Effectiveness of Mirror Therapy, Electrical Stimulation, and CIMT in Restoring Upper Extremity Function after Stroke

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KEYWORDS
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ABSTRACT
Objective: This study aimed to compare the effectiveness of mirror therapy (MT), electrical stimulation (EMS) combined with MT, and Constraint-Induced Movement Therapy (CIMT) in improving upper extremity function among stroke survivors. Methodology: A randomized controlled trial was conducted involving n=45 stroke patients undergoing rehabilitation at Wah International Hospital. The inclusion criteria for the study required participants to be above 45 years of age, to have survived either an ischemic or haemorrhagic stroke, and to have at least 10° wrist extension. Participants were excluded if they had an implanted electrical device such as an artificial pacemaker, paresis instead of paralysis, hemiplegia due to causes other than ischemic or haemorrhagic stroke (such as trauma, tumor, or coordination problems), or impaired sensory integration. Participants were divided into three groups: EMS combined with MT, CIMT alone, and Mirror therapy alone. Treatment sessions were administered four times a week for three months. Outcome measures included the Fugl-Meyer Assessment Scale (FMA) and Motor Assessment Scale (MAS). Results: Analysis revealed significant improvements in upper extremity function across all groups. However, the CIMT group exhibited the most substantial enhancement, with a mean difference of -68.5 ($p < 0.05$) on the FMA and -24.1 ($p < 0.05$) on the MAS compared to the other groups. Conclusion: The findings highlight the superior efficacy of CIMT in improving upper extremity function among stroke survivors. Incorporating CIMT into rehabilitation protocols is crucial for optimizing outcomes in this patient population. Further research is warranted to explore the long-term benefits and optimal implementation strategies of CIMT in diverse rehabilitation settings

1. Introduction

Stroke is clinically recognized syndrome of vascular injury of central nervous system in terms of acute and focal neurological deficit. Its pattern of tissue injury is confirmed by imaging. (1). Worldwide, the second leading cause of death is stroke. About 87% of strokes are ischemic infarction and 10-25% are hemorrhagic stroke.to understand the clinical manifestations of stroke, it is necessary to know the anatomy of blood supply to brain. There are two anterior internal carotids and tow posterior vertebral arteries which form circle of Willis. Ischemic stroke is due to deficiency in blood and oxygen supply of the brain while hemorrhagic stroke is due to bleeding or leaky blood vessels(2). The most commonly experienced symptoms that stroke survivors report are muscular imbalances and weakness, less control on posture and voluntary movements, spasticity, structural malalignment (3). The risk factors of stroke are highly variable and complex. However, on the basis of native and external environment of the body these are classified as internal risk factors (hypertension, hypercholesterolemia, genetic factors) and as external risk factors (smoking, alcohol consumption, air pollution).(4) There are many therapies to recover the function of upper limb in terms of motor control such as exercise medicine and bilateral training of arms. Some recent researches have shown promising results of Mirror Therapy (MT) (5). Electrical stimulation (ES) is a therapeutic modality which, when applied on the skin via adhesive electrodes, produces visible muscular contraction by releasing an electric current.ES is only effective when the LMN is intact otherwise it is impossible to

generate contraction in the affected muscle(6) It was found that that the combination of mirror therapy and electrical stimulation for lower extremity motor function recovery in stroke survivors have a positive effect.(7) A category of rehabilitation which is known as Constraint induced movement therapy (CIMT), is used to improve the function of the upper limb in the cases of stroke patients and in those affected with other neuromuscular disorders(8). It was found that Modified Constraint Induced Movement therapy is more effective than Mirror Therapy in subacute stroke survivers to improve the hemiparetic upper extremity (9). The primary aim of this study is to investigate the therapeutic effectiveness of mirror therapy (MT) combined with neuromuscular electrical stimulation (EMS) in stroke patients, and to compare the outcomes with those achieved through constraint-induced movement therapy (CIMT). Previous research, including a randomized controlled trial (RCT) conducted in 2019, has demonstrated that the combination of EMS and MT can be an effective treatment protocol for stroke patients. Another hypothesis suggests that MT combined with EMS produces significant clinical improvements in the upper limbs of stroke patients. Conversely, an alternative hypothesis posits that CIMT yields better outcomes than the combination of EMS and MT.

