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Authors and Affiliation:

Rida Iqbal[1] ,Muhammad Hassan[2]
[1-2] TIMES University, Multan, Pakistan
*Corresponding Author Email: ridaiqbal137@gmail.com

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Original Article

Effects of modified constraint induced movement therapy and mirror therapy on improving upper extremity motor functions in stroke patients

Rida Iqbal[1*] ,Muhammad Hassan[2]
[1-2] TIMES University, Multan, Pakistan
[*]**Corresponding Author Email**: ridaiqbal137@gmail.com

ABSTRACT

Objective*:* To explore and compare the effect of Modified Constraint-Induced Movement Therapy and Mirror Therapy on the upper limb motor functioning of post-stroke patients.

Methods*:* This was a randomized controlled trial carried out at the Department of Physiotherapy, Faisal Hospital in Multan. Twenty-six patients, 45 to 65 years old who had a first-ever ischemic stroke, were randomly assigned to either of two groups. Group A (n = 13) were treated with Modified Constraint-Induced Movement Therapy and Group B (n = 13) were treated with Mirror Therapy combined with conventional physiotherapy four times a week for four weeks. The Fugl-Meyer Assessment Upper Extremity scale was used to measure motor function at baseline and post intervention. The paired samples t-test, independent samples t-test and Levene's test were used to analyze the data at $p<0.05$.

Results*:* 12 subjects from Group A and 11 from Group B completed the study - both groups showed significant improvements on all FMA-UE subscales ($p < 0.001$). CIMT group demonstrated a mean gain of 17.00 ± 1.65 points while MT group demonstrated a mean gain of 11.36 ± 1.12 points. There were significant differences between the group comparison in which CIMT scored higher on the upper extremity ($p = 0.008$) and wrist ($p < 0.001$), hand ($p < 0.001$), and total score ($p < 0.001$).

Conclusion: Modified CIMT has a significantly higher recovery of upper limb motor function compared to both interventions and it is effective at improving wrist and hand motor function.

Keywords*:* Modified Constraint-Induced Movement Therapy, Mirror Therapy, Stroke, Fugl-Meyer Assessment Upper Extremity, Motor Function, Neurological Rehabilitation.

1. INTRODUCTION

Stroke is a medical emergency wherein the blood flow to the brain is suddenly blocked by a blood vessel or an artery, causing the brain's function to deteriorate rapidly.[1] It is the second leading cause of death and third leading cause of disability in adults worldwide, and is a significant burden on health care systems and societies.[2] Of all stroke cases, around 80% are ischemic, meaning that blood flow is blocked to one part of the brain, and 20% are hemorrhagic (caused by bleeding into or around brain tissue).[3] As the number of modifiable risk factors such as hypertension, diabetes mellitus, obesity, and physical inactivity have been increasing and the world is aging, the burden of stroke has risen.[4] For those who survive, the most frequent impairments that remain six months after the stroke are unilateral weakness (almost half), difficulty walking (about 30%), and daily activity dependence (about 26%).[5] They are ongoing deficits that often affect the upper limb and make it more difficult for the person to do everyday activities, including eating, getting dressed, grooming, and grasping things, and this greatly affects the person's quality of life and functional independence.[6]

Mirror therapy and Modified Constraint-Induced Movement Therapy are two of the most studied and clinically utilized rehabilitation techniques for motor recovery of the UEs following stroke.[7] The concept of modified CIMT is based on the theory of "learned non-use" in which patients gradually stop using their affected limb after multiple inefficient movement attempts.[8] By limiting the affected hand's mobility with a mitt, a glove or a sling, the patient is forced to learn structured task specific activities with the affected hand, intensifying the reorganization of the cortex and the creation of new neuronal pathways by practicing a lot of repetitive tasks.[9] It has been demonstrated that this forced use paradigm has neuroplasticity effects that promote use-dependent recovery in both subacute and chronic stroke.[10]

Mirror Therapy, however, uses a mirror that is placed at the midline of the body to produce a visual illusion of normal movement in the affected limb.[11] The activation of the mirror neuron system and premotor cortex during motor planning and interhemispheric communication and the reorganization of the cortex all contribute to motor recovery during this patient hand-movement task.[12] Systematic reviews and meta-analyses have shown that the motor outcomes and activities of daily living of the upper limb are significantly improved in stroke patients receiving mirror therapy.[13]

There are several studies which directly compare these two approaches. Tharani et al. found that modified CIMT resulted in significantly greater improvements in upper extremity function compared to mirror therapy in subacute stroke patients.[7] Hooria et al. concluded that CIMT significantly improved hand function in comparison with mirror therapy.[14] Omar et al. also noted the most motor recovery in the CIMT group compared to three treatments.[15] But the direct comparison of these interventions under standardisation in the Pakistani clinical context is limited and evidence based guidance for local rehabilitation practice is also missing. The aim of the present study was to find and compare the effect of Modified Constraint-Induced Movement Therapy and Mirror Therapy on motor functioning of patient after stroke in upper limb.

