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Original Article

Physical Medicine and Rehabilitation Section

Effectiveness of Mirror Therapy through Telerehabilitation on Upper Extremity Performance in Hemiparetic Stroke Patients: An Experimental Study

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ABSTRACT

Introduction: A major challenge in stroke rehabilitation is the paresis of the Upper Extremity (UE), resulting in limited functional performance. Recently, motor imagery and Mirror Therapy (MT) have been recommended as an additional rehabilitation strategies that could be beneficial for motor rehabilitation after a stroke.

Aim: To determine the effectiveness of mirror visual feedback through Telerehabilitation (TR) on UE functional performance in hemiparetic stroke patients.

Materials and Methods: An experimental pretest, post-test study design was conducted at SRM Medical College Hospital and Research Centre, SRMIST, Kattankulathur, Chengalpattu, Tamil Nadu, India from January 2021 to June 2021. Total of 60 patients diagnosed with hemiparetic stroke were included in the study through convenience sampling and divided into two groups. The experimental group (n=30) received TR, and the control group (n=30) received face-to-face MT for 12 weeks. A pretest and post-test evaluation were administered using the Wolf Motor Function Test (WMFT) and Fugl-Meyer Assessment for the Upper Extremity (FMA-UE). Within-group analysis was performed using the Wilcoxon Signed-Rank Test, while intergroup analysis was conducted using the Mann-Whitney U Test.

Results: The study revealed statistical significance between the pretest and post-test scores of the WMFT-FAS (Functional Ability Score), WMFT-Time (Performance Time), and FMA-UE in the control and experimental groups. The results showed no statistically significant difference between the post-test scores of the control and experimental groups in the FMA and WMFT-FAS. However, there was a statistically significant distinction in the post-test scores between the control and experimental groups in WMFT-Time.

Conclusion: The study concluded that mirror visual feedback through TR was an effective treatment method to improve UE functional performance among hemiparetic stroke patients by offering an alternative service delivery model for occupational therapy.

Keywords: Cerebrovascular accident, Cognitive retraining, Occupational therapy, Technology-based intervention

INTRODUCTION

The impairment of the UE in stroke survivors is quite complex, as the type of impairment is variable, and two or more deficits may co-exist [1]. One of the primary concerns for stroke survivors is their inability to move their upper extremities. Furthermore, it is important to emphasise that progress in this field is closely linked to an improvement in everyday tasks [2,3]. Approximately 65% of stroke survivors are unable to perform meaningful everyday activities with their affected upper extremities [4]. Only about 12% of stroke survivors are self-sufficient in everyday activities, and between 25% and 74% require human assistance with various activities such as self-care and mobility [5]. The severely paretic arm is one of the most debilitating poststroke conditions [6], and there are few effective therapy options for its relief. A fundamental study established that functional abnormalities following a stroke are defined by anatomical damage and the level of cortical activation during movement of the affected limb, which can be active or passive [7]. Patients with severe hemiparesis are doubly disadvantaged by this process. The motor deficit often prevents the arm from being actively used for functionally relevant activities, leading to a decrease in its cerebral representation [8].

The MT operates by utilising the mirror neuron system, which comprises specific visuomotor neurons located in the premotor cortex, primary somatosensory cortex, and inferior parietal cortex [9]. This system activates through passive observation, imagination, or action execution. Activation of the mirror-neuron system is known to enhance the primary motor cortex, responsible for controlling actions during task performance [10,11]. Numerous studies have demonstrated the efficacy of MT as an additional treatment for stroke patients' upper extremities [12,13]. Furthermore, researchers have explored its effectiveness alongside other neurophysiological or physical approaches [14-16]. Patients undergoing MT have shown superior outcomes compared to control groups in assessments such as the action reach arm test, functional independence measure, and mental imagery poststroke [17]. MT enhances the capacity for self-reliant engagement in daily activities among individuals experiencing right arm weakness following a stroke [18].

Telehealth refers to the utilisation of Information and Communication Technologies (ICT) for delivering health services, enabling providers and clients to be in separate physical locations. This includes administering evaluative, consultative, preventive, and therapeutic services via ICT [19]. Home-based TR is described as a rehabilitation method where rehabilitation physicians provide rehabilitation techniques to individuals with disabilities using telecommunication devices [20]. Studies suggest that TR methods can be equally effective as traditional rehabilitation (CR) in enhancing Activities of Daily Living (ADL) and improving adherence to rehabilitation exercises [21,22].

