Efficacy of Action Observation Therapy and Mirror Therapy on Upper Limb Spasticity, Motor Performance and Functional Activities in Patients with Chronic Stroke: A Randomized Controlled Trial

Dr. Mansi Prajapati (PT)[1], Dr. Anjan Desai (PT)[2*]

[1]Clinical physiotherapist, Dinal's Neurophysiotherapy Clinic, Valsad, Gujarat, India

[2]Professor & Principal in charge, SPB Physiotherapy College, Surat, Gujarat, India

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INTRODUCTION

Stroke, as defined by the World Health Organization, is the rapid development of clinical signs of focal or global disturbance of cerebral function, with symptoms lasting more than 24 hours or leading to death, with no apparent cause other than vascular origin [1]. Risk factors associated with stroke are classified as non-modifiable (age, gender, race, and genetics) or modifiable (hypertension, smoking, alcohol use, physical inactivity, diabetes, and atrial fibrillation) [2-4]. In India, stroke is a leading cause of death and disability, with an estimated annual cumulative incidence of 105–152 per 100,000 persons and a crude prevalence ranging from 44 to 559 per 100,000. Among survivors, 15-30% become severely handicapped, and 40% experience persistent functional deficits, impacting functional independence [5].

Post-stroke impairments are multifaceted, encompassing sensory, motor, cognitive, and psychological symptoms. Motor impairment, particularly hemiparesis affecting the face, arm, and leg unilaterally, is most common. Also in chronic stroke, the prevalence of upper limb impairment (paresis, abnormal tone, decreased somatosensation, and incoordination) ranges from 40-50% [6, 7]. Upper limb deficits—including paresis, spasticity, incoordination, and reduced functional use—severely impact activities of daily living (ADL) and quality of life. [8]

Rehabilitation strategies for upper limb recovery include neurodevelopmental techniques, bilateral arm training, task-specific training, constraint-induced movement therapy (CIMT), mirror therapy (MT), and action observation therapy (AOT). Among various rehabilitation approaches, MT and AOT have gained attention for their ability to activate the mirror neuron system (MNS) without requiring active movement of the paretic limb. MT uses a mirror to create a visual illusion that the unaffected limb is the affected one moving normally, which was originally designed by Ramachandran et al. to reduce phantom limb pain [9-11]. Conversely, AOT requires participants to observe a healthy person performing an action in a video, followed by physical execution of the same action [12, 13].

Standardized outcome measures for this population include the Modified Ashworth Scale (MAS) for spasticity [14], the Fugl-Meyer Assessment Upper Extremity (FMUE) Scale for motor performance [15], and the Chedoke Arm and Hand Activity Inventory (CAHAI) for functional activities [16]. Yu-Wei Hsieh et al. compared the effects of AOT, MT, and active control in sub-acute stroke patients [17]. While individual studies have shown benefits of MT and AOT for upper limb recovery [11-13], direct comparisons in chronic stroke patients are lacking.

Therefore, the present study aims to evaluate and compare the effectiveness of Action Observation Therapy and Mirror Therapy for upper limb spasticity, motor performance, and functional activities in patients with chronic stroke.

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MATERIAL AND METHODS

Study Design and Setting

After getting ethical approval from the Institutional Ethical Committee, this randomized controlled trial was conducted from October 2020 to April 2021 at the SPB Physiotherapy College OPD and various other hospitals and clinics in Surat. A total of 32 chronic stroke patients (including both males and females) were recruited using purposive sampling. Sample size was calculated using G*Power version 3.1.9.2 based on the primary outcome Fugl-Meyer Assessment Upper Extremity (FMA-UE). Using an effect size (Cohen's d) of 0.9 derived from a prior study comparing AOT and MT in stroke (Hsieh et al., 2018) [17], with α=0.05 and power=0.80, the required sample was 15 per group (total 30). Accounting for a 10% dropout, we recruited 16 per group (total 32).

