



Bilateral arm training versus constraint induced therapy on upper limb function in stroke patients: a systematic review and meta-analysis

Wael Salah Tawfik Shendy, Dalia Mohammed Mosaad, Moataz Mohamed El Semary, Amira Mohammed Kamel Ahmed*

Department of Neurological Physical Therapy, Faculty of Physical Therapy, Cairo University, Egypt.

*Correspondence: Amira Mohammed Kamel Ahmed; amira.albadwy@yahoo.com

ABSTRACT

Objective: To compare constraint-induced movement therapy (CIMT) and bilateral arm training (BAT) effects on upper limb function (ULF) post-stroke.

Methods: Two authors independently selected trials conducted on adult stroke patients across PEDro, PubMed, Google Scholar, and the Cochrane website. A systematic review of randomized controlled trials (RCTs) was conducted, focusing on CIMT and BAT interventions for ULF post-stroke. Eight trials were recruited based on specific inclusion and exclusion criteria, and the quality of the selected trials was assessed using the Cochrane risk of bias tool and PEDro scale.

Findings: Five trials, conducted with 151 participants, were included in the meta-analysis, evaluating the Motor Activity Log (MAL), amount of use (AOU), quality of movement (QOM), and the Action Research Arm Test (ARAT). All revealed non-significant variations between CIMT and BAT, with high heterogeneity in all tests ($I^2 = 82\%$, 80% , and 71% , respectively). Primary and secondary ULF outcomes demonstrated patients' satisfaction.

Conclusions: Both CIMT and BAT offer equal benefits regarding the functional performance of ULF post-stroke.

KEYWORDS

Systematic Review; Constraint Induced Movement Therapy; Bilateral Arm Training; Stroke Patients

1. INTRODUCTION

Currently, nearly 77% of post stroke individuals are suffering from disabilities due to associated hemiparesis [1], particularly chronic limited ULF forms around 50%. Most efficient stroke recovery requires three months, but upper extremity recovery might extend for years post stroke [2].

In Egypt, reported national widespread according to Abd-Allah and Mostafa was 963 per one hundred thousand Egyptians, with a huge persistent gap in verifying clinical evidence practice [3].

Although published stroke rehabilitation guidelines focus on ULF aiming to reduce post stroke disability, no precise approach has been advised, yet. To date, there is a lack of evidence that recommends the relative efficiency of specific therapeutic interventions [4].

To provide the most proper therapeutic manoeuvre for post stroke ULF disability, it is necessary to have a good pathophysiological explanation. This is still considered an obstacle because of: **a**; the continuous alteration of the disability nature and sort per each stroke individual across the stroke recovery pathway, **b**; the numerous disabilities that could be assessed at a specific stroke person might influence recovery approach, i.e., hand and/ or ULF affection due to spasticity that manifested post stroke [5].

Post stroke recovery involves BAT that focuses on ULF, which covers the critical need across affected populations for using their upper extremities, mainly elders who require mandatory BAT relay on their hands across most of the daily activities [6].

Neurophysiological expansions for BAT include using transcallosal pathways, i.e., intracortical inhibition (ICI) could be reduced in bilateral hemispheres. In an earlier clinical trial, Waller and his colleagues, reported an increase in both hemispheres' facilitation through short term BAT, and excess activities of related sensorimotor regions through functional reorganization, plus neuroplasticity [7]. Recently, Winstein and his colleagues have highlighted the potential benefits of BAT with clear recommendations for further research to fulfil the evidence practice gap [8].

The CIMT is considered a common post stroke upper extremity approach, with the goal of restoring ULF for daily activities through enforced affected side usage [9]. CIMT was recommended for mild to moderate paretic upper extremity rehabilitation, but further research is needed to fulfil the evidence practice gap [10].

Recently, Chen and his colleagues have concluded that both CIMT and BAT are efficient in regaining motor upper extremity affection, plus recovering functional capabilities [11]. This has been supported by Van Delden and his co-workers, who have respected the upper extremity weakness

grading ‘severe, moderate and mild’ and also the timing of treatment program verification ‘acute, subacute and chronic’, and they have recorded equal efficiency of both approaches, except for patients with mild upper extremity paresis who began therapeutic program at the chronic recovery stage [12].

Additionally, Van Delden and his team have ensured a bit of superiority for CIMT regarding performance based on Wolf motor function test (WMFT), ARAT, MAL, AOU and QOM [12,13], but the multiple bias risks limit constructing a precise conclusion.

Therefore, current literature critical reading reveals the need for a high quality meta-analysis to evaluate both BAT and CIMT on ULF in post stroke individuals.

2. METHODS

2.1. Literature and search strategy

Current study research conducted for the last decade (2010-Dec2020), based on Preferred Reporting Items for Systematic reviews and Meta-analysis (PRISMA) flowchart in Google Scholar, PubMed, Cochrane and PEDro using MeSH vocabularies; BAT, CIMT, bimanual training, unilateral arm training and stroke, CVA, cerebrovascular disease or accident OR hemiparesis, hemiplegia and upper limb or extremity, arm, forearm, wrist, hand and ULF or motor hand function, upper limb motor activity or performance.

