Effects of Constraint-Induced Movement Therapy and Application Time and Duration of Intervention for Lower Extremity in Stroke: A Systematic Review

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ABSTRACT

The primary aim of this review was to determine the effects of CIMT (constraint-induced movement therapy) on gait, balance, and motor functions of the lower extremity in stroke. The secondary aim was to determine the optimal dosage, application time, and duration of CIMT in the lower extremity in stroke. PubMed (1999-July 2021), Pedro (2000-December 2020), Google Scholar (1999-February 2022), and Cochrane Library (2000-February 2022) were searched in February 2022. The risk of bias was calculated through the criteria outlined in the (Cochrane-Handbook for Systematic-Reviews of Interventions). Eight RCTs were included in this review. CIMT was found to be effective in improving balance, gait, and motor functions of lower limbs; however, its superiority in comparison to the control group was not significant, no specific dosage was mentioned for lower limb CIMT as different studies used different durations and intensities of CIMT.

Key Words: Cerebrovascular accident (CVA), Balance, Lower-extremity constraint-induced movement therapy (CIMT), Motor functions.


INTRODUCTION

Stroke is the second leading cause of global mortality and affects 15 million people worldwide each year. There has been a double-fold increase in the cases of stroke in Asian, countries in past two decades. It was reported that in stroke population in South Asia, 13.4% have comorbid conditions like dyslipidemia, diabetes, hypertension and many of these are uncontrolled. Loss of skeletal muscle mass and function are common in patients with stroke. It can adversely affect the mobility of the patients and hamper the performance of activities of daily living (ADLs), leading to a reduced participation in daily life activities. Stroke is a complex clinical condition. Advancement in complexity of health care intervention and provision requires different healthcare professionals to collaborate. Multidisciplinary stroke rehabilitation teamwork is fundamental to deliver effective care across the stroke pathway.

Rehabilitation techniques in stroke vary widely including traditional physiotherapy exercises, neurodevelopmental technique (NDT), motor relearning techniques, circuit training, and constraint-induced movement therapy (CIMT), etc. Their application is determined according to patient requirements, provider skills, and developed clinical practice. A lot of clinical practices are derived empirically, and is poorly understood with their mechanism of action.

CIMT is a technique used for rehabilitation in conditions affecting motor component of central nervous system i.e. stroke, cerebral palsy, spinal cord injuries, traumatic brain injuries affecting one side, etc. It works by constraining unaffected extremity by using a mitt, armrest or specially fabricated glove, thus compelling the use of affected extremity. CIMT has been reported to improve motor function, kinematics, and arm use by including changes in brain structure and function. However, the original protocol has been changed over the years, including the constraint types, total duration for practising the tasks and the use of a transfer-package technique.

CIMT is based on the "learned non-use" theory. In the initial stages after a stroke, learned non-use occurs as patients begin to compensate for the difficulty of using impaired limbs by increasing their reliance on intact limbs. It has been shown that this compensation prevents the recovery of impaired limb function.
CIMT helps enhance gait parameters such as gait ability, speed, momentum and quality, and brain neurophysiological function. One of the difficulties with CIMT protocol is the proper identification of sufficient exercise intensity to induce changes in neuroplasticity and motor functional outcomes recovery. This is because initially both upper and lower-limb CIMT protocols used the exercise time unit duration as a measure of exercise intensity. Especially in lower limb CIMT, practice time ranges from a few minutes to 6 hours per day.

The role of CIMT in improving upper extremity functions has been studied in detail. The protocol designed for upper extremity is practical because of unilateral use of upper limbs in most ADLs. In lower extremities, for ADLs, especially during ambulation, both are used simultaneously. Therefore, the application for ADLs of CIMT protocol is difficult. The promising effects of CIMT in improving upper extremity (UE) motor functions have convinced the neuroscience-community to think about developing the CIMT protocol for the lower limbs. Few studies have been conducted to find out the role of CIMT in lower extremity in improving motor functions, balance, and gait parameters. Few studies with modification of CIMT protocol for use in lower limb post stroke have also been conducted. As modification of CIMT, shorter duration of constraint and practicing of tasks have been reported. Thus, there is a need for randomised controlled trials to check the effects of CIMT on stroke population lower extremity with properly defined time duration and intensity; sufficient and well-designed studies can help establish higher level of evidence.

The previous reviews had included all kinds of studies. Whereas, the authors here only included RCTs. The primary aim of this review was to determine the effects of CIMT on the gait, balance, and motor functions of lower extremity in post-stroke patients. The secondary aim was to determine the optimal dosage, application time and duration of CIMT in lower extremity in stroke.

