Turk J Phys Med Rehab 2020;66(2):154-160
DOI: 10.5606/tftrd.2020.2719

Original Article

The effect of mirror therapy on lower extremity motor function and ambulation in post-stroke patients: A prospective, randomized-controlled study

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Received: February 04, 2018 **Accepted:** December 12, 2018 **Published online:** March 09, 2020

ABSTRACT

Objectives: This study aims to evaluate the effects of mirror therapy (MT) on lower extremity motor function and ambulation in post-stroke patients.

Patients and methods: A total of 42 post-stroke patients (25 males, 17 females; mean age 58 years; range, 32 to 71 years) were included. All patients were randomly divided into two groups as the control group (n=21) receiving a conventional rehabilitation program for four weeks (60 to 120 min/day for five days a week) and as the MT group (n=21) receiving MT for 30 min in each session in addition to the conventional rehabilitation program. The Brunnstrom stages of stroke recovery, Functional Independence Measure (FIM), Berg Balance Scale (BBS) and Motricity Index (MI) scores, six-minute walking test (6MWT), Functional Ambulation Category (FAC), and the degree of ankle plantar flexion spasticity using the Modified Ashworth Scale (MAS) were evaluated at baseline (Day 0), at post-treatment (Week 4), and eight weeks after the end of treatment (Week 12).

Results: There were significant differences in all parameters between the groups, except for the degree of ankle plantar flexion spasticity, and in all time points between Week 0 and 4 and between Week 0 and 12 ($p<0.05$).

Conclusion: These results suggest that MT in addition to conventional rehabilitation program yields a greater improvement in the lower extremity motor function and ambulation, which sustains for a short period of time after the treatment.

Keywords: Lower extremity, mirror therapy, motor impairment, neurorehabilitation, stroke.

Stroke is one of the leading causes of long-term disability with motor impairment in most post-stroke patients.[1] Lower extremity functions are usually affected after stroke. Although it has been reported that 85% of post-stroke patients are still capable of independent ambulation,[2] the majority cannot achieve the speed and strength of ambulation required to continue daily living activities.[3] Independent ambulation is of great importance and after stroke, the most frequently asked question is the probability of regaining ambulation. Therefore, the recovery of motor functions and ambulation is an important goal in the rehabilitation program. Since the neuroplasticity mechanisms which are effective on regeneration play a central role in stroke recovery, different methods are used to induce neuroplasticity.[4]

Mirror therapy (MT) is one of the methods which has been proposed to enhance neuroplasticity. The main principle of MT is the use of the visual reflections produced in the mirror. It was first described by Ramachandran[5] for phantom pain and currently has a wide area of use, such as complex regional pain syndrome and peripheral nerve injury.[6] Most studies of MT in stroke patients have focused on upper extremity rehabilitation.[7,8] In a small number

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Cite this article as:
İkizler May H, Özdolap Ş, Mengi A, Sarıkaya S. The effect of mirror therapy on lower extremity motor function and ambulation in post-stroke patients: A prospective, randomized-controlled study. Turk J Phys Med Rehab 2020;66(2):154-160.

of studies, the effect of MT on ambulation and lower extremity motor function has been evaluated, and MT has been shown to may be effective. However, these studies have provided conflicting results with many parameters, and many outcome measures which can affect lower extremity motor function have not been addressed in these studies.[9,10]

In the present study, we aimed to investigate the effect of MT on lower extremity motor function and ambulation using parameters not previously utilized.

PATIENTS AND METHODS

This prospective, randomized-controlled study included a total of 42 post-stroke patients (25 males, 17 females; mean age 58 years; range, 32 to 71 years) who were diagnosed according to the World Health Organization criteria.[11] *Inclusion criteria were as follows:* having experienced a stroke within the previous year, baseline Brunnstrom Stage 1-4, and being ambulatory before the stroke. *Exclusion criteria were as follows:* the presence of any cognitive disorder that could affect the study results, a history of recurrent stroke, any visual disorder that could affect vision of the image in the mirror, having neglect, apraxia, aphasia, and psychological or emotional problems. A written informed consent was obtained from each patient. The study protocol was approved by the Zonguldak Karaelmas University Faculty of Medicine Ethics Committee. The study was conducted in accordance with the principles of the Declaration of Helsinki.

All patients were randomly divided into two groups using randomization with computer- generated random numbers as the control group (n=21) and MT group (n=21). The patients were evaluated at baseline (Day 0), at post-treatment (Week 4), and eight weeks after the end of treatment (Week 12). All evaluations were performed by a single researcher. All patients in both groups completed the study (Figure 1).

