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Comparison of mirror therapy and constraint-induced movement therapy on motor recovery and functional outcomes in post-stroke patients

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ABSTRACT

Background: Mirror therapy (MT) and constraint-induced movement therapy (CIMT) are rehabilitative techniques for improving upper limb function after stroke; however, direct comparisons of their effectiveness are limited. This study aimed to evaluate and compare the effects of MT and CIMT on upper limb recovery in stroke patients.

Methods: A randomized controlled trial of 30 post-stroke patients was undertaken from June to September 2023. Participants were randomly assigned to either the MT or CIMT groups. The primary objective was the Fugl-Meyer assessment for upper extremities (FMA-UE), whereas the secondary outcomes were surface electromyography biofeedback (sEMG-B) and the box and block test (BBT).

Results: CIMT significantly improved FMA-UE and BBT scores ($p < 0.001$), along with sEMG measurements of the middle, anterior, and posterior deltoid, biceps, triceps, wrist extensors, and wrist flexors ($p < 0.001$). MT also led to significant improvements in FMA-UE, BBT, and sEMG (all $p < 0.001$). Intergroup comparisons showed greater BBT score gains with CIMT (11) than MT (10), while differences in FMA-UE and sEMG were not significant.

Conclusion: Both CIMT and MT enhance upper limb motor function in stroke patients, whereas CIMT results in higher increases in hand dexterity.

Keywords: constraint-induced movement therapy; mirror therapy; motor function; rehabilitation; stroke.

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INTRODUCTION

Stroke is an acute interruption of cerebral vascular perfusion that continues to be the leading cause of disability and death globally.[1,2] According to the Global Burden of Disease 2021, approximately 12 million new stroke cases occur annually, with over 5 million deaths and millions more living with disabilities. In Indonesia, the stroke prevalence reached 10.9% (about 2,120,362 cases) in 2018, with South Sulawesi Province accounting for 10.6% of the national burden.[3]

Post-stroke motor recovery relies on neuroplasticity, the brain's ability to form new neural connections, acquire functions, and compensate for impairments. Motor recovery therapies harness this process to restore functional movement, and rehabilitation programs are designed to promote both neuroplasticity and recovery. Although numerous novel techniques have been developed based on basic science and clinical studies, the effectiveness of these interventions varies widely due to the complex and heterogeneous mechanisms underlying motor recovery.[4]

Mirror therapy (MT) is a rehabilitation technique that uses motor imagery, where a mirror provides visual feedback by reflecting normal body movements to stimulate the affected limb.[5] Studies have shown that MT enhances upper extremity motor recovery and activities of daily living compared to sham treatment.[6] Constraint-induced movement therapy (CIMT) involves intensive use of the affected arm while restraining the less affected arm, combined with structured exercise.[7] Previous research indicates that combining range of motion exercises (ROM) with CIMT further improves upper extremity function, making it an effective alternative therapy for stroke rehabilitation.[8]

Although CIMT and mirror therapy have been widely studied, their effects on Fugl-Meyer assessment-upper extremities (FMA-UE) scores in relation to surface electromyography biofeedback (sEMG-B) and the box and block test (BBT) remain unclear. This study aimed to compare the effectiveness of CIMT and mirror therapy on motor recovery, assessed using FMA-UE and sEMG-B, and functional outcomes, measured by BBT, in stroke patients.

METHODS

This study employed a randomized controlled trial methodology, with 60 post-stroke patients (onset 2 weeks to 6 months) randomly assigned to either mirror treatment (MT) or constraint-induced movement therapy CIMT groups. Participants were recruited sequentially from three Makassar rehabilitation centers (Wahidin Sudirohusodo Hospital, Universitas Hasanuddin Hospital, and Cerebellum Clinic). The sample size was estimated using prior studies (28 per group, 80% power) to identify significant differences. Eligibility was determined using medical records. Inclusion criteria were upper limb hemiparesis (MMT > 2, MAS < 3), while exclusion criteria included significant spasticity, cognitive impairment (MMSE < 17), or uncontrolled medical disorders. Patients who missed more than three sessions or experienced hemodynamic changes during the intervention were termed dropouts.

