. Treatment will occur for 10 weeks as either an in- or out-patient. Assessment of the outcome measures will occur at the end of treatment (post-treatment; T = 10) and following 6 months, (1st retention test) and 12 months (2nd retention test).

6.1.6.1 Usual Care

All patients enrolled in the trial (control and experimental) received usual care. Usual care within in-patient settings typically consisted of 2 hours/day, one hour each of OT and PT. It focused on a variety of therapeutic techniques, including ROM activities, strengthening, manual dexterity exercises and general aerobic conditioning. Once a

patient began outpatient therapy, usual care often consisted of 1 hour of group therapy, 2 times/week emphasizing the same components of in-patient usual care. Documentation was collected throughout the study as per usual clinical practice and reviewed. This helped to ensure that therapies were consistent among subjects.

6.1.6.2 Control Group

Subjects randomized to the control group received a total of 1.5 hours/week of additional usual care as part of the trial. These sessions were typically broken down into 30-minute sessions performed 3 times/week. Since the control group performed the same volume of treatment as the experimental group, any changes in outcome measures could be attributed to the difference in treatment (mCIMT plus usual care vs. dose-matched usual care alone) rather than simply receiving more therapy.

6.1.6.3 Experimental Intervention (mCIMT)

Subjects randomized to the experimental group received a total of 1.5 hours/week of mCIMT. This treatment consisted of 30-minute therapy sessions performed 3 times/week.^{16, 17} As described earlier, the therapy sessions incorporated shaping techniques as subjects performed various functional tasks. Furthermore, the tasks were performed primarily using the affected UE while the unaffected UE was restrained in a mitt. Additional to the therapy sessions, subjects undergoing mCIMT treatment aimed to wear the mitt restraint on the unaffected extremity 5 hours/weekday. This may have occurred in a 5-hour block or smaller intervals throughout the day that summed to 5 hours. I worked in collaboration with the treating physical therapist in the preparation and documentation of mCIMT therapy sessions. Time was spent before each treatment session and outside of normal sessions to prepare the tasks and outline the focus for the

session. Subjects also received homework tasks to complete outside of the structured therapy sessions. Records related to the homework assigned and degree to which they were completed were filled out by myself and the subject. The homework tasks were reassessed at each therapy session to ensure the activities are appropriate for each subject (i.e. the task difficulty matches each person's functional ability).

Each therapy session involved performing and practicing 4-5 functionally relevant tasks. Subjects spent about 5-7 minutes per task, with rest breaks provided as needed.¹² Tasks included as part of the therapy must have been functional and able to adhere to shaping principles. Tasks must have had a performance component that allows for feedback to the subject. For instance, tasks could be performed in timed trials (eg. complete X within a 30 second trial). Furthermore, the tasks must have been able to be modified so they could be progressive and measureable (Appendix G for examples).

6.1.7 Thesis Work

Within the context of the larger clinical trial, this aspect of my thesis work focused on the development and execution of the mCIMT intervention. This was inclusive of task development, mCIMT session planning and execution, behavioural techniques, and homework activities. The case study that follows provides an example of how I planned and executed sessions, and offers a context for a discussion as it relates to the delivery of mCIMT. Additionally the case study provides a preliminary indication of the study effectiveness and feasibility

6.1.7.1 Task Development and mCIMT Session Planning

In preparing therapy sessions, tasks could be selected from a pre-determined database of tasks or new tasks could be created that addressed a subject's motor deficits or aligned with their personal interests. A component of my thesis work involved designing tasks and structuring the mCIMT therapy sessions. Task design and selection were based on the considerations outlined above (i.e., amenable to shaping) and those established in prior work on CIMT.^{12, 13} Subjects identified 4-5 major goals and functional tasks they enjoy (eg. gardening, paddling or fishing). These goals were broken down into functional movements, and then further reduced to their component movements (eg. elbow flexion, wrist extension). Task selection focused on the movements necessary to achieve the larger functional movement as well as the movements that may have had the greatest potential for improvement. As alluded to above, tasks should not only be based on a subject's functional ability, but also should reflect the subjects' interests. The subject valued the activities, either as an identified goal or a subcomponent of the functional movement.

As outlined above, task selection was guided by the ability to develop shaping parameters for that particular task. For each task, a series of potential shaping progressions was established to modify the task and progressively increase task difficulty.^{13, 47} These shaping steps matched subjects' functional abilities to promote success. Creating a shaping program allowed the therapist and I to modify task difficulty in small amounts to better match improvements in motor function and task performance. The shaping progressions developed also provided a means to give the subject positive

feedback related to their performance, which is a key component of the behavioural aspect of mCIMT.^{13, 32}

6.1.7.2 mCIMT Therapy Sessions

A key piece of this aspect of my thesis work involved attending all of the mCIMT therapy sessions to document the overall treatment session, document and implement feedback throughout the sessions, and lastly, document the subject's performance on the individual tasks utilized. This documentation included measures of performance (eg. number of task repetitions performed correctly, number of repetitions in 30 seconds etc.). As outlined above, documentation of performance could be used to provide immediate positive feedback (eg. in reference to throwing a ball to a target: "you completed all 5 throws successfully in half the amount of time"). Documenting performance was important in order to titrate task difficulty as performance improved.^{12, 13} For instance, task difficulty could be altered by changing the object used in the task (eg. heavier or larger diameter object), the distance to a target, temporal aspects of the task (eg. decreased time to complete), or the number of successful repetitions in a given time period (eg. complete 5 times correctly in 30 seconds). Although the typical progression was to increase task difficulty with time, ultimately it was most important to match task difficulty to a subject's functional ability. Task difficulty increased when a task was performed successfully (ie. a particular shaping parameter is achieved). For example, if a subject was asked to repeat a task 5 times accurately in 1 minute and accomplished this goal, the task would then subsequently be altered to be more difficult (more repetitions in the same amount of time, increased distance to perform the task etc.). On the other hand, if a subject was not successful in a task, it was modified to decrease the difficulty level

and help to ensure success on the next trial. (See Appendix G for examples of tasks with potential shaping steps).

Additionally during therapy sessions, I led discussions with subjects regarding challenges they faced in their daily lives and issues specific to the mCIMT treatment. These conversations were opportunities to problem solve with subjects and address functional tasks that could targeted.³²

6.1.7.3 Additional Components of mCIMT

Prior to beginning the mCIMT treatment, subjects reviewed and were asked to sign a behavioural contract, in conjunction with the treating therapist. The intent of this contract was to give subjects another opportunity to review the treatment requirements to fully understand their significance and to help ensure its adherence.^{17, 48} The rationale of including a behavioural contract was to allow subjects to ‘buy-in’ to the therapy and be motivated to participate. Additionally, if compliance was low the contract acts as a reinforcement tool for the treating therapist to remind subjects about their commitment.

Beyond the practice of tasks within structured therapy sessions, subjects within the mCIMT group were to wear the restraint on their unaffected UE for 5 hours per weekday. Subjects wore a protective safety mitt (Stevens Company Ltd.) during a time of frequent use, as identified by each subject. I consulted with the subject and their caregiver (if applicable) to recognize appropriate times for wear. Depending on the subject’s lifestyle, times for wearing the restraint could be broken into smaller intervals rather than a continuous 5-hour block (for example, 2 hours after breakfast, 2 hours after lunch, and 1 hour after dinner). It was preferable to wear the mitt for intervals lasting at least one hour, however individual subjects’ preferences could be accommodated. Times

of frequent use could include recreational activity or usual therapy sessions. Safety considerations related to mitt use (eg. when taking a shower or using a walker) were discussed with subjects and their caregivers. Subjects were also given a document outlining these safety considerations. I followed up with subjects throughout the 10-week intervention period to re-evaluate the appropriate times for wearing the restraint. Compliance with wearing the restraint was measured using a device that was embedded within the padded surface of the mitt (as described on page 77).

6.1.7.4 mCIMT Homework Sessions

During the time that the mitt was worn outside of therapy sessions, subjects were to engage in homework tasks. These tasks were similar to those performed during therapy sessions and were structured such that subjects could perform them independently. At the end of each therapy session, I would plan the homework tasks in consultation with each subject. Tasks could be, though were not necessarily, the same as those performed during the therapy session. Equipment could be loaned to subjects to help them perform homework tasks. Furthermore, subjects were given written/photo instructions for each task (when needed) and were asked to complete a form to record any homework activities they partook in. During the next therapy session, I would re-assess if the homework tasks were still appropriate and interesting to the subject, and would alter as necessary. To complete this assessment, forms were developed that allowed subjects to report information regarding homework tasks (eg. number of times performed, difficulty level, different shaping parameters). Additionally, post-homework discussions with each subject at the subsequent therapy sessions allowed for a review of the previous homework tasks, any other activities subjects engaged in, and tasks that had been

assigned and planned for the following days. Participants could perform the same task for homework over several days, modifying the tasks based on the shaping parameters provided to them to ensure the tasks remained challenging.

6.1.8 Other Methodological Considerations

One of the underlying goals of this aspect of my thesis work was to highlight challenges encountered in the preparation and implementation of mCIMT. Of primary interest was identifying the challenges of delivering mCIMT in an acute clinical setting. Furthermore, the research focus involved the development of individualized treatment plans that make up the tasks and skills component of mCIMT. To this end, I have developed a database of tasks for use in the mCIMT trial (see Appendix G). Moreover, an additional role was to collect information from each subject and their caregiver in order to apply tasks to be used in that individual's treatment. Overall, I led the development of the mCIMT interventions that were used in the trial. Recording and eventually publicizing the mCIMT 'task database' will be essential to more widespread implementation of mCIMT in clinical rehabilitation.

As highlighted previously, the following sections will include the presentation and interpretation of data from a single subject enrolled in the mCIMT group as part of the larger randomized control trial. Presentation of this case study will provide a contextual backdrop to permit discussion related to the implementation and effectiveness (evaluated in a preliminary manner) of mCIMT in this particular setting.

6.1.9 Case Description

The subject was a right-handed 60-year-old white man who experienced a right pontine infarct on April 27, 2012. Upon written consent, the subject was screened on May 1, 2012. The scores for these tests can be found in Table 8. The subject reported some pain in his shoulder and quantified it as 4/10 on the VAS. Because he reported no pain in his arm, he described his overall VAS pain score for the UE as 2/10. The MAS finding of 0 in both the wrist and elbow indicates no tone about the joints. Additionally, the subject met the minimum ROM criteria and presented with deficit in cognitive function according to our initial screen. The subject was also tested on the MAL, using the AOU subscale as another screening tool (see 6.1.8.2 below for information regarding MAL scores). He tested below the exclusion score of 2.5 points.

Table 8 Scores for the case study on tests performed at screening.

VAS	Modified Ashworth Scale		Orientation	Active ROM	Aphasia screen
	Wrist	Elbow			
2/10	0/4	0/4	12/12	14°	5/5

Following the initial screen, it was determined that the subject met the inclusion criteria and thus underwent randomization. The subject, who was part of the lower functioning (he scored ≤ 24 on the ARAT at the baseline assessment; see 6.1.8.2 below) and younger (≤ 60 yrs old) stratification group, was randomized into the intervention group receiving mCIMT.

Prior to the baseline assessment, the subject wore accelerometers on each wrist to measure activity over a 3-day period (see section 6.1.3 for information regarding accelerometry).

6.1.9.1 Baseline Assessments

Baseline testing occurred on May 4, 2013. As highlighted previously, the subject was right-handed and experienced reduced function in his left UE owing to the right-side infarct. Prior to his stroke, the subject was experiencing a number of medical conditions including osteoarthritis, peripheral vascular disease, diabetes, circulatory problems, and high blood pressure. Additionally, the subject was a regular smoker. The subject was not married or living with another person at the time of stroke. The subject was able to talk and was oriented in time and space. Gross movement of the UE was intact (i.e., he was able to lift both arms off his bed), however his mobility was impaired, requiring assistance to walk.

A number of baseline measures, as outlined in Appendix G, are performed as part of routine clinical care and collected for the trial as a means of characterizing the subjects at entry into the trial (e.g., baseline assessment). Table 9 outlines these measures and the date each was performed. On admission (the day of his stroke), the subject's affected UE was quite impaired, with a CMSA score of 1 for the arm and hand (denoting flaccid paralysis). One day post-stroke the subject had a global impairment rating of 'moderate' based on the SSS (impairment in two of the assessed domains). Five days following his stroke he had a Barthel Index of 33 (whereby 100 is completely independent). Thirty-five days post-stroke the subject has little to no cognitive impairment based on the cognitive

sub-scale of the FIM, however he has considerable motor impairment, particularly with regard to toileting (4), bathing (3) and dressing his upper/lower body (4).

Table 9 Baseline clinical assessments collected as part of routine clinical care at the acute stroke unit and rehabilitation centre.

