Original Article

Journal of Health and Rehabilitation Research JHRR

Efficacy of Combined Task-Oriented Training and Mirror Therapy in Post-Stroke Upper Limb Recovery: A Randomized Controlled Trial

Journal of Health and Rehabilitation Research (2791-156X)
Volume 4, Issue 3
Double Blind Peer Reviewed.
https://jhrlmc.com/
DOI: https://doi.org/10.61919/jhrr.v4i4.1713
www.lmi.education/
LINK MEDICAL INTERFACE
SECP Corporate Unique Identification No. 0257154

Amna Abbas[1], **Syeda Rahat Jabeen**[1]

Correspondence
Syeda Rahat Jabeen
drrahatjabeen@hotmail.com
Affiliations
1 Bahria International Hospital, Lahore, Pakistan

Keywords
Stroke rehabilitation, upper limb recovery, mirror therapy, task-oriented training, motor function, spasticity, randomized controlled trial.
Disclaimers

Authors' Contributions	All authors contributed equally to the study design, data collection, analysis, and manuscript preparation.
Conflict of Interest	None declared
Data/supplements	Available on request.
Funding	None
Ethical Approval	Respective Ethical Review Board
Study Registration	N/A
Acknowledgments	N/A

ABSTRACT

Background: Stroke-induced upper limb impairments significantly reduce functional independence and quality of life. Task-oriented training (TOT) and mirror therapy (MT) are established neurorehabilitation techniques. Combining these therapies may enhance recovery through synergistic mechanisms.

Objective: To evaluate the efficacy of combining TOT and MT on upper limb motor function, spasticity, and functional independence in post-stroke patients.

Methods: This randomized controlled trial included 40 post-stroke patients (20 per group) with upper limb hemiparesis. Participants were randomized into an intervention group (combined TOT and MT) and a control group (TOT alone). Both groups received 45-minute sessions, five days per week, for four weeks. Outcomes were assessed using the Fugl-Meyer Assessment Upper Extremity (FMA-UE), Action Research Arm Test (ARAT), Modified Ashworth Scale (MAS), and Barthel Index. Data analysis was performed using repeated-measures ANOVA and SPSS version 25, with $p < 0.05$ considered statistically significant.

Results: The intervention group demonstrated significantly greater improvements in FMA-UE (45.6 ± 4.9 vs. 38.2 ± 5.7, $p < 0.001$) and ARAT (31.2 ± 3.9 vs. 26.4 ± 4.1, $p < 0.001$). Spasticity reduction (MAS: -1.8 ± 0.4 vs. -1.2 ± 0.5, $p = 0.002$) and functional independence (Barthel Index: 8.4 ± 1.2 vs. 5.9 ± 1.3, $p < 0.001$) were also superior in the intervention group.

Conclusion: Combining TOT and MT significantly improved upper limb motor function, spasticity, and functional independence in post-stroke patients, highlighting its potential as an effective rehabilitation strategy.

INTRODUCTION

Rehabilitating upper limb functionality post-stroke is crucial in neurorehabilitation due to the profound disabilities and negative impact on quality of life that accompany motor impairments. Conventional rehabilitation methods such as task-oriented training (TOT) aim to enhance motor skills through structured, repetitive activities that mirror daily tasks. While TOT is beneficial, it often falls short in fully addressing severe motor and sensory limitations, prompting interest in supplemental therapies like mirror therapy (MT). MT utilizes visual feedback from the unaffected limb to simulate movement in the affected limb, thereby stimulating mirror neurons and promoting cortical changes that support motor and sensory rehabilitation.

Emerging research highlights the advantages of combining MT with established therapeutic techniques such as TOT. This integrative approach utilizes MT to initiate motor responses and neural stimulation, while TOT provides targeted, functional practice. Evidence from clinical trials indicates that integrating MT with TOT yields significant improvements in motor function, sensitivity, and everyday functional capabilities, surpassing outcomes from TOT alone. Moreover, enhancing this combination with other treatments like electrical stimulation or non-invasive brain stimulation may further improve recovery by increasing neural plasticity and cortical activity.

However, the variability in research designs, the limited scope of many studies, and inconsistencies in treatment protocols necessitate more comprehensive research to confirm these early results and develop uniform treatment standards. Although the combined treatment shows promise, particularly in the subacute and chronic phases of stroke recovery, its efficacy in the immediate post-stroke period remains ambiguous, with some studies indicating little to no additional benefit compared to placebo treatments. Also, while tasks involving multiple joints and complex mirror therapy activities have shown greater benefits than simpler methods, the lack of clear guidelines on the most effective intervention strategies calls for in-depth exploration into the ideal treatment dosages and personalized approaches. This evolving evidence underscores the importance of tailoring rehabilitation programs to align with individual recovery trajectories and specific patient needs, with the goal of optimizing functional restoration and improving overall quality of life for stroke survivors.

