
Modified Constraint-Induced Movement Therapy for Upper Extremity Recovery Post Stroke: What Is the Evidence?

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Background: Constraint-induced movement therapy (CIMT) is an effective treatment for upper extremity (UE) recovery post stroke. Difficulties implementing a traditional CIMT approach have led to development of protocols featuring varying practice schedules, including a 10-week, 3 times per week intervention, termed modified CIMT (mCIMT). To date, systematic reviews of CIMT have grouped the various protocols, precluding the ability to ascertain the level of evidence (LOE) of specific CIMT protocols. Knowing the LOE for various protocols and their relative effectiveness may facilitate decision making regarding which protocol to implement. **Objective:** The aim of this study was to determine the LOE of mCIMT in promoting UE recovery post stroke. **Methods:** A comprehensive literature search and subsequent analysis identified studies of a range of designs that investigated the mCIMT protocol. Two independent reviewers assigned an LOE to each of the identified studies, which were then examined collectively to determine the overall LOE for mCIMT. Study results were reviewed to assess the effectiveness of mCIMT for improving UE recovery. **Results:** Of 473 studies identified, 15 utilized mCIMT. The lack of randomized controlled trials (RCT) resulted in assigning an intermediate LOE (C). Study results indicated that participants receiving mCIMT experienced clinically significant improvements in UE impairment and activity-level attributes. **Conclusion:** The mCIMT protocol is an effective intervention for UE recovery post stroke. Future research including large RCTs could potentially increase the LOE for mCIMT. Additional investigation into the effectiveness of mCIMT in acute and subacute stroke populations is warranted given the limited number of studies performed to date. **Key words:** cerebrovascular disease, constraint-induced movement therapy, rehabilitation, systematic review, upper extremity

Stroke remains a leading cause of neurologically related death and disability in North America, affecting approximately 50,000 Canadian and 795,000 American adults annually.¹ These figures are likely to increase due to the aging population and the escalating percentage of individuals with risk factors for stroke.^{1,2} Unfortunately, full recovery of upper extremity (UE) function after stroke is elusive, with only approximately 5% regaining full function.³ Post stroke, patients often receive rehabilitation therapy to address functional deficits.⁴ Such treatments, considered part of usual care, help with UE recovery but have limited ef-

fectiveness, which is evident in the high rates of disability and incomplete functional recovery of the UE observed after stroke.^{5,6} To improve UE function after stroke and reduce the long-term disability related to poor functional recovery, effective, evidence-based therapeutic interventions are needed.

Constraint-induced movement therapy (CIMT) promotes UE recovery post stroke; results from

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numerous studies show it to be more effective than usual care.⁷⁻⁹ CIMT combines repetitive task practice (RTP), behavioral training techniques, and restraint of the less affected UE.^{7,10,11} 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.¹² Generally, patients are required to have some active movement in the paretic UE, with a minimum of 10° of active wrist extension and 10° extension of the thumb and at least 2 fingers. The need for this level of movement to actively engage in the treatment limits the number of patients for whom CIMT is an appropriate intervention to approximately 20% to 25% of the entire stroke population.¹³ The traditional form of CIMT follows a massed practice schedule; over the 2-week treatment period, restraint of the less affected limb for 90% of waking hours is combined with 6 hours of functionally oriented RTP using the paretic UE each weekday.^{7,14,15} Behavioral training techniques are also used to help patients transfer functional gains into real-world activities.¹⁶

Even though the traditional CIMT approach has been demonstrated to be effective at improving UE function and use post stroke,⁷ evidence suggests that it can be difficult to implement clinically due to its high resource demand (eg, time, availability of therapists, and resources).¹⁷⁻²⁰ In response to this issue of clinical feasibility, variations of the traditional approach have been tested, including those using a distributed practice schedule.^{8,9,21} The most studied of the distributed practice approaches was developed by Page and colleagues and is termed modified CIMT (mCIMT). In mCIMT, therapy sessions are performed for 30 minutes, 3 times per week over a 10-week period, and incorporate the same 3 key components as CIMT: restraint, RTP, and the application of behavioral techniques including shaping.^{8,11,21} Despite the use of a distributed practice schedule and thus a reduction in the overall clinical treatment time, mCIMT provides patients with more opportunities to engage in home-based practice using the paretic UE.¹¹ Consequently, evidence suggests that mCIMT is as efficacious as CIMT in promoting UE use and functional recovery post stroke. For

instance, mCIMT was found to be superior to a dose-matched program of usual care in improving UE function and use in chronic stroke.⁸

