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COMPARATIVE EFFECTS OF ACTIVITY-BASED MIRROR TRAINING WITH OR WITHOUT RHYTHMIC AUDITORY STIMULATION TO IMPROVE LOWER EXTREMITY FUNCTIONS IN SUBACUTE STROKE PATIENTS: A RANDOMIZED CONTROLLED TRIAL

Original Research

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ABSTRACT

Background: Stroke is a leading cause of long-term disability worldwide, with lower limb impairments often resulting in reduced mobility, impaired balance, and loss of independence. Rehabilitation strategies targeting the restoration of motor function and gait are therefore essential to improve quality of life and reintegration into daily activities. Mirror therapy has been recognized as an effective approach to enhance motor recovery, while rhythmic auditory stimulation provides external cues that may further facilitate gait symmetry and walking performance.

Objective: The purpose of this study was to compare the effects of activity-based mirror training (ABMT) with and without rhythmic auditory stimulation (RAS) on lower extremity function in subacute stroke patients.

Methods: This randomized controlled trial was conducted at THQ Hospital Muridke, Sheikhupura, and Muhammad Ali Physiotherapy Clinic and Rehabilitation Centre, Lahore, between June and December 2023. A total of 40 participants were recruited using non-probability convenience sampling, of which 36 completed the study. Participants aged 45–65 years with unilateral hemiplegia in the subacute phase were randomized into two groups using a flip coin method. Group A received ABMT with RAS, while Group B received ABMT without RAS. Interventions were delivered in 30 sessions over six weeks. Outcomes were assessed at baseline and post-intervention using the Fugl-Meyer Assessment for the Lower Extremity (FMA-LE), the Rivermead Visual Gait Assessment (RVGA), and the 10-Meter Walk Test (10-MWT). Data were analyzed using SPSS version 26.

Results: The mean age of participants was 55.66 ± 6.92 years. In the FMA-LE, scores improved from 14.16 ± 1.94 to 23.38 ± 1.78 in the ABMT with RAS group compared to 15.16 ± 2.00 to 22.00 ± 1.13 in the ABMT group ($p = 0.015$). The 10-MWT improved from 0.704 ± 0.224 m/s to 1.21 ± 0.178 m/s in the ABMT with RAS group versus 0.653 ± 0.230 m/s to 1.032 ± 0.144 m/s in the ABMT group ($p = 0.001$). RVGA scores decreased from 19.94 ± 4.56 to 12.61 ± 1.61 in the ABMT with RAS group, while the ABMT group improved from 21.77 ± 5.73 to 16.55 ± 4.39 ($p = 0.003$).

Conclusion: Both interventions significantly improved motor recovery and gait function in subacute stroke patients. However, ABMT combined with RAS produced superior improvements in lower limb motor control, gait velocity, and gait quality, supporting its role as an effective adjunct to stroke rehabilitation programs.

Keywords: Activities of Daily Living, Auditory Perception, Gait, Mirror Neurons, Rehabilitation, Stroke, Walking Speed.

INTRODUCTION

Stroke is a major global health challenge, ranking as the second leading cause of mortality and long-term disability after cardiovascular disease, with nearly 13.7 million new cases and 5.5 million deaths annually reported worldwide (1). In Pakistan, the burden is compounded by cardiovascular comorbidities such as atrial fibrillation, which significantly increases the risk of ischemic stroke (2). Survivors often live with persistent impairments that compromise independence and quality of life. Among these, sensory and motor deficits of the lower limbs are particularly debilitating, as they interfere with balance, mobility, and functional reintegration. The extent of these deficits is largely determined by lesion location and the degree of neural loss, which typically manifest in muscle weakness, spasticity, impaired coordination, and balance disturbances, culminating in abnormal gait patterns and an increased risk of falls. Additionally, sensory deficits such as impaired proprioception amplify motor dysfunction and slow the rehabilitation process (3). Neurorehabilitation therefore plays a central role in post-stroke recovery, focusing not only on regaining motor skills but also on restoring sensory, cognitive, and psychosocial functioning. The subacute phase, beginning around the fifth week after the cerebrovascular accident, offers a critical therapeutic window during which targeted rehabilitation has the potential to maximize neuroplasticity and functional gains. In this period, structured interventions such as task-specific practice, strengthening, and neuromuscular retraining are emphasized to improve mobility, enhance balance, and reduce fall risk (4,5). Among the strategies employed, mirror therapy (MT) has emerged as a cost-effective, non-invasive approach. By providing visual feedback from the unaffected limb through a mirror placed along the sagittal plane, MT generates the illusion of movement in the affected limb, thereby stimulating cortical areas involved in motor control and proprioception.