Measure	Score		Date of test (2012)
Chedoke-McMaster Stroke Assessment (CMSA)	Arm = 1/7	Hand = 1/7	April 27 (Admission)
	Arm = 3/7	Hand = 5/7	May 24
Stroke Severity Scale (SSS)	6/11		April 28
National Institutes Health Stroke Scale (NIHSS)	Not performed		
Barthel Index (BI)	33/100		May 2
Functional Independence Measure (FIM)	Motor = 58/91	Cognitive = 34/35	June 1

Additionally, the subject underwent a series of tests as part of a cognitive assessment (described in Appendix F). The subject scored 22/30 on the Montreal Cognitive Assessment (MoCA), which is less than the threshold for ‘normal’ (≥ 26).

6.1.9.2 Case Intervention Details

The subject began mCIMT therapy sessions on May 17, 2012. He received mCIMT sessions 3 times per week as an inpatient, beginning at the acute stroke unit (2 weeks) followed by the NSRC (9.5 weeks). Following discharge from the NSRC, the patient attended 45-minute sessions twice a week for 2 weeks to complete the therapy. After all therapy sessions were complete, the ARAT and MAL were re-administered.

The subject again wore accelerometers on each wrist over a 3-day period following the post-treatment assessment.

Prior to initiating mCIMT, the patient was asked to identify major goals that he wanted to achieve via mCIMT, as well as tasks that he would like to focus on as part of his therapy. The subject reported his two favourite pastimes were hunting and fishing and thus were the main activities he wished to get back to doing. Other ADLs he identified as being of importance to him were putting on clothing (in particular doing up buttons), playing cards, reading, throwing and catching balls, and doing laundry. These activities formed the basis of our therapy session and homework tasks. To accomplish his goals over the course of therapy, each goal was broken down into component movements. Tasks performed during mCIMT were selected to address these motor skills, evolving from basic to more complex movement patterns as the subject recovered. For instance, the subject's goal with regard to hunting was to be able to hold a rifle with his left UE. This task requires shoulder flexion (with maintenance of position at approximately 90° of flexion), elbow flexion, gross hand movement (power grip) and isolated use of the digits. For fishing, there are a number of movements required: shoulder mobility as well as shoulder and elbow coupling for casting, gross hand movement (power grip) to hold the rod, and fine finger movements for baiting the hook and gutting fish.

For each mCIMT session, a number of tasks were selected to focus on different component movements (eg. shoulder flexion) that were part of these larger goals, with each being shaped according to the subject's ability. For instance, one task involved pinning clothespins onto different rungs of a baking rack. This task involved finger movement (pincer grasp), elbow extension, shoulder flexion and shoulder mobility.

During one session the task was modified as follows for each trial: (1) with the rack held horizontally on the far left side of the table, 5 pins were to be placed anywhere on the rack, as fast as possible (completed in 1 min, 25 sec); (2) repeat the task, with a goal of completing it in under 1 min, 25 seconds (completed in 1 min, 35 sec); (3) place 5 pins in the centre column only of the top half of the rack; (4) place 5 pins along the top of the rack, focusing on the quality of the movement – aiming to rotate his wrist to pronate the hand (completed successfully); (5) place 5 pins along the top half of the middle column faster than previous trials (completed in 1 min). The subject was challenged to maintain accuracy while increasing his speed. Additionally, placing the clothespins on higher rungs was more challenging for the subject as it involved increased shoulder flexion and shoulder stability. He was required to maintain hand accuracy (by properly placing the pins on the rack rungs) with increased shoulder ROM. This task was performed during subsequent therapy sessions and was further shaped by increasing the number of clothes pins placed in a given amount of time (speed-accuracy), decreasing the space available to place the pins (eg. on one row only), and placing the rack further away and higher up from the subject (requiring increased elbow extension, shoulder flexion and shoulder stability).

It is important to note that throughout the first 7.5 weeks of the mCIMT intervention the subject struggled to stay motivated and his compliance with the mCIMT intervention (in addition to usual care treatment) fluctuated week by week. A number of therapy sessions were cancelled, rescheduled and altered (in terms of length) to accommodate both the subject's and therapist's schedules. Missed sessions were rescheduled but in many instances time would be added onto subsequent sessions (i.e., 45

vs. 30 min sessions) if the schedule did not allow for additional sessions. In total, the mCIMT intervention for this particular subject spanned 13.5 weeks, with the same amount of therapy hours (compared to the typical 10 week intervention) being delivered.

6.2 RESULTS

6.2.1 Primary Outcomes

At baseline the subject attained the maximum score (57) on the ARAT for his unaffected UE. For his affected UE, the subject scored 0 on the ARAT, indicating that he could not perform any part of the assessment tasks. Likewise, the subject scored 0 on both subscales of the MAL (AOU and QOM) indicating that he did not use his affected limb for any of the 14 ADLs assessed over the past week (performed during the screening stage).

Scores on both the ARAT and MAL improved over the course of treatment. Table 10 displays the subject's scores for the ARAT and MAL at baseline, post-treatment and the follow-up. The ARAT score for the affected UE improved by 34 points, well above the MCID of 6 points. MAL scores also increased from pre- to post-treatment, with increases of 2.83 and 2.33 points for the AOU and QOM subscales, respectively. The change in MAL scores was also greater than the MCID of 0.5 points, indicating a clinical difference in use. Upper extremity function as measured by the ARAT remained unchanged at the 6-month follow-up assessment for both the unaffected (score of 57) and affected (score of 34) UE. There were slight decreases in the MAL scores between the post-treatment and 6-month follow-up assessment, however the decreases were minimal and likely did not reflect a clinically significant difference.

As outlined in the methods, accelerometry was used as a quantitative measure of UE amount of use and activity (for both the affected and unaffected UE), and complements the data provided by the MAL. Table 10 displays the findings for each limb at baseline and post-treatment. Accelerometry was also used at the 6-month follow-up; however, these data were not available for use owing to technical challenges associated with the sampling and analysis of data. At baseline, the unaffected (right) UE was being used nearly 3 times as much as the affected (left) UE. Post-treatment, the amount of use for the affected UE had increased by nearly 3 times compared to baseline. Comparatively, the unaffected UE had decreased in its amount of use post-treatment.

Table 10 Scores on the ARAT, MAL and Accelerometry before and after treatment for the case study subject receiving mCIMT.

		Baseline	Post-treatment	6 month follow-up	Change Score	
					Baseline to Post-treatment	Post-treatment to 6 month follow-up
ARAT	Affected	0	34	34	34	0
	Unaffected	57	57	57	0	0
MAL	Amount of Use	0	2.83	2.69	2.83	-0.14
	Quality of Movement	0	2.33	2.31	2.33	-0.02
Accelerometry (x-axis)	Left UE (affected)	978 min	2800 min	NA	1822 min	NA
	Right UE (unaffected)	3293 min	1171 min	NA	-2122 min	NA

The FIM was also performed 2 weeks prior to completion of the mCIMT intervention as part of the subject's usual clinical care (72 days post-stroke), with scores of 84/91 and 32/35 noted for the motor and cognitive subscales respectively. The

subject's score on the motor subscale represented an increase of 26 points from pre- to post-treatment, indicating greater independence on the specific tasks assessed. For instance, in the self-care domain, which he scored the lowest during his first assessment (toileting, bathing and dressing his upper/lower body), he improved and reached the maximal score (7) for each task. Locomotion remained as the only domain for which he required assistance (6: supervising or cueing).

6.2.2 Secondary Outcomes

The subject's compliance to treatment was measured as a means of assessing the clinical feasibility of mCIMT in this particular setting. As described in sections 6.1.3 and 6.1.5.3, the subject wore a mitt containing a compliance device to measure the amount of time he wore the restraint. As noted in the methods, when the mitt was being worn the compliance device would output and measure a voltage, with no voltage produced (and thus detected) when the mitt was not being worn. Figure 13 depicts when the mitt was being worn over the treatment time period from the first to last therapy session. Based on the data obtained from the compliance device, it appears that the mitt was worn extensively throughout the mCIMT intervention. For instance, from the end of June to mid-July there appears a positive voltage, indicating that the mitt was being worn. Interestingly the data obtained from the compliance device conflict with the subject's self-report of mitt use and the therapist's (and my own) observations. Thus, the results obtained from the compliance device may not be valid. The subject was regularly reminded of the importance of wearing the restraint and encouraged to engage his affected UE in ADLs and homework activities. After a series of missed and rescheduled therapy sessions, the therapist reminded the subject of the behavioural contract he signed,

his goals, and discussed if he was committed to continue (to which he asserted he was). At each therapy session, he was asked how much he wore his restraint and the activities he performed while wearing it. While at times he would indicate less than the required 5 hours/day, based on our discussions he likely over reported the amount of time he wore the restraint throughout the treatment. Potential causes of why data obtained from the compliance device are not valid are discussed in the limitations section.

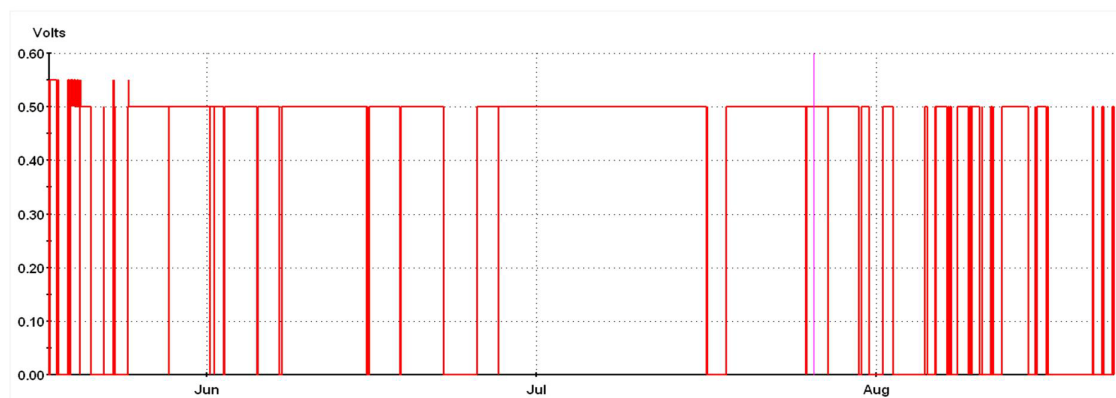


Figure 13 Amount of time as reported by the compliance device in which the case study subject wore the mitt restraint during the intervention period. A voltage of 0.5V indicates the mitt is being worn.

6.3 SUMMARY TO CHAPTER 6 AND TRANSITION TO CHAPTER 7

The third project of my thesis involved investigating the effectiveness and feasibility of mCIMT in Canadian acute and subacute stroke rehabilitation. While the trial as a whole attempts to demonstrate if mCIMT can still be effectively delivered and reasonably implemented into routine Canadian clinical practice, my thesis work focused on specific aspects within the study. The goals of my research focused on the development and execution of the mCIMT intervention by highlighting preliminary

findings regarding effectiveness and feasibility. Furthermore, the purpose of my thesis work was to discuss key features of task development and challenges of mCIMT implementation. These goals are addressed in the context of the case study in the following chapter. Findings and observations from the case study are further discussed more globally in terms of barriers to mCIMT implementation and how to overcome them.

CHAPTER 7 DISCUSSION

7.1 CASE STUDY FINDINGS

Following the mCIMT intervention, the subject experienced clinically significant increases in function, amount of use and quality of movement in his affected UE. These changes are supported by the increase in his ARAT and MAL scores from pre- to post-treatment. The accelerometry data complement and support the MAL findings, indicating that use of his affected UE increased over the course of treatment and was comparatively active to his right UE post-treatment. Furthermore, these clinically relevant changes were sustained over a 6-month period following treatment with mCIMT. Considering the subject was enrolled during the acute stage of recovery and thus was receiving usual in-patient and outpatient therapy, it is not surprising that there was some amount of functional recovery. Page et al. performed a RCT within an acute stroke population to deliver a similar mCIMT intervention.¹⁶ As can be seen in Figures 6, 8 and 9 (Chapter 5), the group receiving mCIMT had significantly greater increases in ARAT and MAL scores compared to the dose-matched usual care control group. While improvements were made, the control group did not exceed the MCID on any measure. The mCIMT group, however, far exceeded the MCID with assessment scores that nearly quadrupled those of the control group (21.7, 2.43 and 2.19 for the ARAT, MAL (AOU), and MAL (QOM) respectively). Comparatively, the subject described in this case study experienced changes on the ARAT that exceeded those of the mCIMT group in the Page study, with similar changes observed for the MAL. This comparison to the results of the Page study provide indirect evidence that the mCIMT treatment received by the case

study subject contributed to his functional gains and increased activity. Additionally, Lang et al. suggest that the MCID for ARAT scores differs when assessing individuals in the acute stage of post-stroke recovery.⁹⁰ Depending on the side affected, the suggested MCID raw scores are 12 (for the dominant side) and 17 (for the non-dominant side). Further research is needed to determine if the suggested MCID is still appropriate when measuring score changes after a 10-week mCIMT intervention (as discussed in chapter 5). Nevertheless, the case study subject demonstrated UE functional improvements greater than the MCID of 17 points as suggested by Lang et al. Thus, the subject's increases in functional ability appear to be clinically meaningful.

