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# Constraint-Induced Movement Therapy To Improve Gait And Mobility Of People With Chronic Stroke: A Mixed Methods Study

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# CONSTRAINT-INDUCED MOVEMENT THERAPY TO IMPROVE GAIT AND MOBILITY OF PEOPLE WITH CHRONIC STROKE: A MIXED METHODS STUDY

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CONSTRAINT-INDUCED MOVEMENT THERAPY TO IMPROVE GAIT AND MOBILITY OF PEOPLE WITH CHRONIC STROKE: A MIXED METHODS STUDY

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REHABILITATION SCIENCE

## ABSTRACT

Walking impairment after stroke impacts on participation and quality of life. Different techniques have been developed in the last decades to overcome walking difficulties after stroke, however, few have been shown to be efficacious. Constraint-induced Movement Therapy (CIMT) is a family of techniques that has been reported as one the most effective intervention for improving functional use and motor skills of a more-affected upper extremity (UE). The intervention protocol includes: 1) intensive supervised training; 2) use of shaping as a strategy for the motor training, 3) a group of behavioral strategies called the transfer package, and 4) procedures to increase the use of the more affected UE including the restraint of the less affected UE. The UE-CIMT protocol has been modified for use with the lower extremity (LE) and a few studies have examined the effect of the LE-CIMT on LE function. However, the studies that have applied the LE-CIMT protocol in people with stroke did not use the complete protocol (i.e., with a fully developed transfer package). Thus, information about the effects of the complete LE-CIMT protocol is greatly needed.

The purpose of this mixed methods study was to investigate the relationship between the effect of the LE-CIMT protocol on gait, mobility and motor function, and examine participants` and caregivers` perceptions regarding the treatment.

The comparison of the scores obtained during pre-, post-treatment and follow up assessments suggest that the LE-CIMT is a potential tool to improve gait, mobility and use of the more affected LE of people with chronic stroke. The results were maintained three

months after the end of the treatment. The quantitative results were confirmed by the perceptions of both caregiver or family members and participants with stroke. Further investigation about the effect of LE-CIMT in comparison with other interventions still needed. Also, studies with larger sample size should be conducted.

Keywords: Stroke, Rehabilitation, Paresis, Constraint-induced movement therapy

DEDICATION

*To the Monteiro dos Anjos family, for everything.*

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I am blessed to have a long list of people to be thankful for. If there is something that I learned during this process is that science without affection and support is a much harder battle to fight.

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To Casey, Bailey, Bella and the Moore family: thank you all for accepting me, loving me, and for always making me feel welcomed.

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| | |
|---|---|
| 10MWT | 10 Meters Walk Test |
| 5TSTS | 5 Times Sit to Stand |
| 6MWT | 6 Minutes Walking Test |
| ADLs | Activities of Daily Living |
| BBS | Berg Balance Scale |
| BCI | Brain-Computer Interface |
| CIMT | Constraint-Induced Movement Therapy |
| COM | Center of mass |
| ES | Effect size |
| FES | Functional Electric Stimulation |
| LE | Lower Extremity |
| LE-CIMT | Lower Extremity- Constraint-Induced Movement Therapy |
| LE-MAL | Lower Extremity- Motor Activity Log |
| LSA | Life-Space Assessment |
| MAL | Motor Activity Log |
| MMR | Mixed Methods Research |
| MMSE | Mini Mental State Examination |
| RCT | Randomized Controlled Trial |
| SSD | Single-subject Design |

| | |
|---|---|
| TP | Transfer Package |
| UE | Upper Extremity |
| UE-CIMT | Upper Extremity- Constraint-Induced Movement Therapy |

# INTRODUCTION

Every year, approximately 795,000 people in the United States experience a new or a recurrent stroke.[1] Approximately 200,000 survivors still present lower extremity (LE) paresis that impacts gait performance after six months from the event.[2–4] Paresis in the LE can cause restriction in participation of social activities,[5] activities of daily living (ADLs), as well increase fall risk.[6]

Two of the main goals of stroke rehabilitation are improvement in gait and balance. The approaches used in LE paresis rehabilitation after stroke include neurofacilitation, motor learning techniques, robotic devices, functional electric stimulation (FES), and brain-computer interfaces.[7] However, the evidence for the effects of each strategy on walking performance is unclear.

## Rehabilitation Interventions for Lower Extremity Paresis After Stroke: What has Been Done?

Studies pointed out that best results for improving paretic LE function are related to combined treatment effects (e.g., FES and robotic training), intensive motor training and self-management strategies.[8,9] Strategies based on the principles of promoting positive neural plasticity have been advocated.[10,11] Likewise, high intensity training has been investigated and shown to be an important tool for motor improvement.[12] Results from meta-analyses indicated that there is a positive dose-response relationship between

intensive motor training and motor outcomes.[8,13] Studies with conventional therapy approaches have suggested that this practice does not provide a sufficient number of repetitions of a specific movement to induce lasting neuroplastic changes.[12,14] This has led therapists on a continuous search for alternative intervention strategies that might increase the intensity of motor practice and retention of results. Considering that people with stroke are very inactive outside of supervised therapy,[15] the development of strategies that might increase the level of activity in real life is essential.

Strategies focusing on behavior management in neurorehabilitation protocols can enhance patient`s adherence and participation outside the clinical setting.[16–18] The combination of motor training and behavior management strategies has been shown to be effective and produce long lasting improvements on motor function and use of the paretic upper extremity (UE) in real life situations of people with neurological disorders.[19–22] Research on the effectiveness of this combination of strategies for paretic LEs is insufficient. Further, only a limited number of behavioral strategies for LE function have been described and explored. In turn, the transfer of within-laboratory improvements to real-world context that are most meaningful to patients (e.g., mobility) could strengthen retention of improvements for extended periods after the end of the intervention.

The Constraint-Induced Movement Therapy (CIMT) Intervention Protocol

CIMT is a group of techniques that systematically applies intensive daily treatment over consecutive days, supervised motor training using a technique called shaping, behavioral strategies to improve the use of the more- affected limb in real life situations called Transfer Package (TP), and strategies to remind participants to use the more-affected extremity; including restraint of the less-affected arm in the upper extremity (UE) protocol.[16,17,23] Numerous studies examining use of CIMT with UE rehabilitation

have demonstrated robust evidence for increasing the amount and the quality of the paretic upper extremity (UE) functional use in daily situations of individuals with brain injuries (e.g. stroke, traumatic brain injury). Also, a line of evidence suggests that the TP component is a particularly important contributor to positive outcomes.[17]

The CIMT was developed based on the studies conducted with primates with abolished sensation after surgery.[21] In these studies, a behavioral phenomenon called "learned non-use" was described. This process occurs as a result of reinforced suppression of movement and promotion of compensatory behaviors. Learned non-use could be reversed through restraint of the less-affected limb, the administration of a group of behavioral strategies, and training of the more-affected limb.[21,23] Also, CIMT promotes use-dependent cortical organization; a form of positive neural plasticity induced by frequent and intensive use of a function being treated.[21]

The transfer package (TP) is a group of strategies used in the behavioral analysis field to treat various health conditions.[17,20] Some of these components have been used in conventional treatment on a limited basis. The use of the TP in CIMT is novel in that it uses these behavior management strategies in a prescribed, integrated and systematic manner to induce the patients to use their more-affected limb for many hours a day for a period of 2 or 3 consecutive weeks.[17,23] The robust results observed after the UE protocol includes improvement on the paretic limb use outside the clinical setting.[20,21] The transference and retention of the results are associated to the TP, which is considered the most important component of the CIMT because it has shown to enhance the effects of treatment 2.4 times when compared to motor training alone.[16,17]

Table 1. CIMT elements used by published studies

| Studies | Intensive training | Shaping | Restraint | Transfer Package | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Behavioral contract | Home Skill Assignment | Home practice | Daily LE-MAL | Weekly LE-MAL |
| Silva et al. (2017) | | | √ | | √ | | | |
| Kalilo, Nilsson-Wikmar, Thorsén (2014) | √ | | √ | | | | | |
| Ding et al. (2013) | √ | | | | | | | |
| Bonnyaud et al. (2013) | | | √ | | | | | |
| Numata, Murayama, Takasugi, Oga (2008) | | | √ | | | | | |
| Regnaux, et al. (2008) | | | √ | | | | | |
| Marklund, Klassbo (2006) | √ | | √ | | | | | |
| Vearrier, Langan, Shumway-Cook, Woollacott (2005) | √ | | | | | | | |
| Rodriguez, Aruin (2002) | | | √ | | | | | |
| Aruin et al. (2000) | | | √ | | √ | | | |

The TP for the UE protocol consists of a behavioral contract, a daily diary, a list of assignments to be performed at home, daily application of the quality scale of the Motor Activity Log (MAL), frequent problem solving to enhance UE use, structured home practice after the intervention, and frequent follow-up phone calls in the first 4 weeks following the intervention to check on continues UE use.[17]

A smaller number of studies have shown promise for CIMT protocol directed at lower extremity (LE) rehabilitation. Although the significant effect of the UE-CIMT protocol has been reported,[17,19] the outcomes of using of a more complete LE-CIMT with a comprehensive TP remains unclear.

The results reported after the UE-CIMT protocol in stroke patients led to the translation for the paretic LE. The CIMT Research Group at the University of Alabama at Birmingham (UAB), directed by Dr. Taub, developed a protocol focused on the paretic LE. [24] However, modifications were necessary to build a LE-CIMT protocol that was suitable for improving gait and mobility. For example, the LE-CIMT procedure does not in any way restrict use of the less-affected limb for safety issues and the fact that an unnatural pattern of gait would be induced during treatment. Instead, use of the more affected LE is encouraged as well as more coordinated use of both LEs as is appropriate. Another difference regarding the LE-CIMT protocol is the nature of the activities performed with the LE which is different from those that demand UE participation. In recent years, a more detailed LE-CIMT TP has been proposed. However, to date, the influence of the more complete TP on motor function, gait and mobility remains not fully explored.

The few studies that have applied a LE-CIMT protocol in people with stroke did not use the full TP component. In addition, most of the studies using LE-CIMT with

individuals with stroke, had utilized different types of restriction devices applied to the less-affected LE (Table 1).[25–32] However the restraint device was excluded from the LE protocol due to safety issues and because it would induce an unnatural coordination pattern. Also, the addition of a more complete TP in the LE protocol might have a great impact on both motor outcomes and retention of the results, as observed in previous studies about the UE approach.[17] Considering the high intensity of the complete protocol, the added safety concerns, and the demand of involvement of the therapist, participant, and caregivers, the acceptability of the TP should also be explored in order to provide a better understanding of the feasibility of this strategy.

Despite the fact the UE-CIMT has been extensively studied, the LE-CIMT protocol has not been not fully explored. The LE-CIMT protocol proposed here consists of: 1) intensive supervised training for 3 hours daily over 2 weeks, 2) use of shaping, and 3) use of a transfer package to promote continues use of LEs while away from supervised training.[16,17]

## Project description

The purpose of this multiphase mixed methods study was to investigate the relationship between the effect of the CIMT protocol on gait and mobility and participants` and caregivers` opinions about the treatment. The goal of the quantitative strand is to assess changes in quality of movement and functional use of the paretic LE and investigate the participants` expectations in regards the intervention. The qualitative strand (participant and caregivers` or family members interviews) explored their perspectives regarding the protocol elements and perception of benefit. For this, the following procedures were conducted.

*. Participants: sampling and selection criteria*

A total of 11 people was selected in this study; nine participants with stroke and four primary caregivers or family members that could provide information about the participant`s routine during the intervention. This purposive sample was selected according to the following criteria: (1) 19 years of age or older; (2) at least 2 years post stroke; (3) present lower extremity motor impairment secondary to stroke, but able to walk at least 25 feet with or without an assistive device, at least three times a day; (4) have no previous experience with either research or treatment LE-CIMT protocol. Participants were excluded if presented uncontrolled clinical conditions, other neurologic conditions, a Mini-mental State Examination score (MMSE) <24, inability to provide the informed consent, and insufficient language skills to answer the interview questions. Caregivers and family members with availability to be interviewed and older than 19 years old or older, English speakers, and able to answer the interview questions were also selected to the qualitative strand.

*. Intervention*

During the intervention phase, the effects of the LE-CIMT was accessed in participants that received repetitive, intensive motor training (using shaping) and TP. All participants received the same treatment protocol. The LE-CIMT lasted 2 weeks, 3.5 hours/day under therapist supervision, a list of activities to be performed outside the laboratory during and after the intervention, without restraint device.[24,33] The components of the LE-CIMT are fully described later.

## Specific Aims

*Specific Aim 1: Assess the effects of the complete LE-CIMT protocol on LE use and motor function.*

This study was a experimental AB project, considering A, as the baseline strand; and B, the intervention phase.[34] Both quantitative and qualitative data were also collected during a follow up period, 3 months after the end of the treatment, in order to assess the long-term retention of the effect. Also, a follow up assessment was conducted after 3 months of the end of the treatment.

Both phases lasted 10 consecutive weekdays, and during baseline phase, the data were collected on 5 different days. During the intervention phase, the treatment was delivered daily, along 10 weekdays, 3.5 hours per day in which the motor training was delivered for 3 hours, and 30 minutes were allocated to the administration of the TP.

*Quantitative data collection*

In order to assess LE physical performance and use, mobility area (e.g. within a room, around their neighborhood, other cities), and balance the following primary outcome tools were used: (1) Lower Extremity Motor Activity Log (LE-MAL); (2) Berg Balance Scale (BBS); (3) 10 meters walk test (10MWT). The secondary outcomes are: (1) 5 times sit to stand (5TSTS); (2) 6 minutes walking test (6MWT); (3) Lower Extremity Motor Function Test (LEMFT). (4) Fear of Falling Avoidance Behavioral Questionnaire (FFABQ); (5) Life-Space Assessment (LSA). Considering the study purpose, it is ideal to administer a group of assessments that provides information of in laboratory and real-life situations. All scales are valid and reliable.

*. Analysis*

The effect was determined by comparison between pre, post-treatment and follow up assessments using paired t-test. Not normally distributed data was transformed using a natural log. The effect size was also calculated considering the standard deviation of the

changes observed between phases. The statistical analysis was conducted using SPSS version 24.

*Specific Aim 2: Explore participants` and caregivers` acceptability of the LE-CIMT protocol.*

*Qualitative data collection*

This phenomenological qualitative strand was conducted after the conclusion of the treatment, participants and primary caregivers or family members were individually interviewed by a researcher that was not involved on the intervention. Face to face interviews were audio recorded and transcribed verbatim. The transcripts were coded by two different researchers and then compared.

*Analysis*

The data were analyzed through thematic analysis procedures in which the main themes collected along the interview were categorized and reported. Two researchers coded the transcripts independently. The themes were compared and revised by both coders.

*Specific Aim 3: Examine how participants and caregivers perceive changes in motor outcomes after LE-CIMT.*

. Mixed Methods Research (MMR) Design

MMR is a method that integrates both quantitative and qualitative data in order to provide a deep understanding of a certain phenomenon.[35] In this dissertation, the main rationale is complementarity as the researcher understands that the phenomenon is not completely explored through only quantitative or qualitative data. Thus, the combination

and integration of both information provided deep and complete perspective of the problem.

