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

Ayesha Afridi[1], Sana Khalid[2], Rana Muhammad Tahir[3], Rabia Zubair[1], Arshad Nawaz Malik[1], Muhammad Farooq Azam Rathore[4] and Furqan Ahmed Saddiqi[2]

[1]*Faculty of Rehabilitation and Allied Health Sciences, Riphah International University, Islamabad, Pakistan*
[2]*Department of Physical Therapy, Foundation University, Islamabad, Pakistan*
[3]*Department of Physiotherapy, Khan Research Laboratory, Islamabad, Pakistan*
[4]*Department of Rehabilitation Medicine, Armed Forces Institute of Rehabilitation Medicine, Rawalpindi, Pakistan*

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-Febraury 2022), and Cochrane Library (2000-Febraury 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*.

How to cite this article: Afridi A, Khalid S, Tahir RM, Zubair R, Malik AN, Rathore MFA, *et al.* Effects of Constraint-Induced Movement Therapy and Application Time and Duration of Intervention for Lower Extremity in Stroke: A Systematic Review. *J Coll Physicians Surg Pak* 2023; **33(12)**:1418-1425.

INTRODUCTION

Stroke is the second leading cause of global mortality and affects 15 million people worldwide each year.[1] There has been a double-fold increase in the cases of stroke in Asian, countries in past two decades.[2] 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.[3] Loss of skeletal muscle mass and function are common in patients with stroke.[4,5] It can adversely affect the mobility of the patients and hamper the performance of activities of daily living (ADLs),[6] leading to a reduced participation in daily life activities.[7] Stroke is a complex clinical condition. Advancement in complexity of healthcare intervention and provision requires different healthcare professionals to collaborate. Multidisciplinary stroke rehabilitation teamwork is fundamental to deliver effective care across the stroke pathway.[8]

Correspondence to: Dr. Muhammad Farooq Azam Rathore, Department of Rehabilitation Medicine, Armed Forces Institute of Rehabilitation Medicine, Rawalpindi, Pakistan
E-mail: farooqrathore@gmail.com
....
Received: December 15, 2022; Revised: August 31, 2023; Accepted: September 01, 2023
DOI: https://doi.org/10.29271/jcpsp.2023.12.1418

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.[1,9]

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.[10]

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.[5]

CIMT helps enhance gait parameters such as gait ability, speed, momentum and quality, and brain neurophysiological function.[11] 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.[11]

The role of CIMT in improving upper extremity functions has been studied in detail.[12-14] 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.[14,15] 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.[15,16] As modification of CIMT, shorter duration of constraint and practising of tasks have been reported.[17,18] 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,[15] 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 motions, stretching 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 (Febraury 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 flow chart (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.[11,19-21] Two studies were graded at high risk[5,22] and two were graded with unclear evidence risk of bias.[23,24] Six studies were graded at high risk of bias for random sequence generation[11,19-24] and only two had low risk of bias for this parameter.[5,23] Blinding of outcome assessment was graded at low risk of bias in three studies,[5,11,24] high risk of bias in four studies,[19-22] and one trial was graded as unclear in this risk of bias.[23] Six trials were graded at low risk of bias for incomplete outcome data,[5,11,19,21,22,24] and two trials were graded as unclear.[20,23] All included trials were graded at low risk for selective outcome reporting, other biases were graded at low risk for 6 studies,[5,11,19,21-24] and unclear risk in one (Figure 1 and 2).[25]

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, fugl meyer assessment, 6-minute walk test (6MWT), 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.[11,19-24,26] The number of participants per study ranged from 18 to 58, Table I.[15,21]

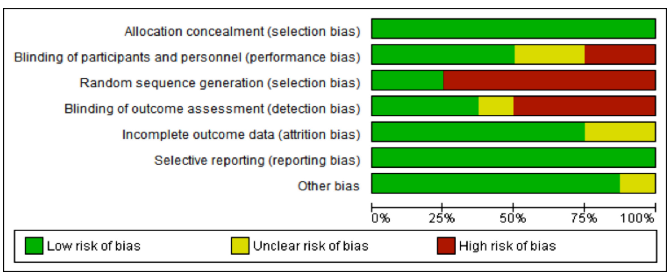

Figure 1: Graph of risk of bias: review of authors' judgments about each risk of bias item presented as percentages across all included studies.