It should be noted however that because the subject also received usual care as part of his routine clinical treatment, some amount of UE recovery was expected. Without direct comparison to a dose-matched control, it is not possible to definitively conclude that the mCIMT intervention led to his functional recovery.

7.1.2 Study Limitations

Although the trial is still underway, there were limitations specific to this case study. As noted above, data from the compliance device may not be a valid representation of the amount of time the subject wore the restraint device. There are two likely causes of this limitation. Firstly, the magnetic reed switch, and in-turn the capacity to generate a voltage output, is controlled by the position of the magnets on the dorsal surface of the mitt. If the device is not oriented properly in the mitt, is it possible for the magnets to not make contact with the reed switch, thus keeping the reed switch in the 'on' mode and thus continually outputting a voltage (indicating the mitt is being worn). In this instance the device would falsely record the mitt as being worn when in fact it is

not. Additionally, this subject (and other subjects in the trial) have reported that an object, such as a water bottle, can be placed inside the mitt, thus mimicking the position of the hand, in-turn making it appear as if it the mitt is being worn. The data obtained from the compliance device, thus, needs to be interpreted in the context of these limitations.

Additionally, the accelerometers are used as a means to assess the amount of UE movement, and thus changes that may result from the intervention. With that said, the data obtained from the accelerometers are not necessarily an absolute reflection of UE movement. Since the accelerometers are placed on subjects' wrists, certain movements will not be reflected in the accelerometer data (for example, finger movements while typing on a computer keyboard since the wrist stays relatively static). Moreover, the use of a threshold value (in this case 2) to determine if a movement occurred or not can lead to an over-estimation of the amount of movement. However, important findings can still be discerned in relative comparisons of the data given that the same conditions applied across limbs and assessment time-points. Thus, while the composite scores from the accelerometer data do not provide an absolute measure of UE movement, the difference between limbs and/or change across time provides valuable information regarding UE recovery.

7.2 CHALLENGES AND BARRIERS TO mCIMT IMPLEMENTATION

7.2.1 Patient Challenges

In addition to the specific limitations encountered in the case study, a number of challenges and barriers relating to the global delivery of the mCIMT intervention were

apparent across subjects in the mCIMT group (which to date included 3 subjects). One of the key aspects to successful rehabilitation, and a vital component of mCIMT, is keeping subjects motivated.^{12, 32} As noted in the case study, and observed across subjects, keeping a high level of motivation proves to be challenging. The behavioural component of mCIMT is intended to help address this challenge, as its focus is to keep subjects motivated through the use of short- and long-term goals, identifying and modifying tasks appropriately to meet those goals, applying shaping principles to the tasks so subjects can be successful in their performance, and lastly working with the subject to address challenges to affected limb use. While these aspects of mCIMT helped the case study subject during structured therapy sessions, outside of the structured sessions it became more difficult to keep the subject engaged. Gillot et al. explored patient experiences and perceptions of CIMT and the factors that influence success with the treatment.¹⁰⁰ Factors related to personal motivational and expectations emerged as a major theme that generates a subject's drive to participate in the therapy. While the case study appeared to have positive experiences during the therapy sessions and asserted as such, a lack of motivation was evidenced by variable compliance with treatment. Not only did the subject need constant reminders to wear his restraint, but in turn it became difficult to ensure that homework activities (or other ADLs) were being performed independently, and for the subject to keep a record of it. Thus, personal motivation needs to be encouraged to ensure proper delivery of mCIMT and to improve the chance of treatment success (and in turn, recovery).

Furthermore, the subject struggled to adhere to the treatment schedule; a number of therapy sessions had to be rescheduled and adjusted for time due to missed sessions

and conflicting appointments. The subject often had busy weekdays including other tests and appointments and would make excuses that he was too tired, too busy, or simply did not want to do it that day. While many people in acute and sub-acute care face similar challenges, this subject in particular seemed to struggle to balance his schedule and meet the everyday demands of an in-patient. The subject also missed his regular therapy sessions and was not consistently compliant with that treatment either (based on conversations with his occupational and physical therapist). In contrast, the two other subjects who have since received mCIMT in the study consistently made their scheduled therapy sessions and were proactive to reschedule as soon as a conflict arose. Another noticeable difference was in how the subjects prioritized therapy sessions. The two recent subjects seemed to schedule their other appointments and activities around the mCIMT sessions, rather than the other way around (as seemed to be so with the case study subject). Nevertheless, all subjects have commented on the challenge of the mCIMT schedule and the number of activities we ask them to do, in and outside of therapy sessions. Additionally, the subjects were commonly fatigued during therapy sessions and treatment would often be modified to address this.

The time and resource intensity of CIMT interventions are often cited as a challenge to implementation, not only for therapists but for subjects as well.^{46, 47, 49, 70} While some aspects of treatment are diluted with the distributed mCIMT protocol, many of the demands are still felt by subjects (as observed and subsequently reported by the trial subjects).

The difficulties with treatment compliance and motivation exhibited by the case study subject reflect challenges that may be tied more generally to working in an acute

and sub-acute rehabilitation setting. Although mCIMT is designed to keep subjects motivated, patients dealing acutely with a stroke are often subject to many other pressures that can affect their emotional state.^{3, 7} For instance, the case study subject had to deal with the likelihood that he could not return to his job, that he could not return home right away, and that he would need to rely on distant family members. He would often discuss these issues during therapy sessions and comment on his feelings; when treatment began he was still trying to accept that he had experienced a stroke and the repercussions of it on his daily life. Unlike in later stages of recovery, patients who are acutely post-stroke have had less time to deal with the practical consequences and the emotional trauma of their stroke. Thus, when dealing with a number of life changes it is not surprising that a subject's motivation to engage in therapy could fluctuate day to day. The challenges associated with environmental and psychosocial factors likely affect all rehabilitation therapies at this stage of recovery, although they may become more prominent with mCIMT because of the associated time demands and commitment.

7.2.2 Therapist Challenges

Beyond the pressures experienced by patients in acute stroke rehabilitation, therapists also face barriers to the implementation of mCIMT.⁷⁰ mCIMT has many different aspects to the treatment and requires a particular attentiveness on the part of the therapist to ensure all the different components are being addressed.^{49, 101} A number of the barriers highlighted by the survey study (see Chapter 4) became apparent while working in the mCIMT trial. The issue of therapist knowledge is particularly prevalent as the study therapist received additional training to deliver mCIMT and was constantly

challenged to employ those skills. Furthermore, I acted as an additional knowledge resource for planning and executing therapy sessions, as well as played a practical role assisting during sessions and following-up with subjects outside of therapy sessions.

During therapy sessions, I would record notes to be able to provide immediate feedback for different tasks being carried out. This is an important part of shaping, but requires time and forces a therapist to attend to several tasks simultaneously if mCIMT is delivered independently. Outside of therapy sessions, a lot of time is spent reviewing the results of the preceding session, and preparing/ planning for the next session. One of my roles with regard to the therapy sessions was to select tasks and have a plan for shaping modifications. A therapist would not normally have someone to assist with these aspects of the therapy, and as such would increase the demands on the therapist's time.

Furthermore, weekly I spent time outside of therapy sessions putting together homework tasks, following up on subjects' progress, as well as addressing everyday challenges and how to overcome those barriers. Again, these aspects of the therapy are time consuming and not necessarily a part of routine practice.^{46, 49} Ploughman et al. noted therapists concerns about the time required outside of scheduled sessions for planning and organizing equipment and the need for ongoing collaboration, at the very least between therapist and subject.¹⁰¹ Without additional assistance, delivery of mCIMT outside of a research study may need modification to ensure its feasibility.

Thus, not only is it important for the therapist to be knowledgeable regarding the treatment, but also having resources in place (personnel and materials) helps ensure the therapy can be carried out as it is intended. With the heavy workloads already facing therapists, it may prove difficult for a therapist to deliver mCIMT independently.^{46, 49, 101}

7.2.3 How to Address the Challenges and Limitations

In identifying that a therapist's ability to independently deliver mCIMT may be a barrier to implementation, two potential resources come about: the relationship between complementary disciplines (i.e., OT and PT), and the role of a caregiver. Within the literature it appears appropriate that either an occupational or physical therapist could deliver mCIMT. Practically within acute post-stroke rehabilitation, patients often receive both OT and PT. What a therapist focuses treatment on may depend on what other treatments the patient is receiving, as well as other areas of need. Considering the potential for both professions to deliver mCIMT, it is plausible that a patient's occupational and physical therapist could work in tandem to deliver the therapy and share the workload. Ploughman et al. performed a case study applying CIMT, with the delivery of CIMT sessions shared between a pair of occupational and physical therapists.¹⁰¹ In examining if CIMT was a feasible treatment option, the researchers decided to split the therapy into 4 sessions, alternating between therapists each session. The therapists noted that while the treatment was resource intensive and required daily communication between therapists, they felt competent to deliver the treatment in their practice. It was stressed that the collaborative approach was vital; the shared workload and family participation likely led to the success of the program. As alluded to above, the subject's caregiver (family) can be an additional resource in therapy sessions, or as a resource at home. How active a role a caregiver is able to play may prove to be an important measure of success. Gillot et al. noted that while personal motivation is critical to participation in CIMT, environmental demands (including family support) could influence the drive to participate and recover.¹⁰⁰ As an example within the case study,

once the subject had a regular caregiver he no longer missed a therapy session, reported increased compliance with regard to wearing his mitt, and regularly reported the activities he performed at home. Additionally, Ploughman et al. noted that not only could family members influence motivation, but also their willingness to participate was fundamental to the treatment's success. Thus, beyond simply motivating subjects to stay engaged, a caregiver can play an active role helping a subject with homework task and has the potential to assist a therapist within therapy sessions.

Aside from additional personnel, resource materials can provide therapists with the tools to more effectively use mCIMIT, independently or within a health care team. Systematic reviews that critically analyze individual CIMIT protocols are relevant and needed so clinicians have access to robust sources of evidence when making treatment decisions that are specific to their patient population.⁵¹ In turn, with a protocol guide in place, a task database can help with clinical implementation by acting as a knowledge source and increasing the efficiency of treatment delivery. A task database can help with mCIMIT implementation by forming the basic foundation of a treatment package with the tasks, equipment needed, and some preliminary shaping parameters, progressions, and suggestions for feedback, set forth as a guideline for therapists. While useful for all therapists no matter the level of mCIMIT experience, a database may particularly target therapists newer to the therapy. Additionally, a task database can help to address issues related to the time required to plan, organize and deliver treatment with regard to choosing activities and potential shaping parameters. Having access to a collection of tasks and their component parts can help a therapist more quickly prepare treatment plans

and maximize therapy time; it would make mCIMT easier to implement as therapists could consult the resource for new ideas and to ensure proper delivery of treatment.

There may be cases though where a therapist does not have access to additional personnel (in terms of a colleague or family member), and access to knowledge resources, such as a task database, and thus cannot overcome the time and resource demands. Given these additional requirements that make mCIMT feasible to deliver clinically, future research should perhaps focus on examining the therapy's component parts to determine what components are critical to treatment and what aspects of therapy can be reduced or removed altogether. Uswatte et al. investigated in a preliminary manner the contribution of shaping and restraint components of CIMT in affecting treatment outcomes.¹⁵ Groups in this particular study used different types of restraint and the training varied to include and exclude shaping. Even though one group did not use a restraint and only received RTP with shaping, no between group differences were found at post-treatment. Functional gains were observed after receiving CIMT even in subjects that were not restrained. Similarly, Sterr et al. were interested in the clinical benefits of a shaping-only training protocol and performed a series of studies to examine this.^{26, 47} Treatment effects were found to be specific for subjects receiving RTP in conjunction with shaping, but not for those who received dose-matched RTP training, highlighting the importance of shaping principles for clinical outcomes. It was asserted that "clinical improvement is neither determined simply by amount of therapy nor the intensity with which it is applied, but by what the patient does in the treatment sessions, that is the therapeutic principles applied."⁴⁷ Hence, functional improvements can be gained even without the restraint; shaping-only protocols may provide a reasonable alternative when

use of a restraint is not feasible. It should be noted however that subsequent findings by Sterr et al. suggest that for patients who experience learned nonuse, constraining the unaffected UE is still most likely the most powerful tool to overcome this behaviour.⁴⁷

In addition to shaping principles, Gauthier et al. investigated the other behavioural training techniques (termed the ‘transfer package’ which included eg. daily monitoring of UE use in ADLs and problem solving sessions with the therapists to overcome perceived barriers to UE use) and their role in treatment outcomes.³² Comparing two subject groups, one that received all aspects of CIMT (including the transfer package) and another that did not receive the transfer package, no between-group differences were found in scores for laboratory-based measures of motor ability (WMFT). While both therapies were equally effective at yielding significant improvements with regard to function, subjects receiving the transfer package saw significantly greater improvements in real-world amount of use (MAL), compared to subjects who did not receive the transfer package. Thus, the behavioural component of CIMT appears to play an important role to promote a highly successful transfer of functional gains into real-world activity. While the restraint appears to be somewhat important, the behavioural and shaping component to treatment has emerged as key aspects of CIMT. Unfortunately, reducing or removing the use of a restraint does not overcome the barriers related to time and resource intensity of treatment.⁷⁰ Thus, not only is there a need to identify the most important aspects of mCIMT, but research is also needed to investigate the minimal combination of components necessary for functional gains. Research needs to establish the dose-response of mCIMT and balance efficacy with an amount of treatment that is still clinically feasible to deliver.