Research indicates that TR is an effective therapy for stroke, enhancing motor function, speech, cognition, and overall quality of life. The interactive video aspects of TR significantly boost patient satisfaction compared to home rehabilitation programs lacking video components [23]. TR includes guided physical therapy, speech therapy, Virtual Reality (VR), robotic-assisted training, and goal-setting approaches. These sessions can be individual or community-focused. TR has the potential to improve accessibility and address healthcare worker-to-patient ratios, especially in underserved areas. Combining TR with home-based interventions enhances patient-centered outcomes, particularly for those without access to traditional rehabilitation [24]. A study found that guiding patients and families in setting daily goals increased satisfaction and improved daily activity performance in areas lacking formal rehabilitation services [25].

A significant hindrance in stroke recovery involves weakness in the upper extremities, leading to limited functional abilities [26]. Current stroke rehabilitation methods encompass exercises targeting the impaired arm, functional electrical stimulation, robotic-assisted therapy, bilateral arm training, constraint-induced movement therapy, and biofeedback [13]. The fundamental principle underlying these therapeutic approaches is that consistent physical practice enhances motor function, enabling the brain to re-establish the pathways responsible for voluntary movement [27]. Nevertheless, these treatments are not widely applicable in severe hemiparesis situations. Some of these methods are expensive and require significant labour, restricting their broader implementation [28]. New studies propose that the utilisation of motor imagery through imagination [27] and MT could serve as supplementary rehabilitation techniques beneficial for poststroke motor recovery [29,30].

Healthcare providers in rural areas frequently lack access to the latest medical advancements and technologies available in larger cities. Research indicates that around 50% of veterans travel more than 25 miles for healthcare services [31]. The absence of accessible healthcare in rural areas leads many individuals to delay or even forgo necessary treatment. Moreover, individuals in urban areas face diminished healthcare quality due to mobility limitations and accessibility challenges.

MT offers a promising approach to address hemiparesis, a condition characterised by weakness on one side of the body, for which there are limited effective treatments. TR, an alternative therapy for stroke patients, utilises electronic ICT to deliver healthcare support, particularly when patients and providers are separated by distance. Given that stroke rehabilitation is a prolonged process, utilising home-based TR through devices like mobile phones and laptops presents an affordable and practical solution for stroke survivors coping with hemiparesis. Currently, there is a lack of evidence regarding the combined use of TR and MT to enhance UE performance in individuals affected by hemiparetic stroke. This study seeks to determine the effectiveness of mirror visual feedback through TR on UE functional performance in hemiparetic stroke patients.

MATERIALS AND METHODS

An experimental pretest, post-test study design was conducted at SRM Medical College Hospital and Research Centre, SRMIST, Kattankulathur, Chengalpattu, Tamil Nadu, India, from January 2021 to June 2021. The study obtained approval from the Institutional Ethical Committee (IEC) of SRM Medical College Hospital and Research Centre, SRMIST, Kattankulathur, Chengalpattu, Tamil Nadu, India. The ethical clearance number was 2082/IEC/2020.

Sixty hemiparetic stroke patients were recruited through a convenience sampling procedure, and participants were randomly allocated into the control group (n=30) and experimental group (n=30).

Inclusion criteria: Subjects diagnosed with hemiparetic stroke aged 18 years and above, one to six months poststroke with a Mini Mental State Examination (MMSE) score >24, and users of smartphones and computers were included in the study.

Exclusion criteria: Subjects with a history of any other neurological disorder, unilateral neglect, and cognitive deficits were excluded from the study.

Screening Tools

Mini Mental State Examination (MMSE): The MMSE is versatile in evaluating cognitive impairment, estimating its severity, tracking changes over time, and monitoring responses to treatment. It covers various cognitive aspects such as attention, language, memory, orientation, and visuospatial skills [32]. It demonstrates a Cronbach's alpha value of 0.76 [33]. Its test-retest reliability within 24 hours is strong, with a Pearson correlation coefficient of r=0.89. Furthermore, it exhibits excellent agreement with the Montreal Cognitive Assessment (MOCA) with a correlation coefficient of r=0.86 [32]. The total score ranges from 0 to 30, with a generally recognised threshold for cognitive impairment being a score of 23 or lower [34]. The degrees of impairment are classified as none (24-30), mild (18-23), and severe (0-17).