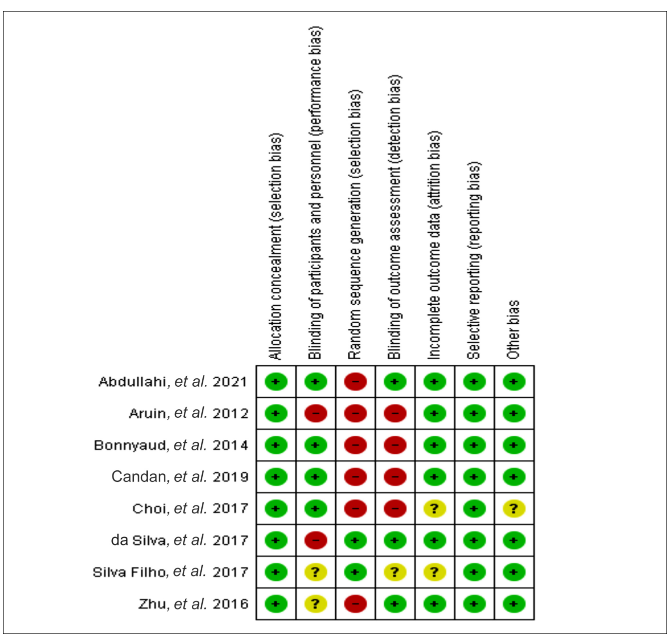

Figure 2: Summary of risk of bias.

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).[19]

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.[23]

In an RCT with 36 participants divided into three groups, game-based CIMT was utilised. The intervention group played ski-slalom 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.