In considering treatment feasibility, it should be considered if the therapeutic benefits of mCIMT outweigh the costs (financial and otherwise). Initial attempts by the Ontario Ministry of Health to examine the cost-effectiveness of CIMT (in this instance the 2 week or ‘traditional’ protocol) suggest that while positive outcomes are reported, they cannot overcome the financial pressures associated with its delivery.⁶⁸ As noted above however, this report only looked at massed practice protocols and focused on short-term outcomes. There needs to be further investigation into the costs of distributed protocols and if these may be more feasible to deliver in a cost-effective manner. Additionally, investigations must consider short and long-term treatment outcomes as many upfront costs could be offset by long-term benefits associated with better functional recovery.

7.3 CONCLUSION

Based on the findings from the case study reported above, mCIMT appears to have potential as a treatment option post-stroke. While the patient and therapist faced challenges in implementing the therapy, ultimately the subject saw marked improvements in his affected UE recovery in terms of function and activity. As demonstrated in the literature highlighted by the systematic review, there is intermediate evidence that supports the use of mCIMT to treat the UE post-stroke. However, findings from the CIMT survey study reflect many of the practical challenges faced by clinicians when trying to implement the therapy. Striving to ensure therapies are successful, we may need to find a better balance between effectiveness and feasibility. Future research should investigate the effectiveness of treatment in larger studies to strengthen the

evidence. Likewise it is also important that research investigates how mCIMT treatments are being delivered and how each component contributes to recovery. In its present form, mCIMT may not be feasible to implement in acute rehabilitation; however it should be investigated if the treatment can be further distilled and simplified while maintaining effectiveness. By better understanding mCIMT and its potential for UE functional recovery, clinicians can be more effective and efficient in delivering treatments and in turn offer better healthcare to their patients.

REFERENCES

1. Heart and Stroke Foundation of Canada. Statistics 2012. Available from: URL: <http://www.heartandstroke.com/site/c.iQlLcMWJtE/b.3483991/k.34A8/Statistics.htm#stroke>.
2. Reorganizing stroke care in Nova Scotia. Halifax, NS: Nova Scotia Integrated Stroke Strategy Committee 2002.
3. Barreca S. Management of the post stroke arm and hand: Treatment recommendations of the 2001 consensus panel. Heart and Stroke Foundation of Ontario 2001;162.
4. Barreca S, Wolf SL, Fasoli S, Bohannon R. Treatment interventions for the paretic upper limb of stroke survivors: a critical review. *Neurorehabil Neural Repair* 2003;17(4):220-6.
5. Lai SM, Studenski S, Duncan PW, Perera S. Persisting consequences of stroke measured by the Stroke Impact Scale. *Stroke* 2002;33(7):1840-4.
6. Mayo NE, Wood-Dauphinee S, Cote R, Durcan L, Carlton J. Activity, participation, and quality of life 6 months poststroke. *Arch Phys Med Rehabil* 2002;83(8):1035-42.
7. Dobkin BH. Clinical practice. Rehabilitation after stroke. *N Engl J Med* 2005;352(16):1677-84.
8. Lindsay MP, Gubitz G, Bayley M, Hill MD, Davies-Schinkel C, Singh S et al. Canadian Best Practice Recommendations for Stroke Care (Updated 2010). Ottawa, Ontario, Canada: Canadian Stroke Network; 2010.
9. Teasell RW, Foley NC, Salter KL, Jutai JW. A blueprint for transforming stroke rehabilitation care in Canada: the case for change. *Arch Phys Med Rehabil* 2008;89(3):575-8.
10. Teasell R, Meyer MJ, Foley N, Salter K, Willems D. Stroke rehabilitation in Canada: a work in progress. *Top Stroke Rehabil* 2009;16(1):11-9.
11. Wolf SL, Winstein CJ, Miller JP, Taub E, Uswatte G, Morris D et al. Effect of constraint-induced movement therapy on upper extremity function 3 to 9 months after stroke: the EXCITE randomized clinical trial. *JAMA* 2006;296(17):2095-104.
12. Taub E, Uswatte G, King DK, Morris D, Crago JE, Chatterjee A. A placebo-controlled trial of constraint-induced movement therapy for upper extremity after stroke. *Stroke* 2006;37(4):1045-9.

13. Taub E, Crago JE, Burgio LD, Groomes TE, Cook EW, 3rd, DeLuca SC et al. An operant approach to rehabilitation medicine: overcoming learned nonuse by shaping. *J Exp Anal Behav* 1994;61(2):281-93.
14. Taub E, Uswatte G, Elbert T. New treatments in neurorehabilitation founded on basic research. *Nat Rev Neurosci* 2002;3(3):228-36.
15. Uswatte G, Taub E, Morris D, Barman J, Crago J. Contribution of the shaping and restraint components of Constraint-Induced Movement therapy to treatment outcome. *NeuroRehabilitation* 2006;21(2):147-56.
16. Page SJ, Levine P, Leonard AC. Modified constraint-induced therapy in acute stroke: a randomized controlled pilot study. *Neurorehabil Neural Repair* 2005;19(1):27-32.
17. Page SJ, Levine P, Leonard A, Szaflarski JP, Kissela BM. Modified constraint-induced therapy in chronic stroke: results of a single-blinded randomized controlled trial. *Phys Ther* 2008;88(3):333-40.
18. Taub E. Movement in nonhuman primates deprived of somatosensory feedback. *Exerc Sport Sci Rev* 1976;4:335-74.
19. Taub E, Uswatte G, Mark VW, Morris DM. The learned nonuse phenomenon: implications for rehabilitation. *Eura Medicophys* 2006;42(3):241-56.
20. Nudo RJ, Milliken GW, Jenkins WM, Merzenich MM. Use-dependent alterations of movement representations in primary motor cortex of adult squirrel monkeys. *J Neurosci* 1996;16(2):785-807.
21. Nudo RJ, Milliken GW. Reorganization of movement representations in primary motor cortex following focal ischemic infarcts in adult squirrel monkeys. *J Neurophysiol* 1996;75(5):2144-9.
22. Plautz EJ, Milliken GW, Nudo RJ. Effects of repetitive motor training on movement representations in adult squirrel monkeys: role of use versus learning. *Neurobiol Learn Mem* 2000;74(1):27-55.
23. Risley T, Baer D. Operant behavior modification: The deliberate development of behavior. *Review of child development research* 1973;3:283-329.
24. Taub E, Perrella P, Barro G. Behavioral development after forelimb deafferentation on day of birth in monkeys with and without blinding. *Science* 1973.
25. Taub E, Perrella P, Miller E, Barro G. Diminution of early environmental control through perinatal and prenatal somatosensory deafferentation. *Biological psychiatry* 1975;10(6):609.

26. Sterr A, Freivogel S, Schmalohr D. Neurobehavioral aspects of recovery: Assessment of the learned nonuse phenomenon in hemiparetic adolescents. *Archives of Physical Medicine and Rehabilitation* 2002;83(12):1726-31.
27. Ostendorf CG, Wolf SL. Effect of forced use of the upper extremity of a hemiplegic patient on changes in function. A single-case design. *Phys Ther* 1981;61(7):1022-8.
28. Wolf SL, Lecraw DE, Barton LA, Jann BB. Forced use of hemiplegic upper extremities to reverse the effect of learned nonuse among chronic stroke and head-injured patients. *Experimental neurology* 1989;104(2):125-32.
29. Halberstam JL, Zaretsky HH, Brucker BS, Guttman AR. Avoidance conditioning of motor responses in elderly brain-damaged patients. *Arch Phys Med Rehabil* 1971;52(7):318-27 passim.
30. Taub E, Miller NE, Novack TA, Cook EW, 3rd, Fleming WC, Nepomuceno CS et al. Technique to improve chronic motor deficit after stroke. *Arch Phys Med Rehabil* 1993;74(4):347-54.
31. Winstein CJ, Miller JP, Blanton S, Taub E, Uswatte G, Morris D et al. Methods for a multisite randomized trial to investigate the effect of constraint-induced movement therapy in improving upper extremity function among adults recovering from a cerebrovascular stroke. *Neurorehabil Neural Repair* 2003;17(3):137-52.
32. Gauthier LV, Taub E, Perkins C, Ortmann M, Mark VW, Uswatte G. Remodeling the brain: plastic structural brain changes produced by different motor therapies after stroke. *Stroke* 2008;39(5):1520-5.
33. Wolf SL, Winstein CJ, Miller JP, Thompson PA, Taub E, Uswatte G et al. Retention of upper limb function in stroke survivors who have received constraint-induced movement therapy: the EXCITE randomised trial. *Lancet neurology*. 2008. p 33-40.
34. Liepert J, Bauder H, Wolfgang HR, Miltner WH, Taub E, Weiller C. Treatment-induced cortical reorganization after stroke in humans. *Stroke* 2000;31(6):1210-6.
35. Dromerick AW, Lang CE, Birkenmeier RL, Wagner JM, Miller JP, Videen TO et al. Very Early Constraint-Induced Movement during Stroke Rehabilitation (VECTORS): A single-center RCT. *Neurology* 2009;73(3):195-201.
36. Wu CY, Chen CL, Tang SF, Lin KC, Huang YY. Kinematic and clinical analyses of upper-extremity movements after constraint-induced movement therapy in patients with stroke: a randomized controlled trial. *Arch Phys Med Rehabil* 2007;88(8):964-70.
37. Lin KC, Wu CY, Wei TH, Lee CY, Liu JS. Effects of modified constraint-induced movement therapy on reach-to-grasp movements and functional performance after chronic stroke: a randomized controlled study. *Clin Rehabil* 2007;21(12):1075-86.

38. Page SJ, Sisto SA, Levine P, Johnston MV, Hughes M. Modified constraint induced therapy: a randomized feasibility and efficacy study. *J Rehabil Res Dev* 2001;38(5):583-90.
39. Page SJ, Sisto SA, Levine P. Modified constraint-induced therapy in chronic stroke. *Am J Phys Med Rehabil* 2002;81(11):870-5.
40. Szaflarski JP, Page SJ, Kissela BM, Lee JH, Levine P, Strakowski SM. Cortical reorganization following modified constraint-induced movement therapy: a study of 4 patients with chronic stroke. *Arch Phys Med Rehabil* 2006;87(8):1052-8.
41. Page SJ, Sisto S, Johnston MV, Levine P. Modified constraint-induced therapy after subacute stroke: a preliminary study. *Neurorehabil Neural Repair* 2002;16(3):290-5.
42. Atteya AAA. Effects of modified constraint induced therapy on upper limb function in subacute stroke patients. *Neurosciences* 2004;9(1):24-9.
43. Maulden SA, Gassaway J, Horn SD, Smout RJ, DeJong G. Timing of Initiation of Rehabilitation After Stroke. *Archives of Physical Medicine and Rehabilitation* 2005;86(12, Supplement 1):34-40.
44. Paolucci S, Antonucci G, Grasso MG, Morelli D, Troisi E, Coiro P et al. Early versus delayed inpatient stroke rehabilitation: A matched comparison conducted in Italy. *Archives of Physical Medicine and Rehabilitation* 2000;81(6):695-700.
45. Horn SD, DeJong G, Smout RJ, Gassaway J, James R, Conroy B. Stroke Rehabilitation Patients, Practice, and Outcomes: Is Earlier and More Aggressive Therapy Better? *Archives of Physical Medicine and Rehabilitation* 2005;86(12, Supplement 1):101-14.
46. Page SJ, Levine P, Sisto S, Bond Q, Johnston MV. Stroke patients' and therapists' opinions of constraint-induced movement therapy. *Clin Rehabil* 2002;16(1):55-60.
47. Sterr A, Szameitat A, Shen S, Freivogel S. Application of the CIT concept in the clinical environment: hurdles, practicalities, and clinical benefits. *Cogn Behav Neurol* 2006;19(1):48-54.
48. Stevenson T, Thalman L. A modified constraint-induced movement therapy regimen for individuals with upper extremity hemiplegia. *Can J Occup Ther* 2007;74(2):115-24.
49. Viana R, Teasell R. Barriers to the implementation of constraint-induced movement therapy into practice. *Top Stroke Rehabil* 2012;19(2):104-14.
50. Walker J, Pink MJ. Occupational therapists and the use of constraint-induced movement therapy in neurological practice. *Aust Occup Ther J* 2009;56(6):436-7.

