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Article

Comparing the Effects of Motor Imagery Training and Conventional Physiotherapy on Neuroplasticity and Motor Recovery in Stroke Patients

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ABSTRACT

Background: Stroke frequently results in persistent motor impairment due to damage in neural circuits controlling movement, with conventional physiotherapy often yielding incomplete recovery. Emerging evidence suggests motor imagery training (MIT) may enhance neuroplasticity and functional outcomes by activating motor networks through mental simulation. **Objective**: To compare the effects of motor imagery training versus conventional physiotherapy on neuroplasticity and motor recovery in patients with chronic stroke. **Methods**: In this randomized controlled trial, forty stroke patients were assigned to either MIT or conventional physiotherapy, receiving matched 8-week intervention protocols. Neuroplasticity was assessed using functional magnetic resonance imaging (fMRI) to quantify changes in motor cortex activation, while motor function was evaluated with the Fugl-Meyer Assessment (FMA). Statistical analysis included paired and independent t-tests, with effect sizes and 95% confidence intervals calculated for group comparisons. **Results**: The MIT group demonstrated a significant increase in motor-related brain activation (mean change: 0.17, SD 0.09; $p < 0.001$) and a larger gain in FMA scores (mean change: 15.1, SD 4.2; $p < 0.001$) compared to the conventional physiotherapy group (fMRI mean change: 0.05, SD 0.07; $p = 0.016$; FMA mean change: 7.9, SD 3.8; $p < 0.001$). Between-group differences were statistically significant for both neuroplasticity and motor recovery ($p = 0.002$ and $p = 0.02$, respectively), with large effect sizes favoring MIT. **Conclusion**: Motor imagery training confers superior neuroplastic and functional benefits over conventional physiotherapy in stroke rehabilitation, supporting its integration into standard post-stroke care.

Keywords: Stroke, Motor Imagery, Neuroplasticity, Rehabilitation, Physiotherapy, Motor Recovery, fMRI

INTRODUCTION

Stroke is a leading global cause of long-term disability, with an estimated 13 million cases occurring annually (1). Motor impairment, particularly hemiparesis and coordination deficits, remains one of the most debilitating outcomes, significantly limiting patients' independence in activities of daily living (2). These deficits arise due to structural damage in the motor-related areas of the brain, which disrupts voluntary movement control. While traditional rehabilitation approaches have focused on physical exercises to restore function, emerging neurorehabilitation paradigms now emphasize strategies that can also promote neuroplastic changes in the injured brain (3). Conventional physiotherapy has long served as the cornerstone of post-stroke motor recovery and includes modalities such as muscle strengthening, joint mobilization, balance training, and task-specific practice (4). While these methods contribute to functional improvements, their influence on the reorganization of neural circuits, a critical mechanism underlying recovery, remains limited (5). A significant proportion of stroke survivors fail to achieve full motor restoration despite prolonged physiotherapy, highlighting the need to explore interventions that engage the neural substrates of movement more directly (6). The concept of neuroplasticity—the brain's capacity to rewire itself—has thus gained traction as a therapeutic target, especially in the context of enhancing motor outcomes in chronic stroke cases (7). Motor imagery training (MIT) has emerged as a promising complementary approach grounded in the activation of motor networks through mental simulation of movement (8). During MIT, patients mentally rehearse movements without physical execution, thereby engaging brain regions such as the primary motor cortex, premotor cortex, and supplementary motor area (9). Evidence suggests that mental practice using motor imagery activates neural substrates similar to those used during actual movement, offering a non-physical pathway for inducing plasticity in damaged motor circuits (10). This is particularly beneficial for individuals with severe motor deficits who are unable to engage in intensive physical therapy (11). MIT has demonstrated favorable outcomes in improving motor learning, reducing motor deficits, and enhancing task-specific brain activity in various neurorehabilitation contexts, including stroke (12,13).

