Effect of Activity-based Mirror Therapy on Gait Parameters in Chronic Stroke Patients

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Abstract

Background: Stroke is the third cause of mortality after cardiac diseases and cancer. One of the impacts of stroke is a decrease in the functional ability and disturbance of different parameters of the gait as step length, speed, cadence and time gap between both feet, therefore mirror therapy is carried out to restore the symmetry of gait. **purpose:** The aim of this study was to investigate the effect of activity-based mirror therapy on gait parameters in patients with chronic stroke. **Subjects and Methods:** Forty ischemic hemiparetic stroke patients of both genders were recruited, the participants were randomly assigned into two equal groups: The control group (A) was treated by a selected physical therapy program only. The study group (B) was treated with activity-based mirror therapy in addition to the same selected program of physical therapy. The treatment was conducted for 45 minutes, with five sessions per week for four weeks. Measurement of selected gait kinematic parameters including step length gap and time gap by using Biodex gait trainer was done for all patients, before and after intervention. The step length gap was measured as the difference between affected and non-affected step length. Similarly, the time gap was measured as the difference between affected and non-affected time of step length. **Results:** The comparison between pre-treatment and post-treatment within both groups showed a significant decrease in the time gap and step length gap in both groups. Post-treatment comparisons between the both groups showed significant differences in the time gap and step length gap with more improvement in favor to the study group. **Conclusion:** Mirror-based therapy showed a more profound effect on gait parameters and improve gait symmetry in chronic stroke patients compared to selected program of physical therapy.

Keywords: Mirror therapy, Motor function, Gait parameters, Chronic stroke.

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INTRODUCTION

Stroke is a cerebrovascular disease. The second biggest cause of death worldwide is stroke. Because of advances in medicine, stroke mortality rates have decreased. Today, there are more stroke survivors than ever before. Many stroke survivors experience post-stroke disabilities, including mobility disorders, sensory abnormalities, visual deficits, and other consequences that hinder independent function. Moreover, walking ability and postural performance are impacted by the motor function of the lower extremity, which is frequently compromised following stroke. The motor function of the lower limb in stroke patients can be improved by utilizing a variety of rehabilitation techniques, including functional electrical stimulation, dual-task training, mental practice, mirror therapy (MT), virtual reality, and robotic assisted training **(Oh et al. 2023).**

In the acute stage of stroke, about 60–80% of the patients present with motor impairments of the upper and lower limb. About 80% of mild stroke cases achieve full function of the upper limb and only 20% of sever cases recover some function of the upper limb. Generally, about 50% of stroke patients with an initial presentation of affected lower and upper limbs restore partial motor function. **(Arya et al. 2017).**

A relatively new therapeutic technique utilized in the clinical rehabilitation of stroke survivors is mirror therapy. The movement of the unaffected limb received as mirrored feedback from the movement. Mirror therapy is a type of cognitive intervention and mental practice that stimulates the motor cortex and improve the motion of the affected limb. By increasing cognitive penetration in action control, mirror therapy can stimulate mirror neurons and have a significant influence on the network of motor system. Mirror treatment helps stroke survivors to restore lower extremity motor function, which enhances their motor function and walking abilities **(Oh et al. 2023).**

The normal gait is characterized by symmetrical spatial and temporal parameters, with less than six percent differences in vertical force and temporal parameters between both lower limbs. Conversely, the hemiparetic gait is characterized by asymmetry, reduced weight bearing on the affected limb, impaired selective motor control, disturbed postural reactions, and impaired smooth forward

progression of the body, with wide gait patterns variation according to the recovery rate. Moreover, coordinated interlimb and intralimb movement is replaced by mass patterns of the affected limb movements (synergies) which require compensatory pelvic and the non-affected side adjustments **(Park & Kim 2019).**

The researchers found that the gait of the patients who performed the non-affected propulsion, is characterized by longer steps of the affected side, indicating that the increased propulsion by the non-affected leg could be a reason of the increasing in step length of the affected limb. Moreover, patients with more severe hemiparesis walk with the longest affected step length relative to non-affected step length **(Tsao et al. 2022).**

SUBJECTS AND METHODS

Study Design

A randomized controlled study was conducted to investigate the effect of activity-based mirror therapy on gait parameters in chronic stroke patients. Data were collected from August 2022 and ended May 2023, and all patients signed informed consent form.

Ethical considerations

Consent number: P.T.REC/012/004196 was reviewed for ethical consideration and authorized for the current investigation. The privacy and anonymity of every patient were ensured.