2.2. Study selection

The recruited trials that matched our inclusion criteria were reviewed by researchers and then confirmed again to identify them as a selected trial if: a; in English, b; RCTs, c; adults elder than eighteen years, d; specify post stroke duration ‘subacute or chronic’ e; specify intervention to BAT or CIMT.

While exclusion criteria were a; available abstracts with no full text articles found, b; trials that investigated one of the included interventions (BAT or CIMT) together with the application of other intervention (i.e., virtual reality or hybrid rehabilitation), c; included BAT with auditory cueing or Robot assisted.

An independent review of all papers for title and abstract to confirm current eligible criteria was carried out by two researchers. Then, a review of the whole papers, where any disagreements revealed were checked, was carried out by a third researcher for precise deciding.

2.3. Quality evaluation

Double scales were verified by two reviewers (DM and AK) and the final decision was made by a third reviewer (WS) to evaluate the quality of the selected trials. PEDro and Cochrane bias risk (CROB), were used to evaluate the RCT methodology quality. PEDro scale contains 11-items, where 2-11 ones were given a point for internal validity, while the first item was checked for external validity. Therefore, PEDro gave a total of ten points so, if rated was ≥ 4 it was considered sufficient quality [14]. CROB has 7 items across 6 domains; selecting (randomize generating sequence, allocating conceal), performing (personnel and participant blinding), detecting (outcome assess blinding), attiring (lack outcome data), reporting (selective) and others, where each domain/ item was rated 'high, unclear, low' and reported separately without a calculated summary [15].

2.4. Statistical analysis

The independent two reviewers have extracted information from RCTs as follows: a; baseline participants' demographics and characteristics i.e., age, sex, lesion side and period of post stroke, b; therapeutic protocol for both controlled and studied population involving intensity and duration, c; inclusion and exclusion criteria, d; outcome measures primary and secondary, e; follow up. The current study main outcomes were ULF and participants' satisfaction. ULF was evaluated by Fugl Meyer (FM), ARAT, for specific alterations and Box/ Block test (BBT), for gross manual dexterity. WMF was used for functional capabilities (WMFT-FAS), performance time (WMFT-Time) and WMFT-strength, also daily activities and function domains of stroke impact scale. MAL was used for perception of affected upper extremity involving AOU and QOM, as well as the Nine Hole Peg test (NHPT), for dexterity of the hand, focusing on fine motor skills and functional independence measure (FIM) for daily functions. The secondary outcome (patient satisfaction) was found only in one study and measured by a self-assessed Canadian Occupational Performance Measure (COPM).

Statistical procedures were done via Review Manger (Rev Man, 5.4.1, Nordic Cochrane centre/ Collaboration /Copenhagen, Denmark: 2021), plus Microsoft Excel 2010 (Microsoft Corp., Redmond, WA, USA). The current meta-analysis for sufficient existing outcomes data, represented mean differences (MD) across trials, then pooled the continuous effect via MD, 95%CI for all trials. The heterogeneity of each trial was quantified via I^2 test. The fixed effect model was used by default due to the significant heterogeneity revealed $<.05$, $I^2 >50\%$. Also, Der Simonian /Laird random effect model was verified. Moreover, no sensitivity, subgroup analysis or publication bias were checked due to the limited number of trials recruited.

3. RESULTS

Regarding data Retrieval, 985 studies were identified from the search of PubMed, Cochrane, PEDro databases and Google Scholar. After excluding all duplicated studies, a total of 248 studies were screened. A total of 214 studies were excluded by title. Then, 22 studies were excluded by abstract (1 study designs were in another language than English, 4 abstracts were available with no full text articles and 17 studies made comparison on both stroke and healthy people). Then, 4 studies were excluded as follows: 1 was a single session study, 2 were in acute stage and 1 was a paper of critical appraisal of the study. Lastly, eight studies with 262 applicants met the inclusion criteria of this review, all of them were about comparing BAT versus CIMT in the stroke patients on the upper limb functional outcome. The results of the search are displayed in Figure 1, according to the PRISMA flowchart.

3.1. Study features

The mean age of the current study participants was 58.4 (50-67) years [16], 55-67 years [17], also includes 158♂ and 105♀, and the mean post stroke time was from 2 weeks [18] to 3 years [19], as presented in Table 1. Trials conducted by Brunner et al. and Renner et al. were concerning subacute stage of recovery, while remaining trials evaluated extended periods of more than three months. All participants were randomized to modified CIMT (m-CIMT) and BAT sections, followed by an initial evaluation involving full orthopaedic and neurological forms for confirming exclusion criteria not concerning upper extremity functional affection.

All included studies of bilateral arm training used both hands simultaneously or alternatively in the functional intervention. The constrained induced movement therapy group only used the affected hand, while the sound extremity was excluded from the use of mitt [19,20]. They used only the affected side across interventions, neglecting usage of the mitt. All studies used the same amount of frequency on both groups (m-CIMT and BAT) except [21] verified altered BAT frequencies (1 hour, 5 sets per week for four weeks).