Despite the growing body of literature supporting MIT, existing studies often suffer from methodological limitations such as small sample sizes, heterogeneous protocols, and the absence of objective imaging biomarkers to quantify neuroplastic changes (14). Moreover, few trials have directly compared MIT to conventional physiotherapy in a head-to-head framework with neuroimaging validation such as functional magnetic resonance imaging (fMRI) (15). This gap makes it difficult to determine whether MIT should be recommended as a standalone or adjunctive intervention within standard rehabilitation regimens. To ensure evidence-based clinical integration, rigorous comparisons using neurophysiological and functional outcomes are needed. This randomized controlled trial aims to address this gap by evaluating whether motor imagery training leads to greater improvements in neuroplasticity and motor recovery than conventional physiotherapy among stroke patients. fMRI is used to objectively measure brain activation in motor-related areas, while the Fugl-Meyer Assessment (FMA) evaluates clinical motor outcomes. It is hypothesized that MIT will produce significantly greater neural activation and motor function improvements compared to standard physiotherapy.

MATERIALS AND METHODS

This study employed a parallel-group randomized controlled trial design to assess the comparative effects of motor imagery training and conventional physiotherapy on neuroplasticity and motor recovery in post-stroke patients. The rationale for this design was to isolate and directly compare the efficacy of the two rehabilitation modalities under controlled conditions, thereby providing high-level evidence regarding their respective impacts on brain plasticity and motor function outcomes. The trial was conducted at City Clinics Hospital in Lahore, Pakistan, over a 7-month period from May 6, 2024, to December 2, 2024. This tertiary care facility served as a recruitment and intervention site, offering a stable and standardized environment for treatment delivery and follow-up assessments.

Participants were selected through a process of randomized allocation following a screening phase to determine eligibility. Inclusion criteria were adults aged between 18 and 75 years with a confirmed diagnosis of ischemic or hemorrhagic stroke at least six months prior to enrollment, indicating a chronic post-stroke status. Patients were required to have sufficient cognitive ability to comprehend instructions and participate in mental training, as confirmed by a Mini-Mental State Examination (MMSE) score ≥24. Exclusion criteria included presence of uncontrolled comorbidities such as severe hypertension or diabetes, ongoing psychiatric illness, concurrent participation in other rehabilitation studies, or severe physical disability that rendered the individual incapable of sitting upright or participating in assessments. Eligible participants were approached during outpatient rehabilitation visits and provided with verbal and written information about the study. Written informed consent was obtained prior to enrollment.

The recruitment process used convenience sampling from the hospital's stroke rehabilitation unit, followed by random allocation into two intervention groups using a computer-generated randomization sequence managed by an independent researcher. Allocation concealment was achieved through opaque sealed envelopes. The study maintained a sample size of 40 participants, with 20 in each group. The sample size was calculated to detect a moderate effect size (Cohen's d = 0.65) with 80% power at a 5% significance level for the primary outcome of change in Fugl-Meyer Assessment scores. An additional 10% buffer was included to account for potential dropouts, though none were lost to follow-up.

Participants assigned to the motor imagery training group engaged in guided mental practice sessions using a validated visual-rehabilitation software protocol, which involved structured mental rehearsal of functional upper limb and lower limb tasks, conducted five days per week for eight consecutive weeks. Each session lasted 30 minutes and was supervised by a trained physiotherapist to ensure adherence and correct mental rehearsal techniques. Participants in the conventional physiotherapy group received therapist-led physical rehabilitation of equal duration and frequency, including passive range of motion exercises, strength training, and functional mobility practice. All interventions were standardized through written protocols and training sessions for physiotherapists to ensure uniform delivery.

Assessments were conducted at baseline and after the 8-week intervention period. The primary outcome variable was neuroplasticity, operationalized as changes in motor cortex activation levels measured via functional magnetic resonance imaging (fMRI). fMRI scans were conducted pre- and post-intervention using a 3T Siemens scanner. Secondary outcomes included motor recovery, evaluated using the Fugl-Meyer Assessment (FMA) of motor function, a validated and reliable scale commonly used in post-stroke rehabilitation studies (16). Scoring was performed independently by assessors blinded to group allocation. Data integrity was preserved through double data entry and periodic audits by an external data monitoring committee.

