MBMJ

Integrative Journal of Medical Sciences
DOI: 10.15342/ijms.2022.682

Efficacy of lower limb constraint-induced (CI) therapy for hemiplegia in stroke patients during the maintenance period

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Received: 21 July 2022
Revised: 23 September 2022
Accepted: 28 September 2022
Published: 27 November 2022

ABSTRACT

A lower extremity constraint-induced movement therapy protocol developed at the University of Alabama was used to treat three stroke patients suffering from hemiplegia. Upon intervention, both walking speed and stability improved, reliance on assistance from an accompanying individual or support device decreased, and both improvements to standing position during daily activities and walking activity were seen.

KEYWORDS:
Stroke, Rehabilitation, Lower Limb, Constraint-Induced Movement Therapy, Forced Use.

1. Introduction

Stroke is the leading cause of adult mortality in Japan [1] and the primary reason for healthcare provision [2]. Therefore, stroke rehabilitation has become necessary to reduce patient disability and improve social/physical function [3]. Many stroke patients experience hemiplegia and an associated sense of burden towards daily activities [4]. In particular, those with hemiplegia experience a decrease in lower limb function, poor walking balance, slower walking speed, increased energy expenditure, and increased risk of falls and fractures [5,6]. Such loss of walking proficiency becomes an impediment to daily activities and social life [7,8], suggesting that recovery of walking ability is a priority for the majority of patients with hemiplegia [9,10]. One rehabilitation intervention following a stroke with a large amount of supporting evidence is constraint-induced movement therapy (CIMT) [11,12]. CIMT was first developed by Dr. Taub at the University of Alabama as a treatment for the upper limbs of adult patients with hemiplegia and has since been reported as effective for this aim [13-15]. Functional recovery of paralyzed limbs by CIMT has been reported to be based on brain plasticity, as reflected in phenomena such as reorganizing neural circuits in the injured brain [16,17]. Later, a pediatric CIMT protocol was developed as well [18,19], and in 2015, a protocol for the lower limbs (LE-CIMT) was developed at the University of Alabama. The LE-CIMT protocol differs slightly from the upper limb and pediatric protocols. One upper limb hemiplegia CIMT protocol involves “multiple methods for promoting the use of paralyzed hands” by binding the unaffected hand in a mitten. However, LE-CIMT consists in applying a load or promoting various exercises for the affected leg rather than binding the unaffected leg. This is because the patient can walk with both legs prior to starting the treatment. Ultimately, the intervention increases the use of the affected limb. A few studies have indicated the effectiveness of LE-CIMT, but most involve binding the unaffected leg by some apparatus [18-20]. Moreover, an original lower limb CI therapy protocol involving task-specific instruction that utilizes shaping by a Lower Extremity Motor Activity Log (LE-MAL) to promote incremental functional improvement has been proposed, and there are reports on the success of this approach with respect to functional recovery and increase in the load-bearing ability of the affected leg. Original LE-CIMT includes giving homework to patients in the form of trying to use the affected leg more while increasing the average load-bearing capacity of both legs. Therefore, this method is expected to increase the use of the affected leg through intrinsic motivation and habit formation. This study tests original LE-CIMT in terms of walking speed, walking endurance, standing position during daily activities, improvements to walking activity, and the development of habits that increase the use of the affected leg.

2. Method

Target participants included stroke patients with hemiplegia who attended a clinic at which the first author worked part-time. Participants were recruited based on the following entry criteria: ① stroke patients with hemiplegia who experienced the onset of symptoms at least one year prior; ② ability to walk at least 10 m without the aid of a cane; ③ normal cognitive function (Mini-Mental State Examination score of 24 or higher); ④ no pain when performing daily activities that require a walking or standing position; ⑤ no botox injection or baclofen administration in the past two months; ⑥ presence of an accompanying individual available during the 2-week program.

Of the five individuals recruited, three met the selection criteria. The study was explained to these selected individuals, and informed consent was obtained before program participation. Table 1 presents the participants' demographic information.

TABLE 1: Demographic Information of Participants

Participant	Age, y, mo	Gender	Involved side	TUG
A	52	M	L	31.5
B	50	M	L	19.7
C	62	F	R	16.6

F, female; TUG, Timed Up and Go; L, left; M, male; R, right.