This visual-perceptual mechanism has been shown to improve motor recovery, coordination, and range of motion while reducing pain, ultimately promoting neuroplastic reorganization and independence in daily activities (6,7). Evidence suggests that MT is particularly effective in lower limb rehabilitation, where patients gain functional improvements through repetitive mirrored movement exercises (8,9). Similarly, rhythmic auditory stimulation (RAS) has gained recognition as an evidence-based technique to improve gait and motor control. By synchronizing movement to rhythmic cues, patients demonstrate improved cadence, gait velocity, stride length, and bilateral step symmetry, with positive effects observed across both acute and chronic stroke phases (10,11). RAS also facilitates smoother transitions between gait phases and enhances motor control through music-based cues, which may be more effective than simple metronome beats (12,13). Although both MT and RAS have individually demonstrated significant benefits in improving lower limb function after stroke, little is known about the synergistic potential of their combined use. Integrating visual and auditory feedback may strengthen multisensory integration, augment neural activation, and enhance motor planning. This dual approach could improve patient engagement, promote higher-order neuroplastic changes, and accelerate functional recovery beyond what either therapy could achieve alone. The present study aims to investigate the effects of combining mirror therapy and rhythmic auditory stimulation in lower limb rehabilitation among subacute stroke patients. The objective is to determine whether this integrated approach provides superior outcomes in motor recovery, gait performance, and functional independence compared to single-modality interventions, thereby addressing a critical gap in stroke rehabilitation research.

METHODS

This randomized controlled trial was conducted at THQ Hospital Muridke, Sheikhupura, and Muhammad Ali Physiotherapy Clinic and Rehabilitation Centre, Lahore, between June 2023 and December 2023. The sample size was determined using a previously published study that reported mean values of 4.2 ± 0.828 and 3.4 ± 0.8 for intervention and control groups respectively. OpenEpi software was employed to calculate the sample size using a t-test for comparing means, with a 95% confidence interval and a power of 80%. The calculated sample size was 36 participants; however, to accommodate an anticipated attrition rate of 20%, a total of 40 participants were recruited (14,15). Patients were enrolled through non-probability convenience sampling and subsequently randomized into two groups: Group A received activity-based mirror training combined with rhythmic auditory stimulation, while Group B underwent activity-based mirror training without rhythmic auditory stimulation. Randomization was carried out using a flip coin method, and a double-blind design was adopted to minimize bias. Eligibility criteria included patients aged 45–65 years with unilateral hemiplegia in the subacute phase of stroke (8–12 weeks post-onset). Participants were required to exhibit spasticity graded 3–4 on the Modified Ashworth Scale, a motor recovery stage consistent with rehabilitation potential, and a Mini-Mental State Examination score ≥24, indicating no cognitive impairment. In addition, a Modified Rankin Scale score of 2 or less was required to ensure functional ambulation. Patients with other neurological disorders, severe musculoskeletal conditions, uncontrolled comorbidities, or cognitive impairment below the set threshold were excluded. Informed consent was obtained from all participants after explaining the study purpose, procedures, and potential risks and benefits. The study protocol was reviewed and approved by the Institutional Review Board of the respective institutes, ensuring compliance with the Declaration of Helsinki.