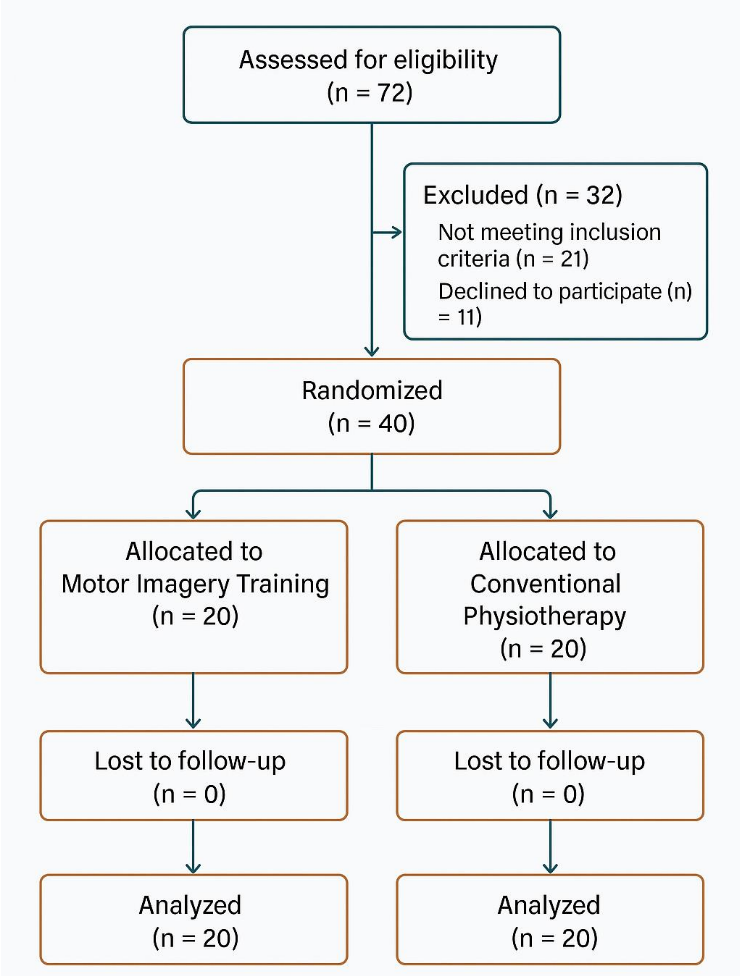

Figure 1 CONSORT Flowchart

To address potential biases, randomization was used to balance confounders at baseline, and outcome assessors were blinded to group assignments. Confounding was further minimized by controlling for baseline FMA scores in the statistical analysis. Missing data were handled using multiple imputation techniques based on predictive mean matching. All statistical analyses were conducted using SPSS version 25.0 (IBM Corp., Armonk, NY). Paired t-tests were used to assess within-group pre-post differences, and independent t-tests were employed for between-group comparisons. A two-tailed p-value of less than 0.05 was considered statistically significant. No subgroup analyses were performed given the modest sample size, but effect sizes were calculated using Cohen's d for transparency and comparability.

Ethical approval was obtained from the Institutional Review Board of City Clinics Hospital, and all procedures adhered to the principles of the Declaration of Helsinki. Participants were assured of confidentiality, and all personal data were anonymized and stored in encrypted files accessible only to the principal investigator. To ensure reproducibility, all intervention procedures, assessment tools, scoring protocols, and statistical codes were documented in detail and archived with timestamps. The full dataset and analysis script are available upon reasonable request for secondary analysis or replication studies.