The 6-week home-based intervention was supervised by trained caregivers following a standardized protocol.[9,10] CIMT and MT were administered for 15 minutes per session, three times per week. During CIMT, the healthy arm was restrained for 3 hours each morning. Primary outcomes included motor function assessed by the FMA-UE (original English version), dexterity measured using the BBT (wooden box: 53.7 × 25.4 × 8.5 cm; center partition: 25.4 cm; block size: 2.5 cm; 150 blocks), and muscle activation evaluated via sEMG-B (NeuroTrac Myoplus 4 Pro) with electrodes placed on the middle, anterior, and posterior deltoid, biceps, triceps, and wrist flexor and extensor muscles. Data were collected through interviews, physical examinations, and pre- and post-test measurements. The FMA-UE assessed wrist and hand function (scores 0–2 per movement), while the BBT measured the number of blocks transferred by the affected and healthy hands within 60 seconds. Statistical analyses included the independent-sample *t*-test, Mann–Whitney test, and paired *t*-test. The Ethics Commission of the Faculty of Medicine, Universitas Hasanuddin (No. 163/UN4.6.4.5.31/PP36/2025) approved the study, protecting data security and participants' right to withdraw. All participants were informed about the study's objectives, procedures, potential risks, and benefits, and they gave written informed consent to participate.

Table 1. Distribution of research subjects in both groups

Characteristic	MT (n = 30)	CIMT (n = 30)	p-value
	Mean ± SD or n (%)	Mean ± SD or n (%)	
Age (years)a	54.60 ± 14.14	58.60 ± 11.11	0.228
Genderb			
Male	13 (43.3)	17 (56.7)	0.302
Female	17 (56.7)	13 (43.3)	
Occupationb			
Employed	13 (43.3)	15 (50.0)	
Unemployed	13 (43.3)	8 (26.7)	0.341
Retired	4 (13.3)	7 (23.3)	
Marital statusb			
Married	21 (70.0)	26 (86.7)	0.117
Unmarried/divorced	9 (30.0)	4 (13.3)	
Hemiparesisb			
Right	16 (53.3)	16 (53.3)	0.091
Left	14 (46.7)	14 (46.7)	
Educationb			
Junior High School	3 (10.0)	2 (6.7)	
Senior High School	13 (43.3)	16 (53.3)	0.830
College	14 (46.7)	12 (40.0)	
Body Mass Index (kg/m2)a	24.59 ± 4.25	24.63 ± 4.05	0.972

aIndependent sample t-test; bChi-Square test; MT, Mirror Therapy; CIMT, constraint-induced movement therapy; n, number of participants; SD, standar deviation

Table 2. Comparative analysis of hand motor function and functional outcomes between pre- and post-intervention

Variable	MT Pre (Mean ± SD)	MT Post (Mean ± SD)	*p*-value (MT)	CIMT Pre (Mean ± SD)	CIMT Post (Mean ± SD)	*p*-value (CIMT)
Fugl-Meyer Assessment (UE)	23.43 ± 8.58	29.23 ± 8.49	<0.001	35.40 ± 8.64	42.60 ± 9.73	<0.001
sEMG – Deltoid middle (μV)	66.17 ± 21.62	77.33 ± 24.82	<0.001	87.68 ± 39.75	106.47 ± 43.02	<0.001
sEMG – Deltoid anterior (μV)	58.97 ± 25.48	72.77 ± 31.10	<0.001	86.03 ± 43.02	101.20 ± 41.98	<0.001
sEMG – Deltoid posterior (μV)	49.93 ± 16.73	62.17 ± 19.61	<0.001	66.57 ± 33.37	82.40 ± 39.09	<0.001
sEMG – Biceps (μV)	77.27 ± 34.17	80.03 ± 34.88	<0.001	101.76 ± 55.16	118.43 ± 57.09	<0.001
sEMG – Triceps (μV)	67.53 ± 29.99	78.03 ± 28.72	<0.001	82.26 ± 49.25	93.96 ± 52.09	<0.001
sEMG – Wrist extensor (μV)	59.17 ± 26.42	70.77 ± 27.38	<0.001	76.79 ± 42.82	92.02 ± 44.52	<0.001
sEMG – Wrist flexor (μV)	61.30 ± 27.64	72.43 ± 25.96	<0.001	65.32 ± 32.93	79.40 ± 31.67	<0.001
Box and Block Test (BBT)	17.90 ± 8.04	23.67 ± 9.01	<0.001	25.47 ± 7.95	33.03 ± 7.79	<0.001