Star cancellation test: This assessment tool is designed for screening unilateral spatial neglect in stroke survivors. It involves marking 56 smaller stars, 13 letters, and 10 short words among 52 large stars on an 8.5″×11″ paper. The maximum achievable score is 54 points. A cut-off of less than 44 indicates the presence of unilateral spatial neglect. All the participants in present study scored below the cut-off. The star cancellation test demonstrated a test-retest reliability of 0.89, and the convergent validity of the star cancellation test showed r=0.63 [35].

Outcome Measures

Fugl-Meyer Assessment of motor recovery (FMA): The FMA [36,37] serves as a standardised test for evaluating poststroke recovery. It covers four major domains: motor function (including UE (five questions), wrist (five questions), hand (seven questions), and coordination/speed (three questions), sensation (two questions), passive joint movement (five questions), and joint pain (five questions). Administering the FMA typically takes around 30 minutes and is available in English and French languages. It is a well-validated, reliable, and freely accessible assessment tool that provides normative data, offering clinicians worldwide a valuable means to efficiently detect and diagnose various causes of motor impairment across diverse age groups. This evaluation entails directly observing performance, utilising a 3-point ordinal scale (0=cannot perform, 1=performs partially, 2=performs fully) for scoring scale items. The total possible score on the scale is 226, and scores are interpreted as follows: 0-35 very severe, 36-55 severe, 56-79 moderate, and >79 mild impairments. The FMA demonstrates good internal consistency with a Cronbach's alpha ranging from α=0.85 to 0.91 and strong test-retest reliability at α=0.95. Interrater reliability was shown to be 0.6.

Wolf Motor Function Test (WMFT): The WMFT [38,39] is used to evaluate the effects of constraint-induced movement therapy on individuals with mild to moderate stroke and traumatic brain injury. Focused on timed and functional tasks, the WMFT evaluates UE motor capabilities. The most common version of the WMFT includes 17 components, covering timed functional tasks, strength measures, and movement quality analyses while performing various activities. Examiners should start with the less affected UE and progress downward in assessment. The items on the WMFT are assessed on a six-point scale, where lower scores correspond to lower functioning levels. The WMFT shows robust internal consistency, boasting an impressive Cronbach's Coefficient Alpha of α=0.92 [40]. Additionally, it exhibits excellent test-retest reliability for both functional ability and performance tests, with Pearson Correlation Coefficients of r=0.95 and 0.90, respectively [39]. In terms of concurrent validity, the WMFT shows strong correlations, particularly with the FMA-UE, with an excellent correlation coefficient of r=-0.88. This concurrent validity was evaluated by comparing the WMFT to the UE-FMA, which is considered the gold standard, in 66 clients with stroke [41].

Study Procedure

The study was initiated by explaining its purpose to both the institution's head and the subjects, ensuring informed consent from both the institution and individual participants. To screen the subjects, a cognitive assessment using the MMSE and the Star Cancellation Test for unilateral spatial neglect was conducted. The 60 subjects were equally and randomly divided into the experimental group and control group for 12 weeks through convenience sampling. The control group underwent face-to-face UE motor training interventions [Table/Fig-1], while the experimental group was provided with a mirror box [40] and a toolbox containing various objects for object manipulation and transport activities. All participants received a mirror box and toolbox for object transfer. Instructions and activities for the TR group were conducted through WhatsApp's web version 2.21.16 using a Windows 10 64-bit-based laptop system.

[Table/Fig-1]: Conventional Mirror Therapy (MT) (Control Group).

Both groups underwent interventions five times a week, each lasting 30 to 45 minutes. Baseline performance was evaluated using the FMA and WMFT. Postintervention, the primary investigator administered the post-test data.

Intervention protocol: Before initiating the intervention, the main researcher provided subjects with instruction on MT, including guidance on setting up and utilising the mirror box, recommended activities for MT, and the advised frequency of MT sessions. The choice of MT activities was based on information derived from published reviews [42]. Participants were directed to place the mirror box centrally between their upper extremities, aligning the mirror to overlay the reflection of the unimpaired limb onto the impaired one. Participants were directed to engage in activities that involved both limbs, with a focus on the mirror image of the unaffected arm and hand. The instruction was to attempt movement of the affected arm and hand within the mirror box during these activities. The recommended duration for MT was 30 to 45 minutes daily, conducted five days a week [Table/Fig-2,3].

