Original Article

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Effect of Home-Based Task-Based Mirror Therapy on Upper Extremity Function in Stroke Patients: A Four-Week Intervention Study

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Abstract:

Objective: This study aimed to investigate the effect of task-based mirror therapy on upper extremity function, and daily living activities in individuals with stroke, after four weeks of training.

Material and Methods: Participants were randomized into two groups, the task-based mirror therapy group and the task training as the control group: as 10 and 7 participants, respectively. The Action Research Arm Test (ARAT), the Fugl-Meyer Assessment (FMA), the Sirindhorn National Medical Rehabilitation Center Functional Assessment (SNMRC) and the Short-Form 36 (SF-36) were assessed before and after training, over a four week period.

Results: The results showed that the home-based programs of both the task-based mirror therapy and the control group improved on all variables, but without statistical significance between groups. However, within group analysis, the task-based mirror therapy group exhibited significant differences between pre- and post-assessments for FMA; whereas, the control group did not.

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Conclusion: The home-based program of task-based mirror therapy, as a task-specific training approach, has demonstrated the potential to enhance the recovery of upper limb motor function after a four-week training period.

Keywords: home-based program, stroke, task-based mirror therapy, upper extremity function

Introduction

In Thailand, stroke is the leading cause of death for both genders[1]. Approximately 50 percent of stroke survivors experience upper extremity function impairment. During the inpatient phase, stroke patients primarily undergo ambulation training with an emphasis on independent walking. As a result, upper extremity training often takes a back seat, as most patients prioritize regaining their walking ability. Following discharge from the hospital, stroke patients frequently continue to face reduced upper extremity function[2]. The critical window for recovery extends from the first week to 18 months after a stroke, underscoring the significance of consistent and sustained rehabilitation. Neglecting appropriate and continuous rehabilitation can lead to significant disabilities, a decreased ability to perform essential daily tasks and ultimately affects overall quality of life[3].

Rehabilitation programs for restoring upper extremity function after stroke encompass a range of methods[2]. Some interventions focus on enhancing muscle strength through strength training, while others target functional improvement through approaches; such as bilateral arm training, biofeedback, task-specific training, virtual reality, electrical stimulation, robotics, and Constraint-Induced Movement Therapy; among others[2]. However, almost all of these methods require the presence of a physical therapist during the majority of training sessions, and some necessitate high-tech or specialized equipment. According to the principles of motor relearning, improving movement control requires continuous and intensive training over a substantial period. In rural areas of Thailand, stroke patients may struggle to consistently attend rehabilitation programs at hospitals or centers, even if they are relatively nearby[4]. Home-based training can offer a simplified, patient-centered approach. Familiarity with the home environment often leads to better emotional well-being and sleep quality. Furthermore, home-based rehabilitation has shown cost-effectiveness and improved essential functions for stroke patients[5]. Therefore, interventions that enable patients to practice independently, without constant therapist observation, within the comfort of their own home should be given serious consideration.

To emphasize the relearning of motor skills, often achieved through physical practice, recent research has highlighted the benefits of cognitive training; such as motor imagery or action observation, for enhancing functional performance in patients. Both spontaneous and therapeutic-induced plasticity mechanisms contribute to functional restoration after a stroke and rely on similar mechanisms[6]. Mirror therapy, which involves patients observing the specific movements of their stronger limb in a mirror, allows them to retrieve the sensation of their own movement through visual feedback of the imagined actions of their impaired limb. Furthermore, the observation of the mirror illusion may activate the mirror neuron system (MNS) in motor recovery. It is conceivable that observing one's own mirrored movements promotes recovery in a similar manner[7].

Mirror therapy is a rehabilitation method employed to restore upper extremity function in stroke patients during their recovery process[8]. The mirror used should be appropriately sized to cover all target body parts and reflect the unaffected side during movements. By observing the mirror's reflection, patients perceive the affected side's movements as a normal pattern[8]. Mirror therapy allows patients to practice independently at their own accommodations without direct guidance from a physical therapist. However, before they are permitted to practice on their own, they undergo training and verification by a physical therapist. This training covers the proper movement program, the accuracy of movement execution, techniques for observing the reflection, and guidelines for actions during the observation.