The purpose of this multiphase mixed methods study is to investigate the relationship between the effect of the CIMT protocol on gait and mobility and participants` and caregivers` expectations and perceptions regarding the treatment.

. *Meta-inferences*

Quantitative data was collected during the baseline, post treatment, and follow up (3 months after the end of the intervention). Quantitative and qualitative data were collected at the end of the treatment. Both quantitative and qualitative data were analyzed concurrently and were merged using side-by-side comparison through joint display. The data were analyzed in order to explore if they converge (better outcomes and positive perceptions regarding the intervention) or diverge (no connection between outcome results and participants` and caregivers` opinions).[36–38]

The articles presented in this dissertation covered: 1) the detailed descriptions of the LE-CIMT protocol, 2) the psychometric properties of the primary outcomes used in this study, the Lower-Extremity Motor Activity Log (LE-CIMT), 3) the report of the changes observed pre and post treatment with a participant with chronic stroke, and 4) a mixed methods study.

The UE-CIMT intervention was previously described, providing details of all components,[23] but until this moment the LE-CIMT protocol was not fully described. Also, as previously reported, the published studies that applied the protocol with people with stroke used a modified version of the protocol, including a restraint device. Thus, the aim of our first publication was to provide detailed description of the leaned misuse phenomena, and of all elements of the LE-CIMT intervention.

The second publication examined the reliability and concurrent validity of the LE-MAL that measures the real-world use of the more affected LE. It measures the level of assistance, quality of movement and level of confidence of the more affected LE while performing 14 daily activities.

The effect of the LE-CIMT was assessed in two articles described here in this dissertation. A case report assessed the quantitative changes regarding motor function, balance, gait speed, mobility and endurance comparing the participant`s performance on both baseline and intervention phases. The second paper examined these changes in a group of 8 participants with chronic stroke and their caregiver and family members. Also, qualitative data were collected through individual interviews in order to better understand their perceptions about the therapy and the changes observed after the treatment. In this study, quantitative data were also collected 3 months after the end of the intervention to examine long term chances related to the LE-CIMT protocol.

# CONSTRAINT-INDUCED MOVEMENT THERAPY FOR LOWER EXTEMITY: DESCRIBING THE INTERVENTION PROTOCOL

by

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ABSTRACT

Constraint-Induced Movement Therapy (CIMT) is comprised of a set of techniques shown to produce significant changes in upper extremity (UE) function following stroke and other disorders. The significant positive results obtained with the UE protocol has led to the development of LE-CIMT, an intervention to improve lower extremity (LE) function. However, some modifications of the UE protocol were needed including: omitting use of a restraint device, development of supervised motor training tasks to emphasize movement of the lower limb, and adaptation of the UE Motor Activity Log (MAL) for the lower-extremity (LE-MAL). The LE-CIMT protocol includes: 1) intensive supervised training delivered for 3.5h/day for10 consecutive weekdays, 2) use of shaping as a strategy for motor training, 3) application of a transfer package, and 4) strongly encouraging use of the more affected LE with improved coordination. The transfer package consists of several strategies to facilitate transfer of the improved motor skills developed during supervised treatment to everyday situations. Research to date has yielded positive results. However, the intervention protocol continues to evolve. Describing the components of the complete LE-CIMT protocol should be helpful in promoting further development and investigation of this approach.

# INTRODUCTION

Constraint-Induced Movement Therapy (CIMT) is a group of interventions that have been shown to produce significant improvement when applied systematically in the amount and quality of movement of the paretic upper-extremity (UE) of individuals with stroke in the chronic phase of recovery.[1,2,3] The protocol was developed after studies conducted in deafferented primates identified a behavioral phenomenon termed "learned non-use" (LNU).[4,5,6] The same phenomenon has been proposed to occur in humans after injury to the central nervous system (CNS) (e.g., after stroke), when the person is unable to use a function during the early phase of recovery as a result of the loss of neural excitability produced by the CNS injury. Consequently, the person learns to rely on compensatory behavior patterns not involving the impaired function. After the precipitating damage, there is a slow recovery of CNS excitability, but because of the operation of the learned nonuse mechanism the person learns to not try to use the impaired function. A combination of strategies has been used to overcome this phenomenon in humans with upper limb paresis resulting from CNS injury occurring as a result a variety of injuries of the nervous system.[1,7-12] The UE-CIMT protocol consists of four basic components: (1) intensive supervised training; (2) motor training based on shaping principles; (3) a transfer package of techniques to facilitate transfer of therapeutic gains from the treatment setting to everyday life situations.; (4) use of a restraint device on the less-affected limb.

As noted, CIMT was developed to overcome the LNU occurring in people with CNS injury that is a result of movement suppression following successive failures while trying to use the more affected extremity; these lead to the avoidance of using that limb.[4,13-16] The CIMT protocol was designed to overcome this process through a

systematic combination of motivation, repetitive and intensive motor training, and reinforcement of positive behaviors. Initially reinforcement is given to any attempt to use the more affected UE, and later to improvements in the quality of movement. The clinical changes observed after the application of UE-CIMT have their counterpart in the brain. There is an increase in grey matter in motor areas of the brain and the hippocampus,[17,18] a process termed use-dependent cortical reorganization; and an increase in the integrity of white matter tracts.[10,19,20]

Numerous studies have reported significant improvements in UE use and quality of movement in participants receiving the UE-CIMT protocol.[3,15,21,22] The positive results observed with the CIMT intervention for the upper extremity led the Constraint-Induced Therapy Research Group (CITRG) at the University of Alabama at Birmingham (UAB) to develop a protocol for lower-extremity (LE).[23-26]

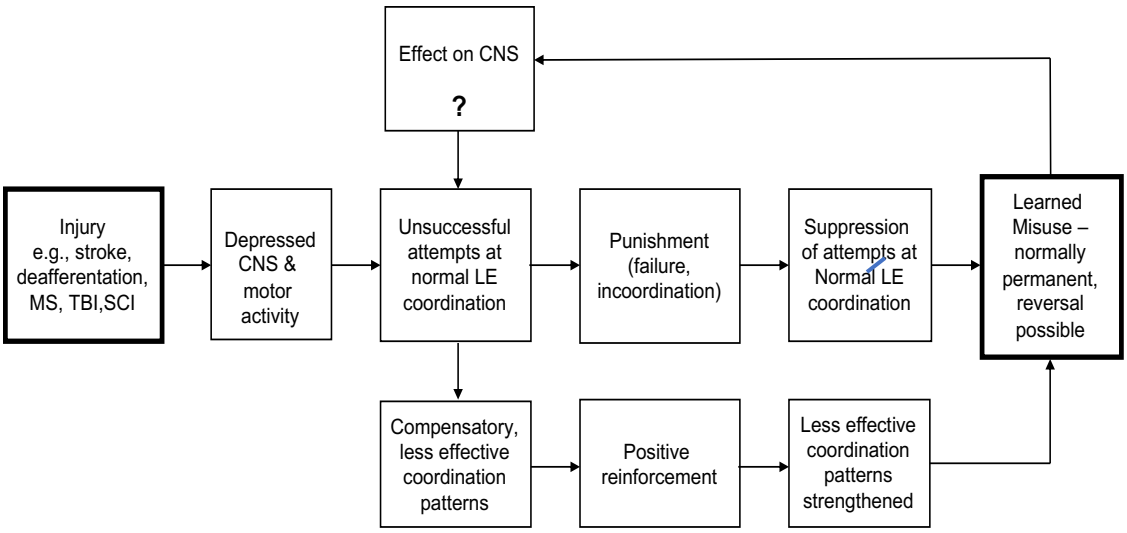
The purpose of this manuscript is to describe the current LE-CIMT protocol, discuss the similarities and differences between the LE- and the UE-CIMT protocols and suggest future directions to better understand the effect of the LE-CIMT intervention.

## MECHANISMS RELATED TO UE LEARNED NONUSE: LE LEARNED MISUSE

The LNU process does not directly apply to the lower extremities because of the bilateral nature of the activities that humans perform with the LEs (e.g., standing, walking) and the fact that the more- affected LE must be used during gait and balance tasks even in the early phase of recovery from injury in order for those activities to be carried out at all, even though they are carried out incorrectly and ineffectively. Thus, the term "learned misuse" may be a more appropriate term for this situation.[23,27] However, while learned misuse may differ in some respects from LNU, the main behavioral

components of reward for relying more on the less-affected LE and punishment for relying on the more-affected LE are still present, making learned misuse a special case of learned nonuse (Figure 1). Moreover, it is of note that neuroplastic changes were observed in a study using a modified version of the LE-CIMT protocol.[28] The development of learned misuse and the way in which LE-CIMT overcomes it are schematized in Figures 1 and 2.

Figure 1. Development of Learned Misuse




CIMT components: translation for the LE

While the LE-CIMT protocol is based on the UE intervention, some modifications were made, particularly omitting use of restraint of the stronger limb (Table 1).

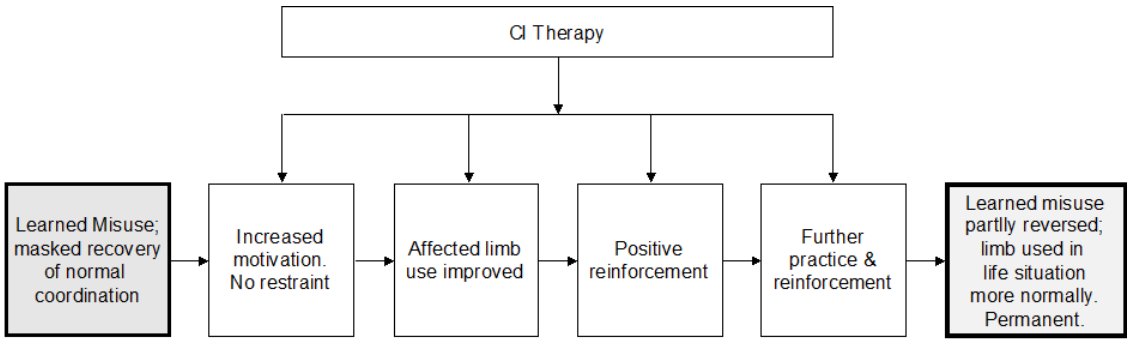
Previous studies examining the elements of the UE-CIMT protocol have reported that the systematic application of a combination of these elements can reverse LNU.[5,21,27,29] It is believed that many of these same principles apply to learned misuse and the LE-CIMT protocol. As shown in Figure 2, a combination of increased

motivation, to make more symmetric use of the more affected lower limb and positive feedback of improved coordination can induce a more coordinated use of both lower extremities.

Table 1. Elements of the UE and LE protocols

| **CIMT Elements** | **UE-CIMT Protocol** | **LE-CIMT Protocol** |
|---|---|---|
| Intense supervised treatment | √ | √ |
| Shaping | √ | √ |
| Restriction device | √ | |
| Behavioral contract | √ | √ |
| Daily diary | √ | |
| Home practice (during intervention) | √ | √ |
| Home practice (after intervention) | √ | √ |
| Daily administration of the MAL (UE- or LE-MAL) | √ | √ |
| Weekly administration of the UE- or LE-MAL (after intervention) | √ | √ |

Figure 2. Method by which LE-CIMT overcomes learned misuse.



*Exclusion of the restraint device*

The rationale behind omitting the restraint device in the LE-CIMT protocol includes safety issues and the fact that wearing such a device would encourage an unnatural gait and postural pattern during the intervention. Safety is a major concern due to the high risk of falling while the individual is performing LE activities outside the supervised treatment setting. Moreover, as contrasted with the UE-CIMT protocol, which focuses only on the more-affected UE, the LE-CIMT protocol encourages use of both LEs to achieve better quality of movement, higher participation of the affected LE in both uni- and bilateral tasks, and improved coordination between both LEs.[27]

Differently from the protocol used by UAB CITRG, studies from other laboratories have reported use of a LE-CIMT protocol in people with stroke, but most of them applied a type of restraint.[30-37] They also omit other important aspects of the full CI Therapy protocol to varying degrees. Most of these studies suggest that the use of a restraint device for a limited time could induce improvements in balance and gait parameters, such as walking speed and more symmetric weight bearing.[30,32-37] However, studies have reported no significant specific effect on the affected LE after the use of the device during supervised treatment.[31,36]

*Intensive supervised training*

High intensity training has been investigated and shown to be an important tool for motor improvement.[38] A meta-analyses of the literature indicated that there is a positive dose-response relationship between intensive motor training and motor outcomes.[39,40] Studies have suggested that conventional therapy approaches do not provide a sufficient number of repetitions of a specific movement to induce lasting neuroplastic changes.[38,41]

This has led therapists on a search for additional intervention strategies that might increase the intensity of motor practice and retention of results.

Initially, the supervised training component of UE-CIMT intervention was conducted for 6 hours daily by the UAB CITRG, but it was later found that there was no significant increase in the clinical changes observed after a long (6h/day) vs. a shorter (3h/day) treatment day.[5,6,15,42,43] Therefore, supervised training of the LE-CIMT protocol is now delivered here for 3 hours daily for 10 consecutive workdays.

*Repetitive motor training following shaping principles*

Shaping is a strategy that combines both approaching a target movement in small steps (i.e., successive approximation) and incrementally increasing the complexity of a task as the participant's performance improves. Shaping also employs structured forms of interaction between therapist and participant; these include modeling, feedback, coaching and encouragement.[13,15,21,22,29,45]

Tasks are performed emphasizing improved use of the more affected LE during sets of ten 30 to 45 seconds trials.[13] Unlike the shaping used in the UE-CIMT protocol, shaping activities in the LE-CIMT protocol also includes involvement of the less-affected LE. Since LE activities are very energy consuming, rest periods are more frequent than for the UE to avoid fatigue. UAB CITRG members have developed a bank of shaping tasks for the LE protocol that can be requested through the website (https://www.uab.edu/citherapy or citherapy@uab.edu). When designing a set of shaping tasks that are tailored to an individual patient`s needs, the therapist should choose activities based on 1) the joints/muscles with greatest potential for improvement; 2) the joints/muscles more severely impaired; and 3) a patient`s preferences (e.g. biking,

walking on grass) so as to induce more effective transfer of trained performance into real life situations. It is important to note that the complexity level of the shaping task should be set at just beyond what the participant can easily accomplish. In this way, the task will be somewhat challenging, yet doable. Since the improvement in task performance will always be within the participant's likely capacity, though just a little beyond it currently, success in improvement will be highly probable. This results in the maintenance of motivation to keep using the more-affected LE in an improved fashion.