2. METHODOLOGY

The design of the study was randomized controlled trial. This study was conducted at the Department of Physiotherapy at Faisal Hospital, Multan for a period of 4 months after obtaining ethical approval from the Institutional Review Board (IRB) of TIMES Institute, Multan. Written informed

consent was obtained from all participants before enrollment and confidentiality was ensured during the process.

The sample size of 26 participants was selected using the G*Power software based on previous literature.[7] To reduce selection bias the participants were approached by purposive sampling and randomly distributed into two equal groups using the sealed envelope technique.[16]

The main outcome measure used was the Fugl-Meyer Assessment Upper Extremity (FMA-UE) scale. This standardised self-assessment tool measures motor impairment in post-stroke hemiplegic patients on a 66 point ordinal score scale consisting of 4 subscale: Upper Extremity (A), Wrist (B), Hand (C) and Coordination/Speed (D). Severity is categorized as severe (0 to 22), moderate-severe (23 to 32), moderate (33 to 42), mild-moderate (43 to 52), and mild (53 to 66). The assessments were carried out at baseline and after the four weeks intervention period.

Both groups were given traditional physiotherapy, which included stretching exercises, range of motion exercises and proprioceptive neuromuscular facilitation techniques. Sessions 4 times per week 30 minutes each.

Group A (Modified Constraint Induced Movement Therapy): Participants were seated comfortably, with the affected limb placed on a table and are supported adequately to prevent injury to the shoulder. The uninvolved hand was immobilized with a mitt, glove or sling to limit its use during the session. This was followed by a series of structured functional tasks done with only the affected hand. These included grasping and releasing activities like picking up blocks or coins and putting them in a box, reaching tasks involving forward, sideways and backward movements to pick up objects placed at different distances, manipulation tasks like turning pages, opening and closing containers, eating with a spoon, brushing teeth, combing hair, holding a cup, solving puzzles, and constructing with blocks.

In Group B (Mirror Therapy), participants were seated in front of a mirror, which was placed along body midline, perpendicular to the trunk, thus dividing the visual field of both sides. Affected limb was placed behind the mirror and the unaffected side was placed in front parallel to the affected side. The participants were instructed to fixate the unaffected hand in the mirror so that they saw the appearance of the unaffected hand moving normally. Structured activities involved hand movements including opening/closing the fist and flexing/extending the fingers, watching the mirror, wrist movements (flexion, extension, supination and pronation), and functional manipulation activities (small objects, ball rolling, grasping and releasing objects). All movements were the same on both hands during each session.

The data were all analyzed through SPSS Statistics version 26.0. Frequencies and percentages are used to summarise categorical variables and the Chi-Square test was used to compare the distribution of categorical variables at baseline. Data from continuous variables were reported as mean ± SD. The Shapiro-Wilk test showed that the data was normally distributed which allowed for the use of parametric analyses. The paired sample t-test was used to assess pre-post comparisons within subjects and the independent sample t-test was used to compare between groups. The homogeneity of variance test was performed using Levene's test. All analyses were done with a statistical significance of $p<0.05$.

3. RESULTS

A total of 26 participants were enrolled, of which three were not followed up during the study period (one in the CIMT group and two in the Mirror Therapy group), leaving 12 participants in the CIMT group and

11 in the Mirror Therapy group for analysis. Group A comprised 7 males (53.8%) and 6 females (46.2%), while Group B comprised 6 males (46.2%) and 7 females (53.8%). There was no significant difference between the gender distribution of the groups as indicated by the Chi-Square test ($\chi^2 = 0.154$, $p = 0.695$). The average total FMA-UE score at baseline was 27.85 ± 3.58 for Group A (CIMT) and 25.77 ± 2.55 for Group B (MT). Post treatment mean total FMA-UE score for Group A was 45.25 ± 3.65 and that for Group B was 37.36 ± 2.87.

Within group comparison of pre-treatment and post-treatment FMA-UE subscale scores for Group A (Modified CIMT) was done using paired samples t-test. All four subscales were statistically significantly improved ($p < 0.001$). The upper extremity subscale (A) was the highest on the absolute gain with a mean score that improved from 17.25 ± 2.63 to 26.00 ± 2.49 following treatment. The hand subscale (C) showed an increase of 3.84 points, the wrist subscale (B) showed an increase of 3.25 points, and the coordination/speed subscale (D) showed an increase of 1.17 points.