51. Mulrow CD. Rationale for systematic reviews. *British Medical Journal* 1994;309(6954):597-.
52. Roger VL, Go AS, Lloyd-Jones DM, Benjamin EJ, Berry JD, Borden WB et al. Heart disease and stroke statistics--2012 update: a report from the American Heart Association. *Circulation* 2012;125(1):e2-e220.
53. Taub E, Uswatte G, Elbert T. New treatments in neurorehabilitation founded on basic research. *Nat Rev Neurosci* 2002;3(3):228-36.
54. Page SJ, Boe S, Levine P. What are the "ingredients" of modified constraint-induced therapy? An evidence-based review, recipe, and recommendations. *Restor Neurol Neurosci* 2013;31(3):299-309.
55. Brunner IC, Skouen JS, Strand LI. Recovery of upper extremity motor function post stroke with regard to eligibility for constraint-induced movement therapy. *Top Stroke Rehabil* 2011;18(3):248-57.
56. Peurala SH, Kantanen MP, Sjogren T, Paltamaa J, Karhula M, Heinonen A. Effectiveness of constraint-induced movement therapy on activity and participation after stroke: a systematic review and meta-analysis of randomized controlled trials. *Clin Rehabil* 2012;26(3):209-23.
57. Shi YX, Tian JH, Yang KH, Zhao Y. Modified constraint-induced movement therapy versus traditional rehabilitation in patients with upper-extremity dysfunction after stroke: a systematic review and meta-analysis. *Arch Phys Med Rehabil* 2011;92(6):972-82.
58. Stevenson T, Thalman L, Christie H, Poluha W. Constraint-Induced Movement Therapy Compared to Dose-Matched Interventions for Upper-Limb Dysfunction in Adult Survivors of Stroke: A Systematic Review with Meta-analysis. *Physiotherapy Canada* 2012;64(4):397-413.
59. COTO. Essential Competencies of Practice for Occupational Therapists in Canada. College of Occupational Therapists of Ontario; 2011.
60. CPA. Essential Competency Profile for Physiotherapists in Canada. Canadian Physiotherapy Association; 2009.
61. Shearer B, Burnham J, Wall JC, Turnbull GI. Physical and occupational therapy: what's common and what's not? *Int J Rehabil Res* 1995;18(2):168-74.
62. Booth J, Hewison A. Role overlap between occupational therapy and physiotherapy during in-patient stroke rehabilitation: an exploratory study. *J Interprof Care* 2002;16(1):31-40.

63. Smith S, Roberts P, Balmer S. Role Overlap and Professional Boundaries: Future Implications for Physiotherapy and Occupational Therapy in the NHS: Forum. *Physiotherapy* 2000;86(8):397-400.
64. Statistics Canada. Census Profile 2011. Available from: URL: <http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/index.cfm?Lang=E>.
65. D'Agostino Sr. RB, Sullivan LM, Beiser AS. *Introductory Applied Biostatistics*. Toronto: Thomson Brooks/Cole; 2006.
66. Corbetta D, Sirtori V, Moja L, Gatti R. Constraint-induced movement therapy in stroke patients: systematic review and meta-analysis. *Eur J Phys Rehabil Med* 2010;46(4):537-44.
67. Salbach NM, Jaglal SB, Korner-Bitensky N, Rappolt S, Davis D. Practitioner and organizational barriers to evidence-based practice of physical therapists for people with stroke. *Phys Ther* 2007;87(10):1284-303.
68. Medical Advisory Secretariat HQO. *Constraint-Induced Movement Therapy for Rehabilitation of Arm Dysfunction After Stroke in Adults: An Evidence-Based Analysis*. In: Services OHQ, editor. Toronto: Ontario Health Technology Assessment Series; 2011. p 1-58.
69. Taub E, Uswatte G, Pidikiti R. Constraint-Induced Movement Therapy: a new family of techniques with broad application to physical rehabilitation--a clinical review. *J Rehabil Res Dev* 1999;36(3):237-51.
70. Fleet A CM, MacKay-Lyons M, MacKenzie D, Page SJ, Eskes G, McDonald A, Boyce J, Boe S. Examining Utilization of Constraint-Induced Movement Therapy in Canadian Neurological Occupational and Physical Therapy. *Physiotherapy Canada* 2013;In Press.
71. Page SJ, Sisto S, Johnston MV, Levine P, Hughes M. Modified constraint-induced therapy in subacute stroke: a case report. *Arch Phys Med Rehabil* 2002;83(2):286-90.
72. Liepert J, Graef S, Uhde I, Leidner O, Weiller C. Training-induced changes of motor cortex representations in stroke patients. *Acta Neurol Scand* 2000;101(5):321-6.
73. Hakkennes S, Keating JL. Constraint-induced movement therapy following stroke: a systematic review of randomised controlled trials (Structured abstract). *Australian Journal of Physiotherapy*. 2005. p 221-31.
74. Bjorklund A, Fecht A. The effectiveness of constraint-induced therapy as a stroke intervention: A meta-analysis. *Occupational Therapy in Health Care* 2006;20(2):31-49.

75. Bonaiuti D, Rebasti L, Sioli P. The constraint induced movement therapy: a systematic review of randomised controlled trials on the adult stroke patients. *Eura Medicophys* 2007;43(2):139-46.
76. Sirtori V, Corbetta D, Moja L, Gatti R. Constraint-induced movement therapy for upper extremities in stroke patients. *Cochrane Database of Systematic Reviews*. John Wiley & Sons, Ltd; 2009.
77. French B, Leathley M, Sutton C, McAdam J, Thomas L, Forster A et al. A systematic review of repetitive functional task practice with modelling of resource use, costs and effectiveness. *Health Technol Assess* 2008;12(30):iii, ix-x, 1-117.
78. Finding What Works in Health Care: Standards for Systematic Reviews. The National Academies Press; 2011.
79. Lyle RC. A performance test for assessment of upper limb function in physical rehabilitation treatment and research. *Int J Rehabil Res* 1981;4(4):483-92.
80. De Weerdts WJG, Harrison MA. Measuring recovery of arm and hand function in stroke patients: a comparison of the Brunnstrom-Fugl-Meyer test and the Action Research Arm test. *Physiother Can* 1985;37(2):65-70.
81. Fugl-Meyer AR, Jaasko L, Norlin V. The post-stroke hemiplegic patient. II. Incidence, mortality, and vocational return in Goteborg, Sweden with a review of the literature. *Scand J Rehabil Med* 1975;7(2):73-83.
82. van der Lee JH, Beckerman H, Lankhorst GJ, Bouter LM. The Responsiveness of the Action Research Arm Test and the Fugl-Meyer Assessment Scale in Chronic Stroke Patients. *Journal of Rehabilitation Medicine* (Taylor & Francis Ltd) 2001;33(3):110-3.
83. Uswatte G, Taub E, Morris D, Vignolo M, McCulloch K. Reliability and validity of the upper-extremity Motor Activity Log-14 for measuring real-world arm use. *Stroke* 2005;36(11):2493-6.
84. Park SW, Wolf SL, Blanton S, Winstein C, Nichols-Larsen DS. The EXCITE Trial: Predicting a clinically meaningful motor activity log outcome. *Neurorehabil Neural Repair* 2008;22(5):486-93.
85. O'Donnell M DJ, Adams R, Butler C, Roxborough L, Damiano D. AACPDPM methodology to develop systematic reviews of treatment intervention. *American Academy of Cerebral Palsy & Developmental Medicine*; 2005.
86. Page SJ, Levine P, Khoury JC. Modified constraint-induced therapy combined with mental practice: thinking through better motor outcomes. *Stroke* 2009;40(2):551-4.
87. Page SJ, Elovic E, Levine P, Sisto SA. Modified constraint-induced therapy and botulinum toxin A: A promising combination. *American Journal of Physical Medicine and Rehabilitation* 2003;82(1):76-80.

88. Page SJ, Levine P, Hill V. Mental practice as a gateway to modified constraint-induced movement therapy: a promising combination to improve function. *Am J Occup Ther* 2007;61(3):321-7.
89. van der Lee JH, Wagenaar RC, Lankhorst GJ, Vogelaar TW, Deville WL, Bouter LM. Forced Use of the Upper Extremity in Chronic Stroke Patients : Results From a Single-Blind Randomized Clinical Trial. *Stroke* 1999;30(11):2369-75.
90. Lang CE, Edwards DF, Birkenmeier RL, Dromerick AW. Estimating minimal clinically important differences of upper-extremity measures early after stroke. *Arch Phys Med Rehabil* 2008;89(9):1693-700.
91. Lang CE, Wagner JM, Dromerick AW, Edwards DF. Measurement of Upper-Extremity Function Early After Stroke: Properties of the Action Research Arm Test. *Archives of Physical Medicine and Rehabilitation* 2006;87(12):1605-10.
92. Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. *Phys Ther* 1987;67(2):206-7.
93. Platz T, Pinkowski C, van Wijck F, In-Ha K, di Bella P, Johnson G. Reliability and validity of arm function assessment with standardized guidelines for the Fugl-Meyer Test, Action Research Arm Test and Box and Block Test: a multicentre study. *Clinical Rehabilitation* 2005;19(4):404-11.
94. Rabadi MH, Rabadi FM. Comparison of the Action Research Arm Test and the Fugl-Meyer Assessment as Measures of Upper-Extremity Motor Weakness After Stroke. *Archives of Physical Medicine and Rehabilitation* 2006;87(7):962-6.
95. Hsueh IP, Hsieh C-L. Responsiveness of two upper extremity function instruments for stroke inpatients receiving rehabilitation. *Clinical Rehabilitation* 2002;16(6):617-24.
96. Uswatte G, Foo WL, Olmstead H, Lopez K, Holand A, Simms LB. Ambulatory monitoring of arm movement using accelerometry: an objective measure of upper-extremity rehabilitation in persons with chronic stroke. *Arch Phys Med Rehabil* 2005;86(7):1498-501.
97. Uswatte G, Giuliani C, Winstein C, Zeringue A, Hobbs L, Wolf SL. Validity of accelerometry for monitoring real-world arm activity in patients with subacute stroke: evidence from the extremity constraint-induced therapy evaluation trial. *Arch Phys Med Rehabil* 2006;87(10):1340-5.
98. Uswatte G, Miltner WH, Foo B, Varma M, Moran S, Taub E. Objective measurement of functional upper-extremity movement using accelerometer recordings transformed with a threshold filter. *Stroke* 2000;31(3):662-7.
99. Enoka RM. *Neuromechanics of Human Movement*. Human Kinetics; 2008.

100. Gillot AJ, Holder-Walls A, Kurtz JR, Varley NC. Perceptions and experiences of two survivors of stroke who participated in constraint-induced movement therapy home programs. *Am J Occup Ther* 2003;57(2):168-76.
101. Ploughman M, Shears J, Hutchings L, Osmond M. Constraint-induced movement therapy for severe upper-extremity impairment after stroke in an outpatient rehabilitation setting: a case report. *Physiother Can* 2008;60(2):161-70.

APPENDIX A Copyright Permission Contract



19 July 2013

Fleet, Alana
School of Physiotherapy, Dalhousie University
5869 University Avenue
PO Box 15000
Halifax, NS
Canada B3H 4R2
a.b.fleet@gmail.com

RE: Your request for permission to reprint the following material:

Journal	Volume	Issue	Year	Author	Article	Pages	Copyright Holder
Physiotherapy Canada	66	1	2014	Alana Fleet, Marion Che, Marilyn MacKay-Lyons, Diane MacKenzie, Stephen Page, Gail Eskes, Alison McDonald, Joy Boyce, Shaun Boe	Examining Utilization of Constraint-Induced Movement Therapy in Canadian Neurological Occupational and Physical Therapy	TBD	Canadian Physiotherapy Association

FEE: **\$0.00 CAD** (Amount to be paid)

We are happy to grant permission for the use of the copyrighted material shown above for the fee indicated and on the conditions set out in this letter. This permission covers only the above material (i.e., it does not cover any material with an independent copyright notice or a separate source notation).