Mirror therapy comprises two training protocols: movement-based and task-based. In movement-based mirror therapy, patients perform simple movements of the affected limb. However, previous studies have indicated that patients benefit from goal-directed practice, repetition, and feedback; commonly referred to as 'task-specific training.' This approach emphasizes motor learning beyond the scope of simple movements. Task-specific training has substantial support in stroke rehabilitation, as it enhances cortical activity and may lead to better motor recovery compared to isolated movements[9]. Therefore, task-based mirror therapy, which involves integrating limb movement into functional tasks while observing the reflection, holds promise for improving upper limb motor recovery in stroke patients[10].

However, there are limited studies in the realm of upper extremity function rehabilitation for stroke patients in Thailand; particularly in the context of task-based mirror therapy. Given that the primary goal of stroke rehabilitation is to restore and maintain the ability to perform daily activities, patients within the optimal recovery period following a stroke are of particular interest for this study. Thus, early rehabilitation is recommended; especially during the critical recovery period. This study aims to investigate the impact of four weeks of task-based mirror therapy on upper extremity function and daily living activities in individuals who have experienced a stroke within 3-18 months.

Material and Methods

Study design

This study adopted a double-blind, randomized controlled trial design. The researcher who generated the sequences remained concealed. All tests were administered by a trained researcher that was blinded to the participant's group allocation. Both the participants and physical therapists delivering treatment in each group were also blinded. Ethical approval for the experimental protocol was obtained from the Ethics Committee for Human Research at the Faculty of Medicine, Prince of Songkla University, on January 28, 2019 (Certificate No. REC. 61-344-30-2). The TCTR identification number is TCTR20230128002.

Participants

This study aimed to evaluate the effectiveness of task-based mirror therapy as a home-based rehabilitation intervention for individuals having experienced their first stroke attack within the past 3-18 months, and were aged between 18 and 70 years. Sample size calculation, based on Kim et al.'s study in 2016[11], determined that 16 stroke patients were required per group: the task-based mirror therapy group and the control group. Recruitment took place at hospitals and healthcare facilities in Songkhla province, Thailand. All participants provided written informed consent for their involvement. Participants that met the inclusion criteria were randomized into either the control or task-based mirror therapy group using computer-generated random sequences.

Criteria

Inclusion criteria encompassed: (a) first stroke patients with Brunnstrom stage between 2-5[11,12], (b) Thai Mental State Examination (TMSE) scores of 24 (corrected for educational attainment and age)[11,12], (c) no upper extremity range of motion limitations affecting the training program (the degree of active range of motion should be at least half of the full or passive range of motion degree), (d) fair dynamic sitting balance by balance grading, (e) ability to sit for at least 30 minutes, (f) upper extremity spasticity not exceeding level 2 on the Modified Ashworth Scale (MAS)[11,12], (g) the presence of a caregiver during training sessions, and (h) the participants' functional ability is at least at an independent with moderate assistance level according to the SNMRC Functional Assessment (more than 35)[13]. Exclusion criteria included: (a) proprioception sensation deficit (<3/5 of sensory testing) in the upper extremity, (b) upper extremity bone fracture within the last six months, (c) musculoskeletal conditions impacting upper extremity movement; such as shoulder pain or upper extremity's muscle strain, (d) unilateral neglect as indicated by bisection test, (e) signs of depression as indicated by 2Q and 9Q questionnaires, (f) receiving botulinum-toxin treatment or surgery for spasticity within the last six months, (g) aphasia via medical record, and (h) visual impairment that couldn't be corrected with contact lenses or glasses via Snellen chart. Termination criteria encompassed (a) voluntary withdrawal from training, (b) injuries that may occur during the training period that could affect upper extremity movements, leading to issues like muscle strains, joint pain, and more, or (c) events preventing continued study.