This study holds substantial societal and academic significance. For society, it aims to identify more effective methods for upper limb rehabilitation in stroke patients, which can improve patient outcomes and quality of life. For the research community, it provides a basis for developing advanced therapeutic protocols that combine EMS and MT and compares their effectiveness with that of CIMT. By examining motor activity, quality of life, and motor restoration in less chronic stroke patients, this study seeks to fill the gap in the literature regarding the comparative efficacy of these interventions. Notably, no existing study has provided a direct comparison between MT combined with EMS and CIMT in upper extremity rehabilitation for cerebrovascular accident (CVA) patients. Therefore, this study aims to address this gap and contribute valuable insights to The Field Of Stroke Rehabilitation.

2. Methodology

This randomized control trial was conducted at Wah International Hospital and approved by the Institutional Review Board (IRB) of Shifa Tamir-e-Millat University Ref: IRB#351-21. The trial spanned a period of six months, from January 2022 to July 2022. Non- probability convenience sampling was performed. The inclusion criteria for the study required participants to be above 45 years of age, to have survived either an ischemic or hemorrhagic stroke, and to have at least 10° wrist extension. Participants were excluded if they had an implanted electrical device such as an artificial pacemaker, paresis instead of paralysis, hemiplegia due to causes other than ischemic or haemorrhagic stroke (such as trauma, tumor, or coordination problems), or impaired sensory integration. Initially, n=60 participants were selected for the study. However, n=15 participants were excluded due to not meeting the inclusion criteria (n=9) or unwillingness to participate (n=6). Thus, a final sample size of 45 participants was selected, all of whom met the inclusion criteria.

Participants were randomly allocated into three groups using a coin toss method. Group A, consisting of n=15 individuals, received EMS (electrical muscle stimulation) with a frequency range of 20-100 Hz and a pulse width of 20-450 microseconds, along with mirror therapy and exercises. Group B, also consisting of n=15 participants, received Constraint-Induced Movement Therapy (CIMT) and exercises. Group C, with n=15 participants, received mirror therapy and exercises. Neuromuscular electrical stimulation (NMES) is a modality widely used in stroke rehabilitation to address motor impairment by improving or assisting volitional movement(10). Constraint-Induced Movement Therapy (CIMT) is a rehabilitation technique designed to provoke the use of the paretic upper limb(11). Mirror therapy is a rehabilitation approach where the reflection of a moving non-affected limb creates the illusion of movement in the affected limb, achieved by placing a mirror between the arms or legs(12). Interventions were administered four days per week for 12 weeks. Evaluations were conducted at three time points: before the intervention (baseline), at 9 weeks after initiating the intervention (midline), and at 12 weeks after initiating the intervention (the end of the

protocol).

A single, blinded investigation assessed motor functions using the Fugl-Meyer Assessment (FMA) and the Motor Assessment Scale (MAS). The FMA is a stroke-specific, performance-based impairment index with a total score of 226, assessing motor functions across five domains, and is recognized as a valid and reliable scale. The MAS is a performance-based scale used to assess motor function in stroke patients. Statistical analysis was performed using SPSS-21. A paired t-test was used for within-group analysis and one way ANOVA was used for between-group analysis. This methodology ensured a rigorous evaluation of the interventions' effectiveness on motor function recovery in stroke patients.