1. This permission covers the use of the above article as a chapter in the requestor's thesis for Dalhousie University, to be deposited into their institutional repository called DalSpace in August 2013. The thesis will also be harvested by Theses Canada and sent to the National Library for their repository. This article must be held under embargo until it appears in print with *Physiotherapy Canada*, in February 2014. In addition, this article will not have gone through the editorial process by the time it is deposited as a chapter in this thesis; therefore an additional acknowledgement must be inserted into the thesis stating that "the official version of this article will be published in *Physiotherapy Canada* 66.1 (2014)."
2. The customary credit must be given to the author, the journal, and the publisher. The acknowledgement must also include the statement, "Reprinted with permission from University of Toronto Press (www.utpjournals.com)" and the copyright notice as it appears in our publication.
3. Unless specifically stated otherwise, this permission does not allow the use of this material in any other edition, or by any other means of reproduction, including (by way of example) motion pictures, sound tapes, phonograph records, nor does it cover book clubs, translations, digest, abridgement, or selections that may be made from the publication. It does, however, include use in Braille, large-type, or other editions of your work by non-profit organizations solely for the use of the visually or physically handicapped, provided no fees are charged. For any requested online content, the material must be password protected (no free internet access). In addition, this permission does not include the online use of any figures, images, tables, or maps.
4. This permission does not include the sale or use of any material by third parties unless expressly allowed by University of Toronto Press.
5. A cheque for the required fees must accompany the signed copy of the agreement. Please make the cheque payable to University of Toronto Press and mail it to the address below.
6. This permission is non-exclusive and unless otherwise stated is valid throughout the world in the language in which it was originally published.
7. Any use not explicitly stated in this agreement is strictly prohibited.

Permissions Department
University of Toronto Press, 5201 Dufferin Street, North York, ON, M3H 5T8
sjuniku@utpress.utoronto.ca — www.utpjournals.com

APPENDIX B Survey Description

Survey content followed three criteria:

- i)** the questions were relevant to the study's purpose;
- ii)** the wording would not be leading (i.e., provide the 'correct' response for subsequent questions); and
- iii)** the time to complete the survey would be less than 15 minutes.

Questions related to two broad categories:

Profile of respondents: the following information was collected to fully describe the sample population and to explore relationships between therapist-related factors and utilization of CIMT.

- a.** gender
- b.** profession (OT/PT)
- c.** percentage of practice treating adult neurological patients
- d.** number of years as OT/PT
- e.** number of years practicing in neurological OT/PT
- f.** practice setting (inpatient acute, outpatient rehabilitation, etc.)
- g.** practice location (urban vs rural + 3 digits of postal code)
- h.** province/territory
- i.** hours/week working as an OT/PT
- j.** level of education
- k.** interventions used to treat UE hemi-paresis

CIMT utilization patterns: the following information was collected to assess the utilization pattern of CIMT amongst therapists working in neurological rehabilitation and to elucidate: i) their understanding of the components of CIMT; and ii) the manner in which CIMT is delivered clinically.

- a.** awareness of CIMT as a treatment
- b.** level of knowledge regarding CIMT
- c.** source of CIMT knowledge
- d.** use of CIMT in clinical practice
- e.** knowledge regarding the components of CIMT
- f.** indications for use of CIMT
- g.** neurological conditions for which respondent uses CIMT
- h.** individuals involved in treatment delivery
- i.** parameters used when delivering CIMT (frequency, time)
- j.** effectiveness of CIMT in clinical practice

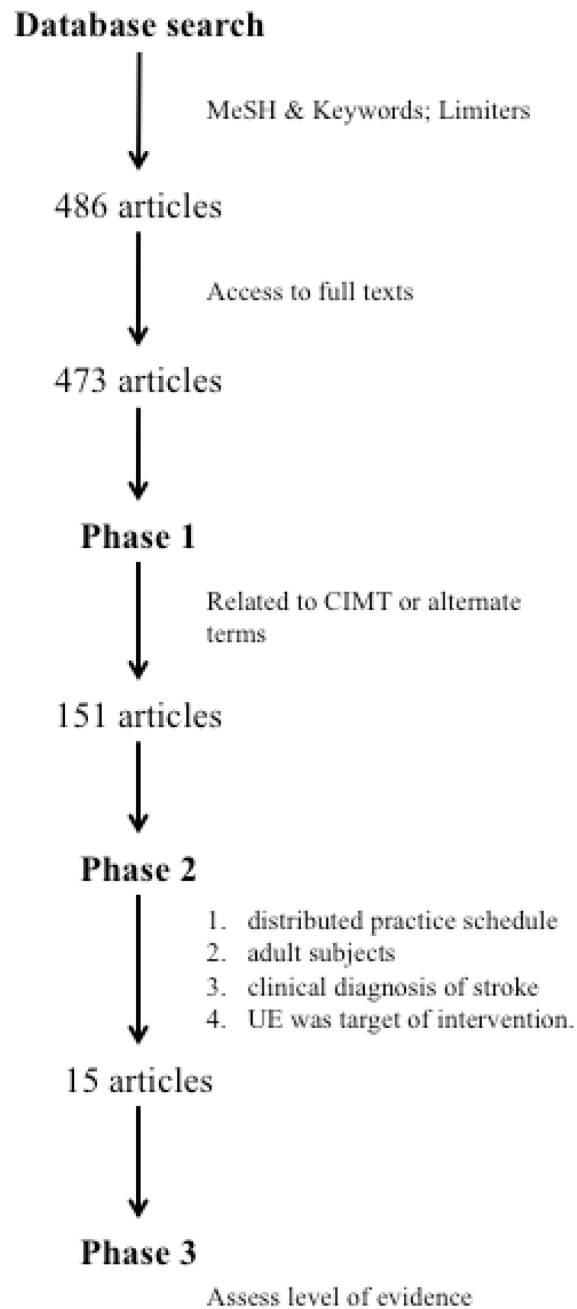
k. barriers to CIMT utilization

APPENDIX C Reported Components of CIMT

List of responses (by theme) provided by CIMT users and non-users when asked to identify the key components of CIMT (see methods and results for details).

Theme	Frequency (CIMT users)	Frequency (Non CIMT users)
Restraint	31	72
RTP	22	37
Shaping/Behavior	19	9
Use Affected Limb	22	57
Motivation	13	0
Treatment Duration & Schedule	12	27
Repetition	11	10
Type of Restraint	9	13
Safety	9	3
Type of Treatment	7	14
Commitment	7	3
Family Support	7	1
Education	6	0
Inclusion Criteria	5	24
Neuroplasticity	5	8
No Knowledge	4	10
UL (Upper Limb)	4	4
Patient Population	4	3
Team Approach	4	0
Bimanual Movements	3	0
Forced Use	2	6
Learned Disuse	2	3
Sensory/Cognition	2	1
Testing	2	0
FITT	1	0
Consistency	1	0
Team Knowledge	0	2
CVA	0	1
Specific Training	0	1
Hand Dominance	0	1
Motor Tasks	0	1

APPENDIX D Search Phases



PHASE 1

For articles that you are uncertain about, please highlight the row and provide a comment				
Endnote #	First Author; Year (eg. Doe, J; 2009)	Journal	Reason for Exclusion	Uncertain (provide comment why uncertain)

PHASE 2

SYSTEMATIC REVIEW ABSTRACT CHECKLIST FORM

For each abstract/article please complete the following form

Abstract reviewer's initials			
Date			
First author; year of publication (e.g., Doe, J P; 2009)			
Journal			
EndNote #			
Brief details of study	Criteria for inclusion in review BOLDED means required	YES (√)	NO (√)
<i>Study Design</i>	Randomized controlled trial		
	Case-control		
	Single cohort		
	Single case studies		
	Case report		
	Another design (specify):		
<i>Population (subjects)</i>	• Adults (≥18 years)		
	• Clinical diagnosis of stroke (ischemic or hemorrhagic)		
<i>Intervention studied</i>	• Distributed practice schedule* (modified CIMT-Page protocol)		
	Other form of CIMT (specify):		
<i>Target of Intervention</i>	• Upper limb		
<i>Comparator intervention</i>	No Comparison		
	No intervention		
	Usual care		
	Wait list		
	Another intervention (specify):		
<i>Outcomes</i>	Primary outcomes (specify):		
INCLUDE		EXCLUDE	UNCERTAIN
Additional Comments			

* Distributed practice schedule

- treatment using CIMT that is 10 weeks in duration, 3 times/week
- NOTE: treatment is referring to task practice, NOT the restraint

PHASE 3

SYSTEMATIC REVIEW LEVELS OF EVIDENCE CHECKLIST FORM

Modified constraint-induced movement therapy for improving motor control and functional use of the hemiparetic upper limb after stroke

For each included article please complete the following form:

Reviewer's initials			
Date			
First author; year of publication (e.g., Doe, J P; 2009)			
Journal			
EndNote #			
Levels of Evidence of a Single Study			
Level of Evidence	Description	YES (✓)	NO (✓)
I	Large RCT (n>100); specify n:		
II	Smaller RCTs (n<100); specify n:		
III	Cohort Studies (with concurrent control group) Please specify control group:		
IV	Case series		
	Cohort Studies (with historical, not concurrent control group)		
	Case-Control Study		
V	Case Study or Report		
	Expert Opinion (based on theory or physiologic research)		
	Expert Opinion		
Additional Comments			

Levels of Evidence of a Body of Knowledge on a Specific Topic	
Level of Evidence	Description
A very strong support	Consistent level I studies
B strong support	Consistent level II or III studies or extrapolations from level I studies
C intermediate support	Level IV studies or extrapolations from level II or III studies
D weak support	Level V evidence or troublingly inconsistent or inconclusive studies at any level

Reference: American Academy of Cerebral Palsy & Developmental Medicine, 2005
O'Donnell M, Darrah J, Adams R, Butler C, Roxborough L, Damiano D. (2204). AACPDM methodology to develop systematic reviews of treatment intervention

Summary of Study – Interventions and Participants

Participants		Total N	Int(n) Con(n)	Ages	Intervention Description
Int					
Con					

Comments:

Conduct Questions

Questions		Yes	No
1	Were inclusion and exclusion criteria of the study population well described and followed?		
2	Was the intervention well described and was there adherence to the intervention assignment? (for 2-group designs, was the control exposure also well described?)		
3	Were the measures used clearly described, valid and reliable for measuring the outcomes of interest?		
4	Was the outcome assessor unaware of the intervention status of the participants (i.e., were the assessors masked)?		
5	Did the authors conduct and report appropriate statistical evaluation including power calculations?		
6	Were dropout/loss to follow-up reported and less than 20%? For 2-group designs, was dropout balanced?		
7	Considering the potential within the study design, were appropriate methods for controlling confounding variables and limiting potential biases used?		

*only perform for studies that have a Level of Evidence of I-III

APPENDIX E Search Strategy

PubMed (1950 – present)

Search #1 (controlled vocabulary):

((("Upper Extremity"[Mesh] AND (Humans[Mesh] AND English[lang] AND adult[MeSH]))) AND (((("Stroke"[Mesh])) AND (((constraint induced therapy)) OR (constraint induced movement therapy)) AND (Humans[Mesh] AND English[lang] AND adult[MeSH]))) Limits: Humans, English, All Adult: 19+ years

Search #2 (keywords):

#1 Search constraint induced therapy

#2 Search stroke

#3 Search upper extremity

#4 Search upper limb

#5 Search arm OR shoulder

#6 Search #5 OR #4 OR #3

#7 Search #6 AND #2 AND #1 Limits: Humans, English, All Adult: 19+ years

CINAHL (1982 – present)

Search #1 (controlled vocabulary):

S1 (MH "Constraint-Induced Therapy")

S2 (MH "Stroke") OR (MH "Stroke Patients")

S3 (MH "Upper Extremity+")

S4 S1 AND S2 AND S3 English Language; Age Groups: All Adult

Search #2 (keywords):

#1 Search constraint induced therapy

#2 Search stroke

#3 Search upper extremity

#4 Search upper limb

#5 Search arm OR shoulder

#6 Search #5 OR #4 OR #3

#7 Search #6 AND #2 AND #1 Limits: Humans, English, All Adult: 19+ years

Embase (1966 – present)

Search #1:

'constraint induced therapy'/exp AND 'stroke'/exp AND ('arm'/exp OR 'shoulder'/exp) AND ([adult]/lim OR [aged]/lim) AND [humans]/lim AND [english]/lim

Search #2 (keywords):

#1 Search constraint induced therapy

#2 Search stroke

#3 Search upper extremity

#4 Search upper limb

#5 Search arm OR shoulder

#6 Search #5 OR #4 OR #3

#7 Search #6 AND #2 AND #1 Limits: Humans, English, All Adult: 18+ years

Cochrane Library and Web Of Science do not use the same type of controlled vocabulary as the previous three databases, so only keyword searches were used:

Cochrane (1993 – present)

"constraint induced" NEAR therap*:ti,ab,kw and (stroke):ti,ab,kw and ("upper extremity" OR "upper limb" OR arm OR shoulder:ti,ab,kw)

Web Of Science (1900 – present)

Topic=("constraint induced therapy" OR "constraint induced movement therapy") AND Topic=(stroke) AND Topic=("upper extremity" OR "upper limb" OR arm OR shoulder)
Refined by: Languages=(ENGLISH)
Databases=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All Years