Procedures

Both groups received a total of approximately one hour of training per day; including a 15-minute baseline program and 45 minutes of task-based training. Six independent physical therapists were responsible for the training sessions: three were responsible for the control group (PJ., SW., and SB.) and another three for the mirror group (NM., WS., and CW.). In addition, two independent physical therapists (AP. for the control group, and WP. for the mirror group), were assigned the responsibility of visiting patients' accommodations to set up the training area. They refrained from discussing the research with each other. The training station was arranged in a room or corner of the patient's home to ensure privacy during practice. The table and chair used by the patients were placed in the same position for each practice session. The physical therapists (NM., WS., and CW.) provided identical mirrors to all patients in the task-based mirror therapy group; ensuring that each mirror was the same size and design. Additionally, in the control group, it was ensured that there was no mirror in the practice area. In this study, the objective was to implement blinding procedures for the physical therapists responsible for both treatment and assessment; as mentioned above. However, it is acknowledged that not achieving complete certainty regarding their total blinding remains a possibility.

The baseline program involved a passive range of motion combined with stretching exercises administered by a physical therapist for the first two weeks, followed by caregiver-led exercises. Active range of motion exercises for upper extremities were performed by the patients. Caregivers recorded daily training activities and sent video documentation to the researcher via a private chat room. Caregivers received training and evaluation from a physical therapist regarding baseline program execution, with weekly re-evaluations.

The training tasks and training intensity in this study were selected based on previous studies that focused on skills commonly applicable to daily life activities and those that required coordinated movements of the upper extremity joints[11,12]. Training tasks were consistent across both groups and included five unimanual tasks: moving a tennis ball around a table, wiping a table with a cotton sheet, pouring water from a bottle into a glass, drawing a circle with a whiteboard pen, and drinking water from a glass. Each task involved 15 repetitions per trial, with four trials per day, for five days a week, over four consecutive weeks. Participants received training from a physical therapist for the first two weeks then conducted self-guided sessions under caregiver supervision for subsequent training days. In this study, a caregiver was defined as a family member responsible for the care of the patient, and who lived with them. The caregivers were instructed to record videos of the patients during their training sessions, and share them with the researcher through a private chat room on the LINE application: a social network service. In addition, they maintained daily logbooks to document the training programs and the patients' activities. This logbook helped ensure the continuity and accuracy of the training program application. Before the training program began, the caregivers underwent training and evaluation by the physical therapist to perform conventional physical therapy treatments. To ensure the correctness of the training program, the same physical therapist conducted weekly reviews and checks.

In the control group, participants executed the described tasks with the affected arm. Conversely, the task-based mirror therapy group performed the same tasks while utilizing a mirror placed along the midsagittal plane. The mirror reflected the unaffected arm's movements, creating an illusion of normal movement during the unaffected arm's motion. Participants synchronized both arms' movements, while observing the mirror's reflection.

Assessment tools

The participant's level of independence in daily activities was assessed using the Sirindhorn National Medical Rehabilitation Center (SNMRC) functional assessment. The SNMRC is a functional assessment specifically designed for the Thai context. SNMRC includes 35 activities, ranging from feeding to mobility; with high validity and reliability (ICC>0.90)[13]. Quality of life was evaluated using the Short Form-36 (SF-36), which is a widely used questionnaire to assess various aspects of an individual's health-related quality of life. Upper extremity function was measured by two assessments: first, the Action Research Arm Test (ARAT): this assessment focuses on the functional use of the upper extremities and evaluates a person's ability to perform specific tasks involving the arm and hand. It provides a quantitative measure of upper limb function; particularly after stroke. Secondly, the Fugl-Meyer Assessment (FMA): this assessment is used to evaluate motor recovery after stroke. It assesses the sensorimotor impairments in the upper extremities; such as coordination, reflexes, movement patterns, and sensation. The FMA provides a comprehensive evaluation of motor function. These assessments were used to gain insights into the quality of life and upper extremity function of the participants in the study. All assessments were conducted before and after the four-week training period. An inter-rater reliability test was conducted before data collection, revealing high reliability ($r>0.9$: p-value<0.05) between the tester and more experienced administrators across all assessments.

Statistical analysis

Baseline characteristics; such as gender, affected side, dominant hand and Brunnstrom stage, were analyzed using the chi-square test, while age, time post-stroke, ARAT, FMA, SNMRC, and SF-36 scores was analyzed using the Mann-Whitney U test. Wilcoxon signed rank and Mann-Whitney U tests were employed to analyze differences within and between groups for ARAT, FMA, SNMRC, and SF-36 scores, respectively. Statistical significance was set at a p-value of <0.05.