The LE-CIMT program lasted 2 weeks and the protocol consisted of the following five items:

① Motor Activity Log-Lower Extremity (LE-MAL) management
② Home Diary (HD)
③ Behavioral Contract-LE (LE-BC)
④ Home Skill Assignment-LE (HSA-LE)
⑤ For training in the walking/standing position, lower limb task practice (TP) and shaping were followed by self-practice (Task Practice After, TPA) following the end of the program.

A therapist performed the following interventions daily at the clinic on weekdays during the program period:

① Evaluation of LE-MAL
② HD Check (check that the LE-BC is being followed)
③ 10-item HSA-LE homework instructions
④ Training by shaping and TP (attending clinic training along with a family member or caregiver, receiving practical instruction on assisted training methods from the therapist, and achieving the ability to perform accompanied at-home training)

LE-MAL evaluation considered 14 key activities representative of walking and standing during daily activities. This score was evaluated on three assistance scale items and other Functional Performance and Confidence items. The Personal Assistance Scale, among other

assistance scales, evaluated how much assistance the accompanying individual provided during a topic performance on a 10-point scale. The Orthotic Scale evaluates assistive devices used to perform tasks. A full score of 10 points is assigned if no devices were used. Accordingly, the score decreases with greater use of the assistive device. The Assistive Device Scale involves assigning 10 points if no walker or cane is used. Otherwise, the score decreases with greater use of an assistive device. The assistance scale was scored by taking the average of the Personal Assistance Scale and Orthotic Scale scores and adding the value to the Personal Assistance Scale score. The resulting number was divided by 2, and the result was taken as the evaluation score. Functional performance was subjectively scored with 10 points if the participant had a sense of normal ability. If the participant felt entirely incapable of performance, a score of 0 was given. Confidence was evaluated on a 10-point scale and considered how confident participants were in their ability to walk without falling. In other words, the LE-MAL score, which primarily involves standing and walking, would be evaluated by the ability to perform without reliance on an accompanying individual, equipment, or assistive devices. Participants who felt that they could move normally and confidently without falling earned more points.

HD is a journal that tracks the participants' agreed-upon LE-BC activities and activities involving the use of the hemiplegic lower limb during walking and other activities. The therapist checks the HD to determine whether or not LE-BC activities are performed. This HD serves to heighten the participants' awareness of how they use their hemiplegic lower limbs.

LE-BC was conducted on the first day (Monday) of each week and lasted for the target duration of that week. LE-BC involved a discussion between the participant and therapist wherein whether or not the daily walking/standing activities (moving around the house, going up and down stairs/elevations, housework, hobbies, walking outdoors, etc.) could be performed independently, with assistance, or not at all. Activities were divided into these three categories following discussion, and the therapist would read the terms of the written agreement to the participant. The participant would then sign the document if they were determined to follow the contract accordingly.

HSA-LE instructs the participant to do their homework of using their hemiplegic lower limb 10 times daily. HSA-LE is useful in promoting the use of the hemiplegic lower limb outside the clinic, which is checked daily following LE-MAL management.

The evaluation took place one month before the intervention, the first day of the intervention, one week following the end of the intervention, and every six months after the intervention and included a 10-Meter Walk Test (MWT), the Timed Up and Go Test (TUG), and the evaluation of LE-MAL.

The direct intervention was provided during occupational therapy clinic visits in the morning, lasting 3 hours.

3. Results.

All 3 participants completed the 2-week program and were present for the 6-month follow-up evaluation. Evaluation results are summarized in Table 2. TUG was initially of a mean duration of 22.5 seconds (±7.6) and was reduced to 15.8 seconds (±3.3) after intervention for an Effect Size improvement of 1.6. LE-MAL was initially a mean sore of 2.7 (±0.7) and was increased to 4.7 (±0.9) for an exceedingly large observed Effect Size of 2.3. 10MWT lasted a mean time of 20.6 seconds (±6.0) before intervention and improved to 13.0 seconds (±2.3) following intervention for an Effect Size of 1.7.