MT, Mirror Therapy; CIMT, constraint-induced movement therapy; UE, Upper Extremity; sEMG, surface electromyography biofeedback

RESULTS

The study involved 60 post-stroke patients from Wahidin Sudirohusodo General Hospital, Universitas Hasanuddin Hospital, and Cerebellum Clinic in Makassar who met the inclusion criteria. Participants were randomly assigned to two intervention groups MT and CIMT with 30 subjects in each group. All subjects completed the follow-up. Baseline characteristics, including age, gender, occupation, education, marital status, hemiparesis, and BMI, showed no significant differences between groups ($p > 0.05$), indicating homogeneity prior to intervention (**Table 1**).

Both MT and CIMT led to significant improvements in all evaluated parameters, including FMA-UE scores, sEMG measurements, and BBT scores (all $p < 0.001$). In the MT group, the greatest sEMG gains were observed in the anterior deltoid (+13.80 μV) and wrist extensor (+11.60 μV), suggesting enhanced local motor activation supporting functional recovery. Similarly, CIMT produced substantial improvements across all muscle groups, with the largest increases in the middle deltoid (+18.79 μV) and BBT performance (+7.56 blocks), indicating superior upper-extremity functional recovery (**Table 2**).

Significant differences between groups remained for FMA-UE scores and BBT results ($p < 0.05$). sEMG analysis revealed notable intergroup differences in the deltoid (anterior, middle, posterior), biceps, and wrist extensors ($p < 0.05$), while no significant differences were found in triceps and wrist flexors ($p > 0.05$). These findings suggest that although both therapies are beneficial, CIMT provides a distinct advantage in improving specific muscle activity and motor function (**Table 3**).

Figure 1 illustrates pre- and post-intervention changes in FMA-UE and BBT scores for both groups. While both MT and CIMT significantly enhanced motor function and functional outcomes (within-group $p < 0.001$), CIMT yielded higher absolute post-therapy FMA-UE scores, though the between-group difference was not statistically significant ($p > 0.05$). Conversely, the CIMT group showed significantly greater improvement in BBT scores compared to MT ($p < 0.05$),

Table 3. Comparative analysis of hand motor function and functional outcomes between MT and CIMT interventions

Variable	MT (n = 30) Mean ± SD	CIMT (n = 30) Mean ± SD	p-value
Fugl-Meyer Assessment (UE)	29.23 ± 8.49	42.60 ± 9.73	< 0.001
Surface-EMG (μV)			
Deltoid middle muscle	77.33 ± 24.82	106.47 ± 43.02	0.002
Deltoid anterior muscle	72.77 ± 31.11	101.20 ± 41.98	0.004
Deltoid posterior muscle	62.17 ± 19.61	82.40 ± 39.09	0.014
Biceps muscle	89.03 ± 34.88	118.43 ± 57.09	0.019
Triceps muscle	78.03 ± 28.72	93.96 ± 52.09	0.148
Wrist extensor muscle	70.77 ± 27.38	92.02 ± 44.51	0.030
Wrist flexor muscle	72.43 ± 31.67	79.40 ± 31.67	0.355
Box and block test	23.67 ± 9.01	33.03 ± 7.79	< 0.001

Independent sample *t-test; MT, Mirror Therapy; CIMT, constraint-induced movement therapy;* UE, Upper Extremity; sEMG, surface electromyography biofeedback

Table 4. Comparative analysis of hand motor function improvement and functional outcomes between MT and CIMT interventions