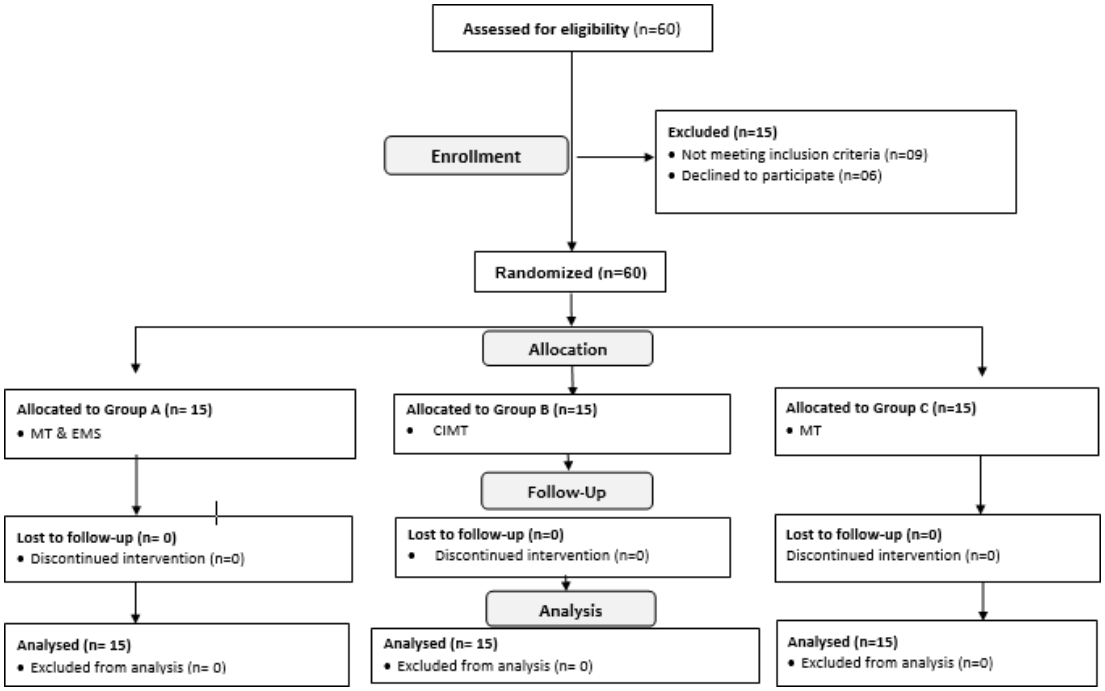

Figure 1: Consort Diagram

Results and Discussion

In this study, a total of 45 participants were included, comprising males (n=24, 53.33%) and females (n=21, 46.67%). The age distribution was diverse, with participants falling between 56-65 years old (n=25, 55.56%), 46-55 years old (n=13, 28.89%), and 66-75 years old (n=7, 15.56%). The study allocated participants into three intervention groups: Group A (EMS+MT), Group B (CIMT), and Group C (MT). Each group had an equal number of participants. Group A received Electrical Muscle Stimulation (EMS) combined with Mirror Therapy (MT), Group B underwent Constraint Induced Movement Therapy (CIMT), and Group C received only Mirror Therapy (MT).

Table 1: Within Group Analysis

Groups	Variables	Pre	Post	MD	p-Value
Group A (EMS+MT)	**Total Score (FMA)**	39.40±9.26	43.20±7.85	- 3.8	0.003
	Total Score (MAS)	16.00±2.56	17.80±2.70	- 1.8	0.000
Group B (CIMT)	**Total Score (FMA)**	43.47±11.28	105.73±10.32	- 62.26	0.000
	Total Score (MAS)	18.93±5.36	44.67±3,97	- 25.74	0.000

Group C (MT)	**Total Score (FMA)**	30.07±13.79	33.80±15.54	- 3.73	0.011
	Total Score (MAS)	18.73±3.17	23.20±3.16	- 4.47	0.000

Table 2: Between Group Analysis

		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Total Score (FMA)	**Between Groups**	45865.91	2	22932.95	167.81	.000
	Within Groups	5739.73	42	136.66		
	Total	51605.64	44			
Total Score (MAS)	**Between Groups**	6058.97	2	3029.48	274.14	.000
	Within Groups	464.13	42	11.05		
	Total	6523.11	44			

The present study aimed to evaluate the efficacy of Mirror Therapy (MT) combined with Electrical Muscle Stimulation (EMS) compared to Constraint-Induced Movement Therapy (CIMT) in the rehabilitation of upper limb function in stroke patients. The results, drawn from a sample of 45 participants, demonstrated significant improvements across all groups in both the Fugl-Meyer Assessment (FMA) and the Motor Assessment Scale (MAS) scores post-intervention. Group B (CIMT) showed the most substantial improvements, followed by Group C (MT) and Group A (EMS+MT). These findings align with existing literature on the effectiveness of CIMT and MT in stroke rehabilitation.

CIMT has consistently been shown to be highly effective in enhancing motor recovery post-stroke. Liu et al. (2019) assessed the effects of CIMT on stroke patients with middle cerebral artery occlusion and reported remarkable improvements in skilled walking, brain activation, neuron recruitment, and synapse numbers. The study highlighted the bilateral enhancement of neural activity in the cortex, suggesting CIMT's capacity to boost brain function irrespective of the lesion's side(13). Similarly, Scordalakes (2020) noted that modified CIMT was significantly more beneficial than mirror treatment in enhancing upper limb function in less chronic stroke patients, further supporting the efficacy of CIMT(14).

Our study's results, which showed significant improvements in both FMA and MAS scores for Group B (CIMT), are in line with these findings. The substantial improvement observed in Group B underscores CIMT's robust impact on motor function recovery and its potential to drive neural plasticity and functional reorganization in stroke patients.

Mirror Therapy (MT) has been another prominent rehabilitation method for stroke patients. Zhu et al. (2020) conducted a cohort study on 46 stroke patients and concluded that Visual Feedback Therapy based on mirror neuron theory could significantly improve motor function of the upper extremity. The study attributed these improvements to increased excitability in the distribution of brain neurons in the mirror image, highlighting the neural mechanisms underlying MT's effectiveness(15).