MATERIAL AND METHODS

This study, a randomized controlled trial, was conducted at Bahria International Hospital in Lahore, Pakistan, and

Manuscript Submitted under JHRR ID 1713: October29/2024 | Accepted: December11/2024

included 40 stroke survivors who had suffered either an ischemic or hemorrhagic stroke within the previous six months. Participants were recruited from nearby rehabilitation facilities and were divided into two groups: one underwent a regimen combining task-oriented training (TOT) with mirror therapy (MT), and the other received solely TOT. Eligibility for the study required participants to exhibit hemiparesis of the upper limb and the cognitive capacity to follow simple instructions. Individuals with significant cognitive impairments, major musculoskeletal complications, or conditions that contraindicated therapy were excluded.

Ethical adherence to the Declaration of Helsinki was ensured throughout the study, with ethical approval provided by the institutional review board. Participants provided written informed consent before their inclusion. Initial evaluations collected comprehensive demographic and clinical data, including the participants' age, gender, time elapsed since stroke, and extent of upper limb impairment. Randomization was executed using a computer-generated sequence, and evaluator blinding to participant group assignments was maintained to prevent assessment bias. The intervention consisted of structured TOT sessions, supplemented by MT for one of the groups. TOT was tailored to each participant's ability level and focused on repetitive tasks that enhance everyday functional capabilities. In MT sessions, participants used a mirror to simulate movement in the impaired limb by reflecting the movements of the healthy limb. Therapy sessions were conducted over a period of four weeks, with each session lasting 45 minutes and occurring five times per week.

Primary measures for the study were the enhancement of upper limb motor functionality, assessed using the Fugl-Meyer Assessment Upper Extremity Scale (FMA-UE), and improvements in functional performance, measured by the Action Research Arm Test (ARAT). Secondary assessments included evaluating changes in spasticity with the Modified Ashworth Scale, range of motion, and daily living skills via the Barthel Index. Assessments were carried out by trained personnel who were blind to the participants' group allocations to minimize bias. Data were rigorously gathered and managed under stringent protocols to uphold the accuracy and reliability of the findings. Statistical analyses were conducted using IBM SPSS Statistics, version 25. Descriptive statistics detailed the demographics and baseline characteristics of the study cohort, while inferential statistical methods, such as paired and independent t-tests and chi-square tests, analyzed the data, with a significance level set at $p < 0.05$. This research offers crucial insights into the synergistic effects of combining TOT with MT for stroke rehabilitation, significantly enriching the current landscape of neurorehabilitation practices.

RESULTS

This study involved 40 participants who were randomly assigned into two groups: an intervention group receiving both task-oriented training (TOT) and mirror therapy (MT), and a control group that received only TOT. Baseline demographics and clinical characteristics such as age, gender, time since stroke, and initial scores on the Fugl-Meyer Assessment Upper Extremity (FMA-UE) and Action Research Arm Test (ARAT) were evenly matched between groups, confirming the homogeneity of the participants as shown in Table 1.

Post-intervention assessments revealed notable enhancements in upper limb motor function in both groups. However, the intervention group achieved significantly better outcomes, as detailed in Table 2. The average increase in FMA-UE scores was 12.9 points in the intervention group, compared to a 5.1 point increase in the control group ($p < 0.001$). In terms of the ARAT, the intervention group improved by an average of 9.7 points, while the control group improved by 5.5 points ($p < 0.001$).

Secondary outcomes also demonstrated meaningful differences between the groups. Spasticity, measured by the Modified Ashworth Scale (MAS), showed a greater decrease in the intervention group, with an average reduction of 1.8 points versus 1.2 points in the control group ($p = 0.002$). Furthermore, functional independence, assessed through the Barthel Index, improved more in the intervention group, with an average increase of 8.4 points, compared to 5.9 points in the control group ($p < 0.001$). These results are summarized in Table 3.

Statistical analysis utilizing repeated-measures ANOVA confirmed a significant interaction effect between the time of assessment (baseline vs. post-intervention) and the group (intervention vs. control) for both FMA-UE ($F(1,38) = 22.8$, $p < 0.001$) and ARAT scores ($F(1,38) = 18.6$, $p < 0.001$). Post-hoc pairwise comparisons further validated the superior improvements in the intervention group over time.

The study reported no adverse events, and all participants completed the study protocol, highlighting the safety and feasibility of the combined therapy approach. These findings strongly support the use of TOT combined with MT in enhancing motor function, alleviating spasticity, and boosting functional independence among post-stroke patients.