Variable	MT (n = 30) Median (Min-Max)	CIMT (n = 30) Median (Min-Max)	p-value
FMA-UE	5.5 (0.0-13.0)	7.0 (0.0-18.0)	0.167
Surface-EMG (μV)			
Deltoid middle m.	5.0 (1.0-16.0)	7.0 (1.0-15.0)	0.159
Deltoid anterior m.	10.0 (1.0-40.0)	11.0 (-1.0-71.0)	0.711
Deltoid posterior m.	11.0 (0.0-48.0)	12.0 (1.0-49.0)	0.382
Biceps m.	11.5 (1.0-28.0)	8.5 (1.0-135.0)	0.173
Triceps m.	10.5 (1.0-31.0)	14.0 (0.0-43.0)	0.818
Wrist extensor m.	10.0 (-2.0-30.0)	10.0 (-14.0-44.0)	0.230
Wrist flexor m.	9.5 (1.0-32.0)	13.0 (1.0-41.0)	0.407
Box and block test	10.0 (1.0-30.0)	11.0 (0.0-35.0)	0.008

Mann-Whitney test, Δ = difference between before and after intervention; MT, Mirror Therapy; CIMT, constraint-induced movement therapy; FMA-UE, Fugi-Meyer assessment-upper extremities; sEMG, surface electromyography biofeedback

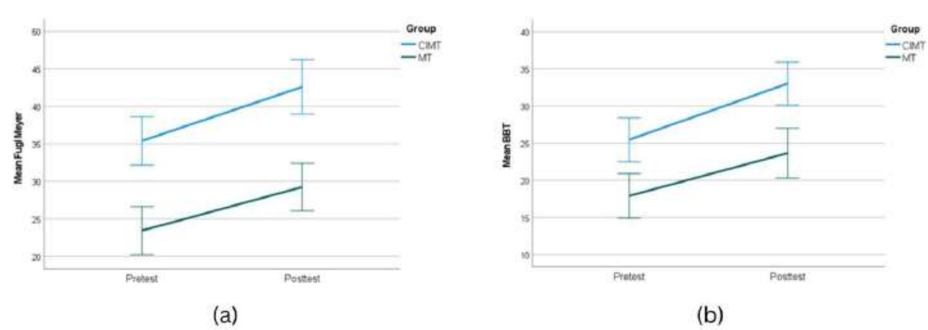

Figure 1. (a) Comparison of Fugl-Meyer Assessment (FMA-UE) scores between MT and CIMT groups before and after therapy. (b) Comparison of Box and Block Test (BBT) scores between MT and CIMT groups before and after therapy.

suggesting superior recovery of hand dexterity (**Table 4**).

sEMG analysis showed no statistically significant overall difference in muscle activity improvements between groups ($p > 0.05$). However, CIMT demonstrated greater gains in the deltoid (anterior, middle, posterior), triceps, and wrist flexor and extensor muscles, whereas MT was more effective in enhancing biceps activity (**Figure 2**).

DISCUSSION

The results of this study show that post-stroke patients who underwent six weeks of MT experienced significant improvements in hand motor function and functional outcomes. These findings align with Wen et al., who reported enhanced upper limb motor function after 30-minute MT sessions, three times per week for three weeks, with improvements significantly greater than those in the control group among acute and subacute stroke patients.[11] Lim et al. reported that 20-minute MT sessions, five times per week for four weeks, significantly improved upper limb motor function in sub-acute stroke patients.[12] Similarly, a meta-analysis by Saragih et al. involving 633 stroke patients found that MT effectively enhanced upper limb motor function.[13] Previous studies have also demonstrated MT's effectiveness in improving hand motor function with shorter therapy durations of 3 to 4 months. In contrast, this study evaluated outcomes after six months of treatment and obtained comparable results.