Participants

Forty ischemic hemiparetic stroke patients were recruited in this study from the outpatient clinic of the faculty of physical therapy, Cairo University. The patients were diagnosed and referred by a neurologist; the diagnosis was confirmed by CT scan or MRI to exclude any other neurological condition that might affect lower limb function. The selected patients were randomly assigned into two equal groups, the control group (A) and the study group (B). The control group (A) was treated by a selected program of physical therapy including (weight bearing exercises, strengthening exercises for anti-spastic muscles, stretching exercises for spastic muscles, active-assistive exercises using activities such as rocker board, medicinal ball, jogger, and cycling. The study group (B) was treated with activity-based mirror therapy in addition to the same selected physical therapy program. The treatment was conducted for 45 minutes, with five sessions per week for four weeks. The whole procedure was explained to every patient. All patients were informed with written consent before participation. The flow chart for the process of recruiting patients is shown in Figure (1).

Randomization

The recruited patients were randomly assigned, after signing consent form, into two groups. A randomized controlled trial was carried out by assigning the even numbers to group (A) and odd numbers to group (B). Following randomization, there was dropping out of patients from the study as showed in Figure (1).

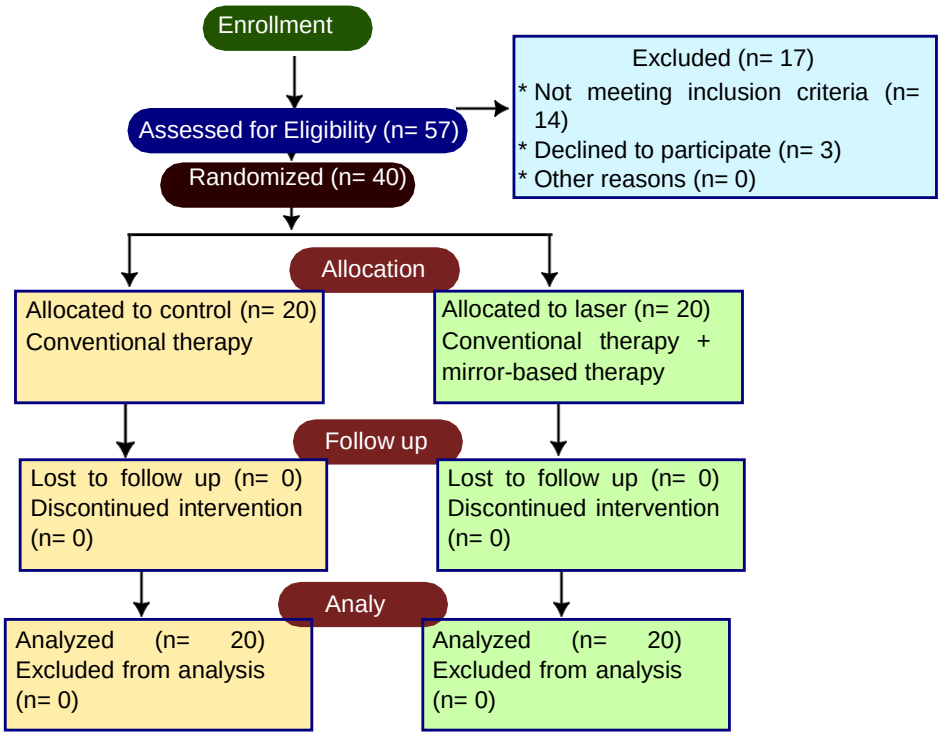

Figure1: The flowchart of recruiting patients.

Sample Size Calculation:
Sample size has been calculaed using G power software, using effect size (0.910), power (0.800), two tailed, and P >0.05 give a sample size of (40), 20 in each group.