Study Population and Selection Criteria

Patients with a first incidence of stroke, aged between 40 and 75 years (both genders, right or left side affected), with a stroke duration of 6 to 18 months were included. Additional inclusion criteria were a Modified Ashworth Scale (MAS) score ≥1 in at least one upper limb muscle, Brunnstrom stage of recovery ≥ stage 3, and a Mini Mental State Examination (MMSE) score ≥ 24 [18]. Patients were excluded if they had any neurological disorder other than stroke, vision impairment, severe dysarthria or aphasia, or uncontrolled hypertension and diabetes. Also, they were excluded if they had any orthopedic condition limiting upper limb movement or were receiving anti-spasticity medications (baclofen, tizanidine, botulinum toxin).

Outcome Measures

Outcome measures were assessed at baseline (pre-intervention) and after four weeks of intervention (post-intervention). Spasticity was assessed using the Modified Ashworth Scale (MAS) [14], which tests resistance to passive movement about a joint, with scores ranging from 0 (no increase in tone) to 4 (rigid in flexion or extension). Motor performance was evaluated using the Upper Extremity section of the Fugl-Meyer Assessment (FMA-UE) [19], an ordinal scale comprising 33 items (reflex testing, movement observation, grasp testing, coordination) rated from 0 to 66, where higher scores indicate fewer motor deficits. Functional ability of the paretic arm and hand was measured using the Chedoke Arm and Hand Activity Inventory (CAHAI) [20], which contains 13 items assessed on a 7-point scale, giving a total raw sum of 91 (minimum score 13), with patients required to use both arms during performance.

Procedure and Randomization

After preliminary screening based on the selection criteria, demographic data and clinical history were collected, and a complete physiotherapy examination was performed. The purpose of the study was explained, and written informed consent was obtained from all patients. Patients were randomly allocated into two groups using a lottery method: the first patient allocated to Group A (Action Observation Therapy + Conventional therapy) and the second to Group B (Mirror Therapy + Conventional therapy), with this sequence maintained throughout the study. All patients underwent a conventional therapy program for 30 minutes, 5 days per week, in addition to either Action Observation Therapy (AOT) or Mirror Therapy (MT) for 45 minutes, 5 days per week, for a total of 4 weeks (20 sessions). Relaxation time was provided as needed. Assessments of spasticity, motor performance, and functional activities were conducted pre- and post-intervention using the MAS, FMA-UE, and CAHAI, respectively.

Conventional Therapy Protocol

The conventional physiotherapy program included stretching of spastic upper and lower limb muscles (30-second hold, 3 repetitions), active exercises for the shoulder, elbow, wrist, hip, knee, and ankle, pelvic bridging, trunk rotation (side to side), strengthening exercises for upper and lower limb muscles, mat activities (prone on hands/elbows, quadruped, kneeling, half-kneeling), manual perturbations, weight shifting (side to side), and reaching out toward the affected side. The therapist provided verbal instructions, cues, feedback, and assistance as needed [21, 22].