Furthermore, the reduction in clinical treatment time and thus a decreased use of resources in mCIMT may make the treatment easier to manage clinically.^{19,20} Systematic reviews are an important tool to inform clinicians of current literature and to help decision making regarding evidence-based practice.²² Several systematic reviews have evaluated the effectiveness of CIMT in promoting UE recovery post stroke.^{9,23-29} Although useful in gauging the overall effectiveness of CIMT protocols collectively, 2 issues regarding these reviews confound the interpretation of findings: focus on randomized controlled trials (RCTs), and the combination of different CIMT protocols.

Focus on RCTs

Although RCTs provide the strongest level of evidence (LOE) to support causality (ie, a given outcome is related to the experimental treatment or intervention), the inclusion of only RCTs in systematic reviews of the effectiveness of CIMT in promoting UE recovery post stroke disregards substantial evidence generated from other designs. Hence, inclusion of non-RCT study designs, an approach that is supported in the literature on systematic reviews,³⁰ would provide a more complete picture of the evidence for or against the use of CIMT post stroke.

Combination of Different Treatment Protocols

Many previous systematic reviews on CIMT pooled data from trials that involved different treatment protocols (eg, refs. 9, 25, 28, 31), thus limiting evaluation of the effectiveness of a specific CIMT protocol. To ascertain the LOE of the body of literature on a specific protocol, more specific systematic reviews are needed.

A recent study examining utilization patterns of CIMT demonstrated considerable variability amongst occupational and physical therapists in both the treatment schedule (number of therapy sessions/week) and session duration (therapy time/day) of nontraditional CIMT protocols (ie, distributed practice greater than 2 weeks in

duration).¹⁹ Also, no one particular protocol was favored by the respondents. Although variations in the delivery of CIMT may be useful in facilitating its clinical use, it is not known how deviations from its evidence-based form impact its effectiveness. Given that therapists use research publications as one source of knowledge to inform their clinical practice,^{19,32} grouping protocols within the systematic review literature may have contributed to the variability observed in the clinical delivery of CIMT. In contrast, by focusing on the evidence of a *single* protocol such as mCIMT across study designs within a review, the LOE of that particular protocol, and hence its clinical utility, could be more accurately assessed.

Accordingly, the objective of this review was to investigate the LOE of mCIMT to promote UE recovery post stroke. Effectiveness was determined based on results of studies of various designs that examined pre-post treatment changes in UE impairment and activity-level attributes.

Method

Criteria for selecting studies for review

Studies selected included those that involved (a) any research design; (b) adult subjects (≥ 18 years) with a diagnosis of ischemic or hemorrhagic stroke and UE impairment; and (c) the distributed mCIMT protocol for the UE performed 3 times per week for 10 weeks as the experimental intervention.^{8,16,21,33} No restrictions were applied in terms of length of therapy sessions, daily duration of restraint, and comparator interventions (eg, usual care control, no treatment control, no comparator group).

Two independent reviewers selected and analyzed the studies to be included in the review in 3 phases. In all 3 phases, disagreements about studies to include or exclude were resolved by a third reviewer. The multiphase approach ensured a broad, comprehensive literature search to identify all potentially relevant sources. Literature searches were conducted on June 20, 2011, and repeated on June 27, 2013, by one of the study authors (A.F.) and a reference librarian. Electronic databases searched included PubMed, CINAHL, Embase, the Cochrane Library, Web of Science, ProQuest, and OpenGrey from inception to present. Key

words and medical subject headings (MeSH; eg, cerebrovascular disease; upper extremity; exercise therapy) were exploded to include related terms and limiters (humans; English; and adults) were then added. Individual citations were exported to a reference manager database (EndNote X4; Thomson Reuters, New York) 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. A total of 486 citations were identified, 13 of which were removed before the first phase of article selection because the full text was not accessible in print or electronic copy.