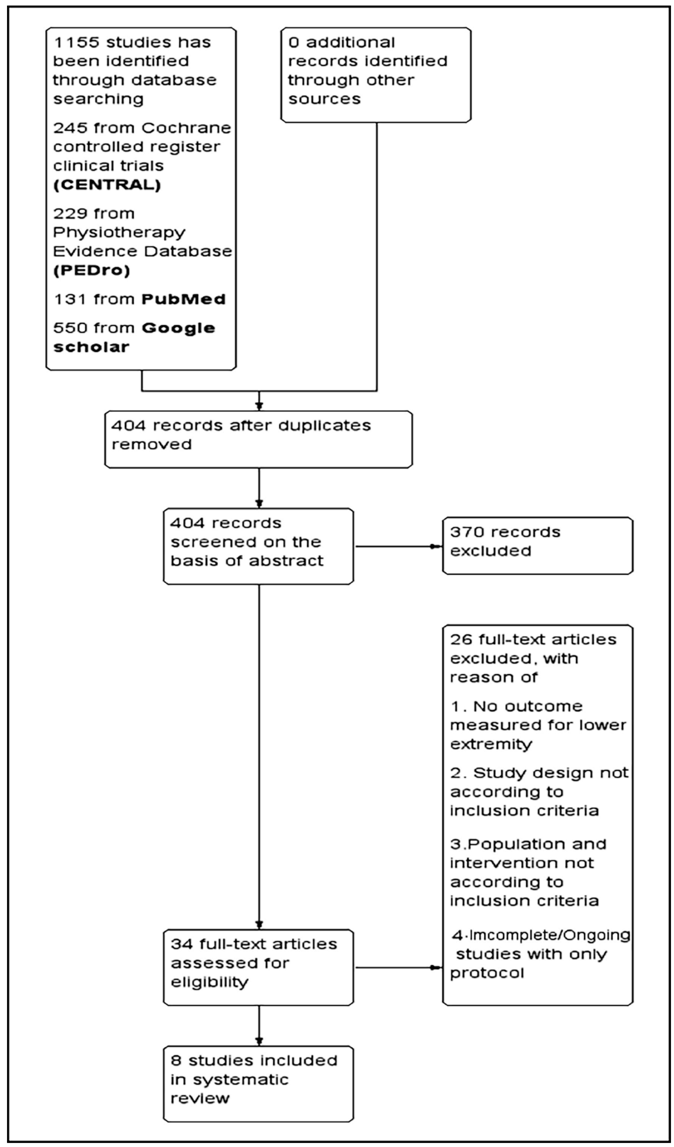

Figure 3: PRISMA flow diagram.

Table I: Characteristics of the included studies.