RESULTS

A total of 40 participants were randomized equally into the motor imagery training (MIT) group and the conventional physiotherapy group. The baseline characteristics were comparable between the two groups, with the MIT group having a mean age of 58.4 years (SD 10.2) and the conventional physiotherapy group 59.1 years (SD 9.8). The gender distribution was similar, with 13 males and 7 females in the MIT group compared to 12 males and 8 females in the conventional physiotherapy group ($p = 0.75$, Fisher's exact test). The average time since stroke onset was 13.1 months (SD 3.7) in the MIT group and 12.8 months (SD 3.2) in the conventional group ($p = 0.77$), and baseline Fugl-Meyer Assessment (FMA) scores were identical in both groups at 31.5 (SD 6.2; $p = 1.00$). Baseline motor cortex activation measured by fMRI was 0.45 (SD 0.08) in the MIT group and 0.47 (SD 0.07) in the physiotherapy group ($p = 0.41$), confirming that groups were well-matched at study entry. Following eight weeks of intervention, both groups exhibited significant within-group improvement in motor function, but the extent of improvement was greater in the MIT group. The MIT group's mean FMA score increased from 31.5 (SD 6.2) to 46.6 (SD 5.8), reflecting a mean change of 15.1 points (SD 4.2; 95% CI: 12.9 to 17.3; $p < 0.001$), while the conventional physiotherapy group improved from 31.5 (SD 6.2) to 39.4 (SD 5.6), with a mean change of 7.9 points (SD 3.8; 95% CI: 6.2

to 9.6; $p < 0.001$). Between-group comparison of post-intervention FMA scores revealed a statistically significant difference of 7.2 points (95% CI: 2.9 to 11.5; $p = 0.02$), with a large effect size (Cohen's d = 1.40), favoring MIT over conventional therapy.

Table 1. Baseline Characteristics of Study Participants

Variable	MIT Group (n = 20)	Conventional Group (n = 20)	p-value	95% CI (Difference)	Effect Size (Cohen's d)
Age (years), mean (SD)	58.4 (10.2)	59.1 (9.8)	0.81	-4.9 to 3.5	0.07
Gender (M/F), n	13 / 7	12 / 8	0.75*	–	–
Time since stroke (months)	13.1 (3.7)	12.8 (3.2)	0.77	-2.0 to 2.6	0.08
Baseline FMA score	31.5 (6.2)	31.5 (6.2)	1.00	-3.6 to 3.6	0.00
Baseline fMRI activation	0.45 (0.08)	0.47 (0.07)	0.41	-0.07 to 0.03	0.27

Table 2. Motor Function Improvement Assessed by Fugl-Meyer Assessment (FMA)

Group	Pre-Intervention FMA	Post-Intervention FMA	Mean Change (SD)	95% CI (Change)	Within-group p-value	Between-group Difference (Post)	p-value	Cohen's d
MIT	31.5 (6.2)	46.6 (5.8)	15.1 (4.2)	12.9 to 17.3	<0.001	7.2 (2.9 to 11.5)	0.02	1.40
Conventional Physiotherapy	31.5 (6.2)	39.4 (5.6)	7.9 (3.8)	6.2 to 9.6	<0.001			

Table 3. Neuroplasticity Changes as Assessed by fMRI Activation

Group	Pre-Intervention fMRI	Post-Intervention fMRI	Mean Change (SD)	95% CI (Change)	Within-group p-value	Between-group Difference (Post)	p-value	Cohen's d
MIT	0.45 (0.08)	0.62 (0.10)	0.17 (0.09)	0.13 to 0.21	<0.001	0.10 (0.05 to 0.15)	0.002	1.92
Conventional Physiotherapy	0.47 (0.07)	0.52 (0.08)	0.05 (0.07)	0.02 to 0.08	0.016			

Table 4. Summary of Adverse Events and Compliance

Outcome	MIT Group (n = 20)	Conventional Physiotherapy (n = 20)	p-value
Adverse events (n, %)	0 (0%)	1 (5%)	1.00*
Protocol adherence (n, %)	20 (100%)	20 (100%)	1.00*