Phase 1: Refining the literature

The 2 independent reviewers received the reference manager database of the 473 citations and the pdf full text of each article. The reviewers used a spreadsheet to record the first author, date of publication, journal, decision to include or exclude, and reason for exclusion (if excluded). Article selection in this phase was based on the title and abstract. Criterion for inclusion was the presence of content related in any way to CIMT or the use of alternate terms (eg, forced use; constraint-induced therapy). By the end of phase 1, 151 articles were included for further review.

Phase 2: Identifying articles examining mCIMT

The abstract and full text of the 151 articles were reviewed in phase 2 to identify those that studied the mCIMT protocol. A checklist form (**Supplemental Appendix A**; doi: 10.1310/tsr2104-319) was used to evaluate the studies and record pertinent data (study design, population, intervention studied, target of intervention, comparator intervention, and primary outcome measures). Studies were selected based on the above-mentioned inclusion criteria. Fifteen studies were identified in phase 2.

Phase 3: Assessing and assigning the level of evidence

The 2 independent reviewers assigned a LOE from 1 to 5 to each of the 15 remaining studies based on the American Academy of Cerebral Palsy Developmental Medicine (AACPDMD) classification

system (**Supplemental Table 1**; doi: 10.1310/tsr2104-319).³⁴ A standardized data collection form (**Supplemental Appendix B**; doi: 10.1310/tsr2104-319) 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 was recorded. Conduct questions on the form were used to assess the risk of bias and methodological quality. Collectively, the studies were reviewed to assign an overall LOE from A to D to the body of knowledge on mCIMT (**Supplemental Table 2**; doi: 10.1310/tsr2104-319).

Results

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. Five of the studies had a LOE of II (RCT < 100 subjects), 7 were level IV (case-based or cohort studies), and 3 were level V (case studies). Given the predominant research design (ie, case-based or cohort studies) and the low subject numbers (ie, a total of 133 subjects in the 15 studies), a LOE of C (intermediate) was assigned for the body of literature reviewed. **Tables 1** and **2** describe the methodological quality, study design, and LOE for each study.

Subject demographics

Demographic information is summarized in **Table 2**. The studies included subjects with ages ranging from 37 to 83 years, with the intervention occurring in different phases of stroke recovery: 10 of the studies treated patients in the chronic stage of recovery (>12 months post stroke; range, 13-156 months); 4 treated patients in the subacute stage of recovery (4 weeks to 6 months post stroke; range, 1-6 months),^{33,35-38} while one took place in the acute stage of stroke recovery (<14 days post stroke; range, 2-9 days post stroke).²¹

Intervention

Consistent with the stated inclusion criteria, all of the studies followed a distributed practice

schedule with treatment sessions occurring 3 times per week for 10 weeks. The majority of the studies (10/15) used 30-minute therapy sessions, whereas the remainder of the studies used 60-minute therapy sessions (30 minutes each of occupational therapy and physical therapy). Each study performed mCIMT, including the 3 key components that are consistently described in the literature and across the different CIMT protocols (ie, restraint, RTP and behavioral techniques including shaping). In several instances (6/15 studies), the mCIMT intervention was compared to a control group, which consisted of either usual care (eg, proprioceptive neuromuscular facilitation techniques focusing on functional tasks, stretching and compensatory techniques using the less affected UE as needed)⁸ or no therapy. Of the 6 studies that used a control group, all compared mCIMT to a dose-matched control group receiving usual care therapy, with 5 of those studies also comparing mCIMT to a no-therapy control group. Although all 15 studies included performed pre- and posttreatment assessments (baseline and at 10 weeks), 3 studies also included a 3-month follow-up assessment.³⁹⁻⁴¹ Information about the treatment delivered in each study is summarized in the supplemental material (**Supplemental Table 3**; doi: 10.1310/tsr2104-319). A number of studies incorporated an additional treatment beyond the standard mCIMT protocol. When this was the case, scores reported in this review are for assessments performed pre-post mCIMT, independent from any other treatment. 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.³⁸ This differed from a 2007 study that began delivering mCIMT a week after the mental practice therapy posttesting.⁴² A case study performed in 2003 by Page et al followed mCIMT with chemodenervation.⁴⁰