The within group comparison for Group B (Mirror Therapy) is shown in table 4. The intervention resulted in significant differences in all four subscales. The upper extremity subscale (A) recorded the greatest improvement of 7.73 points (Post: 23.09 ± 2.30, Pre: 15.36 ± 2.25, $t = 12.782$, $p < 0.001$). The wrist subscale (B) improved by 1.45 points ($t = 9.245$, $p < 0.001$), the hand subscale (C) by 1.18 points ($t = 3.992$, $p = 0.003$), and the coordination/speed subscale (D) by 1.00 point ($t = 4.280$, $p = 0.002$). Both interventions resulted in significant improvements in all motor domains, but the size of the improvements was consistently smaller in the MT group than in the CIMT group.

The within group comparison of total pre-treatment and post-treatment scores of FMA-UE for both groups. Both groups had highly significant improvements in total FMA-UE scores ($p < 0.001$). The CIMT group showed a mean improvement of 17.00 ± 1.65 points (from 28.25 to 45.25), while the Mirror Therapy group showed a mean improvement of 11.36 ± 1.12 points (from 26.00 to 37.36). The mean difference in change between the two groups on the total FMA-UE score was 5.64 points and the mean score of the CIMT group was about 49.6% higher than the mean score of the Mirror Therapy group.

Table 1: Within Group Comparison of Total FMA-UE Score for Both Groups

Group	n	Post Mean ± SD	Pre Mean ± SD	Mean Change ± SD	p-value
Group A (CIMT)	12	45.25 ± 3.65	28.25 ± 3.42	17.00 ± 1.65	<0.001*
Group B (MT)	11	37.36 ± 2.87	26.00 ± 2.49	11.36 ± 1.12	<0.001*

The independent samples t-test results for the pre-treatment and post-treatment FMA-UE total scores of the two groups. The pre-treatment total score was not significantly different between the groups at baseline ($t = 1.703$, $p = 0.101$), indicating an effective randomization process. The post-treatment comparison, however, showed a statistically significant difference between the two groups with the CIMT as 5.724 ($p < 0.001$) and the mean total scores of FMA-UE in post treatment of CIMT group were significantly higher than the MT group.

Table 2: Independent Samples T-Test for Pre-Treatment and Post-Treatment FMA-UE Total Scores

Variable	Group A CIMT Mean ± SD	Group B MT Mean ± SD	p-value
Pre FMA Total	27.85 ± 3.58	25.77 ± 2.55	0.101
Post FMA Total	45.25 ± 3.65	37.36 ± 2.87	<0.001*

The between group comparison of the post treatment FMA-UE subscale scores on the independent samples t-test. Significant

differences favoring the CIMT group were found on the upper extremity subscale ($t = 2.904$, $p = 0.008$), wrist subscale ($t = 7.843$, $p < 0.001$), hand subscale ($t = 4.462$, $p < 0.001$), and total FMA-UE score ($t = 5.724$, $p < 0.001$). The only subscale on which no significant differences were found was the coordination/speed subscale ($t = 0.302$, $p = 0.766$), which suggested that both interventions had similar effects on coordination and speed recovery after intervention. The mean change score was significantly higher in the CIMT group (17.00 ± 1.65) than in the MT group (11.36 ± 1.12); $t = 9.486$ and $p < 0.001$ indicating that Modified Constraint-Induced Movement Therapy resulted in significantly greater improvement in upper extremity motor function compared to Mirror Therapy.

Table 3: Between Group Comparison of Post-Treatment FMA-UE Subscale Scores

FMA-UE Subscale	CIMT (n=12) Mean ± SD	MT (n=11) Mean ± SD	t-value	p-value
A. Upper Extremity	26.00 ± 2.49	23.09 ± 2.30	2.904	0.008*
B. Wrist	6.33 ± 0.89	4.00 ± 0.45	7.843	<0.001*
C. Hand	7.92 ± 1.73	5.36 ± 0.81	4.462	<0.001*
D. Coordination/Speed	5.00 ± 0.74	4.91 ± 0.70	0.302	0.766
Total FMA-UE	45.25 ± 3.65	37.36 ± 2.87	5.724	<0.001*
Mean Change	17.00 ± 1.65	11.36 ± 1.12	9.486	<0.001*

The severity classification of the participants before the intervention was according to the FMA-UE scores. The majority of participants in both groups were in the moderate-severe range (23 to 32) with 11 subjects (84.6%) in the CIMT group and 12 subjects (92.3%) in the MT group being in this range. The CIMT group had 15.4% in the moderate category (score 33 to 42) and 1 participant (7.7%) in the MT group was classified as severe (score 0 to 22). (Figure 4)

The severity of the post-treatment is classified. Both groups showed significant reduction in the severity categories after intervention. Among the CIMT group, there were 9 participants (75.0%) that moved to the mild-moderate category (scores 43-52) and 3 participants (25.0%) who moved to the moderate category (scores 33-42). In the MT group, 10 (90.9%) were in the moderate category and only 1 (9.1%) was in the mild-moderate category.