Table 1. Baseline Characteristics of Participants

Variable	Intervention Group (n=20)	Control Group (n=20)	p-value
Age (years, mean ± SD)	59.4 ± 8.2	58.7 ± 7.9	0.742
Gender (Male/Female)	12/8	11/9	0.781
Time Since Stroke (months)	4.2 ± 1.3	4.4 ± 1.5	0.654
FMA-UE Baseline Score	32.7 ± 5.6	33.1 ± 5.3	0.823
ARAT Baseline Score	21.5 ± 4.2	20.9 ± 4.7	0.712

Table 2. Changes in Upper Limb Motor Function

Outcome Measure	Intervention Group (Mean ± SD)	Control Group (Mean ± SD)	Between-Group p-value
FMA-UE Baseline	32.7 ± 5.6	33.1 ± 5.3	0.823
FMA-UE Post-Intervention	45.6 ± 4.9	38.2 ± 5.7	<0.001
ARAT Baseline	21.5 ± 4.2	20.9 ± 4.7	0.712
ARAT Post-Intervention	31.2 ± 3.9	26.4 ± 4.1	<0.001

Table 3. Secondary Outcomes

Outcome Measure	Intervention Group (Mean ± SD)	Control Group (Mean ± SD)	Between-Group p-value
MAS Reduction	-1.8 ± 0.4	-1.2 ± 0.5	0.002
Barthel Index Improvement	8.4 ± 1.2	5.9 ± 1.3	<0.001

The results advocate for incorporating this combination therapy into standard post-stroke rehabilitation regimens to maximize patient recovery outcomes.

DISCUSSION

The results of this randomized controlled trial reveal that integrating task-oriented training (TOT) with mirror therapy (MT) significantly enhances upper limb motor function, reduces spasticity, and improves functional independence among post-stroke patients, surpassing the outcomes achieved with TOT alone. This supports previous findings that combining MT with other rehabilitation techniques can amplify motor recovery and functional outcomes by exploiting neuroplasticity and task-specific practice. Significant enhancements in Fugl-Meyer Assessment Upper Extremity (FMA-UE) and Action Research Arm Test (ARAT) scores in the intervention group underscore the potential of combined interventions to provide superior rehabilitation results for stroke survivors.

The observed benefits in the intervention group are likely due to the distinct mechanisms of mirror therapy and task-oriented training. MT is known to activate mirror neurons, foster cortical reorganization, and improve neural connectivity between motor and sensory areas, facilitating the recovery of motor functions. When paired with TOT's focus on repetitive, goal-oriented tasks, this combination likely promotes motor learning and functional recovery. This synergy is consistent with reports from studies that have integrated MT with non-invasive brain stimulation or electrical stimulation, enhancing the evidence for the efficacy of these combined therapies. Moreover, the notable reduction in spasticity observed could be attributed to MT's potential to modulate reflex pathways and improve motor control, aligning with prior research.

However, there are limitations to this study that should be noted. The small sample size may affect the generalizability of these findings to a wider population. While the randomization and blinding methods used minimized potential biases, the brief duration of the intervention (four weeks) limits the evaluation of long-term effects. Future research should consider larger sample sizes, longer follow-up periods, and the prolonged impact of combined interventions. Additionally, reliance on self-reported measures like the Barthel Index, although valuable for assessing functional independence, might introduce subjectivity. Employing objective measures such as motion capture or electromyography could strengthen the evidence base regarding the effectiveness of the treatments.

Strengths of this study include its randomized controlled design, the utilization of validated outcome measures, and strict adherence to standardized protocols, all of which bolster the reliability of the results. The inclusion of a diverse participant group with various levels of motor impairment enhances the real-world applicability of the findings. These results contribute to the burgeoning evidence supporting the integration of innovative therapies like MT with conventional rehabilitation methods to optimize recovery potentials in stroke patients.

The study highlights the importance of personalized rehabilitation strategies that are tailored to individual patient profiles, considering factors like stroke severity, time since onset, and initial motor function, to determine the most appropriate therapeutic interventions. Future research could expand the scope to examine the impact of similar combined therapies on lower limb function, balance, and gait, thus broadening the spectrum of evidence for stroke rehabilitation. Additionally, investigating the neural mechanisms through neuroimaging techniques could offer deeper insights into how to optimize these intervention protocols.

CONCLUSION:

Combining task-oriented training with mirror therapy offers significant benefits for improving motor function, reducing spasticity, and enhancing functional independence in post-stroke patients. These findings advocate for the integration of such therapies into routine clinical practices, tailored to meet the specific needs and recovery goals of individual patients. Continued high-quality research is vital to refine these approaches and establish standardized guidelines for their application across various clinical settings.

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