Outcome measures

To identify the directionality of the LOE, we looked to evaluate the effectiveness of mCIMT to improve UE impairment and activity-level attributes. Across the 15 studies, common

Table 2. Subject demographic information and study design employed for each study

First author	Year	Sample size		Age, years mean; range	Time since stroke mean; range	Stroke population	Study design
		Total (int/control)	No. of men				
Atteya	2004	6 (2/2/2)	3	53.5; 45-67	4.7 mo; 2.3-5.8 mo	Subacute	Case series
Page	2001	6 (2/2/2)	3	55.8; 44-77	4.6 mo; 2-5.5 mo	Subacute	Case series
Page	2002a	14 (4/5/5)	9	64.8; 45-83	4.4 mo; 4-6 mo	Subacute	RCT; prospective multiple baseline, pretest-posttest
Page	2002b	1 (1/0)	1	67	2 years, 4 mo	Chronic	Case study
Page	2002c	1 (1/0)	0	68	5 mo	Subacute	Case report; multiple baseline, pretest-posttest
Page	2003	1 (1/0)		44	14 mo	Chronic	Case study
Page	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	2005	10 (5/5)	8	60.4; 46-72	4.4 days; 2-9 days	Acute	RCT; pilot multiple baseline, pretest-posttest
Page	2006	6 (6/0)	2	62.8; 54-75	62.8 mo; 29-131 mo.	Chronic	Case series; single-blinded pretest-posttest
Page	2007a	4 (4/0)	3	62.5; 49-73	32 mo; 14-63 mo	Chronic	Case series; single-blinded pretest-posttest
Page	2007b	4 (4/0)	3	59.7; 55-73	69.3 mo; 13-156 mo	Chronic	Case series; single-blinded pretest-posttest
Page	2007c	4 (4/0)	4	60.2; 53-67	37.5 mo; ±23.2 mo	Chronic	Case series; single blinded, multiple baseline, pretest-posttest
Page	2008	35 (13/12/10)	22	57.9; 47-76	39.8 mo; 20-60 mo	Chronic	RCT; single-blinded, multiple baseline, pretest-posttest
Page	2009	10 (5/5) ^a	7	61.4; 48-79	28.5 mo; 13-42 mo	Chronic	RCT; single-blinded, multiple baseline, pretest-posttest
Szafarski	2006	14 (4/10) ^b	7	59.3; 54-68	72.5 mo; 22-178 mo	Chronic	Case series; pretest-posttest

Note: int = intervention.

^aComparison group not control^b10 control only for MRI.

assessment tools used included the Action Research Arm Test (ARAT),^{43,44} the UE portion of the Fugl-Meyer Assessment of Motor Recovery After Stroke (FM),^{45,46} and Motor Activity Log (MAL).^{47,48} In 4 of the studies, the MAL was administered to the primary caregiver (as opposed to the subject) presumably to avoid subject bias.⁴⁸ In addition to the clinical outcome measures, 2 studies incorporated other measures, including functional magnetic resonance imaging (fMRI) to examine cortical reorganization resulting from treatment⁴⁹ and 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 shown in **Figures 1** through **4**. Considering the different populations and range in time post

stroke, the studies are arranged based on the stage of rehabilitation. As shown in **Figure 1**, the change in ARAT scores for persons receiving mCIMT varied across studies; regardless of the time post stroke, all scores were greater than the minimal clinically important difference (MCID), which is the smallest change that needs to be observed to be clinically relevant. In addition to being based on clinical experience, the MCID is often expressed as being 10% of the score ranges for the outcome measure of interest. In the present review, the MCIDs for the ARAT and FM correspond to Bland-Altman limits of agreement, close to but falling outside of the limits of agreement.⁵⁰ The MCIDs are 6, 7, and 0.5 for the ARAT, FM, and MAL, respectively.^{47,50,51} 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