[Table/Fig-2]: Telerehabilitation (TR) through Mirror Therapy (MT) (experimental group).

STATISTICAL ANALYSIS

The data was analysed using Statistical Package for Social Sciences (SPSS) 24.0 version. Descriptive statistics were applied to evaluate data distribution and summarise the information. Within-group scores for outcome measures were evaluated using Wilcoxon signed-rank test, while group comparisons were conducted through the Mann-Whitney U Test. The hypothesis under scrutiny aimed to ascertain if the treatment administered had a statistically significant effect. A

Category of activity	Activities	Instructions
Exercises for active range of motion	Pronation and supination of forearm flexion and extension of wrist grasp of release of hand abduction and adduction of metacarpophalangeal joints finger tapping and thumb opposition	Directed in completing each exercise 10 times as part of the warm-up routine in every session.
Manipulation of objects	Grasp, release, and attempt to move items of different sizes, shapes, and textures (such as sponges, balls, and straws) using the hand	Motivated to select and engage in one activity each day.
Object usage in functional activities	Cleaning the table through forward and backward as well as side-to-side movements; transporting objects	Encouraged to select and carry out one activity daily.

[Table/Fig-3]: Program for conventional occupational therapy intervention.

significance level of alpha, set at p-value <0.05, was employed to determine statistical significance.

RESULTS

Gender distribution of control group and experimental group comprised 16 males and 14 females. Both control and experimental groups consisted of 12 right-side and 18 left-side affected participants [Table/Fig-4].

Variables		Control group n=30	Experimental group n=30
Age group (years)	35 to 45	5	6
	45 to 55	8	9
	55 to 65	17	15
Gender	Male	16	16
	Female	14	14
Side Affected	Right	12	12
	Left	18	18

[Table/Fig-4]: Demographic distribution of variables.

A statistically significant difference was found between the scores obtained in the pretest and post-test assessments of FMA, WMFT-FAS, and WMFT-time [Table/Fig-5].

Outcome measures	Test	Mean±SD	z-value	p-value
FMA	Pre	40.40±3.435	-2.032	0.042
	Post	56.40±2.966		
WMFT- FAS	Pre	43.40±3.362	-2.041	0.041
	Post	48.00±2.236		
WMFT-time	Pre	176.30±9.322	-2.045	0.044
	Post	115.20±2.582		

[Table/Fig-5]: Effect of Telerehabilitation on Upper Extremity (UE) function of stroke.
The Wilcoxon signed-rank test

There was a significant disparity in scores for the FMA-UE and WMFT-time before and after MT for the UE in hemiparetic stroke. However, there was no noteworthy distinction in the scores of the WMFT-FAS between the pretest and post-test assessments [Table/Fig-6].

Outcome measures	Test	Mean±SD	z-value	p-value
FMA-UE	Pre	40.80±2.775	-2.041	0.041
	Post	53.60±2.702		
WMFT-FAS	Pre	44.80±1.483	-1.890	0.059
	Post	47.60±1.140		
WMFT-time	Pre	174.21±3.419	-2.023	0.043
	Post	118.73±2.022		

[Table/Fig-6]: Effect of Mirror Therapy (MT) on Upper Extremity (UE) function of stroke.
Wilcoxon signed-rank test

The results revealed no statistically significant difference (p-value >0.05) between the pretest scores of the control and experimental groups in the FMA, WMFT-FAS, and WMFT-time [Table/Fig-7].

Outcome measure	Group	Mean±SD	μ-value	p-value
FMA	Control	40.40±3.435	-0.422	0.673
	Experimental	40.80±2.775		
WMFT-FAS	Control	43.40±3.362	-0.849	0.396
	Experimental	44.80±1.483		
WMFT-time	Control	176.30±9.322	-0.522	0.602
	Experimental	174.21±3.419		

[Table/Fig-7]: Comparison of pre-test scores of FMA, WMFT-FAS, and WMFT-time between control and experimental group.
Mann-Whitney U test

The results showed no statistically significant difference between the post-test scores of the control and experimental groups in the FMA and WMFT-FAS. However, there was a statistically significant distinction in the post-test scores between the control and experimental groups in WMFT-time [Table/Fig-8].