Results

Baseline characteristics

Due to the coronavirus disease 2019 pandemic, the data collection process concluded before the required participants count could be achieved. Initially, this study recruited 43 participants; however, only 17 individuals met the study criteria and completed both practice and testing sessions, as shown in Figure 1. These participants were divided into two groups, based on a randomized computer-generated sequence: 7 participants were in the control group and 10 participants were in the task-based mirror therapy group. Notably, no dropouts occurred due to group allocation or treatment effects. Furthermore, no adverse effects were reported during or after the training program in either group. Gender, affected side, age, ARAT, FMA, SNMRC, and SF-36 showed no significant statistical differences between the two groups, except for the dominant hand; as indicated in Table 1.

Table 1 Baseline characteristics

Variables	Control group (n=7)	Task-based mirror therapy group (n=10)	p-value
Age[a] (years)	56.00 (47.00, 64.00)	50.00 (39.00, 54.25)	0.161
Gender: male[b]	4 (57.10)	6 (60.00)	0.467
Duration: poststroke (month)[a]	5.00 (4.00, 11.00)	7.00 (3.00, 12.25)	0.766
Affected side: right[b]	2 (28.60)	4 (40.00)	0.225
Dominant side: right[b]	7 (100.00)	9 (90.00)	<0.001*
Brunnstrom stages of motor recovery[b]			0.470
Stage 2	2 (28.60)	5 (50.00)	
Stage 3	1 (14.30)	2 (20.00)	
Stage 4	1 (14.30)	3 (30.00)	
Stage 5	3 (42.90)	0 (0.00)	
Action Research Arm Test[a]	33.00 (10.00, 54.00)	16.50 (9.75, 25.50)	0.524
Fugl-Meyer Assessment[a]	34.00 (15.00, 47.00)	27.50 (14.00, 34.25)	0.364
SNMRC functional assessment[a]	77.00 (71.00, 85.00)	71.00 (53.00, 82.50)	0.660
Short form 36[a]	35.00 (34.00, 38.33)	34.17 (33.67, 35.50)	0.536

[a] =median (Q1, Q3) analyzed using Mann-whitney U test, [b]=numeral (percentage) analyzed using chi-square test, *p-value<0.05

Table 2 Comparison of ARAT, FMA, SNMRC and SF-36 within and between groups

Variables	Control group (n=7)			Task-based mirror therapy group (n=10)			p-value[b]
	Week 0		Week 4	Week 0		Week 4	
Action Research Arm Test	33.00 (10.00, 54.00)		44.00 (16.00, 57.00)	16.50 (9.75, 25.50)		28.00 (15.25, 38.75)	0.349
p-value[a]		0.027*			0.018*		
Fugl-Meyer Assessment	34.00 (15.00, 47.00)		43.00 (28.00, 60.00)	27.50 (14.00, 34.25)		37.50 (26.25, 45.75)	0.463
p-value[a]		0.089			0.005**		
SNMRC functional assessment	77.00 (71.00, 85.00)		82.00 (78.00, 87.00)	71.00 (53.00, 82.50)		73.00 (68.00, 84.00)	0.695
p-value[a]		0.027*			0.012*		
Short form 36 (SF-36)	35.00 (34.00, 38.33)		36.67 (35.5, 43.50)	34.17 (33.67, 35.50)		34.17 (32.83, 41.33)	0.143
p-value[a]		0.237			0.138		

median (Q1, Q3), analyzed using [a]=Wilcoxon signed rank test, [b]=Mann-whitney U test (at week 4), *p-value<0.05, **p-value<0.01
ARAT=Action Research Arm Test, FMA=Fugl-Meyer Assessment, SNMRC=Sirindhorn National Medical Rehabilitation Center Functional Assessment

Functional assessments

Between-group comparison

Table 2 displays the median and quartile range values for ARAT, FMA, SNMRC, and SF-36 for both groups. However, no significant differences were observed between the groups. It's important to note that there were no significant statistical differences between the groups.