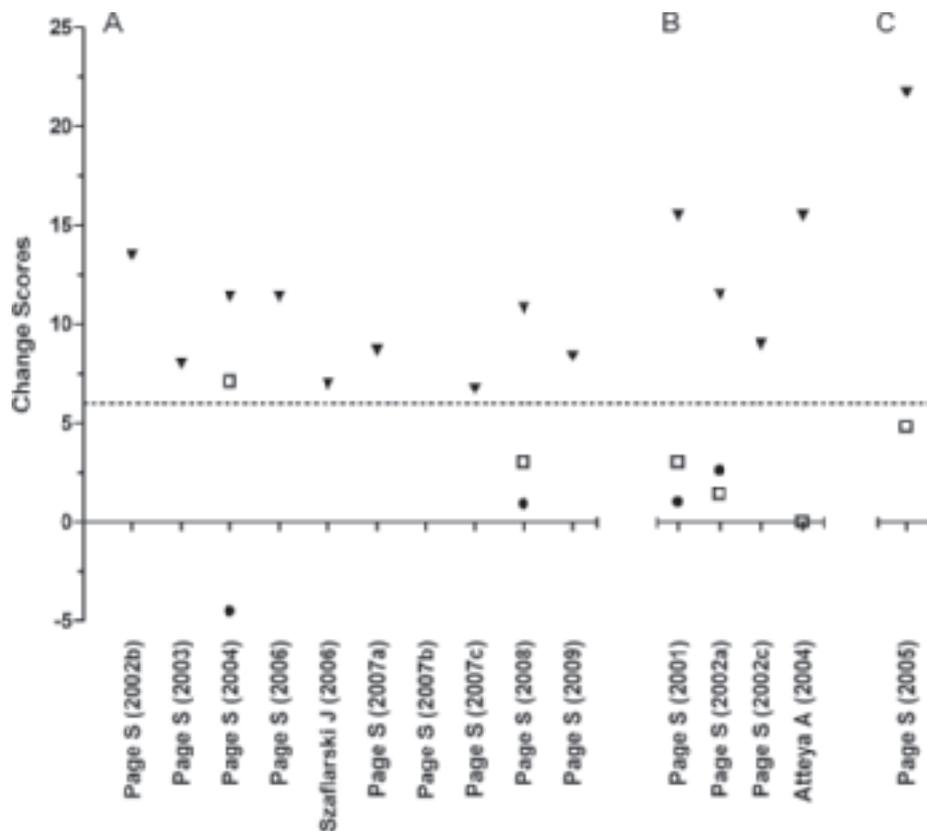


Figure 1. Pre- to posttest change scores for the Action Research Arm Test (ARAT) for studies examining patients in the chronic (A), subacute (B), and acute (C) stage of recovery. The dashed line represents the minimal clinically important difference (MCID), with inverted triangles, squares, and circles representing the mCIMT, usual care therapy, and no-therapy groups, respectively. Note: Atteya³⁵ used a no-therapy group, but did not report the scores.

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.

A trend similar to that of the ARAT is observed for the FM and MAL scores (Figures 2, 3, and 4) in that the mCIMT group in most studies improved more than the MCID, while the usual care and no-therapy control groups did not. The FM results differ however in that the mCIMT group scores fall below the MCID in 3 studies investigating a chronic stroke population. For the MAL (amount of use [AOU]) scores, the studies examining patients in the subacute stage of recovery had varied results. Two of the 4 studies included usual care and no-therapy control groups in which improvement in paretic UE amount of use improved more than the MCID.^{33,35} Additionally, Page found the MAL (quality of movement [QOM]) scores for subjects

receiving traditional therapy were greater than the MCID (Figure 4, panel B).³³

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 (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 impairment and activity-level attributes. In most of the studies, the degree of change was greater than the MCID. Thus, those receiving mCIMT observed a degree