Each task is structured to improve the target movements, with clear formal steps formulated ahead of time on how improvements will be progressed and how they will be measured. The therapist provides feedback to the participant during and after each trial.[13] For example, if the task is stepping to the top of a stool (Table 2), the therapist can count how many times the participant steps to the top of the stool in 30 seconds, or how much time the participant takes to step to the top of the stool a certain number of times. After each 30 second trial, the therapist should provide explicit performance feedback, telling the participant for example how many times he/she stepped to the top of the stool as well as providing qualitative feedback regarding posture, symmetry, speed, and range of motion.[45]

*Behavioral strategies: the Transfer Package (TP)*

The TP is a group of strategies used in the behavior analysis field to treat various health conditions.[21] Used with CIMT, the primary purpose of the TP is to assure continued use of the function being treated during unsupervised periods of the intervention period. In addition, different strategies are used to promote attention to the more-affected LE while performing functional activities. The participant is actively

involved in this through procedures involving self-monitoring and problem-solving with the therapist.[13,21]

Table 2. Example of a shaping task: step to the top of the stool

| | |
|---|---|
| Description | Patient stands with feet comfortably apart (assistive devices are allowed). The stool is placed in front of the patient. The patient is asked to step onto the top of the stool with one foot and come back to the initial position. |
| Movements emphasized | - Hip flexion<br>- Knee flexion<br>- Dorsiflexion |
| Potential Shaping progression | - Height of the stool<br>- Distance between the patient and the stool<br>- Less supportive device or the assistance device is eliminated |
| Feedback parameters | - Number of times that step onto the stool<br>- Time to step onto the stool 5 times. |

Some of the components of the TP have been used in conventional rehabilitation treatment on a limited basis. The use of the TP in CIMT is novel in that it uses these behavior management strategies in a prescribed, integrated and systematic manner to induce the patients to use their more-affected limb for many hours a day both in and outside the treatment setting for a period of 2 consecutive weeks.[13,21] The robust results observed as a result of the UE protocol includes improvement in paretic limb use outside the clinical setting with an effect size of 3.6.[15] The transfer of the treatment effect to everyday situations outside the treatment setting and retention of the treatment effect for

two years after the end of formal training are attributed to the TP, which is considered the most important component of CIMT because it has been shown to enhance the effects of treatment in everyday settings 2.4 times when compared to the same motor training in the treatment setting alone.[21,47]

The TP for LE- CIMT consists of: 1) administration of the Lower-Extremity Motor Activity Log (LE-MAL) daily during treatment 2) problem solving with the therapist to overcome perceived barriers to improved LE use 3) a behavioral contract (BC), 4) home skill assignments (HSA), 5) home practice after the end of treatment, 6) weekly phone calls for the first month after and of formal treatment in which the LE-MAL is administered and problem solving carried out. Each element of the TP is described below:

- Administration of the Lower-Extremity Motor Activity Log (LE-MAL)

The LE-MAL is a version of the Motor Activity Log (MAL) used to assess the use of the more affected UE in daily life situations. It is a patient reported outcome that assesses more-affected LE use in 14 activities (e.g., walking indoors, climbing stairs). The instrument has 3 scales: 1) Assistance Scale, 2) Functional Performance Scale, and 3) Confidence Scale. The first scale indicates the level of assistance that the individual needs while performing these activities; it identifies whether a person needs help from others, uses an assistive device (e.g. cane), or environmental support (e.g. grab bars).[44,45] This instrument is a reliable tool to measure the LE use of people with stroke[44] and Multiple Sclerosis (Anjos, Mark, Uswatte, Taub, unpublished data). The LE-MAL is administered daily during the treatment period and weekly for the first 4 weeks after the end of the intervention.

- Behavioral contract (BC)

The purpose of the BC for the Lower Extremity (BC-LE) is to: 1) achieve safety while engaging in improved use of the LEs, 2) use the more-affected LEs in functional activities whenever possible, and 3) use both LEs in a more coordinated manner. Additionally, the BC-LE formally engages the patient in actively exploring more ways to use their more-affected LE in their home environment and in adopting a problem-solving approach to accomplish that end. The BC-LE should be worked out with the patient at the end of the first treatment day, when the patient will have had some experience with emphasizing improved use of the more-affected LE and the therapist has been able to observe what a patient's current level of performance is. The BC-LE is reviewed and modified on at least one other occasions during the intervention period (e.g. Mondays after the first weekend of the two-week treatment period). Before discussing the BC-LE, laboratory staff should construct with the patient a daily activity schedule from the time of awakening in the morning until they will arrive in the clinic for training on subsequent days, and from the time they will leave the clinic until the time they go to bed at night. This allows the staff to 1) examine the participant's daily routine (e.g., identify activities that are commonly carried out and important to the participant), 2) explore the participant's home and community environment, and 3) identify potential safety hazards that must be discussed. Items from the daily activity schedule serve as a starting point for identifying activities to be listed on the BC-LE. Additional items to consider may come from the items the staff plans to list in the transfer package (TP) activities for facilitating transfer of treatment gains from the laboratory/clinic to the life situation, and/or from the assigned fitness activities as long as they do not lead to excessive fatigue. These items should be modified if necessary, as treatment progress. They are categorized on the BC-

LE as one of the following: 1) activities to be done independently by the participant, 2) activities to be done with the supervision and/or help of a caregiver, or 3) activities not to be done for safety reasons. It is very important that as many items as possible be placed in the activities to be performed independently section whenever they are safe and could possibly improve the participant's function and promote their self-efficacy. In order to achieve this end, problem solving should be carried out intensively with the participant as a team effort between therapist and participant. It may be necessary to modify the way in which a task is normally carried out or to use adaptive equipment to accomplish it. The BC-LE should be signed by the participant, therapist, witness, and/or caregiver. For many participants, this signature process is meaningful and helps with adherence.

- Home skill assignment (HSA)

The LE-HSA process is a transfer technique designed to encourage use of the more-affected LE during activities of daily living (ADL) outside the treatment clinic. The LE-HSA is administered on each treatment day of the intervention period starting on the 2nd day of treatment. The LE-HSA supports and should be in agreement with the LE-BC. It is given to the patient as a written set of activities to be accomplished after the end of the treatment session and it has a check-off component. After each activity is accomplished outside the treatment setting the patient checks that item. The LE-HSA check-off sheet is reviewed daily after administering the LE-MAL and before administering the shaping tasks. The HSA is not administered on the first day of treatment to allow at least one day of focused attention to the terms of the BC for safety purposes.

The activities listed in the LE-HSA are categorized into walking activities and non-walking activities. Each activity should be described to the patient in detail in order to

promote proper execution to assure safety and to encourage more-affected LE use (e.g., assistance from others, equipment, to be used, time dedicated to the activity, distance to be covered, and/or number of repetitions recommended). When UE use is needed for an assigned activity, participants are encouraged to use the UE that they typically would use, whether it is their less-affected or more-affected UE.

- Home Task Practice after the intervention period

The purpose of home task practice after the intervention period is to assure continued progress with LE use after the formal CI therapy program is completed. With home practice, participants are encouraged to engage in functional skills and fitness activities on a daily basis. These activities will maintain improvements in LE use realized during the LE-CIMT protocol and possibly enhance them.

Home practice activities have the character of home skill assignment activities (i.e., functional skills and fitness activities) and are performed independently by the participant after the end of the treatment. Equipment typically found around the participant's home or can be easily purchased is used for home practice activities. Requiring that expensive equipment be purchased for these activities will deter participants from doing them. The tasks prescribed should involve movements that can be accomplished by the participant, yet need improvement. Also, the tasks prescribed should be at a level of difficulty that is compatible with the participant's functional capabilities at the end of formal treatment. Ideas regarding increasing the difficulty of the task as the participant's abilities improve should also be provided.

Toward the end of treatment, a written individualized post-treatment home practice program is developed and given to the patient. The program consists of 7 separate lists,

one for each day of the week, that is to be repeated weekly. Each list contains a fitness program to be carried out for 15-30 minutes and 7 specific functional activities in which the participant is asked to use both LEs. Fitness activities include strengthening, conditioning and stretching exercises. The group of functional activities focuses on using the more affected LE while performing daily activities (Table 3). The tasks are selected from a list of functional skills developed by the laboratory. Each list should contain a variety of activities, so that when participants switch between activities from day to day boredom is prevented and the use of multiple movement patterns is encouraged. Participants should be instructed to perform home practice activities for a minimum of 30 minutes each day.

Table 3. Examples of Home Practice fitness and functional activities

| Fitness activities | Functional activities |
|---|---|
| - Walking in a treadmill<br>- Cycling<br>- Pilates<br>- Yoga | - Walk to the mailbox<br>- Standing and dusting furniture<br>- Rolling in the bed leading with more-affected leg or hip<br>- Standing to wash or wax car |

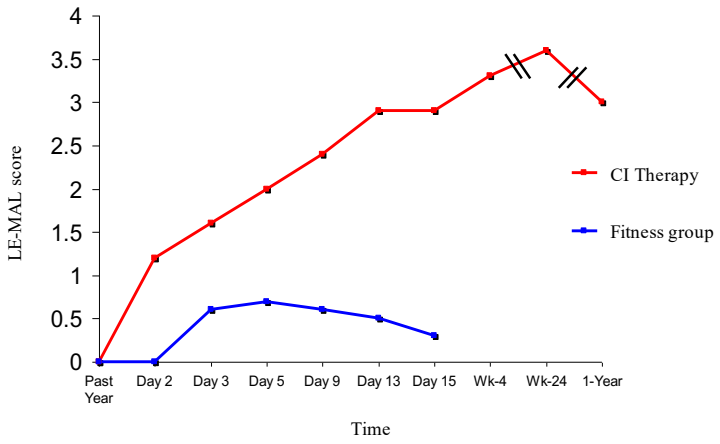
Previous studies

Previous studies in different laboratories have shown that significant improvements occur in balance, walking speed and mobility after intensive motor training.[33,46-48] Study that applied intensive training (at least 3h/day for 2 consecutive weeks – similar to CIMT) reported improvement in the balance of individuals with chronic stroke.[46,47]

The LE-CIMT protocol has been explored by the UAB CITRG with promising results. Initially, the protocol consisted of supervised movement training using shaping for 6 hours daily for consecutive workdays over a 2-week period. The TP was not fully applied in this study. Preliminary findings from a treatment group of 43 individuals with stroke indicated significant improvement in motor function according to several outcome measures.[23,27]

The LE-CIMT protocol was also administered to individuals with spinal cord injury (SCI), and hip fracture.[23,24,25] The primary outcome used in this study was the LE Motor Activity Log (LE-MAL). All individuals with chronic stroke improved in the use of the affected LE in different daily activities. As may be seen from Figure 1, the results for a general fitness exercise group were significant but the treatment change was far less than that for the group receiving LE-CIMT. The effect size for LE-CIMT was 1.5.[49] Another important result was with respect to retention of the improvement. There was a small improvement for the LE-CIMT group 4 weeks after the end of the intervention. One-year after treatment retention was perfect compared to immediately after its termination. There were no reports of adverse events.

Figure 3. LE-MAL scores for LE-CIMT and Fitness intervention



In a case series study of LE function after administration of the LE-CIMT protocol with people with Multiple Sclerosis, the intervention was delivered for approximately 50 hours over three weeks; during which shaping and the TP were employed. The average difference on LE use was 2.3 points on the LE-MAL; 4 years after the end of treatment retention was approximately 50%.[12]

The findings reported above suggest that LE-CIMT is safe and efficacious for people with stroke. It remains unknown if the application of a fully developed TP for the LE-CIMT would amplify the previous results, as has been reported regarding UE-CIMT.[21] The comparison between UE-CIMT protocols that used motor training with and without the TP strongly suggests that the TP is an essential key for the significant improvement reported for UE-CIMT.

None of the previous published studies using LE-CIMT administered a complete TP as described in this manuscript. Considering the small number of studies carried out in the past and use of only a partial protocol (e.g., lacking a complete TP), the effects of application of a complete LE-CIMT protocol on mobility and LE motor function remains unknown. In using a more complete TP, participants might also experience a greater improvement in confidence, self-efficacy, and self-management skills than has been observed in the past.

## Future directions

UE-CIMT was first carried out in 1993 and since then has been extensively studied. It has been shown to be an approach that provides significant improvements in UE function.[2,3] Using similar strategies, the UAB CITRG has developed a LE-CIMT protocol

to improve gait and balance in people with LE motor impairments after stroke and other health conditions.[5,50] Research with an earlier version of this protocol has demonstrated positive results that are similar to UE-CIMT findings. Further research is needed to explore any additional benefit that may result from including the full TP in the protocol.

A classification system for categorizing severity of impairment has been developed for use with the UE-CIMT protocol based on active shoulder, elbow, wrist and fingers range of motion.[21,51] Use of this classification system has been helpful for exploring the effects of CIMT with participants with varying levels of movement capability at the beginning of intervention. No such classification system has been developed for use with the LE-CIMT protocol. Developing such a system would enhance research with LE-CIMT and assist in identifying those categories of participants who may benefit more greatly than others from the intervention. Reliable and validated movement assessment systems like the Fugl-Meyer Motor Assessment and the Chedoke-McMaster Stroke Assessment may be useful in setting up such a classification system.

Studies have reported brain changes after the application of the UE-CIMT protocol. Investigation of potential neuroplastic changes as a result of the LE intervention is needed.

The TP used in the UE protocol was investigated and recognized as being responsible for amplification of the effect of motor training based on shaping procedures.[21,50] Studies should be conducted to determine the influence of the TP administered during LE-CIMT on transfer of the motor skills improved during supervised treatment to real world situations.

Although previous studies have reported a superior effect of LE-CIMT when compared to a fitness exercise control group, further comparison of the LE-CIMT to other interventions is needed.

## CONCLUSION

Since people with stroke and other disabilities are very inactive outside of supervised therapy,[52] the development of such strategies as the TP that might increase their level of activity in real life is essential. The results observed after UE-CIMT led to the development of a version of the protocol that applied to the lower extremity. The LE-CIMT protocol currently contains a set of strategies that aims to increase and improve the use of the more affected LE in real world situations. The combination and systematic application of intensive motor training, shaping, and a group of TP behavioral strategies induced large and significant changes in the LE use of people with stroke and multiple sclerosis.

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# MEASURING THE MORE AFFECTED LOWER-EXTREMITY USE IN REAL WORLD SITUATIONS: THE LOWER EXTREMITY MOTOR ACTIVITY LOG (LE-MAL)

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## PREVIOUS DATA OF THE LE-MAL ADMINISTRATION WITH PEOPLE WITH STROKE

The CI Therapy Research Group at UAB had developed a measurement of real-world use of the more affected LE, the LE-MAL. This assessment is a version of the Motor Activity Log (MAL) for the upper extremity and contains 14 daily activities performed using the LE. Previous reliability analysis had reported that LE-MAL is a reliable measure (r=0.93) with people with chronic stroke. Also, the LE-MAL showed high correlation with other two measurement largely used with this population, the Stroke Impact Scale (SIS) (r=0.87), and the Late Life Function and Disability Instrument (Late-Life FDI) (r=0.93).[7]

The importance of this measure relies on the fact that it is a self-reported instrument that assesses how the individual uses the more affected LE outside the laboratory or clinical setting, in daily life situations.[7] Because the reliability of this tool was previously investigated showing significant results with people with stroke, there was a need to validate and examine the reliability of the LE-MAL in other populations, such as people with Multiple Sclerosis (MS). For this, the following study was conducted across 40 adults with different types of stable MS.

# RELIABILITY AND VALIDITY OF THE LOWER-EXTREMITY MOTOR ACTIVITY LOG (LE-MAL) FOR MEASURING REAL-WORLD LEG-USE IN ADULTS WITH MULTIPLE SCLEROSIS


## ABSTRACT

*Background:* Standard mobility assessments for neurological disabilities primarily evaluate walking but few assess other meaningful lower extremity (LE) activities (e.g., climbing stairs). In contrast, the Lower Extremity Motor Activity Log (LE-MAL) has been used for 20 years to evaluate broad varieties of LE use in diverse neurological disorders, but its psychometric properties have not been established.