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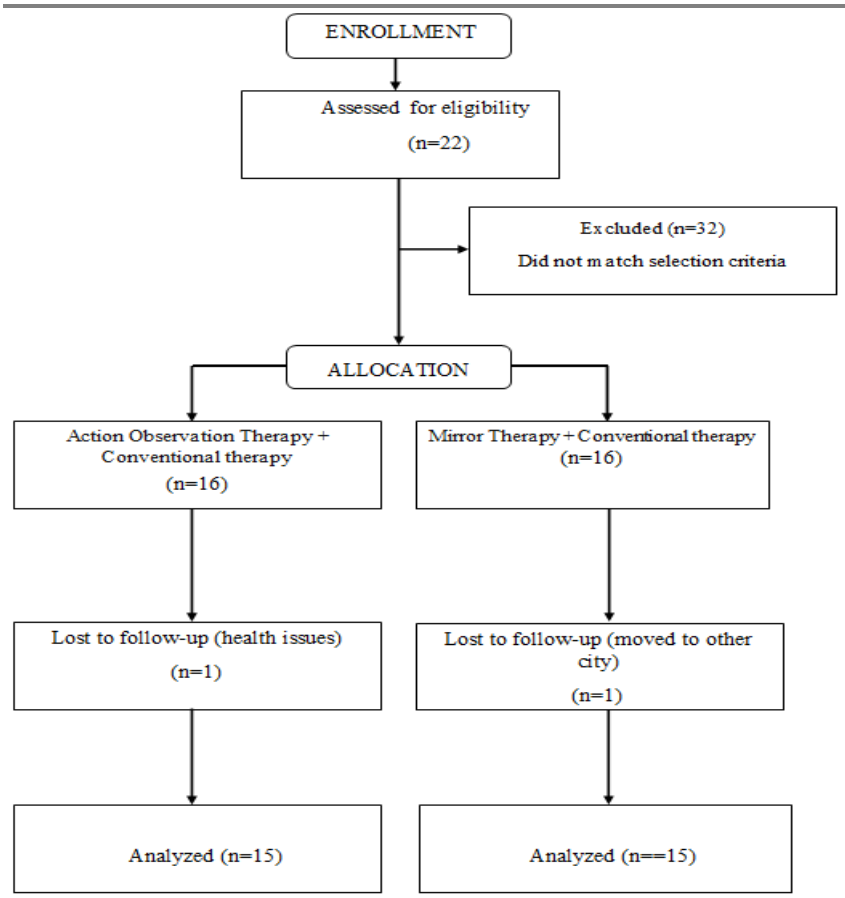


Figure 1: Flow chart

Action Observation Therapy (AOT) Protocol (Group A) [23]

Patients in Group A observed video clips of upper limb movements, object manipulation, and functional tasks displayed from a first-person perspective on a laptop placed 60 cm away [24]. Each session consisted of three categories. First, upper limb active range of motion (AROM) exercises (10 minutes) including shoulder, scapular, elbow, wrist, and finger movements, which patients observed and then executed simultaneously with both arms. Second, reaching and object manipulation tasks (15 minutes) such as grasping and releasing objects of different sizes (sponge ball, cube, cane, spoon, coin, key, etc.) and placing pegs; patients observed each movement for 2 minutes, then executed it for 3 minutes, with three movements introduced initially and more added as proficiency improved. Third, upper limb functional tasks (20 minutes) divided into three motor acts per task (e.g., cleaning the mouth with tissue paper: moving hand toward tissue, taking tissue, bringing to mouth and wiping); patients observed each task for 2 minutes and executed for 3 minutes, performing four functional tasks per session (e.g., screwing a jar lid, building blocks, folding a towel, drinking water, brushing hair).

Mirror Therapy (MT) Protocol [23] (Group B)

Patients in Group B performed exercises with a mirror (30 cm height × 30 cm length × 3 mm width) positioned at the patient's midline. The affected limb was placed behind the mirror and the unaffected limb in front, so the reflection of the unaffected limb was visible. Patients were instructed to watch the mirror reflection of the unaffected limb's movement while imagining it was the affected limb moving; they were encouraged to move the affected limb as much as possible, with therapist assistance if needed. The protocol included three categories. First, upper limb AROM exercises (10 minutes) for shoulder, elbow, wrist, and fingers performed simultaneously by both limbs. Second, reaching and object manipulation tasks (15 minutes) identical to the AOT protocol, where patients performed with the unaffected limb while viewing its reflection and simultaneously attempted the same movement with the affected limb. Third, upper limb functional tasks (20 minutes) were similarly divided into three motor acts per task, with four functional tasks per session performed in the same mirror-based manner. Therapist assistance was provided as needed for the affected limb throughout all activities.