Further supporting the utility of MT, Gandhi et al. (2020) conducted a systematic review of 28

studies and found that MT during the acute and subacute phases resulted in definite improvements in motor and sensory functions, although the extent of these improvements was somewhat limited(12). Additionally, a 2022 systematic review by Zhang et al. identified that MT was beneficial in reducing unilateral neglect and improving activities of daily living (ADLs) compared to sham treatments or no treatment(16).

In the present study, Group C (MT) also demonstrated significant improvements in FMA and MAS scores, albeit to a lesser extent than Group B (CIMT). This finding is consistent with the broader literature indicating that while MT is effective, its impact might be slightly less pronounced compared to CIMT.

The combination of EMS and MT, as implemented in Group A, also yielded significant improvements in our study, suggesting a synergistic effect of these therapies. EMS has been known to enhance muscle activation and strength, potentially providing a solid foundation upon which MT can build to further enhance motor recovery. However, the combined approach did not surpass the efficacy of CIMT, which might be attributed to the distinct neural mechanisms each therapy targets.

The findings of our study are bolstered by numerous other research efforts. For instance, Lee et al. (2021) conducted a meta-analysis and found that transcranial direct current stimulation (tDCS) combined with therapist-led interventions had a greater effect on upper extremity function than equipment-based interventions, emphasizing the critical role of therapists in rehabilitation. This aligns with our study's indication that therapist-led CIMT produced superior outcomes(17).

Rajendran et al. (2021) explored the effects of self-administered MT as an adjunct to regular interventions and found significant improvements in upper extremity function, reinforcing the potential of MT as an effective rehabilitative approach(18). Saha (2021) also highlighted MT's effectiveness in reducing pain, oedema, and improving functional activities in patients with shoulder-hand syndrome post-stroke(19).

In a comprehensive meta-analysis by Jaya et al. (2022), CIMT was found to be superior to other interventions in improving balance-related motor function, although it did not significantly impact functional mobility. This study's findings are reflective of CIMT's potent impact on motor recovery as observed in our study(20).

The evolving landscape of stroke rehabilitation continues to explore novel interventions. For instance, Tseng et al. (2024) highlighted the feasibility and clinical benefits of portable rehabilitation robots, emphasizing the need for further research to enhance their portability and effectiveness(21). Similarly, Okamura et al. (2024) investigated the benefits of Virtual Reality Mirror Therapy (VRMT) and found promising results in improving upper extremity dysfunction, although more high-quality RCTs are needed to clarify its effects(22).

Narang et al. (2023) compared the Motor Relearning Programme (MRP) with MT and concluded that MRP along with conventional physical therapy (CPT) was more effective than MT along with CPT, suggesting the potential of integrating different therapeutic approaches to optimize outcomes(23).

The implications of our study are significant for clinical practice. The pronounced effectiveness of CIMT suggests that it should be a cornerstone of upper limb rehabilitation for stroke patients. However, given the benefits observed with MT and EMS, a multimodal approach might be beneficial, especially in tailoring rehabilitation programs to individual patient needs and preferences.

There is also a critical need for training and skill development among occupational therapists, as highlighted by McCluskey et al. (2020)(24). Enhancing the capacity of therapists to implement CIMT and other advanced therapies effectively can significantly improve patient outcomes.

The current study provides robust evidence supporting the efficacy of CIMT, MT, and EMS+MT in improving upper limb function in stroke patients. CIMT emerged as the most effective intervention, followed by MT, and EMS+MT. These findings align with existing literature and underscore the

importance of personalized, multimodal rehabilitation strategies. Future research should continue to explore novel interventions and their integration into clinical practice to further enhance the rehabilitation outcomes for stroke patients.

Conclusion

There is enough data to prove the superiority of CIMT as a rehabilitation protocol in upper extremity stroke survivors. There is a need to study its impact on the coordination and balance among patients affected with stroke, cerebral palsy and motor neuron diseases. Moreover, physical therapists and rehabilitation experts need to develop their clinical set ups in such a way that allows for more effective application of CIMT. The systematic reviews are also needed to be done to illustrate its effectiveness in lower extremity stroke patients and hemiplegia survivors. The trials with high operational quality and bigger sample sizes are required to find the short-term and long-term effects of suitable mirror therapy procedure for unilateral neglect in future. More trials are needed to confirm the effects of CIMT combined with FES in larger sample sizes.

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