Inclusion Criteria
The patients with the following criteria were included for this study:

1. Their age ranged from 45 to 60 years old.

2. The duration of the stroke ranged from six months to two years.

3. The affected lower limb muscle tone ranged from 1 to 2 according to the modified Ashworth scale.

4. The affected lower muscle strength according to the muscle test is less than grade three.

5. The patients beyond stage three of motor recovery for the lower limb according to Brunnstrom.

6. Patients with sufficient cognition to understand and follow instructions

Exclusion Criteria
Patients with the following criteria were excluded:

1. Patients diagnosed with any other neurological disorder affecting their lower extremities (e.g., MS, Parkinsonism, peripheral neuropathy)

2. Patients with previous fractures in the lower limb (ankle or foot)

3. Patients with musculoskeletal disorders such as severe arthritis, ankle surgery, leg length discrepancy, or contractures of a fixed deformity of the ankle joint

4. Recurrent angina or heart surgery

5. Patients with visual and/or auditory impairments affecting their ability to complete tasks

6. Patients with cognitive impairments using a mini mental state examination

7. Patients with psychological problems or receiving any drugs that may cause any cognitiveor psychological impairment.

Instrumentation for assessment:

The Biodex gait trainer:
The Biodex Gait Trainer device is used for assessment and treatment of the gait disorders in the neurological patients. The device provides the patient with both visual and auditory feedback to improve the performance. The device is consisted of a treadmill and an instrumented deck that measures different kinematic parameters of gait including: walking speed, time distribution right-to-left (step symmetry) and step length **(Gharib et al. 2011).**

The Biodex Gait Trainer was used in the current study for assessing selected gait kinematic parameters including step length gap and time gap. The step length gap was measured as the difference between step length of affected and non-affected lower limb. Similarly, the time gap was measured as the difference between the time of step length of affected and non-affected lower limb.
For measurement of gait parameters, the patients should be familiar with the device before starting the procedures of gait parameters measurement, each patient was asked to walk over the gait trainer for three to five minutes, and to follow the treadbelt movement.
For starting the measurement procedures, the treadbelt will ramp up slowly to 0.3 meter/hour. The setting of the speed was gradually increased to the speed that is comfortable for the patient, the recording of the parameters was started. Each patient was asked for walking for three minutes continuously, then the measurement process was finished and gradually slowed the treadbelt until the device stopped. The data then can be presented on the display. The measurements were repeated three times (with a rest period 1-2 minutes in between) and the average for each parameter of the three trials was taken.

Instrumentation for treatment:
The mirror frame:
The mirror frame was constructed according to **(Arya et al. 2017).** Construction of mirror frames: A frame for a 24 by 72-inch mirror was built for those with limited legroom. The mirror was in a wooden frame that was fastened to a sturdy metal base. The mirror could be seen at an acute angle, between 75 and 85 degrees, the frame could be tilted in the sagittal plane. The set-up provided the best mirror impression of the moving limb possible, eliminating the need to actually see it.
Intervention Protocol:
1. **Control group (A):** The intervention was applied to all patients at baseline, and included the selected program of physical therapy for 45 min/day, 5 days/week for 4 weeks according to **(Bhoraniya et al. 2018)**. The selected program of

physical therapy that was applied to both groups included weight bearing in standing (extended knee), standing on inclined wedge for two to three minutes, movements using associated reactions, strengthening exercise for anti-spastic muscles as (hip flexors, knee flexors and ankle doriflexors) for 3 sets /10 repetitions for each set , stretching exercises for spastic muscles like (ankle planerflexors, hip extensors and hip adductors) and active-assistive exercises using activities such as rocker board, medicinal ball, jogger, and cycling, for hip flexion, knee flexion and extension and ankle dorsiflexion and planter flexion from sitting for 3 sets/10 repetitions for each set.

Study group (B): Patients were treated for 45 minutes per day including 15 minutes for activity based mirror therapy in addition to 30 minutes for the same selected physical therapy program, 5 days/week, for 4 weeks. The activity-based mirror therapy movements consisted of wiping, pedaling, and pillows shifting were applied for the non-affected side to be projected on the mirror, while the affected limb was hidden. The movement of the non-affected lower limb was projected on the mirror as that of the affected limb. The patients were asked to maintain static position of the affected limb during the training. The limb was in the positions of 90° hip flexion, 90° knee flexion, and 90°ankle dorsiflexion, for the short-sitting position and in the positions of 90°hip flexion, 0°knee, and neutral ankle in the long-sitting position. The position of the limb was checked every time. The activities progressed in the form of individual as well as combined movements. while proximal to distal motor control was considered and the maximum time of each session repetition was completed. This technique was also adopted, according to **(Arya et al. 2017).**

2.

Statistical analysis

Data were collected and tabulated using Microsoft Excel spreadsheet then analyzed statistically using R1, (Rcmdr), Jamovi2, and JASP3. Graphs was made by SciDAVis (2.7.0)4 software. Kolmogorov-Smirnov and Shapiro-Wilk tests were used to assess the normality of data. Student's t-test or Welch's t-test was used as appropriate for numerical data to assess the statistical significant differences between groups. Pearson's correlation Coefficient analysis was used to determine the correlation between step length gap and time gap. All the statistical tests were made using R (Rcmdr) and Jamovi software at a level of alpha ≤ 0.05.