Proquest Dissertations and Theses (1966-present)

Searched two phrases: “constraint induced therapy” OR “constraint induced movement therapy”

Open Grey (1997 – present)

Searched two phrases: “constraint induced therapy” OR “constraint induced movement therapy”

APPENDIX F Baseline Assessment Measures

1. Descriptive information from hospital record
 - a. Date of birth
 - b. Sex
 - c. Pertinent medical and medical history
 - d. Pre-morbid handedness
 - e. Type and location of stroke
2. Stroke severity
 - a. Stroke Severity Scale (SSS)
 - i. Measure of global impairment
 - b. National Institutes of Health Stroke Scale (NIHSS) – 15 item impairment scale
 - i. Assesses cognitive, sensory and motor impairments
3. Physical impairment
 - a. Chedoke-McMaster Stroke Assessment – recovery stage of the arm and hand
 - b. Modified Ashworth Scale (MAS)
 - i. Measure of muscle tone
4. Disability
 - a. Functional Independence Measure (FIM) – commonly used in acute and rehab settings to uniformly assess level of disability and associated level of assistance needed to perform activities of daily living
 - b. Barthel Index – used as a record of what a patient does (rather than capability) and assesses level of independence for a number of self care and mobility activities
5. Cognitive Impairment
30-minute protocol as recommended by Hachinski et al. that assesses language, memory, spatial neglect, attention and executive function, depression and other behavioural changes
 - a. Montreal Cognitive Assessment (MoCA)
 - b. Fluency test
 - c. Symbol Digit Modalities Test
 - d. Hopkins verbal learning test – revised (HVLT-R)
 - e. Centre for epidemiological studies – depression scale
 - f. Neuropsychiatric inventory – questionnaire
 - g. Trail-making
 - h. Mini Mental State Exam (MMSE)
 - i. Figure cancellation
6. Active ROM

- a. Of the wrist and fingers via goniometry according to standardized clinical testing methods

* The NIHSS, CMSA and FIM are considered clinical assessments that are performed as part of routine clinical care.

** All of the above measures are only collected once

APPENDIX G Task Database

Example equipment list:

- Aluminum foil
- Binders
- Bingo cards
- Bingo dauber
- Books
- Bottle
- Bouncing ball (various sizes)
 - Small, rubber
 - Tennis ball
 - Volleyball
 - Basketball
- Bowl (various sizes)
- Brown paper bags
- Buttoned shirt
- Calculator
- Cans of food
- Checkers
- Chinese checker board
- Cloth
- Clothes hangers
- Clothespins
- Coins
- Coin wrappers
- Computer mouse
- Connect 4 game
- Containers
 - Various sized openings
- Cooling rack/wire rack
- Cotton balls
- Cups
- Dirt
- Doorknobs/locks
- Dominoes
- Dried beans
 - Various sizes
 - Eg. Kidney; white
- Dusting cloth/dusting mitt/dust buster
- Food items/containers
- Grocery bag
- Iron
- Ironing board
- Jenga
- Keys
- Keyboard
- Light socket adapter
- Magazine
- Marbles (various sizes)
- Masking tape
- Measuring cup
- Mouse pad with pattern
 - 'Mouse game'
- Napkins
- Non-slip mat
 - to stabilizing objects
- Nuts and bolts (variety of sizes)
- Operation game
- Paint brush
- Paint roller
- Pegboard
- Pennies
- Photo album (with photos)
- Piggybank
- Pillow
- Pillow case
- Ping pong balls
- Pitcher/jug
- Placemat
- Plastic fruit
- Plastic golf balls
- Plastic wrap
- Plates
- Playing cards
- Pot holders (larger flower pots/small plant trays)
- Rolodex
- Seeds/plants (plastic or beans)
- Shoe brush
- Shoe polish
- Silverware
- Styrofoam chips
- Spade (different sizes of grips)
- Spoons
 - Teaspoon

- Tablespoon
- Serving spoon
- Straws (or stir sticks)
- Thera-putty (or playdoh)
- Towel
- Unwired light socket
- Wooden blocks (various sizes)
- Wooden pegs
- Zip lock bags

Badminton

Use a badminton racquet and birdie. The subject can play alone, with the assistance of the therapist, or against the therapist. The subject uses the racquet to bounce the birdie.

Shaping progressions:

- Moving the racquet to the left, right, or further away from body
- Bouncing the birdie off the wall
- Hitting a birdie thrown by the therapist
- Rallying with therapist

Feedback parameters:

- Number of hits in certain amount of time
- Number of successful hits without dropping
- Time it takes to complete a number of hits without dropping

Movements emphasized:

- Shoulder mobility
- Elbow extension
- Shoulder-elbow coupling
- Wrist flexion/extension
- Power grip (cylindrical)

Beans

Beans placed in various containers. The subject can pick up and move the beans to a target area. Additionally, objects can be mixed within the beans and selectively targeted. The subject is asked to pick up the objects one at a time and place them on the table, on a target or in a container.

Shaping progressions:

- Different sized containers
 - shallow or deep
 - small or wide opening
- Different sizes of beans
- Placement of container (left, centre, right)
- Sitting vs. standing
- Distance of container from subject
- Distance between bean container and target
- Size of target
 - Size of container opening, working towards progressively smaller openings
- Size of objects placed in beans
- Method to select beans/object
 - Different pincer grips
 - Alternating between fingers

- Using a spoon

Feedback parameters:

- Time to move a certain number of beans/objects
- Time to complete movements without dropping beans/objects

Movements emphasized:

- Shoulder flexion/abduction
- Wrist pronation/supination
- Wrist flexion/extension
- Fine finger movements
- Various grasps (eg. pincer grip; tip-to-tip vs. pad-to-pad)

Bingo

Use bingo cards and have subject mark off the various spaces. The subject can use a bingo dauber and aims to mark off a space without smearing the ink. The therapist can list off the appropriate spaces to mark.

Shaping progressions:

- Size of bingo cards and spaces (smaller are more difficult)
- Using a different utensil (eg. a pen to mark off each space)
- Distance of bingo card from subject
- Height of bingo card

Feedback parameters:

- Number of successfully marked spots (completely marked without ink outside the box)
- Time to complete a row/column or whole card

Book/Magazine/Binder

Place reading material on table. The subject turns the pages while concentrating on turning the pages by either pronating or supinating

Shaping Progressions:

- The position of the reading material
 - Left/centre/right
 - Distance away from subject
- The number of pages to turn
- The size/thickness of the material

Feedback parameters:

- Number of pages turned in a set amount of time
- Amount of time required to turn a set number of pages

Movements Emphasized:

- Wrist pronation/supination
- Pincer or lateral pincer grasp
- Shoulder internal and external rotation

Clothes Pins on Rack

Place a number of clothespins on a wire rack. The rack can be held vertically by the therapist or placed horizontally on a table. The subject can place the clothespins on the rack and/or remove them.

Shaping progressions:

- Distance of rack from subject
- Rack placement (left/centre/right)
- Target placement of clothespins on rack
 - placing to the left/centre/right of the rack)
- Height of the rack
- Height of clothespin placement
- Target size
 - Placing clothespins in a particular quadrant or rung
- The number of clothespins
- The digits used to open or close the clothespins

Feedback parameters:

- Number of clothespins placed in a certain amount of time
- Amount of time to place a certain amount of clothespins

Movements Emphasized:

- Pincer grasps (eg. side-to-pad vs. pad-to-pad)
- Wrist supination/pronation
- Elbow extension
- Shoulder flexion

Checkers

Checkers are placed on the table. The subject is asked to move the checkers either to stack or to push the checkers by extending certain fingers. The checkers are to be stacked or pushed to a target location.

Shaping progressions:

- Increase distance required to push the checkers
- Increase number of checkers
- Change location to stack checkers (left/centre/right)
- Increase distance from subject to stack checkers

Feedback parameters:

- Number of checkers subject is able to push to target in a given amount of time
- Time it takes to push a number of checkers to a target area, or to stack a given number of checkers
- Number of checkers that can be stacked without the stack falling over

Movements Emphasized:

- Fine finger movements
- Elbow extension
- Shoulder flexion

Chopsticks

The subject uses chopsticks to pick up various objects and place them on a target

Shaping progressions:

- Different sizes and weights of objects
 - Cotton balls
 - Styrofoam chips
 - Beans
 - Play-doh
- Distance between objects and target area
- Distance of target area from subject
- Height of container holding objects (deeper requires greater shoulder flexion and longer pinching of object to successfully reach the target area)

Feedback parameters:

- Number of objects moved in a certain amount of time
- Number of successful movements to target ie. without dropping in certain amount of time
- Number of movements to target without dropping in a row
- Amount of time to move a given number of objects

Movements emphasized:

- Fine finger control
- Pincer grip
- Elbow extension
- Shoulder control
- Shoulder flexion/abduction

Cleaning

This includes dusting or any other wiping activity (eg. wiping off a counter). The subject stands at a table (or any other flat surface). The subject uses a cloth/sponge/duster to wipe the table clean. This can be done using a dry cloth, or a wet one in which the subject also wrings out excess water.

Shaping progressions:

- Change the height of the wiping surface
- Increase the surface area needed to clean
 - Greater distance left to right
 - Increase the distance a subject needs to reach forward
 - Change the type of cleaning tool used (different grasps)
 - Different surface types
 - Vertical surface if have shoulder control

Feedback parameters:

- Area wiped clean during a certain time period
- Number of wipes it takes to clean a particular area
- Time it takes to wipe off a particular area

Movements emphasized:

- Shoulder flexion
- Shoulder abduction/adduction
- Elbow flexion/extension
- Gross hand movements
- Various grasps
- Finger flexion/extension

Computer mouse

The subject uses a mouse that is unattached to computer. The subject practices moving it in different directions and picking it up. A particular pattern can be designed by the therapist to follow using a 'mouse pad' with different shapes and colours.

Shaping progressions:

- Distance from subject the mouse is placed and designed to be moved
- Distance between shapes (on 'mouse pad')
- Complexity of pattern designed by therapist
- Height of mouse

Feedback parameters:

- Time it takes to move through a particular pattern
- The number of movements that can be performed in a set time period

Movements emphasized:

- Gross hand movement
- Power grip (spherical grasp)
- Elbow flexion/extension
- Shoulder flexion

Cups/Containers

A subject can use cups (or other containers) to lift, move and stack them. lifting/moving/stacking.

Shaping progressions:

- Difference sized cups and containers
- Containers with different handles for changes in grip
 - Measuring cup
 - Pitcher
- Cups with different weights
 - Plastic
 - Glass
 - Mug
- Distance away from subject the cups are placed
- Distance between the cups and the target areas
- Flipping upside down when stacking or moving

Feedback parameters:

- Amount of time to move a certain number of cups
- The number of cups that can be moved in a certain amount of time
- The time to complete a number of accurate movements (eg. fully rotating wrist to move through supination-pronation; holding the cup with all 5 fingers).
- Amount of time to move cups a certain distance
- Ability to complete a number of movements successfully in a row (eg. flipping cups completely without having them tip over)
- Increase in height to move cups

Movements emphasized:

- Gross hand movements (power grip)
- Hand release
- Wrist pronation/supination
- Elbow flexion/extension
- Shoulder movement (flexion/abduction)
- Various grasps

Cutting food

The subject sits at a table with a knife and plate. Various objects can be used to simulate different food textures and thicknesses (eg. play-doh; cotton balls; Styrofoam chips)

Shaping progressions:

- Different types of objects to cut
 - Eg. Play-doh is softer and easier to cut than foam chips which require more strength and control
- Different thicknesses
- Number of slices for a particular sized object
- Dividing an object into equal sized pieces

Feedback parameters:

- Accuracy of cutting task (e.g. pieces being of even size)
- Number of pieces cut in a particular time period
- Time it takes to cut a particular number of pieces
- Increased strength by ability to cut tougher objects
- Increased strength/grasp as evidenced by cutting putty/food with more resistance

Movements emphasized:

- Power grip
- Shoulder control
- Shoulder flexion/abduction

Dominoes

Dominoes are placed in front of the subject. The subject is asked to reach forward and flip the dominoes using either forearm pronation or supination. The correct movement can be best isolated by asking the subject to rest their forearm on the table during the task. The subject can also be asked to lift and move the dominoes to a target (and stack)

Shaping Progressions:

- The number of dominoes used
- Increasing the distance to move dominoes
- Different sized dominoes
- Requiring subject to rest forearm on the table during the task (or requiring subject to not lean on table if trying to promote shoulder movement)
- Increase height to move dominoes

Feedback parameters:

- The number of dominoes moved or flipped in a set period of time
- The amount of time required to move a set number of dominoes

Movements Emphasized:

- Lateral pincer grasp

- Wrist extension
- Forearm supination/pronation (depending on direction of flip)
- Shoulder flexion
- Elbow flexion/extension

Gardening

The subject stands at a table with flower pot(s) centered in front of them. A container of dirt and the plants/seeds to be planted are positioned to one or the other side. The subject uses a spade to scoop dirt into the container. Seed/simulated seeds (eg. beans) can be planted one by one into the dirt

Shaping progressions:

- Placement of pot and container relative to subject
- Distance between the pot and dirt container
- The size of pot and opening
- Type of spoon (various grasps)
- Number of seeds to be planted
- Amount of dirt to be moved

Feedback parameters:

- Number of pots filled with dirt in a set time period
- Amount of time to move a certain amount of dirt
- Number of seeds/plants planted
- Number of scoops needed to move a certain amount of dirt
- Ability to move a certain amount of dirt without spilling any (accuracy)
- Increased use of specific functional movement patterns (e.g. use of supination when planting 'seeds')

Movements emphasized:

- Shoulder control
- Various grasps
- Wrist pronation/supination
- Elbow flexion/extension

Grocery packing

While sitting or standing, participants lift items (eg. cans, cereal box etc.) from grocery bags and place them on a table/shelf. Items can be repacked from the table/shelf into the grocery bags.