Both groups received 30 intervention sessions, conducted five days per week over a six-week period. Interventions were delivered under the supervision of trained physiotherapists. Group A performed structured activity-based mirror training integrated with rhythmic auditory stimulation using a metronome application, while Group B received the same mirror therapy protocol without auditory cueing. The intervention included a combination of lower-limb strengthening, mobility, and balance training tasks, such as ball rolling, rocker board exercises, pedalling, ball kicking, toe movement tasks, and pillow pushing, performed in short-sitting and long-sitting positions. Gait and balance exercises included weight-bearing activities, tandem standing, toe and heel walking, sideways walking, and walking with associated reactions. For Group A, all activities were synchronized with rhythmic auditory cues to enhance motor coordination and temporal control. Outcome assessments were performed at baseline and after six weeks of intervention. The primary outcome measure was the Fugl-Meyer Assessment for the Lower Extremity (FMA-LE), a validated tool assessing motor function, sensation, and joint mobility on a scale of 0–34, with higher scores indicating greater recovery (16). Secondary outcomes included the Rivermead Visual Gait Assessment (RVGA), which evaluates gait quality across 15 items with high internal consistency and inter-rater reliability (17), and the 10-Meter Walk Test (10-MWT), a standardized measure of gait speed with strong test-retest reliability and significant correlation with functional mobility measures (18). Data collection followed CONSORT guidelines, with evaluations performed by assessors blinded to group allocation to further reduce bias. Statistical analysis was conducted using appropriate tests to compare pre- and post-intervention scores between groups. Normality of data was verified prior to analysis. Between-group comparisons were performed using independent t-tests for continuous variables, while within-group differences were analyzed using paired t-tests. A p-value <0.05 was considered statistically significant.

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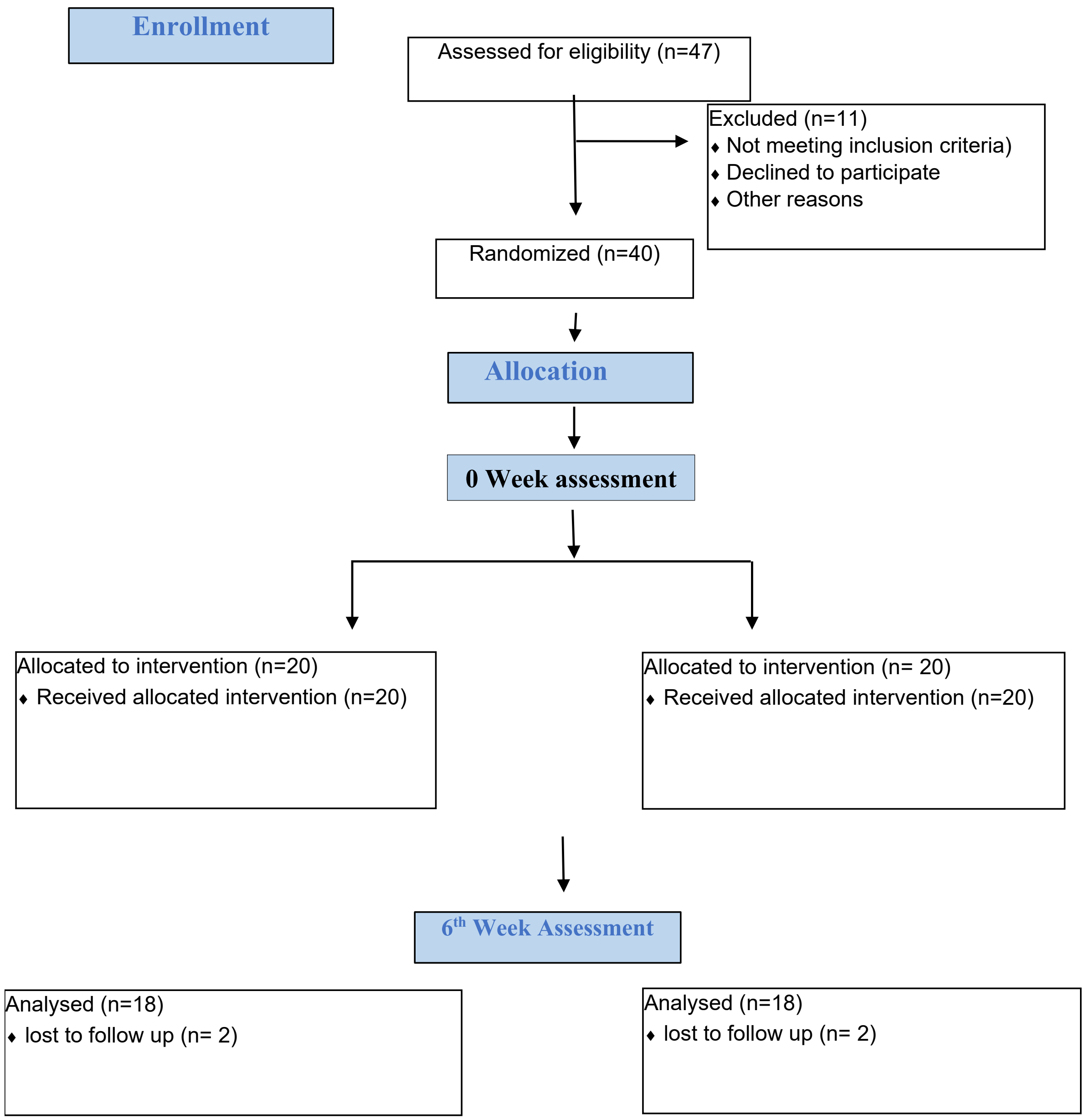
Data collection procedure according to CONSORT guidelines will be as follows