**METHODOLOGY**

The protocol of the review was registered on PROSPERO (CRD42021185218). Search was conducted from 1999 to 2022. RCTs published in English language were considered. All trials which enrolled adult patients (>18 years) with a confirmed diagnosis of stroke (all types) and used CIMT as the intervention to study the effect on balance, gait, and motor functions of lower extremity in patients with stroke were included. The intervention was compared with no intervention, routine stroke care or conventional treatment like active and passive range of motion exercises and strengthening exercise or a different form of device. Medline (July 1999-2021), Pedro (December 2000-2020), Google Scholar (February 1999-2022) and Cochrane Library (February 2000-2022) were searched. Search strategy (keywords and Boolean operators) used were: stroke or cerebrovascular accident (CVA) or cerebrovascular accidents (VAS) or cerebrovascular apoplexy or vascular accident, brain or brain vascular accident or cerebrovascular stroke or cerebral stroke or acute stroke or acute cerebrovascular accident or chronic stroke or chronic cerebrovascular accident and CIMT or constraint-induced movement therapy or mobility limitation or learned non used or constraint induced movement therapy and balance or posture equilibrium or balance, postural or postural equilibrium or musculoskeletal equilibrium or postural control or posture control and gait or gait; paces or walking or walking speeds or gait speed or walking pace or neurologic gait or gait dysfunction or spastic gait or gait analyses and motor function or motor control or motor skill or motor activities.

The results were imported into Mendeley, and duplicates were removed. Full texts of 34 studies were read, included or excluded on the basis of inclusion and exclusion criteria, and finally full texts of the remaining articles were reviewed and were labelled as relevant, irrelevant, or unsure. Disagreement was resolved by discussion between authors. The reason for excluding the studies was documented and shared with all the authors. Only studies published in English language were included. The full process of including and excluding data was recorded in PRISMA flowchart (Figure 3).

Two authors of the review extracted data individually from the studies included. Data were recorded on a data collection form which included authors’ name and year, participants’ age, total number of participants, number of total male and female participants, study duration and dosage of intervention, intervention given and its comparison, major outcome measures and their mean score and finally the result of main outcomes.

Initial search identified 1155 potential studies. Four-hundred and four were duplicates. Four authors screened titles and abstracts of these studies, and 370 studies were excluded. Thirty-four full text articles were read and twenty-six studies were excluded. The exclusion criteria were that outcome measures were not specific for lower extremity gait, balance and motor function, study design was either case series, case report, quasi or single case studies, non-stroke population, not having CIMT as intervention and incomplete/ongoing/only protocol or without analysis, etc.

Two authors assessed the methodological quality of the included studies with Cochrane Risk of bias tool. The parameters assessed were concealment of allocation, blinding participants and personnel, random sequence generation, blinding outcome assessment, incomplete results data, and selective results reporting.

All included studies were rated as low risk of bias for allocation concealment and blinding of participants and personnel was graded as low risk in 4 studies. Two studies were graded at high risk and two were graded with unclear evidence risk of bias. Six studies were graded at high risk of bias for random sequence generation and only two had low risk of bias for this parameter. Blinding of outcome assessment was graded at low risk of bias in three studies, high risk of bias in four studies, and one trial was graded as unclear in this risk of bias. Six trials were graded at low risk of bias for incomplete outcome
data, and two trials were graded as unclear. All included trials were graded at low risk for selective outcome reporting, other biases were graded at low risk for 6 studies, and unclear risk in one (Figure 1 and 2). The outcome tools were all relevant, valid, and reliable scales. For balance, single-leg stance test (SLST), step-test, functional-reach test (FRT), timed-up and go test (TUG), berg-balance scale (BBS) were selected, instrumented measurement tools for measuring posture sway, weight distribution and posture control ability. For gait tools, spatial-temporal gait parameters, kinematic gait parameters, kinetic gait parameters, 10-meter walk test, functional gait assessment, 3D gait analysis and 2D gait analysis, observational gait analysis (OGA), dynamic gait index, and the hemiplegic gait analysis form (HGAF) were included. For motor function assessment of lower extremity, possess Meyer assessment, 6-minute walk test (6MW), river mead mobility, muscle strength and motor-assessment scale (MAS) and modified Ashworth scale were used.

RESULTS

Eight RCTs (247 participants, of either gender and aged >50 years) were selected for the final analysis. The number of participants per study ranged from 18 to 58, Table I. One study with 26 participants compared Lokomat® robotic-assisted gait training constraint, with conventional training based on a pattern of symmetrical kinematic. The robotic training had negative and positive kinematic constraints for smallest (non-paretic) and largest (paretic) range of motion respectively to produce asymmetry of the hip and knee flexion/extension and forcing the paretic-limb to function (group Lokomat® was utilised).