Author (year)	Participants age mean ± (SD), Male / Female	Study duration / dosage	No. of participants	Intervention	Comparator	Outcome measures	Mean / median score	Main outcomes and results
Bonnyaud *et al.* 2014	50.7 ± (11.8) years, 17M/9F	One time intervention for 20 minutes of gait training with Lokomat® constraint training, experimental training, LE with a negative kinematic constraint was applied to the non-paretic 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	26 chronic strokes	Robotic-assisted gait training (Lokomat) asymmetrical restraint paradigm	Conventional symmetrical Lokomat® training	3D gait analyses: 1.Kinematic gait parameters 2.Spatiotemporal gait parameters 3.Kinetic gait parameters	1.Peak knee flexion paretic side (°) Exp grp 45.9 (6.1). 2.Peak knee extension paretic side (°) Exp group −0.7 (9.7) & Con grp −2.1 (7.6) and Peak ankle plantarflexion paretic side (°) Exp −10.3 (7.4) & cont. −9.1 (6.6) 3.Vertical GRF single-support phase paretic side (N/m/kg) cont group: 0.942 (0.03)	1. Peak knee-flexion on the affected side increased for experimental group (p=0.04).2. 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. 3. Vertical GRF single-support phaseparetic side(N/m/kg) increased for cont. group
da Silva *et al.* 2017	56.5 ± [10.0] years, 23M/15F	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 ankle, with load equivalent to 5% of the individual body weight	38 (sub-acute stroke)	Treadmill training with load to restraint the non-paretic ankle	Treadmill training without load	Berg Balance Scale (BBS), Timed-Up and Go Test (TUG), kinematic parameters	BBS mean±SDExp= 52.4 ± (3.7) Cont = 52.1 ± ((3.1) No significant interaction between groups (p = 0.315, 95% CI -2.5 to 3.1) TUG test mean ± SD Exp = 14.3 ± (7.5) Cont = 16.3 ± (9.2) No significant interaction between group (p = .967, 95% CI -9.2 to 3.2) Kinematic parameters post intervention:Turn speed m/s Exp = 0.54(.20), cont = .47(.22) Stride length (m) Exp = .71(.21), cont = .65(.25) Stride time (s) exp = 1.36(.26), cont.48(.29) Stride width (m) exp = .20(.04), cont.18(.03) Symmetry ratio of swing time ex p= 1.39(.61), cont = 1.25(.40)	BBS statistically improved from baseline to post intervention for both groups but no significant interaction between groupsTUG statistically improved from baseline to post-intervention for both groups but no significant interaction between group Kinematic parameters showed significant effect within grp in the turn speed (F = 35.13, p <.001), stride length (F = 29.71, p <.001) and stride time (F = 13.42, p <.001) but no significant interaction between group
Choi *et al.* 2017	Game Based CIMT = 61.25 ± 5.59 years General game Based = 62.58 ± 5.51 years Control = 61.92 ± 6.08 years, 21M/15F	Game-based CIMT and general game based training groups underwent training for 30 minutes a day 3 days a week for 4 weeks modifying the games with focus to use paretic limb by applying the functional limitation of CIMT without the fixation of the non paralysed side	36 (chronic stroke)	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-paralysed side of the knee joint by modifying games.General game-based group received Wii fit games therapy without modifying the game	Conventional physical therapy	Weight bearing symmetry through WBB and MatLab program, balance through (FRT), limits of lateral stability (mFRT), and functional mobility and dynamic balance (TUG)	COP displacement post intervention game-based CIMT group: mean ± SD ML (cm) = 0.77 ± 0.31 AP (cm) = 0.67 ± 0.42 Sway means velocity (cm/s) = 2.26 ± 0.37 Sway area (cm2) = 0.16 ± 0.18 SWB = 0.95 ± 0.10 COP displacement for general game group: mean ± SD ML (cm) = 1.15 ± 0.52 AP (cm) = 0.95 ± 0.44 Sway means velocity (cm/s) = 2.35 ± 0.74 Sway area (cm2) = 0.14 ± 0.11SWB = 0.85 ± 0.13COP displacement for control group: mean ± SD ML (cm) = 1.17 ± 0.70AP (cm) = 0.83 ± 0.23 Sway means velocity (cm/s) = .48 ± 0.43 Sway area (cm2) = .25 ± 0.36 SWB = 0.85 ± 0.13 FRT (cm) post intervention mean ± SD Game based CIMT group = 14.87 ± 4.28 General game group = 15.27 ± 4.60 Control = 15.71 ± 7.37 mFRT (cm) post intervention mean ± SDGame based CIMT group= 13.12 ± 4.34 General game group = 12.56 ± 3.53 Control = 13.95 ± 3.83 TUG (sec) post intervention mean ± SD Game based CIMT group = 14.94 ± 6.72 General game group = 13.63 ± 3.58 Control = 12.92 ± 3.46	All 3 groups showed significant improvement in anterior-posterior axis (AP-axis) distance, sway area, weight-bearing symmetry, FRT, mFRT, and TUG test after the intervention (p <0.05). Post hoc analysis revealed significant differences in AP-axis, and sway area, weight bearing symmetry of the game-based CIMT group compared with the other group (p <0.05)
Zhu *et al.* 2016	m-CIMT group = 59.18 ± 7.34 yearsControl group = 58 ± 6.97 years, 16M/6F	2 hours/day Transfer 200–300 times 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 & totally four times/ day. 5days/week for total 4 weeks Constraint duration or mode is not mentioned	22 (sub-acute stroke)	m-CIMT gait training with sit to stand transfers by using a suitable chair (controlling the position of the paretic leg), indoor walking training under physical therapy guidance, climbing up and down stairs training	Standardised comprehensive rehabilitation treatment with passive exercise: range of motion exercises and stretching exercises; active exercise: balance training and walking training; rehabilitation education and guidance, and some adjuvant therapy such as position transfer practice under families' supervision	Gait kinematic parameters	Gait kinematic parameters post intervention mean ± SD:Exp: 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 Paretic swing time (%gait cycle = 37.28 ± 6.83 Non-paretic swing time (%gait cycle) = 29.80 ± 6.58 Cont:Velocity (m/s) = 0.28 ± 0.11Step 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 Paretic swing time (%gait cycle = 35.26 ± 7.12 Non-paretic swing time (%gait cycle = 23.34 ± 7.57	Gait parameters were significantly improved after four weeks of m-CIMT (p<0.05)