Study Flow Diagram

Figure 1 Data Collection Procedure according to COMSORT Guideline

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Table : Detailed intervention protocol

ABMT With RAS For Motor Functioning			
S.No.	Activity	Target movement	Dosage
1	Ball rolling	Knee flexion-extension	20–50 repetitions, beats and rhythms for 30 min
2	Ball rolling	Hip internal-external rotation	20–50 repetitions beats and rhythms for 30 min
3	Rocker board	Ankle dorsi-plantar flexion	20–50 repetitions beats and rhythms for 30 min
4	Rocker board	Ankle inversion-eversion	20–50 repetitions beats and rhythms for 30 min
5	Pedalling bin	Alternate ankle dorsi-plantar flexion	20–50 repetitions beats and rhythms for 30 min
6	Ball kicking	Knee extension	20–50 repetitions beats and rhythms for 30 min
7	Wiping floor	Hip internal-external rotation	20–50 repetitions beats and rhythms for 30 min
8	Picking-releasing long-pencil pegs Or marbles	Toe movements	20–50 repetitions beats and rhythms for 30 min
9	Pushing pillow	forward Knee flexion-extension, Ankle dorsi planter flexion	10 repetitions × 3–4 sets beats and rhythms for 30 min
10	Pushing pillow	side-ward Hip abduction	10 repetitions × 3–4 sets beats and rhythms for 30 min
S.no.1to8 in short-sitting; 9&10 in long sitting position.			

ABMT With RAS For Gait and Balance		
S.No	Techniques	Dosage
1.	Weight bearing in standing (extended knee)	2–3 minutes with beats and rhythms
2.	Weight bearing in standing on inclined wedge	2–3 minutes with beats and rhythms
3.	Movements using associated reactions	10 repetitions with beats and rhythms
4.	Tandem position (one foot in front of other)	30 min with beats and rhythms
5.	Walking on the tips of toes and on heels	30 min with beats and rhythms
6.	Walking sideways	30 min with beats and rhythms
7.	Walking while raising the leg, and standing in tandem position	30 min with beats and rhythms