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Statistical analysis & results:

All The test and calculations were performed using SPSS version 20.00 software. Analyses were performed using SPSS version 20.0. Normality was tested using the Shapiro-Wilk test. Significance level α=0.05. Baseline characteristics were compared using the Mann-Whitney U test (continuous) and Chi-square test (categorical). Within-group analysis was done using the Wilcoxon signed-rank test and between-group comparisons were done by Mann-Whitney U test on change scores (post-pre). Effect sizes kept by Cohen's d calculated for between-group differences (0.2=small,0.5=medium, 0.8=large). 95% Confidence intervals were reported for all main between-group comparisons. Multiple comparisons correction for MAS was done by Bonferroni correction (α = 0.05/3 = 0.0167) because three muscle groups were tested (elbow, wrist, finger flexors). Per-protocol analysis was used, and drop out data were excluded from analysis.

A total 50 patients were assessed for eligibility. Out of them, thirty-two patients were enrolled in the study and randomized to one of the treatment group (16 in the AOT group and 16 in the MT group). The mean age of participants in the AOT group was 56.1±7.6 years, and of the MT group was 49.9±5.3 years. One patient from both AOT and MT group discontinued intervention in between. So analyses were made on a total of 30 participants (15 in the AOT group and 15 in the MT group) on the first day and after 4 week of intervention. Table 1 shows baseline characteristics of the participants.

Table 1: Baseline characteristics of participants

Variable	Group A (AOT)(n=15)	Group B (MT)(n=15)	Test statistic	p-value
Age (Years) Mean ± SD	56.1±7.6	49.9±5.3	U=152.5	**0.018***
Gender (M/F)	11/4	10/5	χ^2=0.159	0.690
MMSE Mean ± SD	29.6±0.6	29.7±0.6	U=160.0	0.810
Type of stroke(ischemic/hemorrhagic)	13/2	14/1	χ^2=0.370	0.543
Post stroke duration (months)	9.6±2.5	11.6±3.2	U=148.0	**0.041***
MAS –Elbowflexors (median[IQR])	1 (1-2)	1 (1-2)	U=150.0	0.620
MAS –Wristflexors (median[IQR])	1 (1-1.5)	1 (1-2)	U=158.5	0.780
MAS –Fingerflexors (median[IQR])	1 (0-1.5)	1 (1-2)	U=152.0	0.640
FMA-UE (Mean ± SD)	35.9±12.3	29.6±11.7	U=152.5	0.190
CAHAI (Mean ± SD)	50.8±16.7	52.3±20.2	U=160.0	0.850

Both groups were matched in terms of type of stroke, gender, MMSE, Pre- MAS (Elbow Flexors, Wrist Flexors, Finger Flexors) Score, pre-FMA-UE score and pre-CAHAI score. The baseline characteristics were equivalent in the intervention groups (p>0.05).

Wilcoxon signed-rank test was used to compare the values of three outcome measures; MAS, FMA-UE and CAHAI pre-intervention and post-intervention in both groups (Table 2). Confidence interval was set at 95% and p-value <0.05.

In the AOT group, all outcome measures showed statistically significant improvement from pre- to post-intervention: MAS scores for elbow flexors (p<0.05), wrist flexors (p<0.05), finger flexors (p<0.05); FMA-UE

($p<0.05$); and CAHAI ($p<0.05$). In the MT group, FMA-UE and CAHAI showed statistically significant improvement ($p<0.05$). For spasticity, only elbow flexor MAS showed significant improvement ($p<0.05$), while wrist flexor MAS ($p=0.31$) and finger flexor MAS ($p=0.15$) did not reach statistical significance.

Table 2: Intra group comparison of Group A and Group B (Wilcoxon sign rank test)

Group	Outcome	Pre (median [IQR])	Post (median [IQR])	z	p value*
AOT	MAS Elbow	1 (1-2)	1 (0-1)	-3.21	0.001*
	MAS Wrist	1 (1-1.5)	1 (0-1)	-2.84	0.005*
	MAS Finger	1 (0-1.5)	0 (0-1)	-2.52	0.012*
	FMA-UE (mean±SD)	35.9±12.3	43.7±10.2	-3.62	<0.001
	CAHAI (mean±SD)	50.8±16.7	56.1±17.0	-3.52	<0.001
MT	MAS Elbow	1 (1-2)	1 (0-1.5)	-2.58	0.010†
	MAS Wrist	1 (1-2)	1 (1-2)	-1.00	0.317
	MAS Finger	1 (1-2)	1 (1-2)	-1.51	0.131
	FMA-UE (mean±SD)	29.6±11.7	39.7±13.8	-2.79	0.005
	CAHAI (mean±SD)	52.3±20.2	53.6±21.6	-2.87	0.004