Regarding functional outcomes, these findings align with Lekshmy et al., who reported that 3 months of MT significantly improved BBT scores in stroke patients with hemiparesis.[14] Similarly, Kim et al. found that MT performed for 30 minutes per session, five days a week, over four weeks also led to significant improvements in BBT scores. These studies demonstrate that MT enhances hand dexterity across different therapy durations, and in the present study, six weeks of MT effectively improved hand dexterity in post-stroke patients.[15]

Similar research by Verma et al. reported that MT for 30 minutes per day, six days a week, over six weeks significantly improved BBT scores in stroke patients.[16]

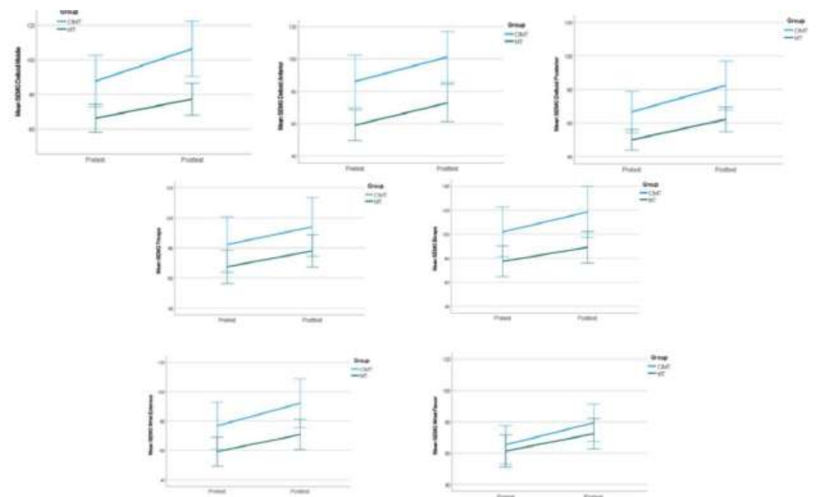

Figure 2. Comparison of Surface Electromyography score results in the MT and CIMT groups before and after therapy.

In a comparable study, Cristina et al. discovered that incorporating MT into traditional physical therapy improved upper limb recovery in subacute ischemic stroke patients, with substantial improvements in Fugl-Meyer upper extremity scores after six weeks of therapy. In their trial, MT was administered 30 minutes each day, five days a week, for six weeks.[17]

The effects of MT on hand motor function and functional outcomes are attributed to its ability to enhance neuroplasticity. By activating multiple neural networks, MT promotes brain reorganization and cortical restructuring through changes in the primary motor cortex and increased excitability of the corticospinal pathway.[18] Using a mirror, MT creates the illusion of normal movement in the affected limb by reflecting the movements of the unaffected limb, effectively tricking the brain. Repetitive, controlled movements further stimulate neuroplasticity, aiding motor function recovery and improving coordination.[19]

The results of this study show that post-stroke patients who underwent six weeks of CIMT experienced significant improvements in hand motor function and functional outcomes. These findings align with previous studies. Abba et al. reported that stroke patients receiving CIMT three times per week for six weeks showed significant increases in chronic upper limb Fugl-Meyer scores.[20] Similarly, Hanphode et al. found that 44 hemiparetic patients who received CIMT for two weeks, five sessions per week, demonstrated improvements in both Fugl-Meyer and BBT scores.[21] Yoon et al. also observed significant enhancements in BBT and Fugl-Meyer scores among 26 subacute stroke patients who underwent CIMT for six hours daily over two weeks.[22] Collectively, these findings suggest that CIMT effectively improves hand motor function and functional outcomes, with some studies indicating potential benefits within just two weeks of therapy.

The effects of CIMT on improving hand motor function and functional outcomes are linked to cortical reorganization, the nervous system's ability to adapt and modify itself in response to activity and environmental changes. This reorganization enhances brain plasticity, which supports hand function recovery.[21] CIMT promotes motor function restoration in the affected upper limb after stroke by increasing AMPAR-mediated synaptic transmission in the ischemic hemisphere. It also enhances dendritic and dendritic spine plasticity in both the ipsilateral and contralateral sensorimotor cortices and upregulates GluR2 expression at ipsilateral synapses. Consequently, CIMT facilitates neurological recovery after stroke by increasing synapse formation, promoting dendritic branching in the motor cortex, and modulating neurotrophic factors.[23]