RESULTS

The study enrolled 36 participants, equally distributed into two groups, with 18 individuals in each. Group A underwent activity-based mirror training combined with rhythmic auditory stimulation, while Group B performed activity-based mirror training without auditory stimulation. Among participants in the experimental group, 11 (61.1%) were female and 7 (38.9%) were male, whereas the control group included 9 females (50%) and 9 males (50%). The mean age of all participants was 55.66 ± 6.92 years, with mean ages of 55.22 ± 7.46 years in the experimental group and 56.11 ± 6.79 years in the control group. At baseline, there were no statistically significant differences between groups across all three outcome measures. For the Fugl-Meyer Assessment of the Lower Extremity, mean scores were 15.16 ± 2.00 in the control group and 14.16 ± 1.94 in the experimental group (p = 0.115). At the end of six weeks, both groups demonstrated significant improvement, though the experimental group achieved a greater mean score of 23.38 ± 1.78 compared with 22.00 ± 1.13 in the control group, a difference that was statistically significant (p = 0.015). For gait speed as measured by the 10-Meter Walk Test, baseline mean scores were 0.653 ± 0.230 m/s in the control group and 0.704 ± 0.224 m/s in the experimental group (p = 0.317). Following the intervention, both groups improved significantly, but again greater improvement was observed in the experimental group with a mean of 1.21 ± 0.178 m/s compared with 1.032 ± 0.144 m/s in the control group (p = 0.001).

The Rivermead Visual Gait Assessment also showed improvement in both groups, with baseline mean scores of 21.77 ± 5.73 in the control group and 19.94 ± 4.56 in the experimental group ($p = 0.335$). After six weeks, the experimental group demonstrated a significantly lower mean impairment score of 12.61 ± 1.61 compared with 16.55 ± 4.39 in the control group ($p = 0.003$), indicating better gait performance. Within-group analysis using the Wilcoxon Signed Ranks Test confirmed significant pre- to post-intervention improvements in all outcome measures for both groups ($p < 0.001$). However, the magnitude of change was consistently greater in the experimental group across all measures, demonstrating the added benefit of integrating rhythmic auditory stimulation with mirror training. In addition to statistical significance testing, effect sizes and confidence intervals were calculated to better understand the magnitude of treatment effects between groups at six weeks. For the Fugl-Meyer Assessment of the Lower Extremity, the experimental group showed a mean improvement to 23.38 ± 1.78 compared with 22.00 ± 1.13 in the control group, yielding a Cohen's d of –0.93 with a 95% CI ranging from –1.61 to –0.24, indicating a large effect in favor of the experimental group. For the 10-Meter Walk Test, post-intervention mean scores were 1.21 ± 0.178 m/s in the experimental group versus 1.032 ± 0.144 m/s in the control group, corresponding to a Cohen's d of –1.10 (95% CI –1.8 to –0.4), again reflecting a large treatment effect. For the Rivermead Visual Gait Assessment, mean scores improved to 12.61 ± 1.61 in the experimental group compared with 16.55 ± 4.39 in the control group, with a Cohen's d of 1.19 (95% CI 0.48 to 1.9), signifying a large effect in favor of the experimental group. These findings confirm that the integrated intervention produced not only statistically significant improvements but also clinically meaningful changes across all outcomes.

Table 1: between group comparison of control and study group

Variable		Control group (n=18) mean ± SD	Study group (n=18) mean ± SD	P-value (between groups)
FMA	At Baseline	15.16 ± 2.00	14.16 ± 1.94	.115
	At 6th week	22.00 ± 1.13	23.38± 1.78	0.015
10-MW	At Baseline	.653 ± .230	.704 ± .224	0.317
	At 6th week	1.032 ± .144	1.21 ± .178	0.001
RVG	At Baseline	21.77 ± 5.73	19.94 ± 4.56	0.335
	At 6th week	16.55 ± 4.39	12.61 ± 1.61	0.003

SD = Standard Deviation, *Significant difference between groups, $P < 0.05$.

Table 2: within-group comparison of pre-intervention and post-intervention assessment. $P < 0.001$ indicates results are significant.