*Objective:* To determine the test-retest reliability and concurrent validity of the LE-MAL for assessing LE use in the community in adults with MS.

*Methods:* Forty adults with relatively stable MS were evaluated by telephone on several measures of LE use. The LE-MAL, which has three subscales (Assistance, Functional Performance, and Confidence), was administered twice, at least two weeks apart. The Multiple Sclerosis Walking Scale (MSWS-12), Patient Determined Disease Steps (PDDS), and Mobility Scale were only administered during the first call.

*Results:* The test-retest reliability of the composite and the three subscale LE-MAL scores was high (ICC > 0.94). The composite and subscale LE-MAL scores were strongly correlated with the MSWS-12, PDDS, and Mobility Scale scores ($r$'s -0.55 to -0.77, $p$'s > 0.0001).

*Conclusions:* This initial study suggests that the LE-MAL reliably and validly measures LE use in the community in adults with MS.



Keywords: Multiple Sclerosis, Outcome measurement, Rehabilitation

# INTRODUCTION

Persons with multiple sclerosis (MS) face diverse impairments, including weakness, spasticity, and sensory loss, which can limit their mobility.[1,2]Mobility impairment in turn strongly limits quality of life. Several common assessments evaluate mobility in persons with MS, but they have notable limitations.[1,3,4] Most of these assessments measure lower extremity (LE) motor *capacity* within the clinical setting under controlled conditions (e.g., the Timed 25-Foot Walk test, the 6-Minute Walk, the Expanded Disease Status Scale), but do not measure spontaneous LE *use* in real life conditions, which for many investigators and stakeholders can be considered a primary objective of rehabilitation. Although the Multiple Sclerosis Walking Scale-12 (MSWS-12) has been validated to assess the impact of disease on community LE use in MS, its focus is primarily on locomotion.[3–5] The scale gives little attention to other forms of LE use (e.g., standing, mobility in bed, rising from a toilet) which nonetheless are meaningful to people with MS. Consequently, a validated way to assess the diverse use of the LEs in the community, beyond locomotion, would be valuable for assessing real-life outcomes in physical therapy for people with MS.

The Lower Extremity Motor Activity Log (LE-MAL) is a Patient-Reported Outcome that was initially developed by this laboratory to assess diverse real-world LE use in patients following stroke, spinal cord injury, or hip surgery who are undergoing a form of physical therapy.[6,7] The LE-MAL evaluates 14 functional tasks using three scales: 1) level of assistance (personal, environmental support, and assistive and/or orthotic device), 2) functional performance, and 3) level of confidence. The activities on the LE-MAL extend beyond locomotion, including LE tasks that demand balance, transitions, and performance without upper extremity support.[8,9]

The principal aims of this study are to assess the test-retest reliability and concurrent validity of the LE-MAL. A secondary aim is to estimate the Minimum Clinically Important Difference (MCID) of the LE-MAL.

## METHODS

### Participants

Participants were 40 adults with MS with mobility limitations. Candidates were either referred from MS clinics or individuals who responded to mass mailings to people with MS who were registered with the Regional Chapter of the National Multiple Sclerosis Society. Screening of candidates was conducted by telephone from July 2013 to November 2016.

Participants older than 18 years with any type of MS were included in this study. They were excluded if they reported (1) a relapse within 3 months prior to screening; (2) changes in their medications for MS within 3 months prior to screening; (3) persisting pain >3/10 on the visual analogue scale (VAS) during LE use;[73] (4) inability to walk at least 8 meters (25 feet) without another person`s help; or (5) concurrently undergoing physical therapy for their LEs.

### Measures

*Lower Extremity-Motor Activity Log (LE-MAL):*The LE-MAL is a structured interview that was developed to assess the quality of spontaneous leg use on 14 routine LE activities in the community by people with common neurologic diseases, such as MS, stroke, or traumatic brain injury. It comprises three subscales: the Assistance Scale (AS), Functional Performance scale (FP), and Confidence Scale (CS). The AS mean score

combines the scores of three subscales: Passive Device (A), Self-Initiated Device (B), and Person Assistance (C). Subscale A (Passive-Device) can be rated using either the Orthotic Subsidiary Subscale (A1) or the Equipment Modification Subsidiary Subscale (A2). The Self-Initiated Device-Scale (B) has three subsidiary subscales: Assistive Device (B1), Upper Extremity (B2), and Environmental Support (B3). Assistance ratings are carried out, according to prespecified combinations of the Assistance subsidiary scales that differ according to the activity as summarized in Table 1.

The AS score for an item is the following combination of the scores for subscales A, B, and C: $Assistance\ Scale = \frac{\frac{A+B}{2}+C}{2}$.

Both Functional Performance (FP) and Confidence (CS) scales are scored for each activity using a Likert scale ranging from 0 to 10, in which 0 signifies either inability to do the activity / no confidence at all, and 10 signifies normal ability / complete confidence. The subject is asked to choose the score that best describes how well or how confidently she performs each activity compared to how she performed that activity before disease onset. For the FP and CS scales, the score is the number provided by the participant after probing by the examiner. For example, if the participant rates his/her ability to walk indoors as a "5", the examiner asks, "So you believe that you walk indoors half as well as before the onset of your disability, is that correct?"

The composite score for an item is the average of the scores for the three scales: AS, FP, and CS. The test score on the LE-MAL, whether for the composite or one of the three subscales, is the average of the item scores.

Table 1. LE-MAL activities and their corresponding Assistance subscales

| LE-MAL Activities | LE-MAL Assistance Subscales |
|---|---|
| 1. Walking indoors | Personal assistance Scale<br>Orthotic Scale<br>Assistive Device Scale |
| 2. Walking outdoors | Personal assistance Scale<br>Orthotic Scale<br>Assistive Device Scale |
| 3. Climbing stairs | Personal assistance Scale<br>Orthotic Scale<br>Environmental Support scale |
| 4. Stepping over an object | Personal assistance Scale<br>Orthotic Scale<br>Assistive Device Scale |
| 5. Turning around when standing | Personal assistance Scale<br>Orthotic Scale<br>Assistive Device Scale |
| 6. Come to stand from a chair | Personal assistance Scale<br>Equipment Modification Scale: chair<br>Upper Extremity Scale |
| 7. Come to stand from a toilet | Personal assistance Scale<br>Equipment Modification Scale: toilet<br>Upper Extremity Scale |
| 8. Getting in and out of the bed | Personal assistance Scale<br>Equipment Modification Scale: bed<br>Upper Extremity Scale |
| 9. Getting in and out of bath or shower | Personal assistance Scale<br>Equipment Modification Scale: shower<br>Upper Extremity Scale |
| 10. Getting in and out of car | Personal assistance Scale<br>Equipment Modification Scale: car<br>Upper Extremity Scale |
| 11. Open a door with a door knob in standing and walking through the doorway | Personal assistance Scale<br>Orthotic Scale<br>Environmental Support scale |
| 12. Wash hands/grooming at the sink in standing | Personal assistance Scale<br>Orthotic Scale<br>Environmental Support scale |
| 13. Reaching into cabinets/closets (above shoulder level) | Personal assistance Scale<br>Orthotic Scale<br>Environmental Support scale |

Table 1. LE-MAL activities and their corresponding Assistance subscales (cont.)

| | |
|---|---|
| 14. Retrieving object from floor | Personal assistance Scale<br>Orthotic Scale<br>Environmental Support scale |

Note: For Items 11-14, respondents were asked to consider only the contribution of their LE function to the completion of the task and to ignore the contribution of their UE function.

*Concurrent Measures.*

The MSWS-12 is a reliable, valid, and widely used patient-reported outcome that assesses the impact of MS on the difficulty of accomplishing 12 common real-world LE activities, which primarily concern locomotion.[3,5,11,12]

The PDDS[13,14] and the Mobility subscale of the MS Performance Scales[15] are also patient-reported outcomes. The PDDS is a valid and reliable tool to assess the general disability and mobility status of people with MS.[5,11,14] It has nine options for the description of quality of general activity or walking; 0 is normal performance and 8 is total gait disability or bedridden. The Mobility Scale rates mobility according to a scale with seven levels: normal, minimal gait disability, mild gait disability, occasional use of cane or unilateral support, frequent use of cane, severe gait disability with bilateral support, and total gait disability or bedridden.[15]

Procedures

Participants were interviewed by telephone twice by a trained interviewer; the minimum interval between calls was 2 weeks. During the first call, participants answered the PDDS, Mobility Scale, MSWS-12, and LE-MAL. The initial assessment required an average of forty minutes. Only the LE-MAL was administered during the second phone call. Training for the interviewer on the LE-MAL and the other tests involved following a script of the manual procedures and administration of the test with volunteers. This study

was approved by the Institutional Review Board for Human Use and was conducted in accordance with the Helsinki Declaration.

Data Analysis

The reliability of the LE-MAL was determined by evaluating the internal consistency, test-retest reliability, and stability of the composite scale and each of the three subscales. Internal consistency was indexed by Cronbach's $\alpha$ using the item scores from the first administration of the LE-MAL. Test-retest reliability was indexed by the Intraclass Correlation Type 3,1[16] between the test scores from first and second administration of the LE-MAL. The stability of the LE-MAL scales was determined by using a paired *t*-test to evaluate if changes took place in mean scores from the first and second administration of the LE-MAL. For this purpose, a *nonsignificant* result supported the stability of a scale.

Concurrent validity was determined by comparing the test scores for the composite scale and each of the three subscale on the LE-MAL with the test scores for the MSWS-12, PDDS, and Mobility Scale. Pearson correlations were used for this purpose. The statistical software package used was SPSS version 24.

The MCID is the minimum improvement that a patient perceives as beneficial.[17] The MCID for the MSWS-12 was found to be a change of 8 points or greater.[18] We used the MCID on the MSWS-12 to estimate the MCID of both the Total and FP scores of the LE-MAL. To do so, we constructed a regression model to permit prediction of LE-MAL Total scores from MSWS-12 scores. Then, we used the model to estimate LE-MAL composite values corresponding to values on the MSWS-12 that were an MCID apart. The difference between the LE-MAL composite values provided an estimate of the MCID on that scale. A parallel approach was used for the LE-MAL FP scale.

# RESULTS

## Participant Characteristics

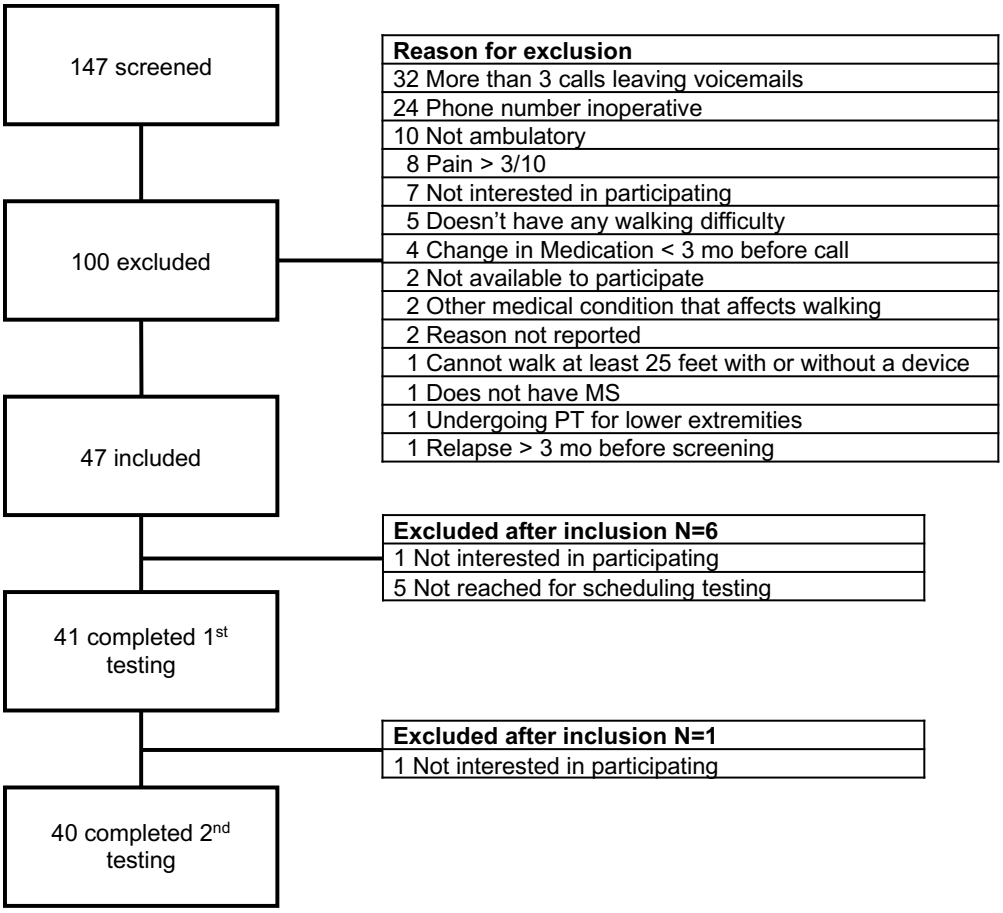
We attempted to contact 146 individuals by telephone. Fifty-six could not be reached or had inoperative phone numbers. Forty-seven of the remaining 90 people were determined eligible for inclusion. The most common reasons for exclusion were: (1) individuals who were either non-ambulatory or not able to walk the minimum distance required (N=10); (2) pain intensity (N=8); and (3) lack of interest in participating or unavailability for evaluations (N=7).Of the 47 eligible individuals, one could not be reached for scheduling, 5 dropped out before the first testing, and one dropped out before the second testing, leaving 40 as the final number of participants (See Figure 1 for study profile).

Data on patient characteristics are presented in Table 2. Most of the participants were women (75%), and 82.5% were European-American. The participants ranged in age from 28 to 72 years (mean age 56.1 years). The most frequent type of MS was relapsing-remitting (62.5%), followed by secondary-progressive (27.5%).

## Reliability

As shown in Table 3, all of the LE-MAL scales had high internal consistency (Cronbach`s $\alpha \geq .96$) and high test-retest reliability (ICCs > 0.94). Test scores for all of the scales were also stable ($p$'s > 0.24; Table 3). Table 4 shows that the Function Performance and Confidence scales were very strongly correlated with one another ($r$ = .89), and that the correlation of the Assistance scale with these two scores was only modestly less strong ($r$, range= .76-.81).

Figure 1. Recruitment flowchart




Validity

The LE-MAL composite score, as well as all the three subscores, was strongly correlated with the MSWS-12 (Table 5). Higher scores on the LE-MAL, corresponded to better quality, independence, and confidence on the activities evaluated. There is an opposite relationship for the MSWS-12, the PDDS and the Mobility Scale. Thus, these assessments were negatively correlated with the LE-MAL in our sample. The correlations ranged from -0.63 to -0.77 for the MSWS-12, -0.58 to -0.73 for the PDDS, and -0.56 to -0.75 for the Mobility Scale (Table 5).