RESULTS

A. Baseline demographic and clinical characteristic of patients, in control and study groups.

In this study, forty patients with ischemic stroke from both genders were participated and assigned randomly into two equal groups. The mean values of age (year) in control group and study group were 53.5 ± 4.71 and 53.2 ± 4.74 years, respectively. The mean values of body weight (kg) in control group and study group were 88 ± 6.15 and 87 ± 9.81 kg, respectively. The mean values of height in control group and study group were 169 ± 6 and 169 ± 7 cm, respectively The mean values of BMI in control group and study group were 30.8 ± 1.48 and 30.4 ± 1.60, respectively. The mean values of duration of stroke in control group and study group were 15.4 ± 5.94 and 16.3 ±5.71 months, respectively.

The results revealed non-significant difference in the mean values of age, height, weight, BMI and duration of illness between both groups p = (0.816), (0.981), (0.702) , (0.352) and (0.667) respectively, as shown in Table (1)

Regarding the gender distribution, there were 10 males and 10 females in the study group while in the control group there were 12 males and 8 females. No statistical significant difference was found related to the gender distribution ($\chi 2 = 0.4$, p-value = 0.527).

Table (1): The mean values of the age of the patients, height, weight, BMI and the duration of illness in control and study groups.

Item	(Control Group)	(Study Group)	*t*	*P*
	mean ±SD	mean ±SD		
Age (years)	53.5 ±4.71	53.2 ±4.74	0.3	0.816
Height (cm)	169 ±6	169 ±7	0	0.981
Weight (kg)	88 ±6.15	87 ±9.81	1	0.702
BMI	30.8 ±1.48	30.4 ±1.60	0.4	0.352
Duration of illness (Months)	15.4 ±5.94	16.3 ±5.71	0.9	0.667

** Significant at ≤ 0.05, SD: standard deviation.*

B. Comparison between control and study groups mean values of step length gap before and after treatment.

In the control group, the mean values of step length gap at pre- and post-treatment were 0.15 ± 0.032 and 0.11 ±0.025, respectively. The results showed a significant difference in the step length gap mean values before and after treatment (p = 0.001).

The results revealed a non-significant difference in the mean values of step length gap at pre-treatment between both groups (p = 0.905), However, there was a significant difference in the mean values of step length gap at post- treatment between both groups (p <0.001), this significant improvement in post-treatment is in favor to the study group, as shown in Table (2).

Table (2): Comparison within and between control and study groups mean values of step length gap before and after treatment.

step length gap	(Control Group)	(Study Group)	*t*	P
	mean ±SD	mean ±SD		
pre	0.15 ±0.032	0.14 ±0.020	0.01	0.905
post	0.11 ±0.025	0.06 ±0.021	0.05	<0.001
t	0.04	0.08		
p	0.001	<0.001		

** Significant at ≤ 0.05, SD: standard deviation*

C. Comparison between control and study groups mean values of time gap before and after treatment.

In the control group, the mean values of time gap at pre- and post-treatment were 0.21 ± 0.038 and 0.18 ± 0.033, respectively. The results showed a significant difference in the time gap mean values pre and post- treatment (p = 0.01).

In the study group, the mean values of the time gap at pre- and post-treatment were 0.21 ± 0.029 and 0.12 ± 0.021, respectively. The results showed a significant difference in the time gap mean values before and after treatment (p <0.001).

The results revealed a non-significant difference in the mean values of time gap at pre- treatment between both groups (p = 0.647), However, there was a significant difference in the mean values of time gap at post- treatment between both groups (p <0.001), this significant improvement in post-treatment is in favor to the study group, as shown in Table (3).

Table (3): Comparison within and between control and study groups mean values of time gap before and after treatment.

time gap	(Control Group)	(Study Group)	*t*	*P*
	mean ±SD	mean ±SD		
pre	0.21 ±0.038	0.21 ±0.029	0	0.647
post	0.18 ±0.033	0.12 ±0.021	0.06	<0.001
t	0.03	0.09		
p	0.01	<0.001		

** Significant at ≤ 0.05, SD: standard deviation*

D. Correlation analysis

A correlation matrix was created for the two parameters used in the current study, the time gap was positively and strongly correlated with the step length gap (m) (R = 0.77, *p*-value < 0.001). The data are shown in table (4) .