Author (year)	**Participants age mean ± (SD), Male / Female**	**Study duration / dosage**	**No. of participants**	**Intervention**	**Comparator**	**Outcome measures**	**Mean / median Score**	**Main outcomes and results**
Abdullahi *et al.* 2021	Frequency group = 50:2 ± 13:9 years Duration group = 47:8 ± 14:7 25M/33F	Stepping forward, backward stepping, side stepping, ball kicking, and stair climbing were performed by both groups. Frequency group performed all activities 40-times each session (total 200 repetitions), 3 sessions/day (total 600 repetitions), five days/week, and with constraint application of only in practice sessions for 4 consecutive weeks. Other group performed modified CIMT with three hours of task practice/day, 5 days/week, and with constraint application during practice sessions for 4 consecutives weeks. constraint was just to tell the patients not to use unaffected limb during sessions	58 (acute, subacute, and chronic) strokes	Both groups were given modified constraint-induced movement therapy with difference of repetition measurement in one group and total duration count in another group	No control groups	FMA-LE, BBS, Rivermead Mobility Index (RMI), knee extensor spasticity assessed using the modified Ashworth scale (MAS), walking speed measured using the Ten-Meter Walk Test (10MWT), and endurance measured using the Six-Minute Walk Test (6MWT)	Post-intervention median (IQR): frequency group: FMA-LE = 64 (7), BBS = 51 (4), functional mobility (RMI) = 13 (2), knee extensor spasticity (MAS) = 0 (0), Walking speed = 0.66 (0.87) &Walking endurance = 205 (117). duration group: FMA-LE = 64 (8), BBS = 50 (7), functional mobility (RMI) = 13 (0), knee extensor spasticity (MAS) = 0 (0), Walking speed = 0.66 (0.62) & Walking endurance = 226 (115)	There was no significant difference between groups for any variable except knee extensor spasticity which was decreased in frequency group
da Silva Filho *et al.* 2017	Median (IQR): Group without constraint: 59.5 years (52.0;66.9), Group with constraint: 52 years (42.4; 61.5), 10M/9F	3 times a week for 4 consecutive weeks to 40 minutes of the paretic opper limb specific training. The patient remained sitting in front of a table and each task was timed. Maximum allowable time was 3 minutes to complete each task. constraint: daily use of constraint for 6 hours by using sling on upper limb.	19 (chronic CVA)	Group 2 constraint was applied for upper extremity	Group 1 no constraint was applied to upper extremity	Berg Balance Scale, the secondary outcomes were gait speed, timed "Up and Go" (TUG) and going up and down stairs	Median (IQ) Post intervention: 1. BBS Group 1 without constraint 48.3 (41.78; 54.82) Group 2 with constraint, 51.8 (48.51; 55.27) 0.591 2. TUG Group 1 without constraint 19.8 (12.78; 26.81), Group 2 with constraint 11.5 (9.29; 13.89) 0.018 3. Stairs Group 1 without constraint 21.1 (15.61; 26.61), Group 2 with constraint 13.0 (9.79; 16.36) 0.014 4. Gait speed Group 1 Without constraint 0.7 (0.48; 0.93), Group 2 with constraint 1.0 (0.81; 1,19) 0.050	No significant difference for most of the variables studied, except for TUG and going up and down stairs, which was improved in group with constraint
Candan *et al.* 2019	mCIMT Group (n=15) Mean ± SD :55.13 years ±14.70, Control Group (n=15) Mean±SD: 57.67 years ± 12.20, 14M/16F	120 minutes/session, 5 sessions/week for 6weeks. restriction: 1. knee immobilisation of the nonparetic extremity with a whole-leg orthosis 2. shoe insert with a 1 cm lift. usage: during treatment sessions and 90% of participants' waking hours	30 (subacute and chronic CVA)	Experimental Group: 1st Phase NDT, 2nd Phase: mCIMT + NDT, interventions in m CINT (the functional activities practiced intensively, constricted use of the normal limb, and transmitting the beneficial effects from the training session to the patient's real life environment with "transfer package"	Control Group: NDT.	The Motricity Index score	Post-intervention mean S.D Experimental group: 61.93 ± 12.53, Control group: 58.07±14.35	Significant difference between groups with improvement in mCIMT group
Aruin *et al.* 2012	57.7 ± 11.9 years, 14M/4F	6 weeks, 1 session of 60 minutes/week	18 (acute, subacute & chronic)	Experimental group:0.6 cm fabricated full-shoe insoles made of medium hardness with ethylene vinyl acetate &covered with Poron® on the unaffected lower extremity during all daily activities	Traditional physiotherapy	Balance Master computerised force platform system (Balance Master®, NeuroCom International, Clackamas, Gait velocity, Fugl-Meyer Test (FMT) & Berg Balance Scale (BBS)	Weight bearing, experimental group = 45.4 ± 2.6 and 39.6 ± 2.64 in the control group. gait velocity = experimental group reaching 0.488 ± 0.7 m/s and control group (0.36 ± 0.8 m/s). berg balance scale = experimental group 45.0 ± 4.1 and control group 34.0 ± 3.5. FMT scores 76.7 ± 3.30 experimental and 75.7 ± 2.9 control group	Weight bearing and gait velocity in experimental group increased on affected side