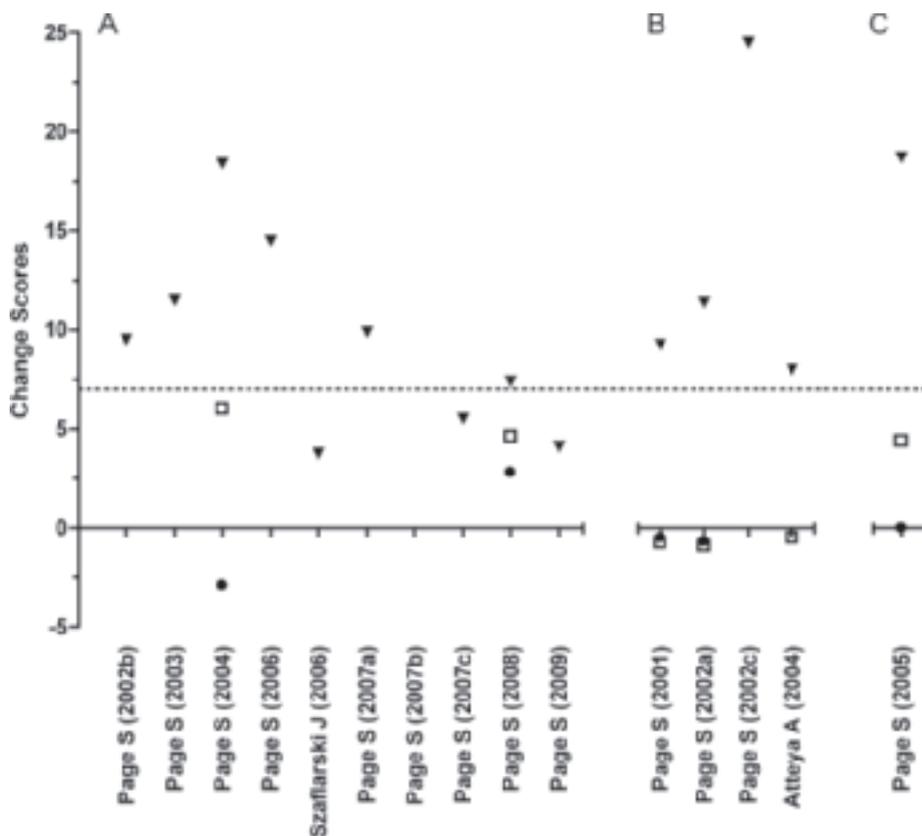


Figure 2. Pre- to posttest change scores for the Fugl-Meyer Assessment (FM) for studies examining patients in the chronic (A), subacute (B), and acute (C) stage of recovery. The dashed line represents the minimal clinically important difference (MCID), with inverted triangles, squares, and circles representing the mCIMT, usual care therapy, and no-therapy groups, respectively. Note: Atteya³⁵ used a no-therapy group, but did not report the scores.