Table (4): Correlation matrix for all parameters used in the current study.

	Step length Gap (m)	
Time Gap	r **value**	***p*-value**
	0.77	<0.001*

*r value Pearson's correlation coefficient. * Significant at ≤ 0.05*

DISCUSSION

The current study, aimed to investigate the efficacy of activity-based mirror therapy on the gait parameters in patients with chronic stroke. The selected patients were assigned randomly and equally into control and study: The control group (A) was treated by a selected physical therapy program only. The study group (B) was treated with activity-based mirror therapy in addition to the same selected program of physical therapy. Intervention was conducted for 45 minutes, with five sessions per week for four weeks.

In the present study, the results revealed that there was non-significant difference regarding the age, height, weight and BMI between both groups at baseline which indicates that both groups were homogenous. The comparison between pre-treatment and post-treatment phases in both groups showed a significant decrease in the time gap and step length gap in both groups which indicates improvement of gait symmetry, Post-treatment comparisons between the two groups showed a significant reduction in the time gap and step length gap in study group much greater than in the control group.

The finding of the current study agreed with **Arya et al. (2017),** who founds that activity-based mirror therapy enhances the lower limb motor recovery as well as decreases the deviations of the gait among patients with chronic stroke.

The finding of the present study also agreed with **Broderick et al. (2018**), who found in their systematic review that, among the main measurements there was good evidence of a significant positive influence on motor ability by mirror therapy compared with control group. Moreover, there was evidence of a significant positive impact of mirror therapy on the secondary outcome measures as walking speed, balance, step length, and passive range of motion of the ankle dorsiflexion.

The finding of the current study agreed with **Bhoraniya et al. (2018),** who found that, there is mirror therapy effect on the parameters of gait in chronic stroke patients, also they found a significant difference in all spatial and temporal parameters of the gait such as affected and non-affected limb step length, stride length, cadence, and walking speed in the study group. Regarding the control group, the results revealed significant improvement in affected limb step length and non-affected stride length but non-significant difference in velocity and cadence.

For the time gap, which is the difference between affected and non-affected lower limb time of step length, there was a significant improvement in both groups. However, the improvement in the study group was significantly much greater in comparison with the control group. The findings of the current study come in agreement with **(Kim et al. 2018).**

The finding of the current study also come in contact with **Cortez et al. (2016)**, who found that, the significant improvement in the step length gap and the time gap between right and left steps for the study group and they reported that the symmetric movement was improved by the mirror therapy, including the improvement of the patients' postural stability, walking performance and reducing the step length gap. The also stated that mirror therapy provides a visual feedback of movement and provides a kind of bilateral training and improves the function of brain and improves brain plasticity and regulate the excitability the primary cerebral cortex through the provided visual stimuli and visual feedback.

The present findings agreed with **(Jaafar et al. 2021)** who reported that, the neurophysiological underlying mechanism of the mirror therapy is not completely clarified, previous researches suggested some possible explanations as decreasing of asymmetrical cortical activation between the both hemispheres and activation of the ipsilateral, and contralateral motor cortex, furthermore, mirror therapy can widely stimulate the mirror neurons, and the pathways of the motor neuron on the affected side, and enhancing remodeling of the brain function. Therefore, the mirror neurons can facilitate the motor recovery (**Rizzolatti et al. (2009)**; **Garrison et al. (2010)**), as it increases the cortical excitability through visual feedback, leading to recovery motor function **(Nojima et al. 2012)**. These facts come in contact with the findings of the present study.

The finding of the current study disagreed with **Colomer et al. (2016)**, who perform a study on twenty stroke patients who received mirror therapy for thirty minutes in combination with traditional physical therapy treatment, five days a week for four weeks, and their results showed no significant improvement in gait performance.

This significant improvement in the time gap might be due to the improvement in the step length gap. The latter might be resulting from a more favorable symmetrical movement. This was evident from the correlation study, where the step length gap correlated significantly with the time gap.

CONCLUSIONS

Mirror therapy is a safe and easily applied, adjunctive therapy with more positive effect on gait parameters and gait symmetry compared to conventional treatment alone in chronic stroke patients.

Author contributions

GM design of study and final revision. MS data

accrual, manuscript preparation and editing. NF assessment and treatment. HS oversight manuscript preparation, and editing. AD manuscript revision, and editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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