Within group comparison

As shown in Table 2, the task-based mirror therapy group demonstrated significant improvements after four weeks of training; with a p-value of 0.05 for ARAT, FMA, and SNMRC. In contrast, the control group only exhibited improvements in ARAT and SNMRC scores. Neither group demonstrated improvement in SF-36 scores

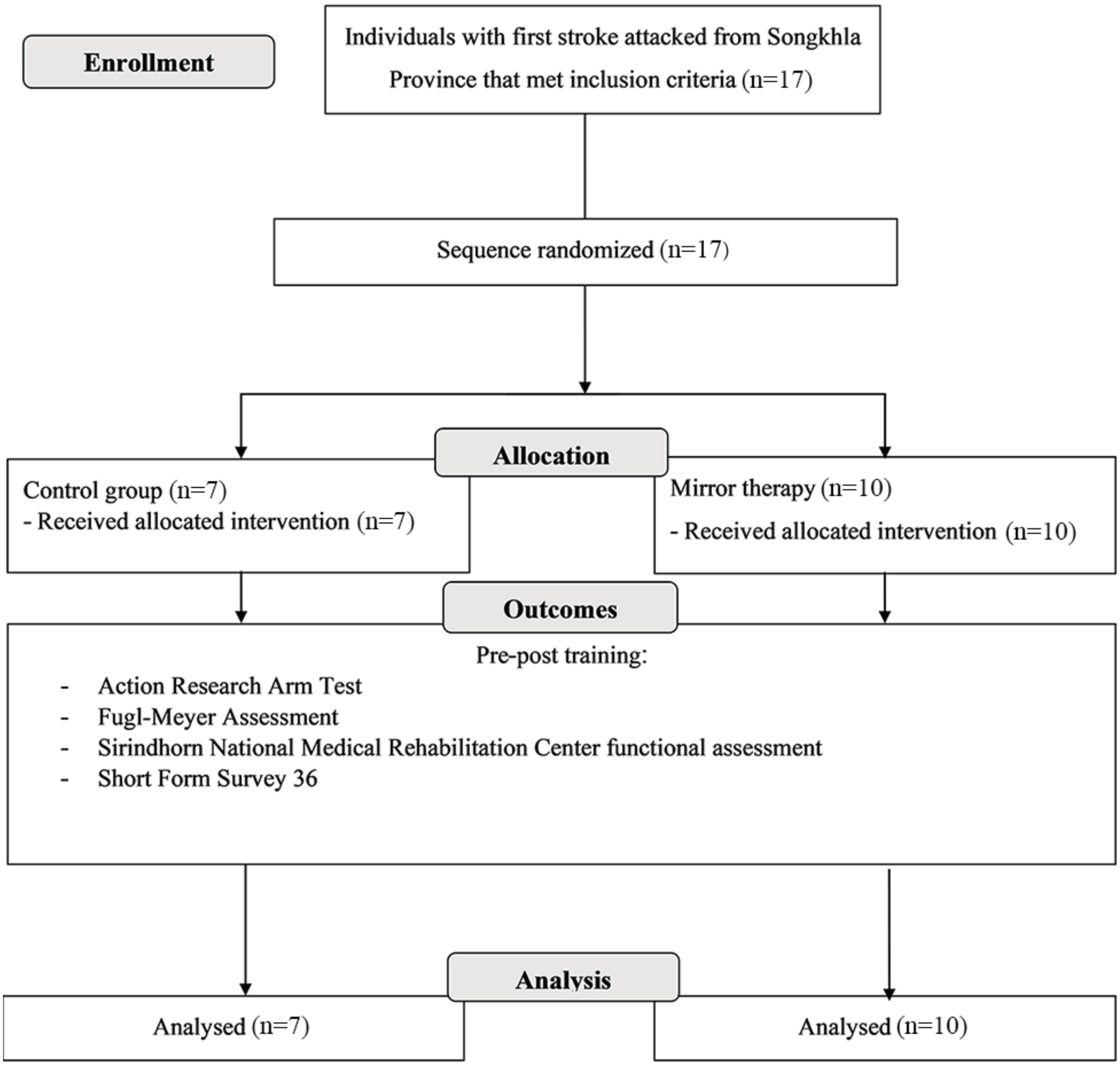

Figure 1 Consort flow diagram

Discussion

To compare the effectiveness of mirror therapy on upper extremity function in stroke patients after four weeks of task-based mirror therapy training, this study observed statistical improvement in upper extremity function for both the control and task-based mirror therapy groups. However, no changes were observed in the quality of life outcome within either group. Moreover, differences between these two conditions were not detected. Considering that participants were recruited within 3–18 months after experiencing a stroke, the potential for spontaneous recovery emerges as a confounding factor in the study's outcomes. Despite this, baseline characteristics showed no significant statistical differences between groups, and patients with similar baseline characteristics were recruited according to the study criteria. Therefore, improvement after the training program should be seen as a training effect.

Characteristics of participants before training; including age, gender, time post-stroke, affected side, Brunnstrom stages, ARAT, FMA, SNMRC and SF-36, showed no statistically significant differences between groups, except for dominant hand differences; as presented in Table 1. It's worth noting that Harris et al. in 2010, discovered that the recovery performance of the affected hand after strength training was not influenced by the dominant hand[14]. There's ongoing debate surrounding predicted motor outcomes after a stroke attack based on anatomical and hemodynamic characteristics[15,16]. Kongsawasdi et al.'s study suggests that lateralization may not significantly impact functional recovery, but actual impairments could be involved[17]. Furthermore, studies exploring the effect of brain lateralization on mirror neuron system activity demonstrated strong bilateral activations, indicating a bilateral spread of activity within the mirror neuron system[18,19]. Thus, this study recruited patients without lesions in any hemisphere to minimize interference with training outcomes. However, due to the pandemic, the data collection process was halted, potentially influencing participant numbers and, consequently, statistical analysis including the ability to detect differences.

Upper limb performance