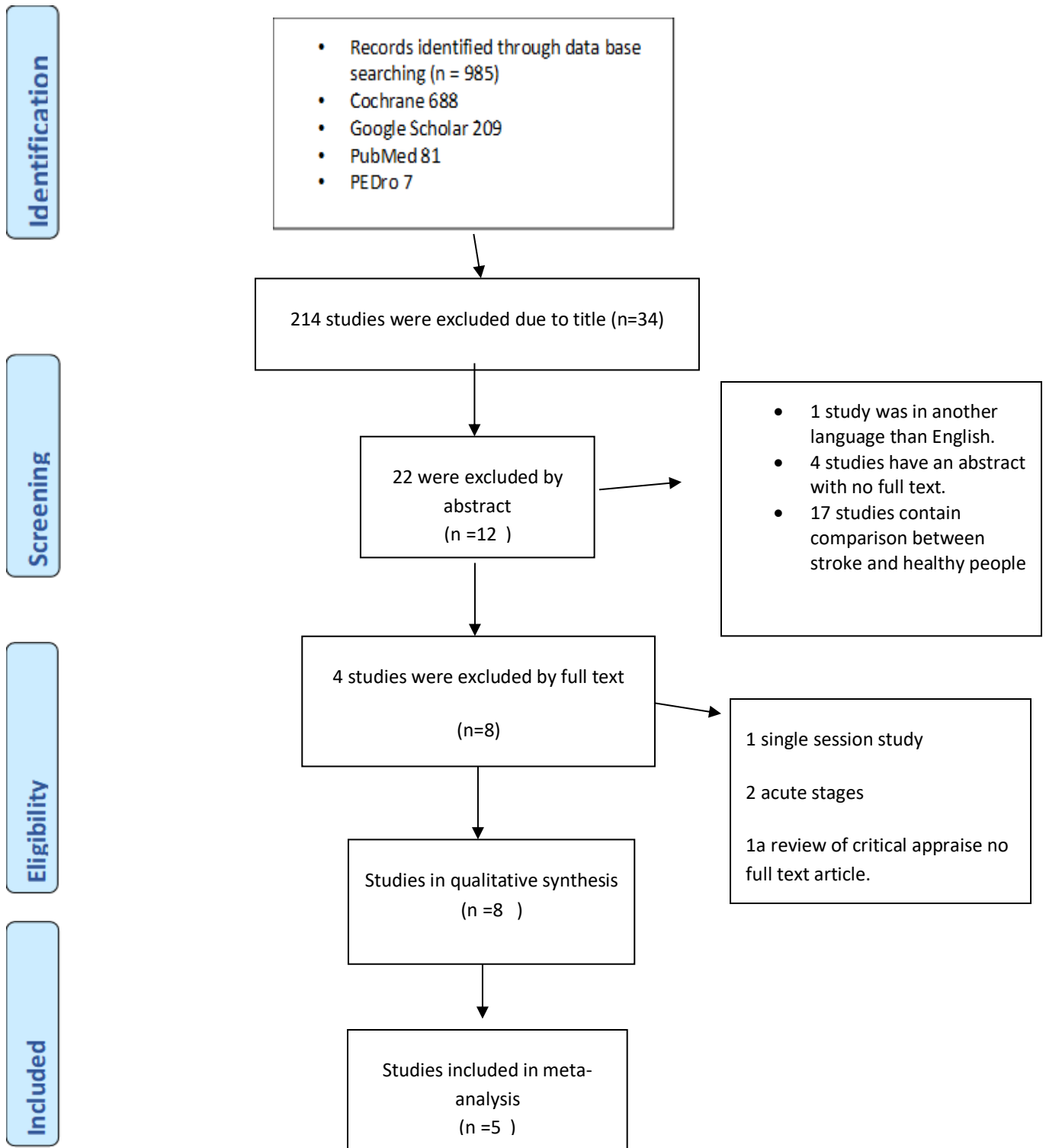


Figure 1. Flow diagram of searching

Table 1. Initial demographics and features

Study	Bilateral group					Constraint induced group				
	No.	♂	♀	Age	Duration (months)	No	♂	♀	Age	Duration (months)
Wu et al. (2011)	22	18	4	52.22+10.72	15.92+13.74	22	15	7	51.91+11.93	14.91+12.04
Mansour et al. (2015)	10	10	-	50.67+2.89	8.64+2.511	10	10	-	51.33+2.14	8.73+1.83
Syed et al. (2015)	15	9:	6	59.6+4.5	6 months to 3 years	15	11:	4	61.7+3.7	6 months to 3 years
Sethy (2016)	14	10:	04	57.34 (11.9)	13.09 (2.86)	14	9:	5	58.11 (9.30)	12.35 (3.21)
Brunner et al. (2012)	16	8	8	64.8 (12.8)	36.9 (25.1)	14	11	3	61.0 (10.0)	48.43 (39.3)
Kale et al. (2019)	15	1	14	50 to 65		15	9	6	50 to 65	
Hayner et al. (2010)	6	3	3	59.50 11.777	In days 2039.00 925.328	6	2	4	54.00 11.628	In days 642.33 421.121
Renner et al. (2020)	35	SubC 10 Cort 6	SubC 12 Cort 7	SubC 66.67+12.27 Cort	SubC 35.33+11.52 Cort	34	SubC 9 Cort 7	SubC 14 Cort 4	SubC 67.55+9.57 Cort	SubC 37.64+13.21 Cort
				58.69+14.17	34.92+10.6				54.55+13.72	36.36+14.89

Note. SubC; subcortical; Cort; cortical

Primary outcome of motor ULF was assessed via FM for [16,17, 22], ARAT by [16,18,21,22], MAL, AOU, QOM by [18,19,22, 23], NHPT by [18,21] and WMF by [20,23]. Only kinematic analysing acquisition plus data reduction and peak velocity (PV) for ULF were verified by [23]. While secondary outcome measures regarding performance and satisfaction could be summarized as self-rate Canadian Occupational Performance Measure (COPM) by [20].