Da Silva Filho and Andrade de Albuquerque conducted a trial with 19 participants and compared the effects of transfer body weight on the paretic-limb with load-discharge exercises on the treadmill with load to restrain the non-paretic ankle for the experimental group and load-free treadmill training for the conventional treatment group.

In an RCT with 36 participants divided into three groups, game-based CIMT was utilised. The intervention group played ski-salmon and soccer-heading games on Wii Fit. Individuals put their feet in the centre of 2 Wii Balance Boards (WBB) placed 31 cm (about 1.02 ft) apart.
### Table I: Characteristics of the included studies.

<table>
<thead>
<tr>
<th>Author (year)</th>
<th>Participants (age mean ± SD, Male / Female)</th>
<th>Study duration / dosage</th>
<th>No. of participants</th>
<th>Intervention</th>
<th>Comparator</th>
<th>Outcome measures</th>
<th>Mean / median score</th>
<th>Main outcomes and results</th>
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<tbody>
<tr>
<td>Bonnyaud et al. 2014</td>
<td>50.7 ± (11.8) years, 17M/9F</td>
<td>One time intervention for 30 minutes of gait training with Lokomat® constraint training, experimental training, LE with a negative kinematic constraint was applied to the non-parietal limb (smallest range of motion as possible) and a positive kinematic constraint was applied to the paretic limb (largest range of motion as possible) to impose the largest degree of hip and knee flexion/extension asymmetry between the paretic and non-paretic limbs during the bipedal gait training</td>
<td>26 chronic strokes</td>
<td>Robotic-assisted gait training (Lokomat®) asymmetric restraint paradigm</td>
<td>Conventional gait training</td>
<td>1. Peak knee flexion paretic side (<em>) Exp group mean ± SD = 45.9 (6.1), Cont group mean = 34.2 (7.6) and Peak ankle plantar flexion paretic side (</em>) Exp = 10.3 (7.4) &amp; cont. = 19.6 (6.6). 2. Vertical GRF single-support phase paretic side (Nm/kg) cont group: 0.942 (0.03)</td>
<td>1. Peak knee flexion on the affected side increased for experimental group (p &lt; 0.04). 2. Significant effect of time, in both groups, on peak knee extension (p = 0.005) and peak ankle plantar flexion (p = 0.02) on the paretic side. No statistically significant differences between the two training conditions (LE and LC) for any of the spatio-temporal parameters. 3. Vertical GRF single-support phase paretic side (Nm/kg) increased for cont. group.</td>
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<tr>
<td>da Silva et al. 2017</td>
<td>56.5 ± (10.0) years, 23M/15F</td>
<td>Load discharge exercises involved the transfer of body weight on the affected-limb in both the antero-posterior and latero-lateral direction in the standing position, consisting of 3 sets of 10 repetitions in each direction and 30-min treadmill training for two weeks with mass attached around the non-paretic, with load equivalent to 5% of the individual body weight</td>
<td>38 (sub-acute stroke)</td>
<td>Treadmill training with load to rest position of the non-paretic ankle</td>
<td>Treadmill training without load</td>
<td>Berg Balance Scale (BBS), Timed-Up And Go Test (TUG), kinematic parameters</td>
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<tr>
<td>Choi et al. 2017</td>
<td>Game Based CIMT = 61.25 ± 5.59 years (General game based training groups underwent training for 30 minutes a day 3 days a week for 4 weeks modifying the games with a focus to use parietic limb by applying the functional limitation of CIMT without the fixation of the non-paralysed side) Game-based CIMT and general game</td>
<td>36 (chronic stroke)</td>
<td>Game-based CIMT consists of ski slalom and soccer heading games from the Wii fit applying the functional limitation of CIMT without the fixation of the non-paretic side of the knee joint by modifying the game</td>
<td>Conventional physical therapy</td>
<td>Weight bearing symmetry through WBB and Matlab program, balance through FRT, limits of lateral stability (mFRT), and functional parameters</td>
<td>COP displacement post intervention for game-based CIMT group: mean ± SD</td>
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<td>Zhu et al. 2016</td>
<td>m-CIMT group = 59.18 ± 6.97 years, Control group = 58 ± 7.34 years (CIMT = 200-2000 minutes per day, indoor walking 20 min and about 1000m per day, not faster than 1.3 km/h, climbing up and down stairs = 18 steps/time, balance training &amp; totally four times/day. 3 days/week for total 4 weeks) Constraint duration or mode is not mentioned</td>
<td>22 (sub-acute stroke)</td>
<td>m-CIMT gait training with sit to stand transfers by using a suitable chair (controlling the position of the paretic leg), indoor walking under physical therapy guidance, climbing up and down stairs training</td>
<td></td>
<td>Gait kinematic parameters</td>
<td>Gait kinematic parameters post intervention mean ± SD: Velocity (m/s) = 0.44 ± 0.22 Step width (m) = 0.16 ± 0.04 Step length (affected side) (m) = 0.32 ± 0.09 Step length (non-affected side) (m) = 0.35 ± 0.11 Paraplegic swing time (Nkigat cycle) = 37.28 ± 6.83 Non-paraplegic swing time (Nkigat cycle) = 29.80 ± 6.58 Cont:Velocity (m/s) = 0.28 ± 0.11 Step width (m) = 0.18 ± 0.05 Step length (affected side) (m) = 0.28 ± 0.06 Step length (non-affected side) (m) = 0.26 ± 0.07 Paraplegic swing time (Nkigat cycle) = 35.26 ± 7.12 Non-paraplegic swing time (Nkigat cycle) = 23.34 ± 7.51</td>
<td>Gait parameters were significantly improved after four weeks of m-CIMT (p &lt; 0.05).</td>
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Games were modified so that small movement on the unaffected side could create large movement on screen character which made it difficult to continue the game as stroke survivors must lower the weight-shift of non-paralysed side to conduct the movements of the ski slalom and soccer heading games by applying the functional constraint of CIMT instead of fixing the non-paralysed side of the knee joint by modifying games. The ‘general game-based’ training group went through the training using one of the WBBs (WiI Balance Boards) without changing the game settings and the control group received conventional physical therapy exercises.