Interventions

A detailed medical history was taken and a physical examination was performed for each patient. Demographic data including age and sex and clinical data including time from cerebrovascular event, the type of cerebrovascular disease (i.e., thromboembolic or hemorrhagic), and the side of hemiplegic involvement were recorded. Each group was applied a conventional rehabilitation program for four weeks, consisting of 60 to 120 min/day for five days a week. A patient-specific conventional rehabilitation program was applied which included neurofacilitation techniques, sensorimotor re-education, active exercises, ambulation techniques, balance, and walking training. All exercises were carried out under the supervision of a single physiotherapist.

The MT group was also administered MT for 30 min in each session in addition to the conventional rehabilitation program. The patients were seated on a chair and a mirror (40×70 cm) was placed vertically between the two lower extremities. The reflective surface of the mirror only showed the non-paretic lower extremity. The patients were instructed to make repeated ankle dorsiflexion and plantar flexion and to watch the movement in the mirror. The patients were not allowed to move the paretic extremity during the procedure. The MT was performed by a single physiotherapist in all patients.

Outcome measures

At each visit (Day 0, Week 4, and Week 12), lower extremity motor recovery, disability, balance, motor function, walking speed, ambulation, and the degree of spasticity of the ankle plantar flexors were assessed. Lower extremity motor recovery was evaluated using the Brunnstrom stages of stroke recovery. Six grades of these stages for the lower extremity are as follows: *(i)* flaccidity of the affected extremities; *(ii)* minimal voluntary movement; *(iii)* the ability of voluntary combined hip flexion, knee flexion, and ankle

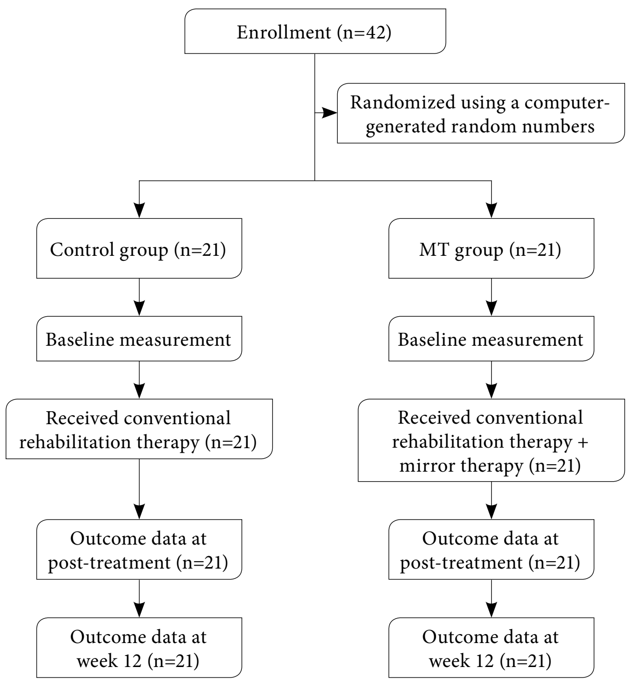

Figure 1. Flow diagram of the study.

dorsiflexion when sitting or standing; *(iv)* the ability to make knee flexion >90° and ankle dorsiflexion with the heel on the floor in the sitting position; *(v)* isolated knee flexion with hip extended and isolated ankle dorsiflexion with knee extended while standing; and *(vi)* knee abduction while standing and ankle inversion or eversion while sitting.[12]

The degree of disability was assessed using the functional independence measure (FIM), which has been documented validity and reliability in the Turkish population.[13] It consists of 18 items which measures independent performance in the sphincter control, transfer, locomotion, communication, social cognition, and self-care. In addition to the total score, the motor function score is also given.

The balance status was evaluated using The Berg Balance Scale (BBS) which has proven validity and reliability in the Turkish population.[14] It measures both dynamic and static balance, and higher scores indicate a better balance level.

For the assessment of motor function, the Motricity Index (MI) was used.[15] As the only lower extremity motor function was assessed in the study, the MI lower extremity score was measured. In the sitting position, ankle dorsiflexion, knee extension, and hip flexion were evaluated separately, and the total score of all these parameters gives the MI lower extremity score.

The speed of walking was assessed using the six-minute walking test (6MWT).[16] Before testing, the patients were rested for 10 min and, then, they were instructed to walk with a constant and confident speed for six min. The distance walked was recorded in meters.

Ambulation was evaluated using the functional ambulation category (FAC).[17] The FAC is a proven valid and reliable tool for the determination of the gait ability. It provides information about the degree of physical support that the patient needs at home or outside.