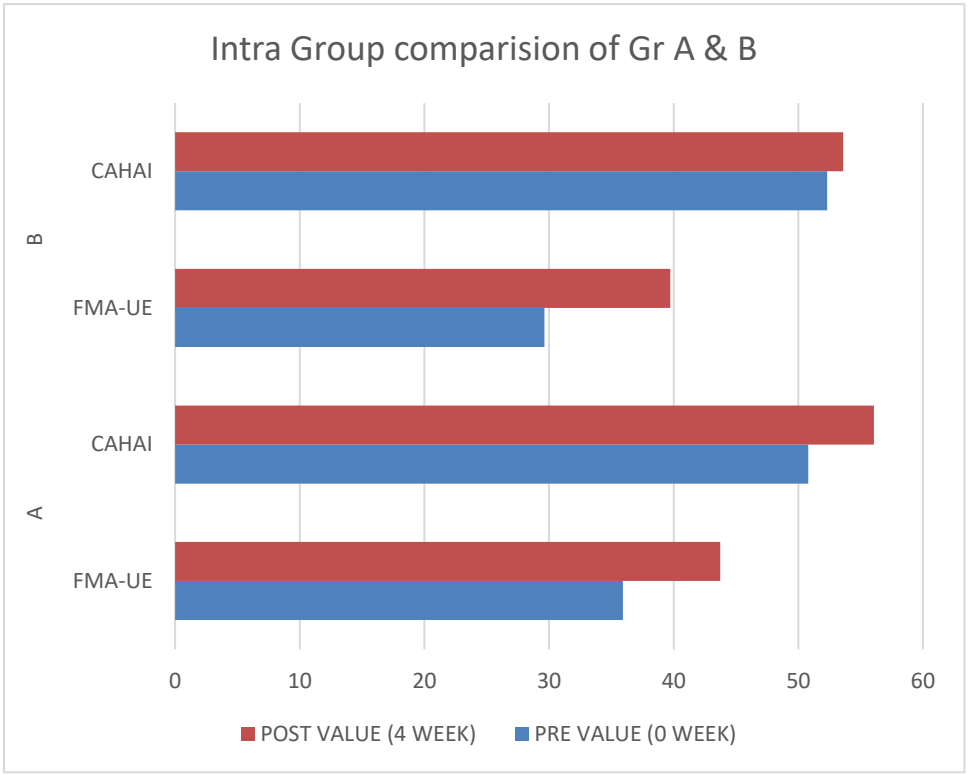


Figure 2: Intra Group Comparision Of Both Groups

Intergroup comparison of all outcome measures was done between group A and B using Mann Whitney U test. Table 3 show that FMA-UE and CAHAI shows significant improvement.

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Table 3: Inter group comparison of group A and B (Mann- Whitney U test)

Outcome	Δ (Post-Pre) Group A (AOT)	Δ (Post-Pre) Group B (MT)	Mean difference (95% CI)	Cohen's d	U
MAS Elbow (change in median)	0 (-1 to 0)	0 (-1 to 0)	-	-	140.0
MAS Wrist	0 (-1 to 0)	0 (0 to 0)	-	-	152.5
MAS Finger	0 (-1 to 0)	0 (0 to 0)	-	-	155.0
FMA-UE	8.4±5.01	3.26±3.75	5.14 (2.17 to 8.11)	1.20 (large)	170.0
CAHAI	5.26±3.53	1.8±1.74	3.46 (1.29 to 5.63)	1.24 (large)	168.5

*Mann-Whitney U; *p<0.05

Achievement of MCID (FMA-UE ≥5.2 points):