CIMT: Constraint-induced movement therapy, Cont group: Control Group, COP: Centre of Pressure, Exp grp: Experimental group, F: Female, FRT: Functional Reach Test, GRF: Ground Reaction Force, LE: Lower extremity, M: Male.

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.[24] 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.[15] One study with 30 participants, in experimental group 1st Phase Neuro Developmental technique (NDT), 2nd Phase: mCIMT + NDT, and the intervention of mCIMT included functional activities practised 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.[21] 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.[23]

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.[22]

One study used 3D gait analyses[19] and the other used 16-camera Eagle Motion Analysis System[24] and Qualisys Motion System[23] to assess the kinematic, kinetic, and spatiotemporal parameters of gait. One study used MatLab program and Wii fit for assessment of weight bearing symmetry.[25] Affected side weight bearing (WB) was analysed by the computerised force-plate system with Balance Master.[22]

Balance was evaluated by Berg Balance Score (BBS) in four studies,[5,11,22,23] timed-up and go test in 3 studies,[20,23,26] and functional reach test[20] in one study. Fugl Meyer assessment (FMA) was used in two studies for motor functions.[11,22] 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.[11] The Motricity index score was used for lower extremity strength in one study.[21]

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).[5,11,20,23] BBS was used by four studies and they reported no significant difference between the groups.[5,11,22,23] Timed-up and go test was used for assessment of balance in three trials which was statistically significant for constraint experimental group[5] and no interaction between the groups was found in the two trials.[20,23] Functional reach test and modified functional reach test was used in a single study and results reported no significant interaction between groups.[20] COP displacement and symmetrical weight-bearing were reported to be significantly different in AP-axis, sway area, weight-bearing symmetry of the game-based CIMT group compared with the other group.[20] Five trials with 163 participants had reported gait in terms of kinetic, kinematic, spatio-temporal, and gait speed parameters. The kinetic parameter was significantly different in the robotic CIMT group for only vertical GRF single-support phase paretic side.[19] Three studies reported kinematic gait parameters and it showed significant difference between groups for Peak knee flexion paretic side.[19] In one trial, no significant interaction between groups was found[23] and there was significant improvement in gait after intervention in the nonparetic side with respect to speed, step width step length and swing time percentage in m-CMIT group as compared to the control group in another study.[24] Gait speed was reported in two trials with no significant difference between groups.[24,26]

Two studies with 88 participants reported motor functions in strength, endurance, spasticity, and mobility.[11,21] One trial reported no significant difference for any motor activity except decrease in knee extensor spasticity[11] and the Motricity Index score was significantly improved for CIMT group.[21]

Four trials used the constraint only during treatment sessions.[11,19,20,23] One trial did not report any duration for constraint used.[24] One study checked effects of constraint upper limb on balance mobility with 6 hours of constraint by using sling.[26] Two studies used shoe lift whole leg orthosis[21] as constraint for lower limb for 90% of waking hours[21] and for all daily activities.[22] No specific dosage was mentioned for lower limb CIMT.[21,22]

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.[11,19,21-26]

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 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.[19,20,23] 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.[15]

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.[12] 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,[11] 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.[24]

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 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.
ANM: 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.