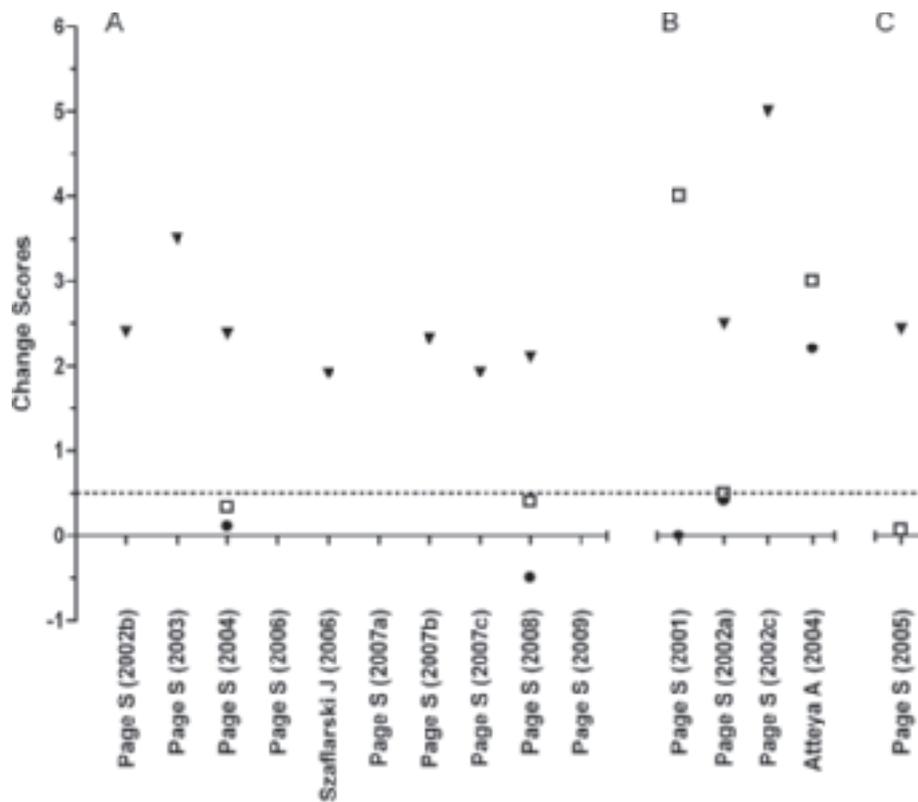


Figure 3. Pre- to posttest change scores for the Motor Activity Log Amount of Use (MALAOU) for studies examining patients in the chronic (A), subacute (B), and acute (C) stage of recovery. The dashed line represents the minimal clinically important difference (MCID), with inverted triangles, squares, and circles representing the mCIMT, usual care therapy, and no-therapy groups, respectively. Note: Atteya³⁵ used a no-therapy group, but did not report the scores.

of UE recovery that is clinically meaningful. This differs from subjects in the control or no-therapy groups who may have experienced some change in outcome measure scores; however these changes generally were not clinically meaningful.

Effectiveness across times post recovery

The improvements in subjects receiving mCIMT were observed across all phases of recovery, providing evidence of effectiveness of a 10-week mCIMT intervention in acute, subacute, and chronic poststroke stages. Although this evidence suggests that mCIMT can be beneficial for patients across the recovery continuum, it is important to note that the bulk of evidence comes from a chronic stroke population. The changes observed amongst the acute stroke population,²¹ although significantly different between the mCIMT and usual care

therapy groups, should be considered cautiously because the study only engaged 8 subjects.

Interpreting the level of evidence: Limitations

The 10-week mCIMT intervention appears to be an effective tool for rehabilitation of the UE post stroke, but the lack of large RCTs ($N \geq 100$) or greater number of small RCTs reduces its overall LOE (ie, 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 research design. 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 an LOE to a specific CIMT protocol. Similarly, there are challenges comparing studies with patient populations ranging across

better tool (relative to the FM) to measure changes in the UE for subjects receiving mCIMT, which helps to explain the difference in change scores observed for the 2 measures (depicted in **Figures 1 and 2**).

In addition to the limitations noted above, it is also important to recognize that all but 1 of the 15 studies were performed by the same research group, which should be considered when interpreting these results. While beneficial in the sense that the therapy was delivered in a consistent manner across studies, the results obtained by novice or less-experienced therapists may not parallel those reported here. This is not a criticism of the research group, but rather a reflection of the impact experience can have on the effectiveness of this (and other) therapy.

Incorporating mCIMT in clinical practice

It is important for therapists and clinicians to know the LOE in support of specific therapy protocols in order to make informed decisions about its use in their clinical practice. For mCIMT, the majority of evidence focuses on chronic stroke and supports mCIMT use at this stage of recovery. Although the studies are fewer in number, the evidence also supports mCIMT as an effective intervention for the UE post stroke in the subacute stage of recovery. Although promising, there is limited evidence to support the use of mCIMT

for people with acute stroke. Overall, for patients meeting the criteria for CIMT, clinicians should consider their patients' stage of recovery and which protocol is reasonable to implement for their particular practice setting, in the context of the evidence supporting a given CIMT protocol.

Conclusion

There is an intermediate LOE in support of mCIMT as an effective treatment for UE hemiparesis post stroke. This intermediate LOE is specific to the mCIMT protocol examined in the current review, as other reviews examining modified CIMT protocols collectively indicate a strong LOE (ie, 1A) in each of the phases of stroke rehabilitation.⁵³ Future research including large RCTs would strengthen the LOE for mCIMT. Additional investigation into the effectiveness of mCIMT in acute and subacute stroke populations is warranted. 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. By improving clinical use of mCIMT, we can improve the rehabilitation outcomes for people who have experienced a stroke.

Acknowledgments

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