Variable	Groups	Mean ± SD		P-value (within groups)
FMA	Control Group	At baseline	15.16 ± 2.00	< 0.001*
		At 6th week	22.00 ± 1.13	
	Study Group	At baseline	14.16 ± 1.94	< 0.001*
		At 6th week	23.38± 1.78	
10-MWT	Control Group	At baseline	.653 ± .230	0.001
		At 6th week	1.032 ± .144	
	Study Group	At baseline	.704 ± .224	<0.001*
		At 6th week	1.21 ± .178	
RVGA	Control Group	At baseline	21.77 ± 5.73	< 0.001*
		At 6th week	16.55 ± 4.39	
	Study Group	At baseline	19.94 ± 4.56	< 0.001*
		At 6th week	12.61 ± 1.61	

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Table 3: Between-group effect sizes and confidence intervals at 6th week

Variable	Control Mean ± SD	Study Mean ± SD	Cohen's d	95% CI
FMA	22.00 ± 1.13	23.38 ± 1.78	–0.93	–1.61 to –0.24
10-MWT	1.032 ± 0.144	1.21 ± 0.178	–1.10	–1.8 to –0.4
RVGA	16.55 ± 4.39	12.61 ± 1.61	1.19	0.48 to 1.9

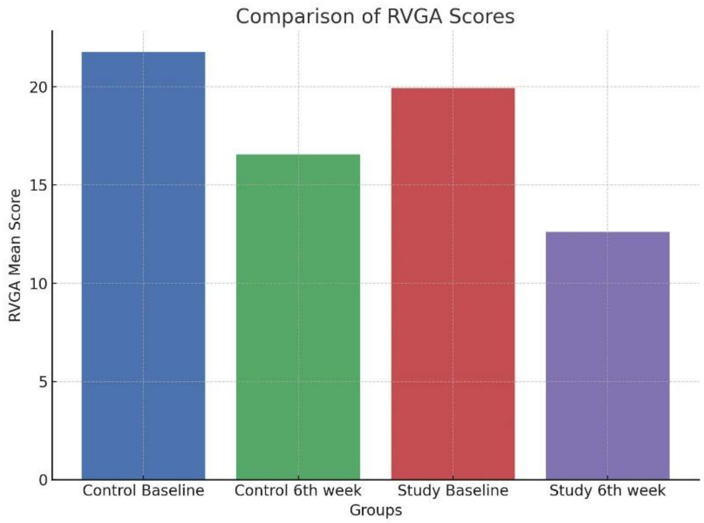

Figure 2 Comparison of RVGA Scores

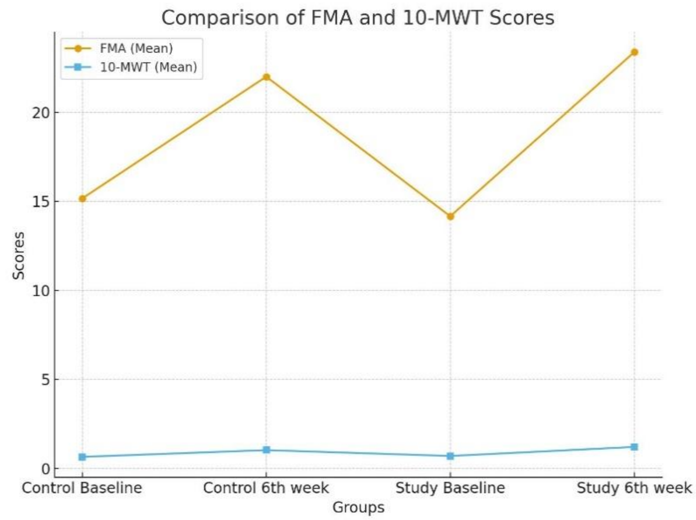

Figure 3 Comparison of FMA and 10-MWT Scores

DISCUSSION

The purpose of this study was to investigate whether combining activity-based mirror training with rhythmic auditory stimulation could yield superior improvements in lower limb motor recovery and gait function compared with mirror training alone in subacute stroke patients. The findings clearly demonstrated that both interventions were effective, yet the combined approach produced more significant gains across motor control, walking speed, and gait quality. These results confirm the therapeutic value of mirror training and highlight the potential advantages of multisensory integration in stroke rehabilitation. The improvement in Fugl-Meyer Assessment scores in both groups reflects the well-documented benefits of mirror therapy in facilitating neuroplasticity and motor recovery. Mirror therapy utilizes visual feedback to activate cortical networks associated with movement planning and execution, thereby enhancing motor control of the affected limb (17). The addition of rhythmic auditory stimulation appeared to amplify these effects, likely by engaging auditory–motor pathways that regulate movement synchronization and cadence. The observed gains in the experimental group support prior evidence that auditory cueing can accelerate motor planning and execution, resulting in better performance outcomes in stroke rehabilitation (18). The improvements in gait performance, as measured by the 10-Meter Walk Test and Rivermead Visual Gait Assessment, were greater in the combined intervention group. The rhythmical cues provided by auditory stimulation are known to facilitate step length, cadence, and bilateral gait symmetry, contributing to increased walking velocity and smoother gait transitions (19,20). The present findings reinforce the concept that auditory stimulation not only complements visual feedback but also enhances proprioceptive integration, thereby producing a more coordinated and efficient walking pattern. Evidence from systematic reviews and meta-analyses further supports the positive impact of music-based auditory stimulation on balance and gait outcomes in stroke survivors, indicating that the integration of rhythmic cues within rehabilitation protocols is both clinically relevant and scientifically grounded (21,22).