3.2. Quality assessment

PEDro scale and Cochrane bias risk assessing tools were verified for measuring the quality of the recruited trial methods. For PEDro scale, two [18,22] have 8 yes in their scores and that was the highest score among trials with good quality. The lowest scores were 5 yes [16], and 4 yes [21], of fair and poor quality respectively. The remaining trials were between 6 and 7 yes, indicating good quality. The mean of PEDro for all included trials was 6.3 which is of good Quality.

All recruited trials have a random allocation of their participants and concealment allocation was performed only in 4 trials [17,18,19,23]. Initial features were similar in all trials. No blinding of participants nor therapists was performed, but blinding of the assessors was performed in all, except [16,19,20]. Most of the included trials described their intervention well (BAT and m-CIMT) and clearly

described the outcome measures used. Additionally, CROB values regarding [18,20,21,23] were in between some concerns, while [16,17,18,19,22] were at higher bias risk.

Table 2. Recruited trials features

Reference	Study vs control	Procedure	Frequency	Outcome	Conclusion
1. Wu et al. (2011)	BAT vs d-CIT vs control group.	BAT: raising up 2 cups, raising up 2 pegs, holding and releasing 2 towels, washing the table with 2 hands, and so on. dCIT: using a mitt for 6 hours daily and intensively train the affected UE in functional tasks, including attaining to move a cup, raising up coins, raising up a utensil to eat food, hold and unhold various blocks, and other functional movements in daily activities.	dCIT :2 hours daily for 5 d/wk for 3 consecutive weeks BAT: 2 hours daily for 5 d/wk for 3 consecutive weeks.	Kinematic analysis acquisition, Data reduction for kinematic variables, PV, Functional assessments: WMFT,MAL AOU and the quality of movement (QOM)	BAT and dCIT exhibited similar beneficial effects on movement smoothness but BAT is better in force at movement initiation and dCIT is better in functional performance.
2. Mansour et al. (2015)	m.CIT versus BAT versus the selected physical therapy program.	BAT: Holding and folding a towel, opening a bottle, where the non-affected hand holding the bottle and the affected hand unscrew the cover, raising up 2 cups, moving forward or upward to push blocks, Alternative movements included exercises such as Alternative movement forward or upward. mCIT: wearing mitt for 4 hrs daily, functional tasks: moving forward or upward , Box and blocks exercising , raising up a utensil to eat food, turning cards, holding and releasing various blocks, Emptying from glass to another, turning paper in a book, putting a ball in a basket.	2-hour per day, 5 days per week, for 3 weeks for both groups.	Modified Asworth Scale, The arm section of the FM Scale, ARAT, - Box and Block Test.	Both modified constrained induced movement therapy and bilateral arm training improves upper extremity function with more superiority of modified constrained induced movement therapy on improving hand dexterity
3. Syed et al. (2015)	Bilateral extremity training versus unilateral extremity training.	Bilateral: block positioning, cup reversal and act as drinking. Unilateral: block movement cup reversal and act as drinking.	Bilateral: 15 minutes each session for 5 sessions in a week for 3 weeks. Unilateral: 5 sessions a week for 3 weeks only for the affected extremity	AOU and QOM subscales of MAL	Bilateral arm training improved functional tasks better than unilateral arm training .
4. Sethy et al. (2016)	m-CIMT versus BAT versus Conventional Therapy)	m-CIMT: •Eating, Drinking, Simulated showering ,Combing hair; •using switches, taps, latches, writing, using telephones, play game activities like Plastic peg activity, stacking blocks, making up bed and preparing table.	m-CIMT: one hour session of occupational therapy, 5 days/week for 8 weeks. BAT: one hour per day, 5	FMA), ARAT, MAL	Bilateral arm training may be used to improve upper arm function and m-CIMT may be used to improve hand functions, while the