- AOT group: 11/15 (73%) patients achieved MCID
- MT group: 4/15 (27%) patients achieved MCID
- Chi-square: χ^2=6.65, p=0.010

Achievement of MCID (CAHAI ≥6.3 points):

- AOT group: 6/15 (40%) patients
- MT group: 1/15 (7%) patients
- Chi-square: χ^2=4.66, p=0.031

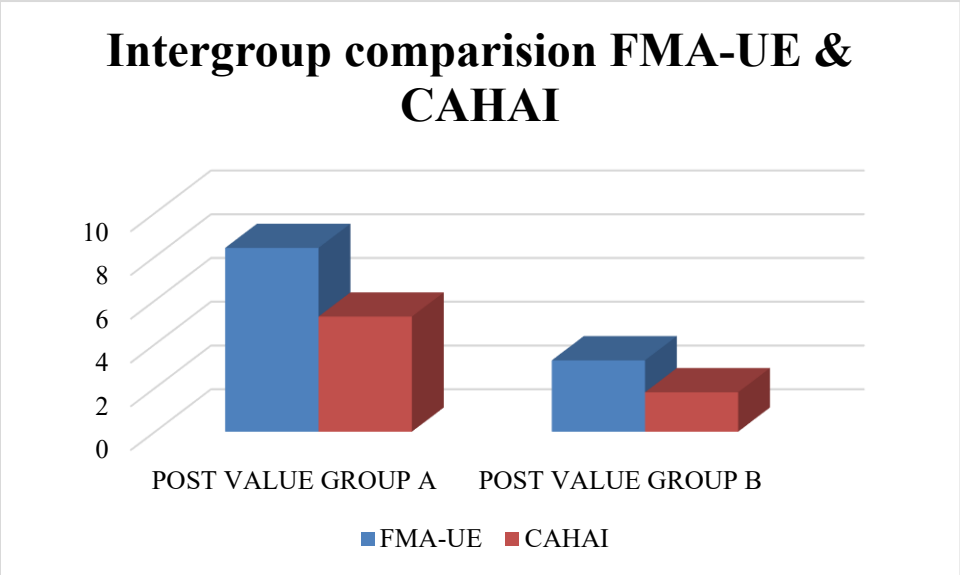


Figure 3: Inter Group Post Intervention Comparision of Outcome Measures

Both outcome measures showed a statistically significant reduction from baseline to post-intervention (or between groups, depending on study design), with p-values < 0.01 indicating strong evidence against the null hypothesis. So AOT is significantly improving motor performance and functional activities than MT.

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DISCUSSION

This comparative interventional study evaluated the effects of conventional physiotherapy combined with either Action Observation Therapy (AOT, Group A) or Mirror Therapy (MT, Group B) on spasticity, motor performance, and functional activities in chronic stroke patients using the Modified Ashworth Scale (MAS), Fugl-Meyer Assessment Upper Extremity (FMA-UE), and Chedoke Arm and Hand Activity Inventory (CAHAI).

Within-group analysis revealed highly significant improvements in motor performance (FMA-UE) and functional activities (CAHAI) in both groups ($p<0.05$). Regarding spasticity, Group A showed significant reduction in MAS scores for elbow, wrist, and finger flexors ($p<0.05$), while Group B demonstrated significant improvement only for elbow flexors ($p<0.05$), with no significant change for wrist and finger flexors ($p>0.05$). The mean improvement in Group A for FMA-UE was 7.8 (35.9 to 43.7) representing a 21.7% improvement from baseline, and for CAHAI was 5.25 (50.81 to 56.01). In Group B, FMA-UE improved by 10.11 (29.6 to 39.7), representing a 34.1% improvement from baseline and CAHAI by 1.29 (52.3 to 53.6). AOT was significantly more effective than MT (mean difference: 4.00, $p<0.05$).