Table 2: Results 1 month prior to LE-CIMT, pre-intervention, post-intervention, and 6 months following LE-CIMT intervention

	TUG				LE-MAL				10MWT(sec)			
	BL	pre	post	6M	BL	pre	post	6M	BL	pre	post	6M
case A	31.5	31.1	19.2	20.9	2.2	2.1	4.5	3.9	27.6	27.3	15.5	17.3
case B	19.7	19.5	15.7	16.8	2.8	2.6	3.9	3.5	18.4	18.7	12.7	14.8
case C	16.6	16.8	12.6	13.5	3.3	3.4	5.6	5.1	16.1	15.8	10.9	11.7
Effect size		1.3				0.9				1.7		

NOTE: TUG; Timed Up & Go Test, Lower Extremity Motor Activity Log; LE-MAL. 10MWT; 10-Meter Walk Test, Effect size represents the value between pre and post.

1) Shaping Tasks Used in This Program

Case A: Cone step-over, rotational kicking of the target, foot slides, ankle dorsiflexion in standing, side-stepping on the treadmill to the right, stepping to the Xs with less involved LE, Swiss ball squats, and other activities

Case B: 20 m tandem walk, walking and stepping over objects, theraband dorsiflexion, seated march, terminal knee extension, mini squat in parallel bars, and other activities

Case C: Supine ankle pumps, self-sway, heel lifts in standing, marching in place, walking backward on the treadmill, foot slides, ring transfer, and marble transfer with toes

2) Home Skill Assignment Homework

Case A: Wipe the table, cross at the railroad crossing, walk on the sidewalk, overcome park elevation differences, cross-step, cross at the crosswalk, walk down a narrow alley, wipe the windows, water the plants, and go shopping at a department store.

Case B: Wipe window glass, cook standing up, move laterally in the restroom, walk to a friend's house, pass the bicycle parking lot, pass the crosswalk, step back and forth, and shop at the supermarket.

Case C: Wipe the table, wipe the windows, go up and down the inside stairs, go up three elevated areas outside the house, ride the escalator, and cross the 4-way crosswalk.

3) Behavioral Contract: Details of the Agreement

Activities are classified as "independent activities" to be performed without accompaniment, "accompanied tasks" to be performed with another individual, and "prohibited" tasks not to be performed. When performing the agreed-upon tasks, an adequate amount of load is to be

placed on the paralyzed leg.

Case A: Independent, walk three blocks around the house and walk 50 m down the sidewalk; accompanied tasks, go up the elevated areas around the house and wipe the windows; prohibited, walk up/down the stairs at home without using the handrail.

Case B: Independent, walk four blocks around the house; accompanied tasks, walk on the sidewalk and use all stairs and elevated areas; prohibited, bathing tasks.

Case C: Independent, walk four blocks around the house and walk on the sidewalk; accompanied tasks, surpass elevation changes; prohibited, going up and down stairs.

4. Discussion

A LE-CIMT protocol developed at the University of Alabama was used to treat three stroke patients suffering from hemiplegia. Upon intervention, walking speed and stability improved, reliance on assistance from an accompanying individual or support device decreased, and improvements to standing position during daily activities and walking activity were observed. Previous studies on LE-CIMT have described a training regimen focused on center of mass, balance, treadmill walking, and other training exercises meant to recover motor function. However, these studies did not employ shaping with training regimens[20-24]. Marklund and colleagues evaluated LE-CIMT using TUG in a manner similar to the present study. However, the effect size was 0.6, whereas, in the present study, it had a larger value of 1.3. The effect size on standing position and mobility during daily activities, as evaluated by LE-MAL before and after the intervention, improved to a larger value of 2.3. David and colleagues cited activity-based therapies (ABTs) as the most effective intervention modality for neurorehabilitation[25]. Recovery of motor function in patients with hemiplegia returns to baseline following the conclusion of intervention when a training-focused program is used, which is why it is essential to introduce lifestyle activities that utilize the affected upper and lower limbs. Such habit formation promotes the long-term recovery of upper/lower limbs suffering from hemiplegia. This study involved the implementation of LE-CIMT, a protocol developed under the principle of long-term recovery. Even six months following the intervention, LE-MAL, as measured by 10MWT and TUG, was comparatively maintained. This suggests that interventions based on ABTs can produce long-term, sustained improvement.

5. Summury

In order to validate the efficacy of LE-CIMT developed at the University of Alabama, we performed original CIMT in treating three stroke patients suffering from hemiplegia. The results showed an effect size improvement of 1.6 for TUG mean duration, LE-MAL a very large effect size improvement of 2.3, and 10MWT an effect size improvement of 1.7.

Acknowledgements

The authors thank the study subjects and the registered physiotherapists and occupational therapists for participating in this study.

COMPETING INTERESTS:

None declared.

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