		<p>The un affected hand was restricted for 5 hours by a cotton glove.</p> <p>BAT: Block positioning ,Peg localizing , Peg turning ,moving object.</p>	<p>days/week for 8 weeks.</p>	<p>group that received modified constraint induced movement therapy had greater improvement.</p>	
5. Brunner et al. (2012)	m-CIMT versus Bimanual training	<p>m-CIMT: wearing a mitt on the less affected arm for 4 hours a day and calculate the actual wearing time of the mitt in their notebook with affected hand only</p> <p>ex: Grasp objects of different sizes and shapes, fold a towel, raising up a glass, using the keys of a keyboard, Point toward a target, pick up a ball, hold an object.</p> <p>Bimanual: both hands moves symmetrically and alternately: grasp objects of different sizes and shapes, Fold a towel, pick up a glass ,using the keys of a keyboard , Point toward a target, pick up a ball, lift up an object.</p>	<p>4 hours a week for four weeks for both groups.</p>	<p>Action Research Arm Test, Nine-Hole Peg Test, Motor Activity Log</p>	<p>Bimanual training was as effective as modified constraint-induced movement therapy in improving arm motor function.</p>
6. Kale et al. (2019)	CIMT verses bimanual	<p>CIMT: wore a mitten on the normal side and perform daily activates with the affected one.</p> <p>BMT: emptying water in a glass, tie a button, wearing on or removing a shirt, folding towels, and washing windows.</p>	<p>BMT: 1 hour five times a week, for four weeks.</p> <p>CIMT : 3 hours, five times a week, for 4 weeks.</p>	<p>ARAT, NHPT</p>	<p>Constraint induced movement therapy appears to be optimal treatment options for improving the motor hand function in subjects with stroke.</p>
7. Hayner et al. (2010)	CIMT versus bilateral.	<p>CIMT: The participants wore a padded mitt on the unaffected hand and practiced functional activities with only the affected UE. preparing the table, cleaning hands, cleaning dishes with the paretic limb.</p> <p>Bilateral training: preparing the table,cleaning hands,cleaning dishes using two upper limb together.</p>	<p>CIMT: 6 hr of occupational therapy for 10 days plus additional home practice.</p> <p>Bilateral training: 6 hr of occupational therapy for 10 days plus additional home practice.</p>	<p>WMFT, COPM</p>	<p>High-intensity occupational therapy using a CIMT or a bilateral approach improve UE function .Treatment intensity rather than restraint may be the critical therapeutic factor.</p>

8. Renner et al. (2020)	Unilateral versus bilateral.	<p>in bilateral group, applicants received a 20-minute intensive BT on an arm cycle (MOTomed viva2a). Applicants in unilateral group (UT) received a 20-minute intensive UT on an arm cycle twice a day plus a 20-minute intensive UT session of repetitive distal hand exercising per work day for 6 weeks (total of 30d), only training the affected upper limb.</p>	<p>Bt:20 min.twice a day, plus a 20-minute progressive BT session of repetitive distal hand training per workday for 6 weeks (total of 30d).</p> <p>Ul: received a 20-minute progressive UT on an arm cycle twice a day plus a 20-minute progressive UT session of repetitive distal hand training per work day for 6 weeks (total of 30d).</p>	<p>The primary outcome measure was the FMA motor score of the upper extremity (FMA, 0-66). Secondary outcome measures were measures of isometric force and rate of rise of tension (RRT) of grip, dorsal hand extension, elbow flexion and extension, and tone of the affected extremity.</p>	<p>The benefit of bilateral arm training followed by repetitive bilateral hand training for motor control may depend on lesion location.</p>
-------------------------	------------------------------	--	---	---	--

Table 3. Trials PEDro assessment

Criteria	Wu et al. (2011)	Mansour et al. (2015)	Syed N et al. (2015)	Sethy D et al. (2016)	Brunner et al. (2012)	Kale et al. (2019)	Renner et al. (2020)	Hayner et al. (2010)
1. Specific eligibility criteria*	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
2. Random allocation of participant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3. Concealed allocation	Yes	No	Yes	No	Yes	No	Yes	No
4. Similar prognosis at baseline	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
5. Blinded participants	No	No	No	No	No	No	No	No
6. Blinded therapist	No	No	No	No	No	No	No	No
7. Blinded assessor	Yes	No	No	Yes	Yes	Yes	Yes	No
8. More than 85% follow up for at least one key outcome	Yes	No	No	Yes	Yes	No	No	Yes
9. Intention to treat analysis	No	No	Yes	Yes	No	No	No	No
10. Between group statistical analysis for at least one key outcome	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
11. Point estimates of variability for at least one key outcome	Yes	Yes	Yes	yes	Yes	Yes	Yes	Yes
Total PEDro score (/10)	6	5	7	8	8	4	7	6
Quality	Good	Fair	Good	Good	Good	Fair	Good	Good