These findings align with previous studies. Mei-Hong Zhu et al. reported that AOT combined with conventional treatment significantly improves motor function, activities of daily living, and alleviates spasticity in stroke patients [25]. Similarly, Mauro Mancuso et al. and Keziya Marry Philip et al. demonstrated significant improvements in motor performance and functional activities following AOT [26, 27]. The observed improvements can be attributed to mirror neuron system activation, recruitment of the cerebellar-thalamic-cortical system, enhanced visual feedback, repetitive training-induced neural plasticity, and motor relearning.

For mirror therapy, Luciana Protasio de Melo et al. [28] and Roshini Rajappan et al. [29] found significant improvements in upper limb spasticity and motor function in chronic and sub-acute stroke patients. Marian E. Michelson et al. reported cortical reorganization and altered neural activation patterns in the primary motor cortex of the affected hemisphere following MT [30]. The mechanism underlying MT benefits includes visual feedback substitution for reduced proprioceptive input and premotor cortex recruitment.

MT significantly reduced elbow flexor spasticity but not wrist or finger spasticity. This may be due to the fact that hand and fingers have larger but more complex cortical representations. Also, Visual illusion from MT may preferentially activate proximal (elbow) circuits over distal [31]. After 6 months, distal spasticity may become fixed due to soft tissue contracture or irreversible neural changes, making it less responsive to illusion-based therapies. Moreover, our MT protocol emphasized proximal movements (shoulder, elbow) in early sessions; distal tasks were introduced later. A distal-focused MT protocol might yield different results.

Between-group comparison using the Mann-Whitney U test demonstrated that Group A (AOT) was significantly more effective than Group B (MT) in improving motor performance (FMA-UE mean difference: 8.4±5.01 vs. 3.26±3.75, $p<0.05$) and functional activities (CAHAI mean difference: 5.26±3.53 vs. 1.8±1.74, $p<0.05$). However, no significant between-group differences were observed for MAS scores of elbow, wrist, or finger flexors ($p>0.05$). These results are consistent with Yu-Wei Hsieh et al., who reported that AOT produced greater improvements in activities of daily living compared to MT in sub-acute stroke patients [17].

The superior effectiveness of AOT over MT for motor performance and functional activities may be explained by the more intuitive nature of action observation and imitation during motor learning. Observing and imitating actions may facilitate easier understanding and learning compared to mirror visual feedback. Neurophysiological evidence from electroencephalography (EEG), magnetoencephalography (MEG), and brain imaging studies demonstrates recruitment of the pre-central motor cortex and frontoparietal areas during action observation, with activation patterns similar to actual execution, particularly when observed actions are familiar to the patient.

Based on these results, it is stated that the interventions used in this study are inexpensive and readily applicable in clinical practice. Therefore, AOT should be incorporated into the rehabilitation phase for chronic stroke patients to improve motor performance and functional activities and reduce spasticity within a shorter training period. This study has several limitations. The trial registration was not done as it was a part of a post-graduation

programme. The sample size was small, which limits generalizability of the findings, and accessor was not blinded, which may produce selection bias. Also, intention-to-treat was not performed. We have used alternate allocation instead of true randomization. This method does not provide adequate concealment of allocation and may introduce selection bias, as the sequence of assignment is predictable. Future studies should employ computer-generated random sequences with concealed allocation (e.g., sealed opaque envelopes or web-based randomization) to ensure proper randomization. The number of male and female participants was unequal, preventing gender-based comparisons. Additionally, post-intervention follow-up was not conducted, so the long-term benefits of the interventions remain unknown.

Future studies should replicate this research with a larger sample size and equal representation of males and females to enable gender comparison. Comparative studies including different age groups and acute stroke patients are recommended. Furthermore, long-term follow-up assessments should be incorporated to evaluate the sustainability of treatment benefits.

CONCLUSION

This study concludes that conventional physiotherapy with additional AOT or MT positively affects spasticity, motor performance, and functional activities in chronic stroke patients. However, AOT is more effective than MT for improving motor performance and functional activities. Thus, AOT should be included in chronic stroke rehabilitation to achieve greater improvements in motor performance, functional activities, and spasticity reduction within a shorter training period.

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