The implications of these results are noteworthy, as they suggest that rehabilitation approaches which simultaneously target multiple sensory pathways may accelerate recovery and enhance functional independence in subacute stroke patients. Incorporating rhythmic auditory stimulation alongside mirror training could therefore be considered as an adjunct to conventional physiotherapy programs, particularly for patients aiming to regain ambulatory independence. This study also demonstrated several strengths. The randomized controlled design and use of validated outcome measures increased the reliability of the findings. The structured intervention protocol ensured consistency, and blinding of outcome assessors minimized the risk of bias in data collection. The results provide evidence that is both clinically meaningful and supported by large effect sizes, underscoring the practical relevance of the intervention. However, certain limitations must be acknowledged. The relatively small sample size restricted the generalizability of the findings and reduced the ability to explore subgroup differences such as the influence of age or gender on treatment response. Non-probability convenience sampling increased the risk of selection bias and limited representativeness. Although the study was designed as double-blind, true blinding of participants and therapists was not feasible due to the visible and auditory nature of the intervention. This methodological limitation is common in physiotherapy research and should be recognized when interpreting the results. Moreover, long-term follow-up data were not collected, preventing conclusions about the sustainability of the observed improvements. Future studies should address these limitations by employing larger, more diverse samples and using probability-based sampling methods to improve external validity. Multicenter trials may help confirm these findings and increase generalizability. Additionally, long-term follow-up is essential to determine whether the observed benefits of combined mirror therapy and rhythmic auditory stimulation persist over time. Investigating potential moderators such as stroke severity, lesion location, and psychosocial factors would also provide greater insight into patient-specific responses to multisensory interventions. In summary, this study adds to the growing body of evidence that combining visual and auditory modalities enhances neuroplasticity and functional recovery in stroke rehabilitation. The findings support the clinical integration of activity-based mirror training with rhythmic auditory stimulation as a promising approach to improve lower limb function, gait velocity, and quality of movement in subacute stroke patients.

CONCLUSION

In conclusion, this study demonstrated that activity-based mirror training is an effective intervention for enhancing lower limb function in subacute stroke patients, while the addition of rhythmic auditory stimulation further amplified these benefits. The combined approach promoted greater improvements in motor recovery, gait performance, and functional mobility, highlighting the value of integrating multisensory strategies into rehabilitation programs. These findings emphasize the practical significance of incorporating rhythmic auditory stimulation alongside mirror therapy as a complementary tool to optimize outcomes and support patients in regaining independence and quality of life after stroke.

AUTHOR CONTRIBUTION

Author	Contribution
Nazish Mushtaq*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Hifsa Waheed	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Fatima Tariq	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Laiba Khalid Butt	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Fizza Sabir	Contributed to Data Collection and Analysis Alishah Malik Has given Final Approval of the version to be published
Alishah Malik	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Azka Yaseen	Contributed to study concept and Data collection Has given Final Approval of the version to be published

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