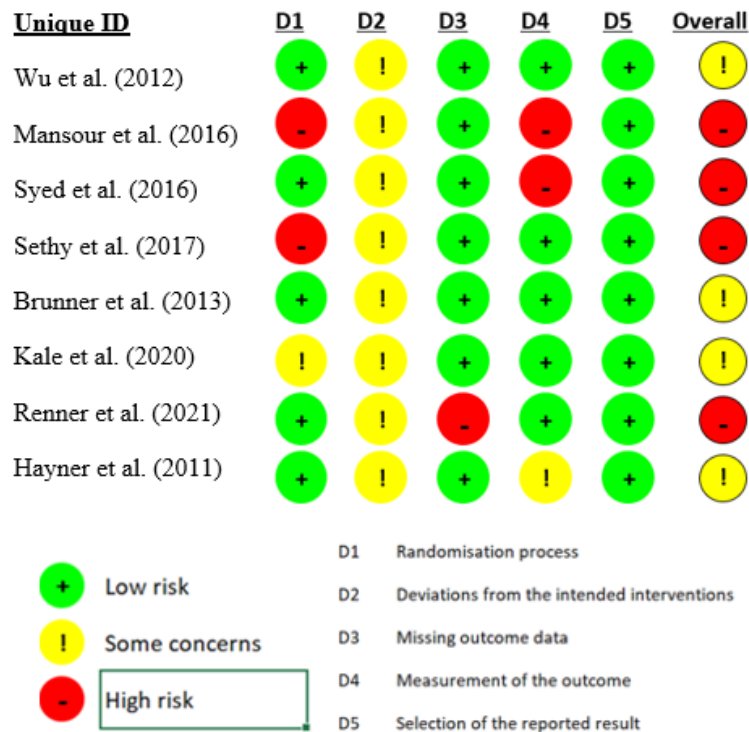


Figure 2. Cochrane Bias assessing tool

3.3. Meta-analysis results

Only five trials were recruited [16,18,21,22,23] involving 151 participants, with ULF as the primary outcome, MD along the current trial. The secondary outcome was ‘satisfaction’ and existed in one trial, thus neglected, and we couldn’t measure its effect in our review. Also, the long-term effect of both interventions on the paretic upper limb couldn’t be measured as there was high diversity in the period of follow-up post intervention in the included studies, therefore the results of meta-analysis are done on pre and post intervention only due to their homogeneity.

The five studies were divided into 2 subgroups according to the used assessment scale. Three trials [19,22,23] measured MOL for 51 participants in BAT group and 50 participants in m-CIMT group. MAL-AOU overall results revealed non-significant difference between BAT and CIMT group. Heterogeneity across the studies was considerably high, $I^2 = 82\%$. MAL-QOM overall results also revealed non-significant difference between BAT and CIMT group. Heterogeneity across trials was also considerably high, $I^2 = 80\%$. Could not assess publication bias because of the small number of recruited trials.

Table 4. Comparison BAT vs CIMT, primary outcome 1.2 MAL-AOU

Study or Subgroup	Bilateral		Total	Constrain		Total	Weight	Mean Difference IV, Random, 95% CI
	Mean	SD		Mean	SD			
Sethy et al, 2016	0.69	0.525	14	0.79	0.485	13	33.4%	-0.10 [-0.48, 0.28]
Syed et al, 2015	0.7	0.34	15	0.39	0.2	15	39.2%	0.31 [0.11, 0.51]
Wu et al, 2011	0.51	0.915	22	1.09	0.935	22	27.4%	-0.58 [-1.13, -0.03]
Total (95% CI)			51			50	100.0%	-0.07 [-0.56, 0.42]

Heterogeneity: Tau² = 0.15; Chi² = 10.97, df = 2 (P = 0.004); I² = 82%
 Test for overall effect: Z = 0.29 (P = 0.77)

Table 5. Comparison BAT vs CIMT, primary outcome 1.3MAL-QOM

Study or Subgroup	Bilateral		Total	Constrain		Total	Weight	Mean Difference IV, Random, 95% CI
	Mean	SD		Mean	SD			
Sethy et al, 2016	1.07	0.455	14	0.85	0.51	13	34.6%	0.22 [-0.15, 0.59]
Syed et al, 2015	0.62	0.4	15	0.4	0.4	15	37.2%	0.22 [-0.07, 0.51]
Wu et al, 2011	0.5	0.9255	22	1.24	0.92	22	28.2%	-0.74 [-1.29, -0.19]
Total (95% CI)			51			50	100.0%	-0.05 [-0.55, 0.45]

Heterogeneity: Tau² = 0.16; Chi² = 10.17, df = 2 (P = 0.006); I² = 80%
 Test for overall effect: Z = 0.20 (P = 0.84)

Three trials [16,21,22] measured the ARAT for 39 participants in BAT group and 38 participants in m-CIMT group. The overall effect of trials revealed non-significant difference between BAT and CIMT group. Heterogeneity across trials was considerably high, I² = 71%. Could not assess publication bias because small number of recruited trials.

Table 6. Comparison between BAT vs CIMT, primary outcome: 1.1 ARAT

Study or Subgroup	Bilateral		Total	Constrain		Total	Weight	Mean Difference IV, Random, 95% CI
	Mean	SD		Mean	SD			
Kale et al, 2019	0	1.46	15	1.8	1.254	15	46.9%	-1.80 [-2.77, -0.83]
Mansour et al, 2015	8.67	8.875	10	13.87	7.565	10	23.5%	-5.20 [-12.43, 2.03]
Sethy et al, 2016	11.26	6.945	14	5.93	7.83	13	29.5%	5.33 [-0.27, 10.93]
Total (95% CI)			39			38	100.0%	-0.49 [-5.42, 4.43]

Heterogeneity: Tau² = 13.19; Chi² = 6.99, df = 2 (P = 0.03); I² = 71%
 Test for overall effect: Z = 0.20 (P = 0.84)

4. DISCUSSION

The current review and the meta-analysis purpose was to compare the effect of CIMT and the effect of BAT on the functional outcome of upper extremity in post stroke patients. Only five trials were recruited by the current meta-analysis, including 151 participants measuring the pre and post effect of each intervention (BAT versus CIMT) on paretic ULF post stroke using two scales (ARAT and MAL).