REFERENCES

1. Li Q, Wu H, Yue W, Dai Q, Liang H, Bian H, *et al*. Prevalence of stroke and vascular risk factors in China: A nationwide community-based study. *Sci Rep* 2017; **7(1)**:1-7. doi: 10. 1038/s41598-017-06691-1.
2. Kamalakannan S, Gudlavalleti ASV, Gudlavalleti VSM, Goenka S, Kuper H. Incidence and prevalence of stroke in India: A systematic review. *Indian J Med Res* 2017; **146(2)**: 175. doi: 10.4103/ijmr.IJMR_516_15.

3. Xing L, Jing L, Tian Y, Liu S, Lin M, Du Z, *et al*. High prevalence of stroke and uncontrolled associated risk factors are major public health challenges in rural northeast China: A population-based study. *Int J Stroke* 2020; **15(4)**:399-411. doi: 10.1177/1747493019851280.
4. Su Y, Yuki M, Otsuki M. Prevalence of stroke-related sarcopenia: A systematic review and meta-analysis. *J Stroke Cerebrovasc Dis* 2020; **29(9)**:105092. doi: 10.1016/j.jstroke-cerebrovasdis.2020.105092.
5. E Silva EMGS, Ribeiro TS, da Silva TCC, Costa MFP, Cavalcanti FAD, Lindquist ARR. Effects of constraint-induced movement therapy for lower limbs on measurements of functional mobility and postural balance in subjects with stroke: A randomized controlled trial. *Top Stroke Rehabil* 2017; **24(8)**:555-61. doi: 10.1080/10749357.2017.1366011.
6. Zakharov AV, Bulanov VA, Khivintseva EV, Kolsanov AV, Bushkova YV, Ivanova GE. Stroke Affected lower limbs rehabilitation combining virtual reality with tactile feedback. *Front Robot AI* 2020; **7**:81. doi: 10.3389/frobt.2020.00081.
7. Carey LM, Matyas TA, Baum C. Effects of somatosensory impairment on participation after stroke. *Am J Occup Ther* 2018; **72(3)**:7203205100p1-10. doi: 10.5014/ajot.2018.025114.
8. Singh R, Küçükdeveci AA, Grabljevec K, Gray A. The role of interdisciplinary teams in physical and rehabilitation medicine. *J Rehabil Med* 2018; **50(8)**:673-8. doi: 10.2340/16501977-2364.
9. Wittenberg GF, Chen R, Ishii K, Bushara KO, Taub E, Gerber LH, *et al*. Constraint-induced therapy in stroke: Magnetic-stimulation motor maps and cerebral activation. *Neurorehabil Neural Repair* 2003; **17(1)**:48-57. doi: 10.1177/0888439002250456.
10. Corbetta D, Sirtori V, Castellini G, Moja L, Gatti R. Constraint-induced movement therapy for upper extremities in people with stroke. *Cochrane Database Syst Rev* 2015; **2015 (10)**:CD004433. doi: 10.1002/14651858.CD004433.pub3.
11. Abdullahi A, Aliyu NU, Useh U, Abba MA, Akindele MO, Truijen S, *et al*. Comparing two different modes of task practice during lower limb constraint-induced movement therapy in people with stroke: A randomised clinical trial. *Neural Plast* 2021; **2021**:6664058. doi: 10.1155/2021/6664058.
12. Etoom M, Hawamdeh M, Hawamdeh Z, Alwardat M, Giordani L, Bacciu S, *et al*. Constraint-induced movement therapy as a rehabilitation intervention for upper extremity in stroke patients: Systematic review and meta-analysis. I*nt J Rehabil Res* 2016; **39(3)**:197-210. doi: 10.1097/MRR.0000000000000169.
13. Page SJ, Levine P, Leonard AC. Modified constraint-induced therapy in acute stroke: A randomised controlled pilot study. *Neurorehabil Neural Repair* 2005; **19(1)**:27-32. doi: 10.1177/1545968304272701.