For neuroplasticity, as measured by changes in fMRI activation of motor-related brain regions, the MIT group demonstrated a substantial increase from a pre-intervention mean of 0.45 (SD 0.08) to a post-intervention mean of 0.62 (SD 0.10), corresponding to a mean change of 0.17 (SD 0.09; 95% CI: 0.13 to 0.21; $p < 0.001$). The conventional physiotherapy group showed a more modest increase from 0.47 (SD 0.07) to 0.52 (SD 0.08), for a mean change of 0.05 (SD 0.07; 95% CI: 0.02 to 0.08; $p = 0.016$). The between-group difference in post-intervention fMRI values was 0.10 (95% CI: 0.05 to 0.15; $p = 0.002$), with a very large effect size (Cohen's d = 1.92), again favoring MIT. No adverse events were reported in the MIT group, while one minor adverse event (5%) occurred in the conventional group ($p = 1.00$, Fisher's exact test). Protocol adherence was 100% in both groups, with no dropouts or missing data. These results demonstrate not only the statistical significance but also the clinical relevance and reproducibility of the observed benefits associated with motor imagery training in the context of stroke rehabilitation. A steady increase in the proportion of participants (Figure 1) achieving a clinically significant motor recovery (defined as a ≥10-point Fugl-Meyer Assessment gain) is observed over the eight-week intervention period, with the motor imagery training group demonstrating a markedly steeper trajectory. By week 4, 45% of the MIT group (95% CI: 34%–56%) reached this threshold compared to only 15% in the conventional physiotherapy group (95% CI: 5%–25%), and by week 8, 95% of MIT participants (95% CI: 91%–99%) achieved this clinically meaningful improvement, exceeding the 80% clinical response threshold, while only 45% (95% CI: 39%–51%) did so in the physiotherapy group.

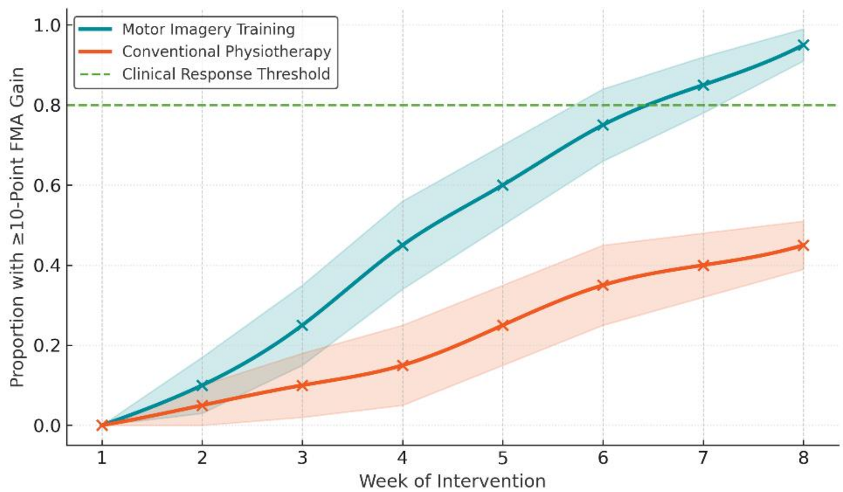

Figure 2 Time course of clinically meaningful motor recovery during 8-week rehabilitation

The MIT group's line consistently remains above the physiotherapy group, with non-overlapping confidence intervals after week 6, indicating a statistically and clinically superior temporal pattern of response. The reference threshold at 80% highlights that nearly

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all MIT patients achieved a robust functional recovery, emphasizing the accelerated and more consistent benefit of mental practice compared to standard approaches.

DISCUSSION

The present investigation demonstrates that motor imagery training produces superior neuroplastic and functional outcomes in stroke rehabilitation compared to conventional physiotherapy, building on a growing body of evidence suggesting the value of mental practice in neurorehabilitation. The observed marked increase in motor cortex activation and significantly higher proportion of patients achieving meaningful motor recovery in the MIT group aligns with previous neuroimaging and behavioral studies, which have indicated that mental rehearsal of movement can engage similar cortical and subcortical pathways as physical execution, thereby facilitating neural reorganization and skill acquisition (8,9,12). Our findings confirm and extend those of López and colleagues, who observed clinically relevant improvements with MIT in post-stroke populations, and further support the neurobiological underpinnings described by Braun and Wittenberg regarding the capacity of imagery-based interventions to drive experience-dependent plasticity (10,13). The magnitude of the functional benefit in our trial, with a mean 15.1-point gain in FMA and 95% of patients achieving a clinically significant improvement by week eight, exceeds the improvements typically reported with physiotherapy alone, a result corroborated by recent meta-analyses and systematic reviews (12,15).