This meta-analysis has neglected any significant difference between BAT versus CIMT on ARAT. However, in the detailed analysis of ARAT values, one trial [21] was more in favour of CIMT over BAT, which is ensured by the result of a prior review done by Pollock et al. [4], where moderate

quality evidence means that CIMT might have over gains than BAT. But insufficient information prevents evaluating such relative efficacy. Furthermore, in the present review, AOU and QOM of MAL scale were measured and recorded non-significance differences on values between both interventions on paretic upper extremity. But, on sub analysis results of MAL across the current review, one trial [19] recorded superiority in AOU in favour of BAT, while other trial [23] ensured superiority in favour of CIMT in measuring QOM. Later findings agreed with Van Delden et al. [11], which reported a slightly significance MDs for perceived upper extremity QOM in favour of CIMT, while all other MDs were insignificance.

The current review ensured non-significance difference between BAT and CIMT on ULF in ARAT and MAL (AOU) and (QOM). Recently, Chen and his co-workers have aimed their meta-analysis [10] to evaluate the benefits on motor affection and functional performances of post stroke regarding BAT and CIMT, which resulted in non-significant MD, based on WMFT time consuming, plus standard mean difference (SMD), as well as functional capability values on WMFT, BBT and ARAT. Moreover, Pollock et al. [4] have synthesized their reviews on popular approaches advised to improve ULF post stroke. The moderate-quality evidence of the selected trials ensured that CIMT is more favourable than BAT, but limited data prevents us to spotlight such comparative effectiveness. In addition, a systematic review done by Chen et al. [10] has recorded that BAT and CIMT have improved generally equal UL motor affections, as well as functional performance.

On the other side, CIMT was a better choice than BAT in functional performance resulted of RCTs [23], based on timing and functional capabilities of WMFT regarding the CIMT group. Furthermore, CIMT section had achieved improvement in the amount of use and quality of use of the affected upper extremity, as measured by MAL. Such findings might be due to the CIMT program nature that involves repeating numerous functional tasks, only by the affected hand, that often require dexterity training. CIMT is also more intensive than BAT because it requires more time spent wearing the restrain mitt out of the clinic. So, all findings support CIMT for better functional performance than BAT.

The functional motor tasks in BAT are usually fulfilled by using both upper extremities, simultaneously or alternatively such as holding a banana while peeling it with the other hand. Thus, BAT approach might not be able to gain the same as CIMT, directly. Therefore, the comparison between the effect of BAT and CIMT is still in debate and more studies with high quality evidence are still needed to compare the effect of both interventions (BAT and CIMT) on paretic upper extremity regarding post stroke recovery stage, plus stroke severity.

There were several limitations to highlight for the current review: **a**; almost all trials were at the chronic post stroke stage and two trials [17,18] only in the subacute stage, which is considered a limit number. **b**; the homogeneity in the number of follow up weeks between trials was very variable and limited us to do meta-analysis for follow up and long term gains. **c**; the limitation in the number of trials downgrade overall quality of evidence. **d**; it was not possible to measure the second outcome, ‘satisfaction’, which was found in only one trail [20]. Finally, **e**; the quality of the trials measured was between some concerns and a high risk that downgrade the overall quality of the evidence and the gained results.

5. CONCLUSIONS

The current systematic review and meta-analysis ensured that both CIMT and BAT have equal benefits regarding functional performance of paretic upper extremity in post stroke. However, further work involving extra and higher quality RCTs is needed to precisely judge any superiorities between BAT and CIMT on functional outcomes of paretic upper extremity in post stroke.

6. REFERENCES

1. Simpson LA, Hayward KS, McPeake M, Field TS, Eng JJ. Challenges of estimating accurate prevalence of arm weakness early after stroke. *Neurorehabilitation and Neural Repair*. 2021 Oct;35(10):871-9.
2. Kwakkel G, Kollen BJ, van der Grond J, Prevo AJ. Probability of regaining dexterity in the flaccid upper limb: impact of severity of paresis and time since onset in acute stroke. *Stroke*. 2003 Sep 1;34(9):2181-6. <https://doi.org/10.1161/01.STR.0000087172.16305.CD>
3. Abd-Allah F, Moustafa RR. Burden of stroke in Egypt: Current status and opportunities. *International journal of stroke*. 2014 Jul 7;9(8):1105-8. <https://doi.org/10.1111/ijis.12313>
4. Pollock A, Farmer SE, Brady MC, Langhorne P, Mead GE, Mehrholz J, et al. Interventions for improving upper limb function after stroke. *Cochrane Database Syst Rev*. 2014 Nov;(11): 1-171. <https://doi.org/10.1002/14651858.CD010820.pub2>
5. Aluru V, Lu Y, Leung A, Verghese J, Raghavan P. Effect of auditory constraints on motor performance depends on stage of recovery post-stroke. *Front Neurol*. 2014 Jun 23;5:1-13.
6. Kilbreath SL, Heard RC. Frequency of hand use in healthy older persons. *Australian journal of physiotherapy*. 2005;51(2):119-22. [https://doi.org/10.1016/S0004-9514\(05\)70040-4](https://doi.org/10.1016/S0004-9514(05)70040-4)
7. McCombe WS, Whitall J, Jenkins T, Magder LS, Hanley DF, Goldberg A, et al. Sequencing bilateral and unilateral task-oriented training versus task oriented training alone to improve arm function in individuals with chronic stroke. *BMC neurol*. 2014 Dec 14;14(236):1-9. <https://doi.org/10.1186/s12883-014-0236-6>
8. Winstein CJ, Stein J, Arena R, Bates B, Chorney LR, Cramer SC, et al. Guidelines for adult stroke rehabilitation and recovery: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke*. 2016 Jun;47(6):98-169. <https://doi.org/10.1161/STR.0000000000000098>