14. Nijland R, Kwakkel G, Bakers J, van Wegen E. Constraint-induced movement therapy for the upper paretic limb in acute or sub-acute stroke: A systematic review. *Int J Stroke* 2011; **6(5)**:425-33. doi: 10.1111/j.1747-4949.2011.00646.x.
15. Abdullahi A, Truijen S, Umar NA, Useh U, Egwuonwu VA, Van Criekinge T, *et al*. Effects of lower limb constraint induced movement therapy in people with stroke: A systematic review and meta-analysis. *Front Neurol* 2021; **12**:343. doi: 10.3389/fneur.2021.638904.
16. Ribeiro T, Oliveira D, Ferreira L, Costa M, Lacerda M, Lindquist A. Constraint-induced movement therapy for the paretic lower limb in acute and sub-acute stroke. *Austin J Cerebrovasc Dis Stroke* 2014; **1(6)**:1-6.
17. Abdullahi A. Neurophysiological effects of constraint-induced movement therapy and motor function: A systematic review. *Int J Ther Rehabil* 2018; **25(4)**:167-76. doi: 10.12968/ijtr.2018.25.4.167.
18. Dromerick AW, Lang CE, Birkenmeier RL, Wagner JM, Miller JP, Videen TO, *et al*. Very early constraint-induced movement during stroke rehabilitation (VECTORS): A single-center RCT. *Neurology* 2009; **73(3)**:195–201. doi: 10.1212/WNL.0b013e3181ab2b27.
19. Bonnyaud C, Zory R, Boudarham J, Pradon D, Bensmail D, Roche N. Effect of a robotic restraint gait training *versus* robotic conventional gait training on gait parameters in stroke patients. *Exp Brain Res* 2014; **232(1)**:31-42. doi: 10.1007/s00221-013-3717-8.
20. Choi HS, Shin WS, Bang DH, Choi SJ. Effects of game-based constraint-induced movement therapy on balance in patients with stroke: A single-blind randomised controlled trial. *Am J Phys Med Rehabil* 2017; **96(3)**:184-90. doi: 10.1097/PHM.0000000000000567.
21. Candan SA, Livanelioğlu A. Efficacy of modified constraint induced movement therapy for lower extremity in patients with stroke: Strength and quality of life outcomes. *Turk J Physiother Rehabil* 2019; **30(1)**:23-32. doi: 10.21653/tfrd.406349.
22. Aruin AS, Rao N, Sharma A, Chaudhuri G. Compelled body weight shift approach in rehabilitation of individuals with chronic stroke. *Top Stroke Rehabil* 2012; **19(6)**:556-63. doi: 10.1310/tsr1906-556.
23. da Silva Filho EM, Andrade de Albuquerque. Influence of constraint-induced movement therapy on functional performance in stroke patients: A randomised clinical trial. *Fisioter e Pesqui* 2017; **24**:184-90.
24. Zhu Y, Zhou C, Liu Y, Liu J, Jin J, Zhang S, *et al*. Effects of modified constraint-induced movement therapy on the lower extremities in patients with stroke: A pilot study. *Disabil Rehabil* 2016; **38(19)**:18939. doi: 10.3109/09638288.2015.1107775.
25. Choi MS, Kim YM, Lee JS. Effects of treadmill gait training according to different inclination on pulmonary function in patients with chronic stroke. *Indian J Public Heal Res Dev* 2020; **11**:7.
26. Kim DG, Cho YW, Hong JH, Song JC, Chung H, Bai D, *et al*. Effect of constraint-induced movement therapy with modified opposition restriction orthosis in chronic hemiparetic patients with stroke. *Neuro Rehabilitation* 2008; **23(3)**:239-44.

• • • • • • • • • •