4. DISCUSSION

In the present study, the authors aimed to compare the efficacy of Modified Constraint-Induced Movement Therapy and Mirror Therapy on upper extremity motor function in stroke patients in a four-weeks randomized controlled trial at Faisal hospital, Multan. Results showed that both interventions resulted in statistically significant within group improvements across all FMA-UE subscales, validating the effectiveness of both rehabilitation strategies to promote motor recovery of the upper limbs after stroke. The between group analysis always revealed significantly better results for Modified CIMT for the upper extremity, wrist, hand, and the total FMA-UE scores as compared to Mirror Therapy.

Demographic analysis revealed no significant difference in gender ($\chi^2 = 0.154$, $p = 0.695$) or pre-treatment total FMA-UE scores ($t = 1.703$, $p = 0.101$) between both groups. This confirmed that the randomisation was effective and any treatment difference after the treatment could be confidently attributed to the differential effect of the two treatments and not to any pre-treatment differences between the two groups. The CIMT group earned 17.00 points while the MT group earned 11.36 points, yielding a difference of a minimally clinically important difference (5.64 points) statistically and clinically significant in the literature cited in stroke rehabilitation.[17] The CIMT group had more significant improvements on the wrist subscale (3.25 versus 1.45 points) and on the

hand subscale (3.84 versus 1.18 points), indicating that the forced use paradigm inherent in Modified CIMT has a significant effect on distal upper extremity function by encouraging patients to perform intensive fine motor hand use that they may otherwise not have engaged in.

These results are consistent with several previous studies that have contrasted constraint induced interventions with mirror interventions. The present study findings were similar to those of Tharani et al. who reported that modified CIMT resulted in significant improvement of performance of the upper extremity in subacute stroke patients compared to mirror therapy on Fugl-Meyer scale.[7] The results showed that the CIMT group experienced a significant improvement in hand functionality compared with the MT group.[14] Omar et al. reported that of three treatment modalities, CIMT showed the highest improvement.[15] Patowary et al. found that CIMT had better hand function recovery results in acute stroke patients.[16] In an outpatient rehabilitation setting,[18] Mubarak et al. have confirmed that there were significant differences between CIMT and mirror therapy in their respective gains of hand dexterity; motor strength gains were slightly greater in CIMT, with no significant difference. de Sire et al. performed a randomized controlled trial (RCT) in which they compared the effectiveness of CIMT to mirror therapy in a home-based treatment of hemiparetic patients after stroke and found that both interventions were effective compared to a control group, with no significant difference in motor strength gains between the two methods.[19] Another finding of Newaz et al. was that CIMT group performed best on the Fugl-Meyer scale as compared to the combined therapy and mirror therapy group of subacute stroke patients.[20] Preetha et al. also found that constraint induced movement therapy (CIMT) produces better hand functional recovery in hemiplegic individuals than task based mirror therapy.[21]

The superior results seen with Modified CIMT can be attributed to the forced use mechanism by physically restricting the use of the unaffected limb and forcing intensive, repetitive use of the affected one.[8] This direct activation of the motor system leads to the reorganization of the brain and reinforcement of new motor pathways, via use-dependent plasticity.[9] The principle behind Mirror Therapy is completely different, using visual feedback through the Mirror Neuron System to assist in motor recovery by vicarious motor learning and interhemispheric communication.[11] In both approaches, there are neurophysiologically and clinically valid mechanisms and effects, but more robust neuroplastic changes seem to be obtained by the direct physical interaction required of CIMT, especially for motor functions involving precise voluntary control of the wrist and hand. This was also supported by the severity classification analysis, which showed that 75.0% of the participants in the CIMT group improved from moderate-severe to mild-moderate, while 9.1% of the participants in the Mirror Therapy group improved to the same degree.

This study had a number of limitations. The sample size was relatively small (26 participants and 23 at post treatment due to 3 dropouts) and the study was performed in one center, which can reduce the statistical power and generalizability. First time ischemic stroke patients aged 45-65 years were included; no long-term follow-up after post treatment. Only one outcome measure was used: FMA-UE scale, which may have resulted in performance bias. More multicenter, long-term follow-up is needed for future studies to assess the durability of motor changes for both interventions.

5. CONCLUSION

The effectiveness of the upper extremity motor function improvement in patients with stroke using Modified

Constraint-Induced Movement Therapy and Mirror Therapy is comparable. However Modified CIMT yields greater recovery of motor function over almost all motor domains and is recommended as a top rehabilitation technique to maximize motor recovery from stroke in the upper limb.

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