9. Sirtori V, Corbetta D, Castellini G, Moja L, Gatti R. Constraint-induced movement therapy for upper extremities in people with stroke. *Cochrane Database Syst Rev.* 2015 Oct;(10):1-118. <https://doi.org/10.1002/14651858.CD004433.pub3>
10. Chen S, Qiu Y, Bassile CC, Lee A, Chen R, Xu D. Effectiveness and Success Factors of Bilateral Arm Training After Stroke: A Systematic Review and Meta-Analysis. *Front Aging Neurosci.* 2022 Apr 25;14:1-21. <https://doi.org/10.3389/fnagi.2022.875794>
11. Van Delden AE, Peper CE, Beek PJ, Kwakkel G. Unilateral versus bilateral upper limb exercise therapy after stroke: a systematic review. *J Rehabil Med.* 2012;44(2):106-17. <https://doi.org/10.2340/16501977-0928>
12. Cauraugh JH, Lodha N, Naik SK, Summers JJ. Bilateral movement training and stroke motor recovery progress: a structured review and meta-analysis. *Hum. Mov. Sci.* 2010 Oct;29(5): 853–70. <https://doi.org/10.1016/j.humov.2009.09.004>
13. Wolf A, Scheiderer R, Napolitan N, Belden C, Shaub L, Whitford M. Efficacy and task structure of bimanual training post stroke: a systematic review. *Top. Stroke Rehabil.* 2014 May 1;21(3):181-96. <https://doi.org/10.1310/tsr2103-181>
14. Maher CG, Sherrington C, Herbert RD, Moseley AM, Elkins M. Reliability of the PEDro scale for rating quality of randomized controlled trials. *Physical therapy.* 2003 Aug 1;83(8):713-21. <https://doi.org/10.1093/ptj/83.8.71>
15. Higgins JPT, Green S, editors. *Cochrane handbook for systematic reviews of interventions.* Version 5.0.2 [updated September 2019]. The Cochrane Collaboration; 2019.
16. Atteya A, Mansour WT, Fahmy EM, ElBalawy YM. Efficacy of constrained induced movement therapy versus bilateral arm training on upper extremity functional outcomes in stroke patients. *Med. J. Cairo Univ.* 2015 Sep; 83(2):79-85.
17. Renner CI, Brendel C, Hummelsheim H. Bilateral arm training vs unilateral arm training for severely affected patients with stroke: exploratory single-blinded randomized controlled trial. *Archives of physical medicine and rehabilitation.* 2020 Jul 1;101(7):1120-30.
18. Brunner IC, Skouen JS, Strand LI. Is modified constraint-induced movement therapy more effective than bimanual training in improving arm motor function in the subacute phase post stroke? A randomized controlled trial. *Clinical rehabilitation.* 2012 Dec;26(12):1078-86. <https://doi.org/10.1177/0269215512443138>
19. Syed N, Biswas A, Hanifa N, Parameswaran RV, Sundaram P. Bilateral versus unilateral upper extremity training on upper limb motor activity in hemiplegia. *Int J Neurorehabilitation.* 2015;2(1):78-86.
20. Hayner K, Gibson G, Giles GM. Comparison of constraint-induced movement therapy and bilateral treatment of equal intensity in people with chronic upper-extremity dysfunction after cerebrovascular accident. *The American journal of occupational therapy.* 2010 Jul;64(4):528-39. <https://doi.org/10.5014/ajot.2010.08027>
21. Kale AA, Kekatpure V, Mahendrakar N. Effect of Constraint Induced Movement Therapy Versus Bimanual Task Training for Improvement of Motor Hand Function in Stroke Patients. *Indian Journal of Physiotherapy & Occupational Therapy.* 2019 Jan 1;13(1):23-7. <https://doi.org/10.5958/0973-5674.2019.00005.4>
22. Sethy D, Bajpai P, Kujur ES, Mohakud K, Sahoo S. Effectiveness of modified constraint induced movement therapy and bilateral arm training on upper extremity function after chronic stroke: A comparative study. *Open journal of therapy and rehabilitation.* 2016 Feb 15;4(1):1-9.
23. Wu CY, Chuang LL, Lin KC, Chen HC, TsayPK. Randomized trial of distributed constraint-induced therapy versus bilateral arm training for the rehabilitation of upper-limb motor control and function after stroke. *Neurorehabilitation and neural repair.* 2011;25(2):130-9.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

FUNDING

This research received no external funding.

COPYRIGHT

© 2023 by the authors. This is an open-access article distributed under the terms of the [Creative Commons CC BY 4.0 license](https://creativecommons.org/licenses/by/4.0/), meaning that anyone may download and read the paper for free. The use, distribution or reproduction in other forums is permitted, provided the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms. These conditions allow for maximum use and exposure of the work, while ensuring that the authors receive proper credit.