Table 2. Participant characteristics

| Characteristics | | |
|---|---|---|
| Age (mean yrs-range) | | 56.1 (28-72) |
| | | **N (%)** |
| Sex | Female | 30 (75) |
| | Male | 10 (25) |
| Ethnicity | African-American | 6 (15) |
| | European-American | 33 (82.5) |
| | Native-American | 1 (2.5) |
| MS Type | Relapsing-remitting | 25 (62.5) |
| | Primary-progressive | 3 (7.5) |
| | Secondary-progressive | 11 (27.5) |
| | Unknown | 1 (2.5) |
| | | **Mean (SD)** |
| Mobility Impairment | PDDS | 4 (1.3) |
| | Mobility Scale | 3.2 (1.3) |
| | MSWS-12 (average) | 67.6 (23.0) |

Abbreviations: PDDS= Patient Determined Disease Steps; MSWS-12=Multiple Sclerosis Walking Scale-12

Table 3. Reliability and stability of the LE-MAL

| LE-MAL scores | Test-retest reliability | Internal consistency | Test 1 to 2 Stability |
|---|---|---|---|
| | Intraclass correlation | Cronbach`s α | *p* |
| Composite | 0.95 | 0.96 | 0.42 |
| Assistance Scale | 0.97 | 0.97 | 0.88 |
| Functional Scale | 0.96 | 0.96 | 0.24 |
| Confidence Scale | 0.94 | 0.96 | 0.42 |

Table 4. Pearson correlations between the LE-MAL scales

| LE-MAL Scores | Composite | Assistance Scale | Functional Performance | Confidence Scale |
|---|---|---|---|---|
| Composite | . | 0.89 | 0.96 | 0.95 |
| Assistance Scale | | . | 0.81 | 0.76 |
| Functional Performance | | | . | 0.89 |
| Confidence Scale | | | | . |

Table 5. Concurrent validity of the LE-MAL with 3 tests

| LEMAL | MSWS-12 | *p* | PDDS | *p* | Mobility Scale | *p* |
|---|---|---|---|---|---|---|
| Composite | -0.75 | <0.0001 | -0.72 | <0.0001 | 0.71 | <0.0001 |
| Assistance Scale | -0.73 | <0.0001 | -0.73 | <0.0001 | 0.75 | <0.0001 |
| Functional Scale | -0.77 | <0.0001 | -0.73 | <0.0001 | 0.70 | <0.0001 |
| Confidence Scale | -0.63 | <0.0001 | -0.58 | <0.0001 | 0.56 | <0.0001 |

Abbreviations: MSWS-12=Multiple Sclerosis Walking Scale-12; PDDS= Patient Determined Disease Steps.

Thresholds for Meaningful Changes

As determined by the method described in the Data Analysis, the MCID for the LE-MAL composite score was 0.4 (95% CI= 0.03 – 0.77). The MCID for the FP score was 0.6 (95% CI= 0.21 – 1.01).

## DISCUSSION

The participants included in this study reflect the demographics of the disease, which is most prevalent in women and European-Americans.[19] The most common type of MS in this sample was the relapsing-remitting type, which is in accord with the commonly-reported relative frequencies of the recognized subtypes for this disease.[20] That the

participants of this study presented characteristics similar to the general population with MS supports the generalizability of our findings. The PDDS and Mobility Scale scores indicate that all participants reported mobility difficulty in that they needed unilateral support or an assistive device (e.g., a cane) to walk.[14,15]

The concurrent validity of the LE-MAL was addressed by comparing it to the MSWS-12, the PDDS, and the Mobility Scale, which are valid evaluations of the impact of the disease on the mobility of persons with MS.[3,5] The correlation of the scores on the LE-MAL with scores on each of these tests was high, suggesting that the construct measured by the LE-MAL is similar to that measured by the other tests, i.e., quality of ambulation in the community. The high values of Cronbach's $\alpha$ suggest that all the items on the LE-MAL measure a single, underlying construct.

In contrast to the relatively narrow range of information that is sampled by these scales, the LE-MAL yields substantially more information regarding the quality of spontaneous LE use in the community. Only the LE-MAL provides information on the level of mobility, performance, assistance and confidence of disabled adults in the community. In addition, only the LE-MAL assesses lower extremity function in the context of multiple types of activities, e.g., coming to stand from a toilet and getting out of bed in addition to ambulation. These features of the LE-MAL provide a rich, descriptive analysis of how the individual uses his/her LEs in the community that, in the context of clinical care, can serve a basis for designing a comprehensive treatment plan for a patient. These features also permit the LE-MAL to provide a detailed picture of the effect of LE interventions on LE function in the community.

The very strong correlations between LE-MAL scores from the first and second administration suggest that the relative rank of LE-MAL scores is highly consistent. In

other words, an individual who scores higher than another on initial administration of the LE-MAL is very likely to score higher than the same individual on a second administration, holding all other factors constant. The negative findings on the paired *t*-tests suggest that absolute value of individuals' scores is also stable when there are no changes in the underlying construct.

The high correlations among the LE-MAL scales suggests that is possible to use the composite score as the main outcome to identify changes before and after research intervention protocols. For use in clinical settings, we suggest that the confidence scale can be withdrawn from the assessment to decrease the evaluation application time, if necessary.

Study Limitations

Administration of the LE-MAL by phone call may yield a somewhat different set of responses than when the test is given in face-to-face interviews. Future studies should compare both methods in order to determine if there are potential differences in LE-MAL scores when the tests are administered in these two different fashions. However, for the Upper Extremity version of the MAL, from which the present LE version was derived, this has not been found to be the case in the experience of our laboratory. Moreover, the present sample size is small. Therefore, these results must be considered preliminary.

In some circumstances, correction of α values is called for when testing multiple, related constructs to prevent inflation of family-wise Type I error. For example, if multiple measures of functional independence are used in a rehabilitation trial without correction of *α,* a positive finding on a single outcome measure might prompt rejecting the null hypothesis. Rejecting the null hypothesis, in this case, would be inappropriate

because a plausible explanation of the single positive finding is the operation of chance. In the case of the current study, correction of $\alpha$ for multiple testing is uncalled for because similar positive findings were found for all of the related constructs, i.e., the different scales of the LE-MAL. It is implausible that chance would result in similar findings for all four scales. Rather, the convergent findings on the different but related scales increases confidence in the results.

## CONCLUSION

The LE-MAL appears to be a reliable and valid assessment of mobility quality in the community of people with MS. The Minimum Clinically Important Difference for the composite score on the test was 0.48 units and 0.56 for the FP scale. The LE-MAL would appear to be a useful tool for the assessment of mobility in the community of people with MS that should be applicable in both research and clinical settings. Direct measurement of LE use in the community is important because evidence indicates that laboratory assessments, which are commonly used in research on MS, do not reflect how adults with MS walk, move or use their LE in real-world situations.[21]

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# CONSTRAINT-INDUCED MOVEMENT THERAPY FOR IMPROVING MOTOR FUNCTION OF THE PARETIC LOWER-EXTREMITY AFTER STROKE: A CASE REPORT

by

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ABSTRACT

A 56-year-old woman with chronic stroke was selected for this study due to lower-extremity paresis that impacts her walking. A Lower-Extremity Constraint-Induced Movement Therapy (LE-CIMT) protocol was given consisting of 3.5 hours/day of supervised intervention activities on 10 consecutive weekdays. Motor training was intensive and involved shaping. In addition, a group of behavioral strategies was employed to induce adherence and transference of motor skills from the laboratory to real world situations. Changes in functional mobility, walking speed, balance, level of assistance, quality of movement and level of confidence while performing daily activities were assessed five times in both baseline and intervention phases. The data was visually analyzed using two methods, 2-standard deviation band and celeration line. Significant changes in quality of movement, level of confidence and walking at self-selected and fast speeds were observed.

Key words: Stroke, rehabilitation, paresis, gait

# INTRODUCTION

Lower-extremity paresis due to stroke can cause restriction in participation in social activities,[1] and activities of daily living (ADLs), and in increased fall risk.[2] While many rehabilitation techniques have been developed in the past decades for improving LE paresis after stroke, further enhancement of methods to improve walking and mobility would be advantageous. Best results to date have been observed with combined interventions, such as those that include functional electrical stimulation and robotic training.[3,4] Similarly, high intensity training has been shown to be an important tool for motor improvement.[5]

Constraint-induced Movement Therapy (CIMT) was originally developed to improve use of the more-affected UE after stroke.[6,7] It has now been expanded to a family of techniques that systematically applies four components: 1) intensive treatment daily over consecutive days, 2) supervised motor training using a technique called shaping, 3) behavioral strategies to improve the use of the more- affected limb in real-life situations called the Transfer Package (TP), and strategies to remind participants to use the more-affected extremity including restraint of the less-affected arm in the upper extremity (UE) protocol.[7-9] As noted, the initial focus of CIMT work was the upper extremity (UE) To adapt the UE protocol to the lower extremity (LE), some changes were needed. The LE-CIMT protocol retains three of the four UE components: 1) intensive motor training for 3 hours/day for 10 consecutive workdays; 2) use of shaping as a motor training strategy; and 3) the application of a group of behavioral strategies called the "transfer package" (TP).[10-13] However, restraint of the less affected extremity has been eliminated from the protocol. Instead, the participant is frequently encouraged to focus attention on improving coordination and motor patterning of the more affected LE. A small number of studies

have shown promise for modified CIMT protocols directed at lower extremity (LE) rehabilitation. These studies did not use a formal transfer package as part of the intervention protocol. Upper-extremity CIMT research suggests that the transfer package may be the most important protocol component for achieving optimal outcome,[7] especially in everyday life situations outside the treatment setting. Some of the previous LE-CIMT studies employed restraint of the less-affected LE during the intervention period on analogy with the UE-CIMT protocol.[14-18]

The purpose of this case study is to describe the changes observed in a participant with chronic stroke before, during and after the application of a LE-CIMT protocol that included the transfer package and did not use restraint of the less-affected LE.

## CASE PRESENTATION

A.Z., a 56-year-old, African-American woman with chronic stroke (2.5 years prior to intervention) was selected for this study. After the stroke, she presented paresis on her right lower- and upper limbs which led to limitation in her walking and mobility. She was able to walk at least 25 feet without personal assistance, using a straight cane and an ankle-foot orthosis (AFO).

Her participation in this study lasted 4 weeks; 2 weeks each in baseline and intervention periods. In each period motor function, balance, walking speed, endurance, and use of the paretic lower-limb were assessed five times.

A complete CIMT protocol was based, as noted, on three of the four principles proposed by the Constraint-Induced Therapy Research Group (CITRG) for the UEs: 1) intensive and repetitive training, 2) motor training following shaping principles, and 3) a group of behavioral strategies called the transfer package (TP).[7,9,13]

The treatment was delivered during ten consecutive work days for 3.5 hours daily. Shaping tasks were chosen according to the movements targeted (e.g. ankle dorsiflexion, knee flexion). The level of complexity of the tasks was progressed periodically and frequent feedback was provided during task execution. Each task was performed for 10 trials, each lasting 30-45 seconds.

The TP is a group of procedures designed to enhance adherence to the protocol and appropriate use and coordination of the paretic lower limb in real life situations.[6-9] The behavioral contract is an agreement signed on the first day of treatment stating a commitment by the participant to the intervention and to carrying out a list of routine activities that can be safely performed at home away from the treatment setting, and emphasizing the use of the paretic lower-extremity. The participant was also given a daily written list of activities and exercises to be performed at home daily after treatment and during weekends, both during and after the intervention. In addition, the Lower-extremity Motor Activity Log (LE-MAL) was given daily during the 10 intervention days. It was also administered weekly during the first month after the intervention. The LE-MAL elicits information about how well and how often 14 different LE activities are engaged in (e.g., walking over different types of terrain, climbing stairs, getting in and out of a car). Problem solving is engaged in when performance in everyday life situations lags behind what is observed to be possible in the treatment setting.

Outcomes used in this case-study included the LE-MAL,[19] Berg Balance Scale (BBS),[20] Six-Minutes Walking Test (6MWT),[21] and Ten-Meters Walking Test (10MWT).[22] The LE-MAL is a reliable and valid tool that measures how much and how well a person is using the LEs while performing 14 daily activities.[19] The activities examined include going up and down stairs, getting in and out of the shower, and

walking outdoors. In terms of three scales: how much assistance is required (Assistance Scale), how well the individual performs the activity (Functional Performance Scale) and how much confidence (Confidence Scale) the individual has while performing the task. The total score is a combination of the scores of all three scales. For both calculations (each scale separately and the total score), higher scores represent, better performance on a scale increases from 0 to 10.

The data analysis followed the recommendations previously published for data analysis in single-subject design studies by Nourbakhsh & Ottenbacher (1994).[23] The data were analyzed by two different methods: two-standard deviation band and split middle method of trend estimation (also known as celeration line). In the first method the standard deviation of the baseline is calculated, and bands are drawn across both baseline and intervention phases. Significant results are considered to have occurred if two or more successive points are above or below the bands. The celeration line shows the trend of the baseline phase, indicating if the data points are increasing, decreasing or steady. The result is considered significant if the majority of the data points of the intervention phase are above the celeration line.[23]

This study was approved by the Institutional Review Board for Human Use of this university and the participant signed an informed consent.

## RESULTS

During the 10 days period examined, the participant engaged in 35 hours of supervised intervention. Also, A.Z. performed approximately 87% of the tasks listed on her home skill assignment during the intervention.

As seen on Figure 1, A.Z. significantly improved on the total score of the LE-MAL. Thus, the quality of the movement of her paretic lower-limb and her perceived confidence with LE activities significantly increased as a result of the intervention. The participant`s walking speed also increased significantly on both the self-selected and fast speed measures. Although there were changes in endurance and balance (Table 1), they were not significant for this single subject. No adverse event was observed.

Table 1. Changes* on visual analysis in balance, endurance and assistance level.