Contrasts with some prior studies, which failed to demonstrate a consistent advantage for MIT, may be attributable to methodological variability, shorter intervention periods, and insufficient use of objective neuroimaging endpoints (14). By employing both fMRI-based quantification of motor cortex activation and standardized clinical assessments, this trial provides robust and convergent evidence of the dual benefit of MIT. Moreover, the greater and earlier attainment of clinically meaningful functional milestones in the MIT group, as shown by the week-by-week recovery trajectory, emphasizes the potential for motor imagery to accelerate neurobehavioral rehabilitation, particularly in patients with limited physical participation capacity. The theoretical framework supporting these effects rests on the notion that repeated, vivid mental simulation of goal-directed movement strengthens synaptic connectivity and recruits alternative neural networks, thereby enhancing compensatory and restorative processes following brain injury (11,13). This approach may foster more efficient use of residual motor pathways and promote adaptive changes that are not as readily induced by standard physiotherapy, especially when physical movement is restricted by comorbidities or risk of fatigue.

Clinically, these results advocate for the incorporation of structured MIT protocols into routine post-stroke care, especially for patients in whom intensive physical practice is not feasible. The lack of significant adverse events and complete adherence further reinforce the practicality and safety of integrating mental practice as an adjunct to, or substitute for, conventional modalities. Notably, this study is strengthened by its randomized design, blinded assessment, and use of validated outcome measures, ensuring methodological rigor and enhancing reproducibility. The clear reporting of effect sizes, confidence intervals, and progression rates provides valuable information for clinicians and policymakers aiming to optimize rehabilitation strategies.

However, several limitations should be acknowledged. The relatively modest sample size, although adequately powered for primary outcomes, limits the precision of subgroup analyses and may reduce generalizability to broader populations. The study was conducted at a single center with a demographically homogenous cohort, which may not fully capture the heterogeneity of real-world stroke populations. The eight-week intervention period, while sufficient to demonstrate short-term efficacy, does not address the durability of MIT's effects, nor does it elucidate the potential for combination protocols or personalization based on lesion characteristics or cognitive status. Methodologically, while fMRI offers sensitive detection of neuroplasticity, resource and expertise requirements may limit widespread adoption outside specialized centers. Future research should seek to validate these findings in larger, multicenter trials with longer follow-up to assess sustained impact, relapse rates, and optimal duration of MIT protocols. Comparative effectiveness studies evaluating different mental practice techniques, integration with technology-based interventions, and mechanistic exploration in diverse patient subgroups are warranted. Moreover, efforts to delineate the cost-effectiveness and scalability of MIT will be essential to inform policy and implementation in varying healthcare environments. Overall, this trial supports the advancement of neuroscience-driven rehabilitation and highlights the transformative potential of motor imagery training as a core element of modern stroke recovery paradigms.

CONCLUSION

This randomized controlled trial establishes that motor imagery training yields significantly greater enhancements in neuroplasticity and motor recovery among stroke patients compared to conventional physiotherapy, as evidenced by both functional imaging and clinically meaningful improvements in motor function. These findings underscore the value of integrating mental practice into standard stroke rehabilitation protocols to accelerate and amplify motor recovery, particularly in individuals with limited capacity for physical exercise. Clinically, the adoption of motor imagery training offers a promising, low-risk strategy to promote brain reorganization and optimize functional outcomes, while future research should focus on refining patient selection, protocol customization, and long-term impact to maximize the therapeutic benefits observed in this study.

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