In this study, CIMT and MT demonstrated similar effectiveness in improving hand motor function in post-stroke patients. These findings align with Adelusola et al., who reported significant improvements in upper limb motor function with both MT and CIMT after seven weeks of therapy, with no significant difference between the two.[24] Conversely, Preetha et al., in a study of 30 hemiplegic stroke patients following subacute cerebrovascular events, found that although both groups improved significantly after four weeks, the CIMT group showed a greater increase in Fugl-Meyer scores than the MT group.[25] Similarly, Hooria et al. reported that four weeks of CIMT and MT (45 minutes per session, five days per week) improved hand function in patients with cerebrovascular infarction, but CIMT yielded more significant gains.[26]

In this study, CIMT increased BBT scores by 11, slightly higher than the 10-point increase observed with MT. These results suggest that CIMT is more effective than MT in improving hand dexterity in post-stroke patients. Direct comparisons of CIMT and MT on hand dexterity in stroke patients are limited. However, previous studies provide indirect support: Corbetta et al. reported significant improvements in upper limb dexterity with CIMT.7 found that CIMT led to greater BBT score increases than the Bobath Approach in post-stroke patients.[27]

Mirror therapy is a cost-effective, patient-centered intervention for post-stroke upper limb rehabilitation. By focusing on the unaffected limb, it creates the illusion that the paralyzed limb is functional, allowing visual input to stimulate the affected side. Mirror neurons integrate visual, proprioceptive, and motor signals, reactivating motor units and promoting neuroplasticity in the premotor cortex. This therapy has been shown to improve upper limb function and self-care in subacute patients. Similarly, constraint-induced movement therapy promotes use of the affected arm by restricting the unaffected limb with a sling or splint, further enhancing cortical reorganization and neuroplasticity.[28]

The primary difference between MT and CIMT is which limb is actively engaged in rehabilitation. In MT, the unaffected arm remains passive, and the patient relies solely on visual feedback from the mirror. In CIMT, the unaffected arm is restrained, forcing deliberate use of the affected arm, which promotes motor recovery.[25] Consequently, the CIMT group showed greater improvement in hand function than the MT group, likely due to repeated, intensive practice with the affected limb. Such prolonged engagement may enhance neuroplasticity by encouraging the formation of new neural pathways.[29]

This study was among the first to compare the effects of MT and CIMT on sEMG-B and BBT scores, extending prior research that mainly relied on FMA-UE scores. Strengths included a randomized controlled design, standardized home-based intervention, and comprehensive evaluation of both muscle activation and dexterity. Limitations comprised a single post-therapy follow-up, short intervention duration, and use of the FMA-UE tool, which has not been validated in Indonesia.

CONCLUSION

Six weeks of MT and CIMT improved hand motor function in post-stroke patients. CIMT yielded superior outcomes, particularly in dexterity and daily upper-extremity use, supporting its preference for functional recovery. MT remained a valid option, especially in early rehabilitation, and could serve as an initial or adjunct therapy. Both interventions were suitable for integration into rehabilitation programs, with CIMT prioritized for patients targeting practical hand function. Future studies should include multiple follow-up points to identify the optimal timing of treatment.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

FUNDING

None.

ETHICAL CONSIDERATION

The study was carried out with ethical approval from the Ethics Commission of the Faculty of Medicine at Universitas Hasanuddin (approved no. 163/UN4.6.4.5.31/PP36/2025). All participants were informed about the study's objectives, procedures, potential risks, and benefits, and they gave written informed consent to participate.

AVAILABILITY OF DATA AND MATERIAL

The corresponding author will provide data and materials upon request.

AUTHORS CONTRIBUTIONS

O handled data collection, methodology development, and manuscript drafting. HM oversaw study conceptualization, design, and critical revisions. SEA contributed to data interpretation and manuscript drafting. AAZ and AS provided critical revisions and technical feedback. MW assisted with data analysis and literature review. All authors contributed to drafting and approved the final manuscript.

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