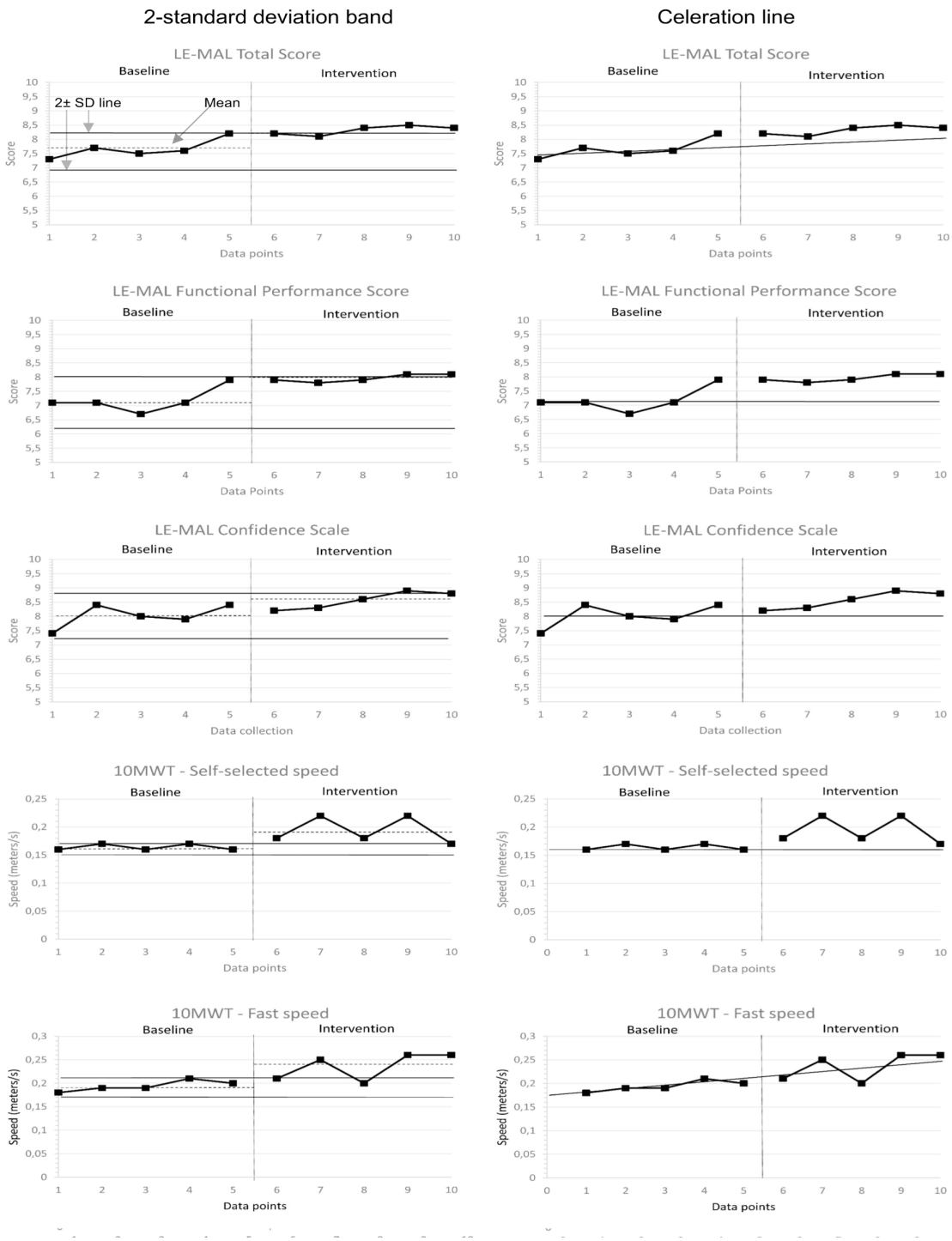
| Assessment | Pre-treatment Mean(range) | Post-treatment Mean (range) |
|---|---|---|
| 6MWT (distance ambulated in meters) | 87.4 (84.3-89.6) | 88.3 (78-94.5) |
| BBS | 43 (38-48) | 48 (41-53) |
| LE-MAL – Assistance Scale | 7.7 (7.3-8.2) | 8.3 (8.1-8.6) |

6MWT – Six-Minutes Walking Test, BBS – Berg Balance Scale, LE-MAL = Lower-Extremity Motor Activity Log.
*Note: all changes were not significant

## DISCUSSION

This case study explores a protocol used in a larger study examining the effectiveness of LE-CIMT. The protocol used in this study differs from interventions previously reported because of inclusion of a use of the transfer package. The effect of LE-CIMT has been investigated before, but no previous studies used a TP. Most of the studies applied only a restraint device on the non-paretic LE; some used the intensive training component only or a combination of some of the LE-CIMT elements.[14-18]

Figure 1. Significant changes on LE function after LE-CIMT protocol




SD: standard deviation.
NOTE: Arrows point to SD bands and mean lines.

For the UE, the application of the transfer package has been found to enhance the effect of CIMT compared to protocols that used only intensive motor training combined with a restraint device and no Transfer Package.[7,9] However, it was still unknown if adding the TP to LE-CIMT produces better outcomes than protocols that do not use it. Although no previous study had applied a complete TP, there are studies that used a combination of a list of activities to be performed at home, a restraint device, and motor training.[14,15] These studies reported improvement on mobility, balance, and walking.

Another difference between this case study and many previous studies is the absence of use of a restraint device; this is not a component of the LE-CIMT protocol employed here. A comparison of protocols with and without a restraint on the LE showed no difference between groups.[14] This finding reinforces the idea previously discussed in UE-CIMT protocols that the restraint device is not the most important component of the intervention.[24-26] Also, the main original rationale for the exclusion of the restraint device of LE-CIMT was the fact that it seeks to improve the abnormal movement pattern resulting from stroke by substituting another abnormal movement pattern produced by the restraint device.[10] Safety was also another important consideration. This case study provides both an example of how the use of CIMT, originally developed for the UE, can be appropriately modified when applied to the LE and another example of how CIMT principles can be applied without a restraining device.

A.Z. significantly improved the total score of the LE-MAL, which means that she changed how much she moves and uses her paretic LE in daily living. The quality of movement and how confident she is in keeping her balance while performing daily activities also improved significantly. Similar results regarding the total score of this assessment were reported by Taub and colleagues.[6,10-12] The scores of the total score of

the LE-MAL as well as Functional Performance and Confidence scales rose on the last assessment of the baseline phase. A similar phenomenon has been observed in other CI Therapy studies. Specifically, this has occurred between the pre-treatment screening administration and the pre-treatment testing of the UE CI therapy research projects. In this instance, it was believed that this was associated with high expectation for motor and behavioral changes after the protocol intervention.[7] In another example, studies had shown a rise in the MAL score when administered with control groups not receiving CI therapy (seen in both UE and LE studies). A possible explanation of this increase may be that administering the MAL induces a self- monitoring process whereby participants are more likely to remember to try and use the more-involved UE or LE. This is particularly true when they anticipate being asked the questions in subsequent testing. Of note, this change is typically not significant, is dramatically less than in comparison to the treatment effect in the treatment group, and is not sustained during follow-up.[7,27]

Studies that applied part of the protocol have reported improvement in balance, which was not observed on this study.[14,16,17,28,29] We suggest that this difference occurred due to the specificity of the tasks during the intensive training. During the LE-CIMT most of the activities performed by A.Z. emphasized knee control, dorsiflexion, weight bearing and coordination, but not balance. Few studies have reported significant improvement on endurance,[16,17] which was also not observed on this study. However, since the present study involved only one subject, a study with more subjects may yield different results. Future randomized controlled trials with substantial samples are needed.

# CONCLUSION

In this single-subject design study, the complete LE-CIMT protocol was applied with a chronic stroke participant. After 10 consecutive weekdays of intervention, there was no significant changes in endurance, balance, and level of assistance during the performance of daily activities. The participant significantly improved the quality of movement of her paretic lower limb and her level of confidence while performing daily activities. Also, her walking speed in both self-selected and fast speeds improved.

An incomplete version of the LE-CIMT protocol has been applied with people with stroke in previous studies in that they failed to use a formal transfer package and often did not use a shaping procedure during practice of LE use. . Some of the previous work is also different from the LE-CIMT protocol used in this case study in that they included restraint of the less-affected LE as part of the intervention. This approach is inconsistent with the opinion of the CITRG; the team first proposing the LE-CIMT protocol.

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# LOWER EXTREMITY CONSTRAINT-INDUCED MOVEMENT THERAPY (LE-CIMT) TO IMPROVE GAIT AND MOBILITY OF PEOPLE WITH CHRONIC STROKE: A MIXED METHODS STUDY

by

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ABSTRACT

Purpose: Constraint-induced Movement Therapy (CIMT) is known to be one of the most effective interventions to improve use and motor function of the affected upper extremity of people with stroke. However, less of known of the effects of the protocol adapted to the lower extremity (LE) treatment. The protocol is a combination of intensive supervised training, shaping as a strategy for motor training and the application of a group of behavioral strategies called the transfer package. One aim of this is study is to investigate the effect of the LE-CIMT on LE use and function with people with chronic stroke. Another aim is to investigate the relationship between the motor and behavioral changes with participants` and caregiver/family members` perceptions about the protocol and the effect of the intervention.

Methods: Assessments were administered during baseline, post-treatment and follow up phases. The LE-CIMT was delivered for 10 weekdays, 3.5 daily hours of supervised treatment. Qualitative data were collected through individual interviews with participants with stroke, caregiver or family members separately. Quantitative and qualitative data were merged using a joint display.

Results: Significant changes were observed on LE use, motor function, balance, gait speed and mobility. The results were maintained 3 months after the end of the treatment. Participants` perceptions validated the quantitative results, confirming the changes in real life situations and acceptability of the intervention protocol.

**Keywords:** Stroke, Paresis, Lower Extremity, Rehabilitation, Mixed Methods.

# INTRODUCTION

Approximately 66% of stroke survivors present with gait impairment and mobility limitation.[1] In recent decades, researchers have investigated a variety of rehabilitation techniques to remediate limitations in walking and mobility. Findings favor interventions which are delivered at high intensity using a combination of training strategies..[2,3]

One such intervention, CIMT has gleaned significant improvements to arm function following stroke and other health conditions.[4,5] CIMT combines four elements: 1) daily intensive protocol over two weeks, 2) supervised motor training using shaping, 3) behavioral strategies to promote use of the affected limb outside the laboratory (the Transfer Package - TP), and 4) different strategies to remind the individual to use the more-affected limb, which includes using a restraint device in the less-affected upper extremity.[6–8]

The significant results observed in the UE CIMT intervention led to the adaptation of the original protocol to the lower extremity (LE). The LE-CIMT protocol includes the same components of the original intervention, but with exclusion of the restraint device for safety issues and due to the fact that the device would induce an unnatural gait pattern. Also, the activities performed by the participants during the supervised treatment and at home involve coordinated use of both legs.[7–9]

Although the UE-CIMT protocol has been largely investigated, a smaller number of studies have shown promise for modified versions of the LE-CIMT. Also, the few studies that have applied a LE-CIMT protocol in people with stroke did not use the full TP component as proposed in this study. Thus, information about the effects of the complete CIMT protocol (i.e., including the TP) is greatly needed. The addition of a more complete TP in the LE protocol might have a great impact on both motor outcomes and retention of

the results, as observed in previous studies using the UE approach.[7] Considering the high intensity of the complete protocol, the added safety concerns, and the demand of involvement of the therapist, participant, and caregivers, the acceptability of the TP should also be explored in order to provide a better understanding of the feasibility of this strategy.

The purpose of this mixed methods study is to investigate the relationship between the effect of the LE-CIMT protocol on gait and mobility and examine participants` and caregivers` expectations and perceptions regarding the treatment (e.g., intensity, physical and emotional demands, changes in routine). The goal of the quantitative strand is to assess changes in quality of movement and functional use of the paretic lower limb after the treatment and to investigate the participants` expectations about the intervention. The qualitative strand explored caregiver and participant perspectives regarding protocol acceptability. We hypothesize that: 1) the enhanced LE-CIMT protocol would be effective for improving functional use of the paretic LE in people with chronic stroke; and 2) participant`s and caregivers` perspectives about the treatment are related to changes in functional use (e.g., weight shift, alternating feet while going upstairs).

## METHODS

*Participants: sampling and selection criteria*

A total of 11 people were selected for this study; eight participants with stroke and three primary caregivers or family members that supervised those participants with stroke during the intervention protocol. Participants were included according to the following criteria: 1) 19 years of age or older; 2) at least 2 years post stroke; 3) demonstrating lower extremity motor impairment secondary to stroke, but able to walk at least 25 feet with or

without an assistive device, at least three times a day; 4) having no previous experience with either research or treatment using the LE-CIMT protocol; 5) undergoing physical therapy or other intervention to improve LE function. Participants were excluded if they presented with uncontrolled clinical conditions, other neurologic conditions, a Mini-mental State Examination (MMSE) score ≥24; an inability to provide the informed consent, and insufficient language skills to answer the interview questions. Caregivers and family members with availability to be interviewed and who were 19 years old or older, English speakers, and able to answer the interview questions were also selected to the qualitative strand.

The primary investigator first contacted participants by phone to fully explain the study and complete an interview screen. During this first telephone screening the inclusion criteria and the availability of the participants was then checked. An in-person screening examination was scheduled in order to assess the cognitive and motor functions.

This study was approved by the Institutional Review Board for Human Use of this institution and all subjects voluntarily provided their written consent.

*Intervention: the LE-CIMT protocol*

During the intervention phase, the effects of the LE-CIMT was accessed in 8 participants with stroke that received repetitive, intensive motor training (using shaping), and a transfer package consisting of strategies to encourage the participant to use the more affected lower-extremity in daily life situations. All participants received the same treatment protocol.

The LE-CIMT was delivered for 2 weeks, and consistent of: 1) 3.5 hours per day (3 hours of motor training and 0.5 hour to the administration of the TP), 2) encouragement to continue using the paretic LE as much as possible and with good quality during all

waking hours. The LE-CIMT protocol did not use any form of restraint on the nonparetic LE.[8–10]

The principal investigator administered the full LE-CIMT intervention protocol was in this study. During the supervised training a behavioral technique called shaping was used. Following shaping procedure, the activities performed under the therapist supervision were gradually progressed in order to improve the target movement.[6–8,11]

The full transfer package used in this study included a behavioral contract, a daily list of activities to be performed outside the laboratory (the Home Skill Assignment), and the administration of the LE-MAL (daily during the intervention and weekly over the phone during the first month after the intervention).[7] Also, a list of activities to performed daily after the treatment (Home Practice) was provided on the last day of treatment.

*Quantitative measures*

The assessments were administered five times during the baseline phase to assure stability. Post-treatment assessments were conducted on the last day of intervention, where both quantitative and qualitative data were collected. Only quantitative data were collected during the follow up period, 3 months after the end of the treatment in order to assess the long-term retention of the effect.

Different assessments were conducted as primary measures of LE use, function, balance, and mobility including the (1) Lower Extremity Motor Activity Log (LE-MAL); (2) Berg Balance Scale (BBS); (3) 10 meters walk test (10MWT). The secondary outcomes measures used were the: (1) 5 times sit to stand (5TSTS); (2) 6 minutes walking test (6MWT); (3) Fear of Falling Avoidance Behavioral Questionnaire

(FFABQ); (4) Lower Extremity Motor Function Test (LEMFT); and (5) Life-Space Assessment (LSA).

The LE-MAL is a semi-structured interview, that consists of questions about the participants` level of assistance, how well her/his performance is, and level of confidence while executing 14 different daily tasks.[9] Data from a reliability analysis showed that the LE-MAL is a reliable tool in both test-retest results ($r$=0.93) and internal consistency (Cronbach`s alpha = 0.96).[13]

The Berg Balance Scale (BBS) is a valid and reliable tool to assess balance control in both static and dynamic activities with people with different health conditions.[14] The 10 meters walking (10MWT) is a gait speed measurement, which is an easy and reliable assessment of locomotion.[15]

Functional strength in the LEs and energy expenditure during walking are commonly assessed by the 5-times-sit-to-stand test and 6-minutes walking test (6MWT) , respectively. Both assessments are valid and reliable in a variety of populations, including stroke,.[16],[17]

The LEMFT examines performance time, and functional performance (including level of assistance, use of orthotic and assistive device) while performing 16 functional activities, such as walking in- and outdoors, go up and downs stairs, and forward reach.[9,18]

Avoidance behavior due to fear of falling was measured using the FFABQ, which is a questionnaire that identifies how the fear of falling has affected the performance of 14 activities.[19]

The Life-Space Assessment (LSA) determines the area of action (e.g., distance and place) that a person uses to perform his/her daily activities.[20] The FFAQ and the LSA

were only administered three times: baseline, post-treatment and follow up because the change on area of action would naturally change during the daily intervention (e.g., the participants would leave home every day to go to the laboratory), and because we hypothesized that the avoidance behavior would not change during baseline phase.