There was no statistically significant difference in ARAT and FMA between both groups after four weeks of training. The percentage change in ARAT for the task-based mirror therapy group was more extensive compared to the control group, which aligns with previous studies. Geller et al. (2021) found that participants that received a home based program mirror therapy, as per this study, also exhibited a significant ARAT improvement after training[12]. Similarly, Kim et al. (2016) observed that the improvement in ARAT after four weeks of training in the control group was notably significant; whereas, such improvement was not observed in FMA[11]. A previous study elucidated how task-specific training leads to changes in cortical activation and enhances the typical movement pattern, This indicates neuroplastic changes and regained brain function post-stroke, driven by the motor learning process[20].

In this study, a task-specific training program was designed, with repeated movements; resulting in improvements seen in both groups. However, although FMA displayed no statistically significant differences between the groups, ARAT exhibited greater changes. A study by van der Lee et al. (2001) noted that the sensitivity of improvement in upper extremity recovery was more pronounced in ARAT than in FMA after stroke rehabilitation[21]. Nonetheless, the task-based mirror therapy group demonstrated significant statistical differences after training sessions, suggesting that this therapy might enhance upper extremity function beyond conventional treatment; even with a test of lower sensitivity. Furthermore, in this study, the training period lasted for 4 consecutive weeks, which is consistent with previous studies. However, recent research has shown that the improvement in FMA-UE and ARAT scores continued to exhibit significant enhancements for up to 3 months after the resumption of rehabilitation therapy[22]. Therefore, the training duration in this study might be a potential factor influencing the inability to detect significant changes in these assessments between the groups.

The effect of mirror therapy on upper extremity performance in stroke patients is believed to stem from factors; such as mirror illusion, motor imagery, or mirror neurons. When moving the unaffected arm, the brain perceives the affected arm's movement through synchronizing with its mirror reflection; thus encouraging motor memory[7]. This process aligns with the "Top-Down" learning theory, activating cognitive functions for movement and enhancing motor learning[23].

This mechanism elucidates how mirror therapy may more effectively aid movement recovery compared to conventional treatment. While both groups exhibited upper extremity function improvement, differences between the groups, potentially influenced by their adapted daily living routines due to disabilities, might not have been large enough to be detected[24]. Hence, although this study did not demonstrate significant differences in motor function, quality of life, or ADL ability between the groups, mirror therapy, as a home-based exercise holds promise for enhancing upper extremity function in stroke patients.