One study with 22 participants applied modified-CIMT gait training to the participants with sit-to-stand transfers with...
use of suitable chair, controlling the position of the paretic-leg compared to the control group, receiving standardised comprehensive rehabilitation treatment including passively performed exercise, range of motion (ROM) exercises and stretching, active range of motion exercise (AROMs) training, balance and gait training, rehabilitation guidance and education, and some additional therapy such as position-transfer practice under the supervision of family caregivers.  

One study with 58 participants applied modified CIMT with difference of repetition measurement in one experimental group and total duration count in other experimental group and no control group was introduced in the study.  

One study with 30 participants, in experimental group 1° Phase Neuro Developmental technique (NDT), 2° Phase: mCIMT + NDT, and the intervention of mCIMT included functional activities practiced intensely, limited use of the non-paretic extremity and conveying the gains from the training to the patient’s real-life situations with “transfer-package while the control group received only NDT.  

One study with 19 participants had checked the upper extremity constraint effect on balance outcomes and the control group had no constraint of upper extremity.

One study with 18 participants constrained the intervention group by providing modified shoe-insoles made of medium hardness ethylene vinyl acetate and covered with Poron® layer on the un-affected lower limb during all ADLs. The control group had been treated conventionally.

One study used 3D gait analyses and the other used 16-camera Eagle Motion Analysis System and Qualysis Motion System to assess the kinematic, kinetic, and spatiotemporal parameters of gait. One study used MatLab program and Wii fit for assessment of weight bearing symmetry. Affected side weight bearing (WB) was analysed by the computerised force-plate system with Balance Master.

Balance was evaluated by Berg Balance Score (BBS) in four studies, timed-up and go test in 3 studies, and functional reach test in one study. Fugl Meyer assessment (FMA) was used in two studies for motor functions. Rivermead mobility index (RMI), modified Ashworth scale (MAS), walking speed using Ten-Metre Walk Test, and endurance using the Six-Minute Walk Test (6MWT) in one study were evaluated. The Motricity index score was used for lower extremity strength in one study.

In four trials, 151 participants were assessed for balance through different balance assessment tools like BBS, timed-up and go test, functional reach test and modified functional reach test (mFRT). BBS was used by four studies and they reported no significant difference between the groups. Timed-up and go test was used for assessment of balance in three trials which was statistically significant for constraint experimental group and no interaction between the groups was found in the two trials.

Two studies with 88 participants reported motor functions in strength, endurance, spasticity, and mobility. One trial reported no significant difference for any motor activity except decrease in knee extensor spasticity and the Motricity Index score was significantly improved for CIMT group.

Four trials used the constraint only during treatment sessions. One trial did not report any duration for constraint used. One study checked effects of constraint upper limb on balance mobility with 6 hours of constraint by using sling. Two studies used shoe lift whole leg orthosis as constraint for lower limb for 90% of waking hours and for all daily activities. No specific dosage was mentioned for lower limb CIMT.