. *Analysis*

Normality of the data was assessed with Shapiro-Wilk test. Not normally distributed data were transformed using a natural log. The effect was determined by comparing the mean of the scores obtained during the pre-treatment (baseline) phase, to the assessment administered after the last day of the intervention (post treatment) and the follow up assessment (3 months after the end of the intervention). We conducted a paired t-test for this purpose. Also, the effect size (*d'*) was determined by comparing pre and post-treatment scores, using the statistical software SPSS version 24.

*Qualitative data*

In this phenomenological qualitative strand, participants` experiences with the intervention protocol was the main phenomenon explored. Semi-structured, in-depth, individual interviews were conducted after the conclusion of the treatment to determine their perspectives, weaknesses, strengths, and feasibility of the LE-CIMT. The interview questions addressed time demands of the treatment (in- and outside the clinical setting), physical demands, routine modifications, and perceptions of the results. The interviews were conducted by researchers who were knowledgeable and skilled in qualitative interviewing and were uninvolved in the delivery of the treatment to avoid influence on participants` and caregivers` responses. The interviews were audio recorded and

transcribed verbatim. The interviewer followed a script in order to provide an overview of the interview to the participants.

The interview questions were based on a previous study that assessed participants` perceptions of an intensive training protocol for individuals with stroke.[21] The interviews began with "ice-breaker" questions and then, addressed the questions listed below. Participants with stroke answered 9 questions regarding their impressions about the treatment protocol. The caregivers` and family members interview contained 7 questions (Table 1).

*Analysis*

The data was analyzed through thematic analysis procedures, categorizing the main themes identified in the interview. As described by Braun and Clarke (2006, p.10), a "theme" was considered as "*something important about the data in relation to the research question, and represents some level of patterned response or meaning within the data set*".[22] Two researchers coded the transcripts independently. The themes were compared and revised by both coders. The themes were refined if needed, and the final list of themes were reported in a joint display.

Researchers used three validation or trustworthiness strategies described by Creswell (2014) to enhance the quality of the findings.[23] First, the investigator contacted participants by phone to confirm in case of discrepancy or need of clarification (member checking). Also, two different researchers coded the interviews independently and then compare results. The researchers richly described all procedures and setting in order to enhance transference to other potential contexts. Also, this process is essential for other researchers who are interested in replicating this study.[24]

Table 1. Questions addressed during interviews

| Participant with stroke | Primary caregivers |
|---|---|
| 1. What are your overall impressions of the therapy? | 1. What are your overall impressions of the therapy? |
| 2. Is there anything you would change about this therapy? | 2. Is there anything you would change about this therapy? |
| 3. What did you like about this therapy? | 3. What did you like about this therapy? |
| 4. What did you dislike about this therapy? | 4. What did you dislike about this therapy? |
| 5. What are some of the similarities, and differences between this therapy and therapy you have had in the past? | 5. What are some of the similarities, and differences between this therapy and therapy you have had in the past? |
| 6. Talk to me how physically demanding this therapy is (e.g. fatigue, muscle soreness) | 6. Talk to me how demanding this therapy is for you (e.g. routine changes, intensity of supervision). |
| 7. Would you do it again? | 7. Would you do it again? |
| 8. Talk to me about your experience with the behavioral contract. | |
| 9. Talk to me about your experience with the Home Skill assignment. | |

*Mixed Methods Research (MMR) Approach*

Our aims were to investigate the relationship between the effect of the LE-CIMT protocol on gait and mobility and participants` and caregivers` expectations and perceptions regarding the treatment. In this multiphase, mixed methods study the main rationale for using a MMR approach is to provide complementarity, as the researcher understands that the phenomenon is not completely explored through only quantitative or qualitative data.

Considering that the quantitative data were collected sequentially (pre, post treatment, and follow up), and qualitative and quantitative data were collected

concurretnly on post treatment assessment, is it possible to classify this study as a sequential design with a convergent component (Figure 1).[24]

. *Meta-inferences*

Quantitative data was collected during pre, post, and follow up phases. The analysis was conducted using side-by-side comparison through joint display in order to explore if they converged (better outcomes and positive perceptions regarding the intervention) or diverged (no connection between outcome results and participants` and caregivers` opinions).[23,25,26]

*Quality assurance*

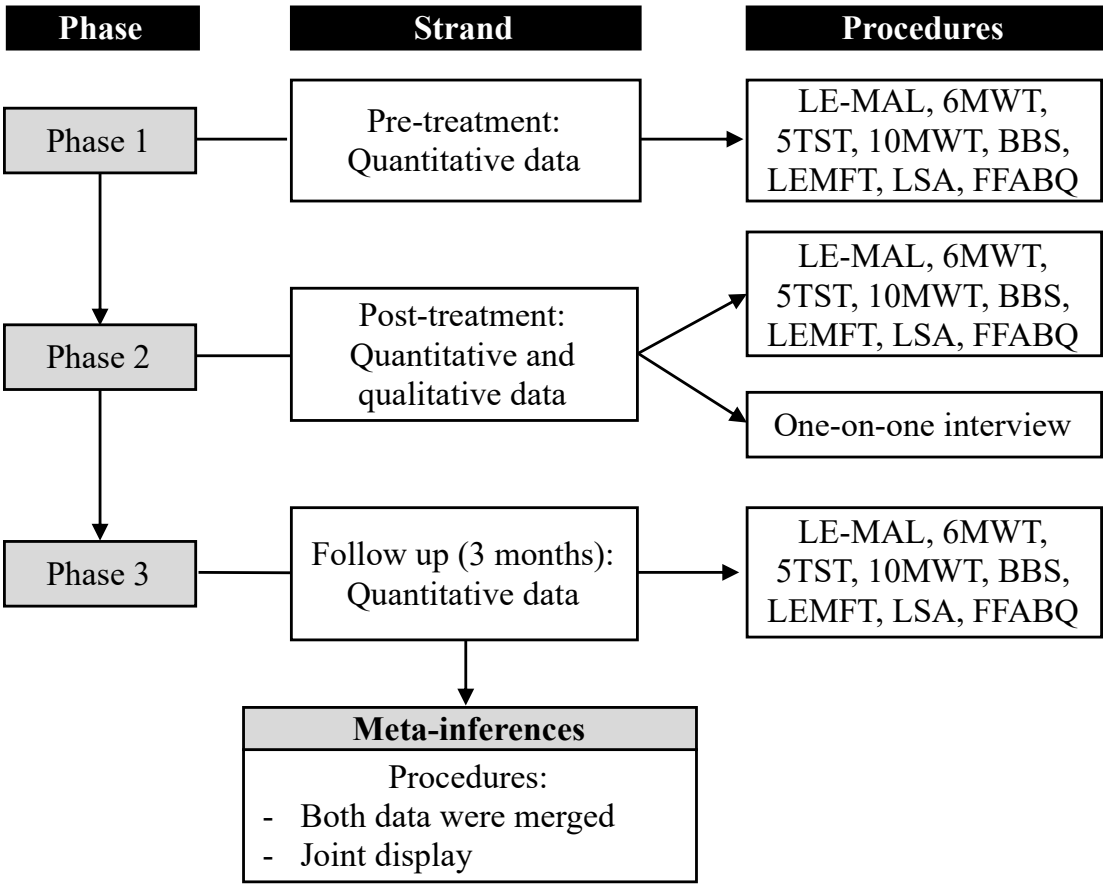
The critical appraisal framework described by Curry & Nunez-Smith (2015) provides a guide to assure quality in different levels of a mixed methods study.[27] Based on this framework, the quality of this mixed methods study was addressed in two different levels: (1) conceptualization: showing that the study was planned to appropriately answer the research questions; (2) design: because the experimental mixed methods design was chosen to investigate the effect of the intervention and also assess how acceptable the protocol is. Nevertheless, different quality strategies in both strands were applied to avoid bias and other risk of potential errors. Data was merged at the level of the interpretation. Also, transparency is being addressed describing in detail the findings of each strand in order to clarify the inferences.

## RESULTS

Participants included in the study from May 2017 to May 2018. All participants completed all visits, except from PT8 who missed follow up assessment due to injury

unrelated to the study. Missing data was treated using last observation carried out forward (LOCF) analysis. The results did not change after the conservative replacement of the missing data with the pre-treatment value or after the exclusion of the participant in question.

Figure 1. Mixed Methods Study procedural diagram




As shown on Table 2, participants with chronic stroke (2-28 years) were included and 50% were women. Two family members and one caregiver were also included.

Table 2. Participants characteristics

| Participant | Age | Gender | Time since stroke (years) | MMSE | Caregiver / family member |
|---|---|---|---|---|---|
| PT2 | 64 | M | 2 | 27 | Caregiver |
| PT3 | 40 | M | 4.5 | 30 | Parent |
| PT4 | 43 | M | 4 | 30 | NA |
| PT5 | 41 | F | 8 | 29 | NA |
| PT6 | 66 | F | 28 | 28 | NA |
| PT7 | 55 | M | 4.5 | 28 | Spouse |
| PT8 | 74 | F | 22 | 29 | NA |
| PT9 | 58 | F | 10 | 29 | NA |

NA: not applicable.

*Quantitative Analysis*

Participants improved LE use, balance, and motor function after LE-CIMT (Table 3). There was a significant change comparing pre to post treatment on all measures except for avoidance behavior and mobility area. However, there was significant improvement on avoidance behavior when comparing pre-treatment and follow up.

Significant results were found comparing pre, post and follow up assessments. The effect size (*d'*) ranged from 0.17 to 2.60.

*Qualitative Analysis*

Both participants with stroke and their caregiver or family members were interviewed separately. Caregiver pointed out that (Table 4) that the main difference between the LE-CIMT protocol and previous experience with traditional rehabilitation were the intensity, the structure of the protocol (e.g., the list of activities).

Caregiver and family members also identified participants` improvements that were different from past experiences including motivation, balance, motor function, and performance in daily activities. One caregiver noticed that after the protocol, the

participant with stroke showed a reduction of spasticity on the affected UE resulting in relaxation in his hand.

Table 3. Quantitative effect of the LE-CIMT

| | **Pre (Mean ±SD)** | **Post (Mean ±SD)** | **Effect size (*d'*)** | **Follow up (Mean ±SD)** |
|---|---|---|---|---|
| LE-MAL | 7.1 ±1.1 | 8.1 ±1.2* | 1.55 | 8.8 ±1.2* |
| 6MWT (m) | 225.3 ±98.6 | 262.6 ±116.1* | 1.39 | 256.0 ±112.4* |
| LEMFT (Adjusted performance time rate) | 170.2±54.2 | 222.3 ±68.7* | 2.60 | 232.3 ±76.7* |
| BBS | 46.8 ±6.4 | 49.6 ±6.3* | 2.00 | 50.1 ±5.2* |
| 5xSTS (sec) | 26.1 ±17.3 | 21.6 ±16.3* | 0.88 | 20.8 ±16.3* |
| 10MWT self- selected speed (m/s) | 0.76 ±0.32 | 0.84 ±0.36* | 1.27 | 0.81 ±0.34* |
| 10MWT fast speed (m/s) | 0.95 ±0.41 | 1.04 ±0.46* | 0.95 | 1.01 ±0.44* |
| FFABQ | 10.8 ±7.6 | 7.9 ±6.5 | 0.46 | 5.0 ±3.6** |
| LSA | 65.5 ±21.1 | 68.3 ±28.1 | 0.17 | 64.9 ±20.5 |

*p-value <0.05 – compared to baseline; **p-value <0.05 – compared to post treatment
LE-MAL = Lower-Extremity Motor Activity Log; 6MWT = Six Minutes Walking Test; BBS = Berg Balance Scale; 5xSTS = Five Times Sit to Stand; 10MWT = Ten Meters Walking Test; FFABQ = Fear of Falling Avoidance Behavior Questionnaire; LSA = Life Space Assessment. m= meters; SD = standard deviation.

Caregiver and family members were asked to supervise the participants with stroke outside the laboratory and to help with the performance of tasks for safety and to provide feedback regarding quality of movement. As seen on Table 4, the caregiver and family members did not find their role in the intervention to be demanding. In fact, they recommended an extended time for the protocol.

Participants with stroke reported similar improvements to those pointed out by the caregiver and family members (Table 5). Also, they observed changes in daily activities

performed outside the laboratory during the intervention protocol. For example, PT4 said, "(…) my leg, for instance, it kind of bends over to the right, hard for me to have a muscle to hold my leg up straight. Suddenly, I was able to keep my leg straight while I`m sitting down.".

Also, six participants reported change in their awareness of what they were able to do with the paretic LE and their ability to monitor the quality of movement performed with that limb.

The higher intensity of the supervised training was identified as a factor that was different from traditional therapy. All caregivers and family members (N=3) as well as the majority of the participants with stroke (N=7) referred to this difference as a positive aspect. One participant (PT6) pointed out that the intense therapy did not give her time to "*absorb all of it*". Most participants (N=4) reported that the exercises performed during the supervised treatment were similar to their previous experience on the traditional therapy. However, how the shaping tasks were structured (e.g., repetition, gradual increment of complexity) was reported as a difference between LE-CIMT protocol and conventional therapy.

Physical and/or mental exhaustion were reported by seven participants with stroke. However, it did not impact on their commitment with the protocol. Another side effect reported by three participants was soreness.

Participants were asked about each element of the LE-CIMT. All participants reported that the behavioral contract brings about commitment to protocol requirements and provides and understanding of the protocol as a whole. PT7 said, "Pretty much if I say I`m going to do something, I like doing what I say I`m gonna do."