Outcome measures	Group	Mean±SD	μ-value	p-value
FMA	Control	56.40±2.966	-1.467	0.142
	Experimental	53.60±2.702		
WMFT-FAS	Control	48.00±2.236	-0.319	0.750
	Experimental	47.60±1.140		
WMFT-time	Control	115.20±2.582	-1.984	0.047
	Experimental	118.73±2.022		

[Table/Fig-8]: Comparison of post-test scores of FMA, WMFT- FAS, and WMFT-TIME between control and experimental group.
Mann-Whitney U test

DISCUSSION

The MT improves UE functional performance among hemiparetic stroke patients. The significance of the study was attributed to function-based activities monitored with adequate guidance by the occupational therapist. This was achieved through repeated practice and encouragement via synchronised or video conference-based TR, where the therapist and patient communicated in real-time through video conferencing technology. Participants were able to perform activities with TR-based MT as they were task-oriented, and the mirror box provided immediate visual feedback of the unaffected side, enhancing participant motivation. Participants followed instructions provided through synchronised video streaming, and even if were not able to perform an activity, they attempted to continue or repeat the task.

These findings are consistent with a previous study that concluded self-administered MT at home, following detailed instructions from a physician through TR, could alleviate phantom limb pain. The study suggests that relief can be achieved by using home-based MT with initiation, feedback, and follow-up provided entirely through TR by healthcare professionals [43]. Furthermore, a systematic review on the use of TR as physical therapy for poststroke patients concluded that various TR techniques, including portable transcutaneous electrical stimulation, MT, home exercise programs, and Virtual Reality (VR) exercises, can be utilised for the physical exercise of stroke patients [44].

The study's findings demonstrate that MT effectively enhances UE functional performance in individuals with hemiparetic stroke. This aligns with research suggesting the feasibility and effectiveness of a home-based MT program for poststroke UE improvement. MT involves using a mirror to create the illusion of the affected limb's reflection, tricking the brain into perceiving pain-free movement or providing positive visual feedback. By placing the affected limb behind the mirror, the reflection of the unaffected limb replaces the hidden limb, capitalising on the brain's preference for visual feedback over somatosensory or proprioceptive feedback on limb position [45].

MT has the capacity to boost cortical and spinal motor excitability, potentially influencing the mirror neuron system, comprising about 20% of all human brain neurons. These neurons play a vital role in reconstructing laterality, distinguishing between the left and right-sides. By employing a mirror box, the activation of these mirror neurons facilitates the recovery of impaired body parts.

A study found that incorporating MT into the rehabilitation of inpatients recovering from subacute stroke, along with standard rehabilitation, led to enhanced hand functioning. This improvement was noted immediately after four weeks of treatment and during the six-month follow-up, compared to a control treatment [46]. The present study reveals a difference in post-test scores of the FMA and WMFT-FAS based on the mean difference on the WMFT between the control and experimental groups. There was a statistically significant difference in WMFT-Time between the control and experimental groups. This aligns with findings from a prior study, which assessed the clinical effectiveness of a VR-based TR program for balance recovery in hemiparetic individuals poststroke, comparing it with an in-clinic program while examining subjective experiences. The study results reviewed several key findings. Firstly, VR TR interventions have the potential to facilitate the recovery of locomotor skills related to balance, comparable to in-clinic interventions, when combined with a conventional therapy program. Secondly, the usability and motivation for utilising both interventions can be similar. Lastly, TR interventions may offer cost savings, the extent of which depends on specific circumstances in each scenario [47]. A study described TR as a valuable complement to traditional poststroke rehabilitation for stroke survivors at home, facilitated through home visits and telephone communication. The study results revealed enhanced physical function lasting up to three months postintervention, suggesting that TR serves as a valuable addition to conventional poststroke rehabilitation. This is particularly beneficial considering the constraints on resources for at-home rehabilitation for stroke survivors [21]. In a trial study, a self-instructional video-based therapy program was employed as an intervention method for stroke survivors in a home setting [48]. TR offers an alternative service delivery model for occupational therapy, not only bridging distance but also offering user-friendly treatment for patients at home.

Limitation(s)

Small sample size was the limitation of the study which made generalisability difficult.

CONCLUSION(S)

The study concluded that MT through TR might be an effective treatment method to improve UE functional performance among hemiparetic stroke patients by offering an alternative service delivery model for occupational therapy. This study recommends continuous follow-up of participants to identify the effects of MT through TR over the long process. Further research is recommended on a larger sample size and longer duration of intervention.

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