**DISCUSSION**

This systematic review aimed to find out the effects CIMT on different outcomes of lower limbs after stroke. The number of RCTs available for assessing the effects of CIMT on lower extremity has increased over the past years, but the studies included were poor in relevance of findings and quality of reporting. Only 8 out of 1155 studies were found relevant in assessing desired outcomes of motor functions, balance, and gait. The applicability of CIMT in lower extremity characterised by studies included is uncertain. More specified dose, methods of constraint and treatment should be defined to have a certainty of its applicability in improving motor functions of lower extremity after stroke.

Different constraints used by the studies included in the review were robotic-assisted gait training through Lokomat® constraint training having negative and positive kinematic constraint, load discharge exercises, shoe insoles, modified...
Effects of constraint-induced movement therapy and application time and duration of intervention for lower extremity in stroke

chair and game based CIMT for managing transfer on paretic limb. There was no significant difference in improving balance in CIMT and comparator group except for COP displacement, and symmetrical weight bearing was significantly improved in game based CIMT group. No significant improvement was seen in kinematic gait parameters between groups, however, kinetic gait parameters were significantly improved by robotic assisted CIMT. A review conducted in 2021 on effect of lower limb CIMT in people with stroke reported that balance, mobility, speed of gait, quality of life is improved after CIMT. However, on the basis of available evidence, CIMT is only better when it comes to improving quality of life.

A review conducted in 2016 on the effect of CIMT in rehabilitation of upper extremity in stroke patients reported that evidence supporting superiority of CIMT in comparison to other rehabilitation protocols in improving upper extremity after stroke is weak. However, very few studies were found related to the effect of CIMT on lower extremity. Heterogeneity was observed while considering the dosage, intervention applied, methods used for constraining the unaffected extremity among the studies included in the current systematic review. No clear statement regarding superiority of CIMT over other treatment methods was stated in any of the RCT included in the study. No significant difference for any motor activity except decrease in knee extensor spasticity and the Motricity index score was significantly improved for CIMT group.

Dosage is important in determining function improvement, but the studies in the current systematic review did not mention a specific dose of CIMT. To develop neuroplasticity, high repetition (300 times a day/1hour) of given tasks is required. For further improvement in applicability of the CIMT, specific dose with specific tasking should be designed for lower extremity functions improvement. Equally, the number of repetitions of task practice as the measure of intensity during lower limb CIMT should be encouraged.

Millions of individuals around the world are affected by stroke which is a serious public health issue. However, rehabilitation varies widely in developing nations with multiple barriers influencing stroke rehabilitation, including human resources, evidence-based practice, proper clinical guidelines. This systematic review will be beneficial in terms of identifying the effects of lower limb constraint induced movement therapy on different outcomes with evidence-based methods of application of CIMT to promote outcomes-based intervention for developing countries.

Only a few studies have been published to evaluate the effect of CIMT on outcomes of lower extremity after stroke which was one of the important limitations of the study as the superiority or effectiveness of CIMT in improving outcomes of lower extremity after stroke cannot be clearly stated. Another limitation of the review was that it included only the review which were published in English; RCTs published in other languages could not be included because of the issue of translation.

The findings of the current systematic review have implications for both clinical practice and future research. For future, high-level studies with larger sample size and defined dose should be conducted to determine the effect of CIMT on lower extremity outcomes in stroke. For clinical practice, the number of repetitions/task practice, required to restore motor function after stroke is known, and lower limbs CIMT should be developed with use of the same number of repetitions in their protocols. Moreover, the constraints that can alter the biomechanics of lower extremity should not be used for restricting movements.

CONCLUSION

CIMT is effective in improving lower extremity outcomes in terms of balance, gait, and motor functions, however, its superiority in comparison to the control group is not significant. No specific dosage was identified through literature as each study had individualised protocol dosage.

COMPETING INTEREST:
The authors declared no competing interest.

AUTHORS’ CONTRIBUTION:
AA: Conception or design of the work, acquisition, analysis, or interpretation of data drafting and the work or revising it critically for important intellectual content, and final approval of the version to be published.
SK: Conception or design of the work, acquisition, analysis, or interpretation of data drafting and the work or revising it critically for important intellectual content, and final approval of the version to be published.
ANM: Drafting the work or revising it critically for important intellectual content and final approval of the version to be published.
RMT, RZ: Drafting the work or revising it critically for important intellectual content and final approval of the version to be published.
FAR, FAS: Drafting the work or revising it critically for important intellectual content and final approval of the version to be published.

All authors approved the final version of the manuscript to be published and agreed to be accountable for all aspects of the work.

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