This study did not detect any significant statistical differences in SNMRC between the groups. Despite this difference not reaching a significant level, both groups showed significant statistical improvements by the fourth week of training compared to their baseline levels. Vandana et al. (2017) discovered that task-based mirror therapy enhances upper extremity function, leading to improved activity levels, as indicated by significantly higher scores on the modified Barthel Index than those in the control group[25].

Evident improvements were observed after practice and training for both groups in this study. The enhanced upper extremity function resulting from the practice program likely impacted the ability to perform daily life activities, even though the practiced tasks were not identical to specific daily activities. Additionally, improvement in FMA was noted in the task-based mirror therapy group; indicating greater upper extremity function performance compared to the control group. Therefore, in this study, the act of drinking water during the practice sessions potentially translated to improved daily life hand use, aligning with the activities assessed in SNMRC.

However, it's important to note that the SNMRC functional assessment evaluates activities involving both upper and lower extremities. As a result, the total score presented in the results might not fully reflect the performance of the upper extremity alone. When combined with home-based training, this approach encourages the execution of daily activities in familiar settings under the supervision of caregivers. As a result, this strategy has the potential to enhance overall performance in daily tasks[5].

Quality of life

Following training for both groups, there were no statistically significant differences in the quality of life, both when compared between and within the groups. This outcome could potentially be attributed to the nature of the SF-36 questionnaire, which primarily emphasizes questions related to the mental domain rather than the physical one. Consequently, the total SF-36 score did not demonstrate improvement post-practice. Although the percentage change in scores for both groups showed an increase, these changes were not substantial enough to attain statistical significance. Tung et al. (2021) conducted a study that highlighted the cost-effectiveness of home-based rehabilitation over hospital-based stroke rehabilitation. While they observed overall improvements in the total Barthel Index score, differences between various training methods were not significant[5]. In a broader context, a meta-analysis focusing on exercise and quality of life in stroke patients reported a minor to moderate effect of exercise on HRQOL outcomes. However, the study also underscored the need for effective strategies to engage stroke patients in community-based exercise programs[26]. Hence, the absence of improvement in this variable, within the scope of this research, could potentially be explained by these factors.

This study revolved around a home-based program for task-based mirror therapy in stroke patients. The primary objective was to facilitate the execution of the home program, enabling patients to practice in the comfort of their own environment, especially when hospital or rehabilitation center visits are unfeasible. Nonetheless, the study does have limitations. Despite the researchers' efforts to maintain consistency and engagement through logbooks and social networking services (SNS), the lack of control over the training environment and caregiver involvement may impact the efficacy of the training program. Even with intensive researcher follow-up, the quality of training inevitably hinges on both caregivers and patients. As such, the effectiveness of the training program could potentially be influenced by these variables. Additionally, the small number of participants in this study, which did not meet the sample size calculation in addition to the wide range of stroke onset times, covering both subacute and chronic phases of stroke, should be considered as limitations of this study.

Conclusion

In this study, the impact of four weeks of home-based training on upper extremity function and daily living activities was examined. The results revealed improvements in both areas, following both control and task-based mirror therapy training. However, no significant statistical differences were found between the two training groups in terms of quality of life. These findings indicate that both conventional task-based training and task-based mirror therapy may have the potential to facilitate motor relearning of upper extremity function in stroke patients. It's important to note that this study solely focused on the effects of task-based mirror therapy during the training period, leaving the question of retention effects after practice unanswered. Additionally, the participant count fell below the calculated ideal, potentially affecting the statistical test's ability to detect differences between the groups effectively. Future studies should delve into retention effects following practice, tailor practice tasks to individual needs, increase the sample size, and implement stratified randomization based on factors such as age, gender, and lesion side. Such enhancements would contribute to a more comprehensive understanding of the therapy's long-term effects as well as its potential benefits for stroke patients.

Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article.

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Conflict of interest

It appears that there are no conflicts of interest to declare.

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