Table 4. Caregiver/family member codes

| Themes | Sub-themes | Quotes |
|---|---|---|
| Comparison between LE-CIMT and traditional rehabilitation | Differences: Intensity, number of repetitions, structure of the motor training, works the whole-body, therapist (knowledge, interaction), type of exercises.<br>Similarities: none; one-on-one. | "*More intense and that's what they need, I think that's what an individual needs is, the intensity."* (Caregiver PT2)<br>"*I liked how well-organized it was. Getting the piece of paper delineating each exercise that he needed to do."(*Family member PT3)<br>"*There are some different exercises."* (Caregiver of PT7)<br>"*The one-on-one individuality where you can spend more time with that person*." (Caregiver of PT2) |
| Benefits | Function: balance, motor function, mobility;<br>Daily activities performance: going up and down stairs and walking;<br>Autonomy;<br>Changes on other segments;<br>Motivation. | "*With this assignment he's been doing it on his own.(...) He's gotten more independent*" (Caregiver of PT7)<br>"*But I can see progress and not only physical progress, but also he's positive about making improvements, and that's important for him, to not give up."* (Family member of PT3)<br>"*Even with him doing his hand exercises, his muscles are more loose and mobile."* (Caregiver of PT2) |
| Caregiver burden | None | "*The therapy is not demanding for me at all*." (Caregiver of PT7) |
| Suggestions for change | Nothing;<br>Longer intervention;<br>Transfer concepts into the traditional therapy. | "*I wish it wouldn`t end for him. I really do because it seemed to be beneficial, and he's ready to get his life back. So I wish it could continue (...)"(*Caregiver PT2) |

Table 5. Participants with stroke codes

| Themes | Sub-themes | Quotes |
|---|---|---|
| Perceived benefits | - Body function (e.g., motor function, balance)<br>- Personal factors (e.g., motivation, confidence, awareness)<br>- Activities performance | *"It helped me with being aware of my left leg, and range of motion."* (PT3)<br>*"I felt like my leg woke up and I could actually start using it a lot more and being more confident about this leg."* (PT5)<br>*"(...) It is showing me the quality of work that I can do and the quality of work I am able to do if I just do the right thing. (...) Before, I was just working because that`s what the therapist said I needed."* (PT6) |
| Differences from traditional therapy | - Intensity and duration<br>- Interaction with the therapist / supervision<br>- Neuro specialization<br>- Individualized intervention | *"(...) so many were just weird* (talking about traditional therapy)*, or they didn`t care, or they were not neuro, so they`re like – 'I don`t know what`s wrong with you'."* (PT3)<br>*"The therapist* (talking about the traditional therapy*) can only do so much in one hour"* (PT4)<br>*"Well, it sounded to me that she* (the therapist) *looked at you and kinda found where you need some work and she tailored her program to your needs."* (PT5)<br>*"I liked the fact that it is not rushed."* (PT6) |
| Similarities from traditional therapy | - None<br>- Exercises | *"I remember the movements and the type of exercises I was doing then (talking about traditional therapy)."* (PT6)<br>*"I think that they all have some stretching of contracted muscles. I think they have that in common." (*PT8) |

Table 5. Participants with stroke codes (cont.)

| Themes | Sub-themes | Quotes |
|---|---|---|
| Side effects | - Physical (e.g., soreness, tightness)<br>- Mental and physical exhaustion | *"It was fatigue, definitely. It was a lot of fatigue*." (PT4)<br>*"(...) mentally and physically, it was intense, but great."* (PT5)<br>*"I didn`t expecting to be as demanding as it is. (...) Well, I did have some soreness in this left leg; I did have some tightness in this left leg."* (PT6)<br>*"It was physically demanding but it didn`t discourage me."(*PT7) |
| LE-CIMT elements | - Behavioral contract<br>- Home Skill Assignment / home practice<br>- Shaping<br>- Problem solving | *"Oh well, you get what you put in. So, you work hard here, you go home and work hard, and you see benefits by the end of your two weeks. (...) I made a commitment to her (the therapist) that I would work hard here and that I would go home at night and work hard that night"* (PT5)<br>*"If you`re going to do something like this, you really need to put your mind into working and doing everything you say you`re going to do."* (PT6)<br>"*Okay, we`re doing this trial, and we`re seeing if we get any faster*." (PT3)<br>"*The thing I like about it is, with her, you get to see what you're doing and for her to correct the things that may kinda go out of whack a little bit. And she can adjust it back*." (PT4) |
| Suggestions / recommendations | - Integration into the traditional therapy settings<br>- Change duration<br>- None<br>- Logistic issues (e.g., transportation) | "*It needs to exist. I hope it`s replicated after she* (the therapist) *leaves*" (PT2)<br>*"I would say I`m crazy about it."* (PT4)<br>"*I really wish they would get this out more to therapy places."* (PT5) |

When asked about adherence to carrying out the activities listed in their daily home skill assignment, the answers ranged from 50% to 100%. From the seven participants that provided a percentage, 6 reported that they had performed more than 85% of the tasks assigned to them daily. The use of shaping as a motor training technique was also mentioned as a positive characteristic of the protocol. Participants appeared to enjoy the challenge that came from gradual progression of tasks complexity during training. PT4 pointed out that the flexibility of the shaping tasks according to the participant`s level of impairment makes the protocol an individualized intervention.

Participants and caregivers suggested that the LE-CIMT should be integrated into traditional therapy settings. Also, one participant (PT6) suggested that the protocol should be delivered a few times per weeks, instead of every weekday. All participants reported that the protocol should be longer.

Although a few participants (N=3) reported logistics issues (e.g., transportation, parking, traffic) all of them would do it again.

As shown on Table 6, both quantitative and qualitative data were merged in a joint display. The quantitative results were classified in domain according to the outcomes and the themes and codes developed by both coders. The perceptions and opinions of all participants confirmed the changes observed in the quantitative data as same aspects were reported in the interviews.

Table 6. Joint display of participants and caregivers/ family members perceptions per changes after intervention

| Outcomes domain | Change Pre-post | Themes / sub-themes | Quotes |
|---|---|---|---|
| LE use (LE-MAL) | + | - Perceived benefits / personal factors<br>- Perceived benefits / body function<br>- Perceived benefits / Activities performance | *"I felt like I was using this leg a lot more than I was before the therapy. (...) It`s almost like my leg woke up, like saying 'hey, I am still attached to your body'."* (PT5)<br>*"(...) keep my body straight and don`t bend over when I walk."* (PT7)<br>*"Like normally when I would walk down the stairs my leg would just, the weak leg would just shake like this some. (...) When I get ready to step that it stays steady like this. Step it down without it shaking."* (PT7)<br>*"I am using my left side a little more."* (PT8)<br>*"I could see there is a way to sometimes not use the scooter to go ahead and be a walker, walking person and carry things."* (PT8) |
| Motor function (6MWT, 10MWT, LEMFT, 5xSTS) | + | - Perceived benefits / Activities performance | *" (...) you can actually step over a box. You know at home that you can step over a pencil or something or a pair of glasses. But look at those boxes. Look at the size of them. I had no idea I could actually learn to do that."* (PT8)<br>"*When I walk without the cane, I shift my weight*." (PT9) |
| Balance (BBS) | + | - Perceived benefits / body function | *"When I wasn't going to the program, my balance wasn't as good. When I got to the program, it was good."* (PT9) |
| Avoidance behavior (FFABQ) | - | - Perceived benefits / personal factors | No quotes referred to this aspect. |
| Mobility area (LSA) | - | - Perceived benefits / environmental factors | "*I see that his mobility is better without the cane."* (Caregiver of PT2) |

NOTE: + significant changes observed after the intervention; - non significant changes.

## METAINFERENCES

Previous studies have suggested significant results after modified LE-CIMT protocols. The specific protocol elements varied from study to study. Elements reported included a type of restraint device on the less affected LE,[28–35] an intensive training program,[30,32,36,37] and a list of activities to be performed at home.[28,29] This is the first study to report the results of the combination of all of those elements of the LE-CIMT systematically administered with people with chronic stroke. Additionally, a full transfer package that parallels elements used in the UE-CIMT protocol was used.

This study showed significant changes on motor function, gait speed, balance, LE use and mobility when comparing pre and post- treatment assessments. The results were maintained 3 months after the LE-CIMT intervention. A single subject study applied massive motor training 6 hours/day for ten consecutive weekdays. The intervention focused on mobility, balance, and motor function. The change on the LE-MAL scores on this study is similar to our findings. However, the long-term retention of these effect is not reported.[36] Another study reported a significant change on the BBS scale was also observed after an intensive treadmill training protocol while wearing a mass on the non-affected LE in addition to a list of activities to be performed at home. The results were maintained 40 days after the end of the protocol.[28]

We hypothesize that the retention of the results is related to the application of the transfer package. The TP was previously reported as the most important element of the UE-CIMT protocol, and is associated to an increment the effect of the intervention 2.4 times.[7,8] Also, the significant decrease on avoidance behavior observed on follow up might be associated with increase on confidence (measures by the LE-MAL) and level

activity a list of activities to be performed daily was provided to the participants on the last day of treatment.

The results observed in the quantitative strand were validated by the qualitative data. Both caregiver/family members and participants with stroke reported changes on motor function, awareness and daily activities performance.

Most participants reported muscle soreness and fatigue during the protocol. Another study that investigated the acceptability of an intensive intervention also reported soreness as a common side effect of the treatment.[21]

The transference of the changes perceived by the participants to real-life situations can also be associated with the application of the TP. This component contains many strategies to induce generalization of the motor skills emphasized during the supervised training to different contexts.[7] For example, the part of the behavioral contract identifies usual daily activities that can be performed in a way to emphasize the use of the more affected LE.

The intensity and format of the UE-CIMT was previously reported as a barrier to implementation of the protocol in clinical settings.[38,39] However, the opposite was reported during our interviews. In our study, both participants and their caregivers or family members were willing to extend the protocol ever repeat it again. Even reporting fatigue, soreness, and some logistic issues, the experience was overall described as positive and they were motivated to participate in a longer intervention. A previous phenomenological study also reported that participants with stroke perceived an intensive intervention as feasible.[21]

In this study, the LE-CIMT was effective in improving LE motor function, mobility, confidence, and LE use in the real world for participants with chronic stroke. Although

the results are promising, further investigation regarding the effect of each element of the protocol is needed. The main limitation of this study is a small sample size.

*Study limitations and future directions*

Although this study has shown that the LE-CIMT may be a valuable technique to improve LE motor function and use of the affected limb, further studies with larger samples are needed. Furthermore, randomized controlled trials are recommended for comparing the effects of the LE-CIMT interventions other interventions and to a control group. Also, further investigation regarding the neurological mechanisms involved on the LE-CIMT should be conducted.

Future studies should also examine the difference between more and less intensive supervised treatment.

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# DISCUSSION AND CONCLUSIONS

## What we knew and what we learned

CIMT has been extensively studied and has been shown to be effective to overcoming a phenomenon called learned non-use observed in people with stroke and other health conditions.[9,16,17] The systematic combination of the components of this therapy, particularly the Transfer Package, is responsible for long term retention of the results observed after the intervention protocol.[17]

The adaptation of the protocol for the lower extremities demanded some modifications and a better understanding of how the learned non-use phenomenon is established. First, the term "learned non-use" (LNU) was substituted with the term "learned misuse". Dr Edward Taub, who developed the theory and the CIMT protocol, suggested that the origin of the misuse is the same (e.g., successive failures after attempts to move the limb that lead to punishment). However, due to the bilateral nature gait and mobility, even the more-affected LE must be used in any standing or walking is attempted following stroke; even in the early stages. Use of the more-affected LE is likely abnormal and the less-affected LE is relied upon heavily. As such, the term "misuse" is more accurate than the term "nonuse" in this situation.

Also, use of shaping during the supervised training portion of the protocol had to be modified slightly. Since most LE functional skills require the use of both LE's together and in a coordinated fashion, bilateral tasks were included in the supervised movement

training portion of the protocol. In the UE CIMT protocol, unilateral activities with the more-affected UE are used exclusively during shaping activities performed in the supervised movement training portion of the protocol.

Another important change to the protocol was the omitting use of a restraint device on the less-affected LE. The rational for excluding this device includes the fact that use of such a device would induce and unnatural and unsafe movement pattern. Further rationale for omitting the restraining device during the LE CIMT protocol includes that although the UE protocol includes a restraint device, studies that explored the effect of each protocol element on the final results, concluded that the transfer package was most responsible for overcoming learned non-use and promoting neuroplastic change; not the restraint device used on the less-affected UE. As such, the exclusion of the restraint device for the LE protocol should not significantly impact the outcomes observed after treatment.[17,33]

The qualitative data collected in this study confirmed the results observed in the quantitative strand. Participants with stroke and their caregiver or family members were able to identify important changes after the intervention. Additionally, important information was obtained through the interviews conducted in this study that might be useful for considering possible modifications to the protocol in the future.

Participants with stroke reported mental physical exhaustion throughout the protocol. Sometimes, this condition negatively influenced the performance of the activities listed on their Home Skill Assignment. Frequent rest periods and a better choice of less complex activities might be indicated.

Previous studies have investigated concerns and low acceptability of the UE-CIMT protocol by potential.[39,40] In this study, however, 100% of participants with stroke

expressed a high level of acceptability and reported that they would do it again. Caregiver and family members reported a high level of acceptability and that the therapy was not demanding for them.

## Transference to clinical practice

Participants in this study reported that they were surprised by the significantly positive changes in function that they observed after only such a relatively short period of time (i.e., 2 weeks). Also, most of the participants pointed out that they believed that the LE-CIMT protocol should be available at all rehabilitation settings.

As shown in this project, all studies published prior to this study used a modified protocol to improve balance, gait and mobility of people with stroke.[25–32] Thus, the first step for transferring the LE-CIMT protocol to other settings is disseminating information about the intervention and providing accurate educational opportunities for therapists.

## Future directions

The LE-CIMT has been shown to be a valuable tool to improve LE motor function and use of the more affected LE. However, due to the small number of participants in this study, research with a larger sample of participants is needed. Furthermore, randomized controlled trials are recommended for comparing the effects of the LE-CIMT interventions other interventions and to a control group.

Also, neurological mechanisms involved on the effects of the LE-CIMT should be better understood. A study has shown positive neuroplastic changes after the application of the LE-CIMT.[41] However, this study also utilized a modified CIMT protocol. Such outcomes should be explored with the complete LE CIMT protocol.

Studies investigated the difference between more and less intensive supervised training as part of the UE-CIMT protocol (i.e., 3 hours versus 6 hours daily during the intervention). Results indicate that both supervised training schedules have similar effects.[42] Early work by Taub et. al demonstrated similar findings with the LE-CIMT protocol. Further studies should analyze the difference of protocol with different intensity and duration of the LE-CIMT. This could be particularly important for overcoming logistics barriers (e.g. transportation) and for decreasing fatigue experienced by participants during the intervention period.

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# APPENDIX A

# PROJECT INSTITUTIIONAL REVIEW BOARD APPROVAL

THE UNIVERSITY OF ALABAMA AT BIRMINGHAM

Institutional Review Board for Human Use

Form 4: IRB Approval Form
Identification and Certification of Research
Projects Involving Human Subjects

UAB's Institutional Review Boards for Human Use (IRBs) have an approved Federalwide Assurance with the Office for Human Research Protections (OHRP). The Assurance number is FWA00005960 and it expires on November 8, 2021. The UAB IRBs are also in compliance with 21 CFR Parts 50 and 56.

| | |
|---|---|
| Principal Investigator: | Dos Anjos, Sarah |
| Co-Investigator(s): | |
| Protocol Number: | **X170412007** |
| Protocol Title: | *Constraint-Induced Movement Therapy to Improve Gait and Mobility of People with Chronic Stroke: A Mixed Methods Study* |

The IRB reviewed and approved the above named project on 5/16/17. The review was conducted in accordance with UAB's Assurance of Compliance approved by the Department of Health and Human Services. This Project will be subject to Annual continuing review as provided in that Assurance.

This project received EXPEDITED review.

IRB Approval Date: 5/16/17

Date IRB Approval Issued: 5/16/17

IRB Approval No Longer Valid On: 5/16/18

Expedited Reviewer
Member - Institutional Review Board
for Human Use (IRB)

Investigators please note:

The IRB approved consent form used in the study must contain the IRB approval date and expiration date.

IRB approval is given for one year unless otherwise noted. For projects subject to annual review research activities may not continue past the one year anniversary of the IRB approval date.

Any modifications in the study methodology, protocol and/or consent form must be submitted for review and approval to the IRB prior to implementation.

Adverse Events and/or unanticipated risks to subjects or others at UAB or other participating institutions must be reported promptly to the IRB.

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