Shaping progressions:

- Sitting compared to standing
- Height of grocery bag (on floor or table)

- Height of table/shelf to place items
- Size and weight of grocery items
- Shelf size (smaller shelf requires participant to arrange grocery items and determine the appropriate placement)
- Feedback parameters:
 - Number of items moved in given time period
 - Successful movements of objects with different weights and sizes
 - Height of table/shelves and associated shoulder movement
- Movements emphasized:
 - Shoulder flexion
 - Shoulder abduction/adduction
 - Elbow flexion/extension
 - Various grasps

Jenga

A Jenga game is comprised by a number of wooden pieces. The subject removes the pieces and builds a tower. Once the tower is built, pieces are removed and placed on top of the tower, without having the tower topple over. Can be performed alone or with the therapist

Shaping progressions:

- Number of pieces that can be stacked on top of each other before falling over
- Building tower using cardboard guide or independently
- Placement of tower (distance from subject)
- Height of tower
- Standing vs. sitting

Feedback parameters:

- Number of pieces stacked in a certain amount of time
- Amount of time to stack a given number of pieces
- Number of pieces that can be successfully removed and placed on top of tower without it falling over
- Amount of time to build tower of a given height

Keyboard

Place keyboard on the table. Have the subject place hand on table and ask him to depress a key repeatedly with one finger at a time. Subject is instructed to isolate the individual finger movements by keeping their hand as flat as possible on the table.

Shaping progressions:

- Move keyboard farther away from subject
- Have subject alternate fingers over trials and within a trial
- Increase the amount of time the task is to be performed for
- Have subject concentrate on a particular rhythm or pattern

Feedback parameters:

- The number of depressions accomplished in a set period of time
- The amount of time required to depress key a set number of times

Movements Emphasized:

- Finger flexion
- Finger extension
- Wrist flexion/extension

Laundry (folding and sorting)

The subjects sits/stands at a table with clothing placed in front (can be in a container such as a laundry basket). There are a number of different items and colours. The clothing is to be sorted (eg. by colour) and folded. Also can be hung on hangers

Shaping progressions:

- Number of different ways to sort the clothing (eg. only shirt or pants vs. long-sleeve, short sleeve, shorts, pants, etc.)
- Different sized items (eg. cloth vs. pants)
- Distance that clothing needs to be moved

Suggested Feedback:

- Number of items sorted and folded in a time period
- Quality of folding (e.g. symmetrically)

Movements emphasized:

- Shoulder movement (flexion/extension/abduction)
- Elbow flexion
- Shoulder/elbow coupling
- Gross hand movements (power grasps)

Light bulb

An unwired light socket is mounted on a board/wood piece. The piece can be held vertically or horizontally. A light socket adapter is used to twist into the light socket (instead of light bulb due to safety concerns). The subject is asked to either twist the adapter into the light socket, or to twist it out, or both.

Shaping progression:

- The position of the light socket (lower or higher up)

- The number of times required to twist the adapter
- Type of grip on the socket adapter

Feedback parameters:

- Number of times the subject can twist the adapter into/out of the socket in a set period of time
- Amount of time it takes subject to twist adapter into/out of socket a given number of times

Movements Emphasized:

- Various grasps (eg. Cylindrical grasp vs. pincer)
- Forearm supination/pronation
- Shoulder flexion and control (when socket placed higher)

Locks and doorknobs

A number of doorknobs and locks are mounted onto a board/wood piece. The subject locks or unlocks the doorknobs, and twists them.

Shaping progressions:

- Height of knobs
- Type of lock
 - Twist or needing a key
- Number of locks

Feedback parameters:

- Number of times can be locked and unlocked in certain time period
- Amount of time to unlock a certain number of locks
- Number of turns required to turn knob completely
- Quality of turning (all the way or not)

Movements emphasized:

- Wrist pronation/supination
- Pincer grasp
- Power grip (cylindrical grasp)
- Shoulder flexion (when placed higher)

Marbles

Marbles can be used to balance. Subject must balance marble in a spoon while performing various tasks (eg. moving left to right; sit to stand; walking down the hall; up a stair)

Shaping progressions:

- Size of spoon

- Distance needing to travel
- Size of marble
- Number of marbles in spoon (fewer is harder because harder to control)
- Distance from body that spoon is held at

Feedback parameters:

- Time it takes to travel a given distance
- Performing a certain movement without dropping the marble
- Performing a certain movement a given amount of times in a set time period

Movements emphasized:

- Wrist control
- Power grip
- Shoulder stability
- Elbow extension

Nuts and Bolts

A variety of nuts and bolts are fastened onto a board. The subject is asked to screw on or unscrew the nuts and washers from the bolts. Additional nuts are kept in a container so can be picked up and placed onto bolts.

Shaping progressions:

- Size of nuts and bolts (smaller is more difficult)
- Different bolt heights
- The position of the board and distance from the subject
- The distance between the container and the board

Feedback parameters:

- Number of nuts placed in a certain time period
- Amount of time to screw on or unscrew a given number of nuts
- Number of turns it takes to screw on or unscrew a given number of nuts
- Type of grasp used to turn nuts

Movements Emphasized:

- Pincer grasp (pad-to-pad vs. side-to-pad)
- Wrist extension
- Elbow flexion/extension

Pegboard (vertical)

Participants lift wooden pegs and place them into holes on a pegboard. The pegboard rests vertically on a table.

Shaping progressions:

- Pegboard distance from participant
- Pegboard location on table (to the right or left of participant)
- Height of peg placements on board
- Location of peg placements on board (left or right side)
- Pegboard rotated horizontally
- Feedback conditions:
 - Number of pegs in particular board location (accuracy)
 - Amount of time to place certain number of pegs
 - Number of pegs placed over given period of time
- Movements emphasized:
 - Shoulder flexion
 - Elbow extension
 - Wrist extension
 - Forearm pronation/supination
 - Pincer grasp

Pennies

Subject moves pennies and placed them into paper wrappers or to a different target area.

Shaping progressions:

- Distance of target from container
- Target placement relative to subject (left/centre/right)
- Height of target
- Size of opening
 - Open container
 - Piggy bank slot
- Number of pennies that can be picked up at once

Feedback conditions:

- Time it takes to move a certain number of pennies
- Number of pennies that can be moved in a given time period
- Number of movements that can be performed accurately (Eg. placing pennies into piggy bank slot without dropping)

Movements emphasized:

- Pincer grasp
- Elbow flexion/extension
- Shoulder control

Ping pong balls

Ping pong balls are placed on a table and the subject is asked to pick them up one at a time and place them in a container. If the subject has trouble picking up the balls because they roll too fast, the balls can be placed on a towel to slow them down.

Shaping progressions:

- If a towel was used to decrease rolling, remove the towel
- Decrease the size of opening of the container
- Increase the number of balls
- Change the position of the container relative to the subject
- Increase the height of the container
- Use balls of different weights (eg. golf balls)
- Require the subject to use different types of grasps

Feedback parameters:

- Number of balls placed in a container in a set period of time
- Amount of time it takes to place a certain number of balls in the container
- Number of balls moved accurately into the container without dropping

Movements Emphasized:

- Various grasps (eg. pincer grip vs. spherical grip)
- Elbow extension
- Shoulder flexion

Polishing shoes

The subject sits at a table with a shoe in front of them stabilized on a non-slip surface. The subject uses a shoe brush to stimulate applying polish and then “wipes off” the polish with a soft cloth

Shaping progressions:

- Different shoes - firm shoes will be easier to polish than softer shoes
- Vertical motion (requiring more proximal upper extremity use) can be incorporated into this activity by using boots instead of shoes
- Change in shoe placement relative to subject and height

Feedback parameters:

- Number of shoes polished in allotted time period
- Amount of surface area polished in a certain time period

Movements emphasized:

- Fine finger movements
- Wrist flexion/extension

- Wrist pronation/supination
- Shoulder movement

Pouring

The subject sits at the table with the container(s) in front. Liquid to be poured is placed in one container/cup. Several containers and pouring items can be set up in advance to enable the subject to practice the task more than once.

Shaping progressions:

- The size of cups/containers
- Pouring items of various consistency
 - Beans
 - Marbles
 - Liquid
- Change the weights of items being poured
- Alter the number of times to pour
- Alter how full a cup is when pouring
 - Fuller cups are harder to control
- The size of container pouring into (size of opening)
- Change the type of handle/grip
- Distance to move cup before pouring
- Perform sitting or standing

Feedback parameters:

- Amount of spillage noted during pouring task
- Number of containers filled in the allotted time period
- Ability to pick up heavier items

Movements emphasized:

- Wrist pronation/supination
- Power grips
- Shoulder control
- Shoulder abduction/adduction

Scooping

Subject sits or stands at the table. Items to be scooped are in a container or on a plate/bowl. The container that the subject scoops into is placed in front of them. The subject scoops items one by one with a spoon from the plate/bowl to the next one.

Shaping progressions:

- Altering the type of container to scoop into (size of opening)
- Distance between container and target

- Type of spoon – alter grasp
- Items to be scooped can be graded from easy to scoop (e.g. cubes) to more challenging (e.g. beans, marbles)

Feedback parameters:

- Number of items scooped within the set time period
- Number of scoops in a row without dropping
- Time it takes to make a number of scoops
- Number of scoops required to move a given amount of items
- Feedback related to functional movement patterns (e.g. decreased use of compensatory trunk movements, increased use of forearm and wrist movements)

Movements emphasized:

- Power grasps
- Shoulder control
- Shoulder flexion
- Elbow extension
- Shoulder-elbow coupling
- Wrist pronation/supination

Sticks/Straws into cup

Sticks and cup are placed on table. The subject is asked to pick up the sticks/straws and place them in the bottle by either pronating or supinating the forearm.

Shaping progressions:

- Move cup farther from subject
- Increase height of cup
- Use cups/bottles with progressively smaller openings
- Increase time or number of stirrers
- Change type of grasp required

Feedback parameters:

- Number of straws in cup/target area in set period of time
- Amount of time required to get set number of straws into cup/bottle

Movements Emphasized:

- Various grasps
- Forearm supination
- Forearm pronation
- Shoulder flexion
- Elbow extension

Storing food items

The subject sits at the table with simulated food items (e.g. plastic fruit/vegetables) in front of them. Storage items (e.g. aluminum foil/zip lock bags) are placed to the more affected side. Food items are placed/wrapped in storage items one by one. Once all the food items are placed in bags/foil they are removed and placed back into the original container. Storage prep can be combined with the “putting groceries away” task

Shaping progressions

- Use of storage items can be graded from least challenging (e.g. brown paper bags) to most challenging (e.g. foil wrapping, closing zip lock bags)
- Height performing activity
- Number of items wrapped/stored

Feedback parameters:

- Number of items successfully placed in storage container
- Amount of time to wrap a certain number of objects
- Use of increasingly more challenging storage containers

Movements emphasized:

- Fine finger movement
- Gross hand movement
- Wrist movement

Throwing/Catching/Playing with a ball

The subject plays with a ball independently or with the therapist. Ball can be bounced, thrown and caught independently, thrown against a wall and caught, or thrown and caught between subject and therapist.

Shaping progressions:

- Different sized balls (and weights)
- Distance throwing and catching (either wall or therapist)
- Performing the task while standing or walking
- Using a target area (accuracy)
- Changing the distance to target area

Feedback parameters:

- The number of bounces/throws/catches accomplished in a set period of time
- The amount of time required to bounce and catch the ball a set number of times
- The number of bounces/catches accomplished before subject loses control of the ball (number of drops)

Movements Emphasized:

- Massed flexion/extension of hand
- Forearm supination and pronation
- Shoulder movement (flexion, extension, abduction)
- Shoulder-elbow coupling