The degree of ankle plantar flexion spasticity was assessed using the modified ashworth scale (MAS).[18] It classifies the resistance of the extremity during passive soft tissue stretching in six stages. Higher MAS scores indicate a higher degree of spasticity.

Statistical analysis

The *post-hoc* power analysis of the study was performed using the G*Power version 3.0.10 software (Heinrich-Heine Universität Düsseldorf, Düsseldorf, Germany). For the two-way repeated measures analysis of variance (ANOVA) from the F-test family, the *post-hoc* power was calculated as 0.72 using the FIM total score measure for two groups and three repeats. Higher power values indicate more sensitive measurement to find the difference (The *post-hoc* power is expected to be above 0.8 or 0.7. If the power is lower than 0.50, the results are often misinterpreted).[19]

Statistical analysis was performed using the SPSS version 13.0 software (SPSS Inc., Chicago, IL, USA). The fitness of quantitative variables to normal

TABLE 1
Demographic and clinical characteristics of the study groups

	Mirror therapy group (n=21)					Control group (n=21)					
	n	%	Mean±SD	Median	Min-Max	n	%	Mean±SD	Median	Min-Max	*p*
Age (year)			57.2±7.6					58.8±9.8			0.565†
The time since the cerebrovascular event (day)				60.0	15.0-365.0				30.0	15.0-300.0	0.456‡
Gender											0.209§
Female	6	28.6				11	52.4				
Male	15	71.4				10	47.6				
Type of cerebrovascular disease											0.410¶
Thromboembolic	19	90.5				16	76.2				
Hemorrhagic	2	9.5				5	23.8				
The side of hemiplegic involvement											0.753§
Right	13	61.9				12	57.1				
Left	8	38.1				9	42.9				

SD: Standard deviation; Min: Minimum; Max: Maximum; † Independent Samples t test; ‡ Mann Whitney U test; § Yates' chi-square test; ¶ Fisher's exact test; p value of <0.05 is considered statistically significant.

TABLE 2
Motor recovery, disability, balance, motor function, walking speed, gait ability, and spasticity degree of patients at before and after treatment

	Day 0		Week 4		Week 12		A		B	
	Mirror	Control	Mirror	Control	Mirror	Control				
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	F	*p*	F	*p*
Brunnstrom	2.4±1.1	2.4±1.1	4.1±1.0	3.0±1.2	4.8±1.0	3.4±1.5	7.2	0.010*	67.1	<0.001*
Functional independence measure motor	37.4±16.2	31.3±18.1	71.5±11.7	41.8±19.2	74.1±11.7	43.7±20.0	22.7	<0.001*	109.3	<0.001*
Functional independence measure total	70.1±19.7	58.6±21.6	105.2±12.8	69.9±22.1	107.4±13.3	74.3±22.5	24.8	<0.001*	88.7	<0.001*
The Berg Balance scale	12.0±9.3	8.6±12.3	36.1±9.0	14.9±13.8	39.5±11.2	15.9±14.3	23.2	<0.001*	111.8	<0.001*
Motricity index	22.2±16.8	22.8±19.5	52.7±22.3	28.1±22.5	59.7±18.5	29.9±22.6	9.9	0.003*	48.5	<0.001*
Six-minute walking test	33.3±41.1	19.3±38.4	104.5±82.0	26.4±42.9	116.4±78.0	39.1±50.5	12.7	0.001*	26.3	<0.001*
Functional ambulation category	0.4±0.7	0.4±1.0	2.3±1.4	0.7±1.2	2.9±1.5	0.8±1.3	13.4	0.001*	61.6	<0.001*
Modified Ashworth scale	1.2±1.2	1.1±1.2	1.4±1.0	1.4±1.2	1.5±1.0	1.8±1.2	0.1	>0.05	5.0	<0.05*

SD: Standard deviation; A: The differences between groups; B: The differences between day 0 and week 4 and week 12; p: Two-way repeated measures for ANOVA; F: Test statistics (analysis of variance with repeated measurements); a *p* value of <0.05 was considered statistically significant (shown with*).

distribution was assessed using the Kolmogorov-Smirnov test. Descriptive statistics for quantitative variables were expressed in mean ± standard deviation (SD) and median (min-max) values, while categorical data were expressed in number and percentage. Difference between the groups in categorical variables was assessed using the Yates chi-square and Fisher's exact chi-square test. The groups were compared using the Independent samples t-test and the Mann-Whitney U test for parametric and non-parametric variables, respectively. The groups were compared in terms of the Brunnstrom, FIM, BBS, MI, 6MWT, FAC, and MAS scores at baseline and at follow-up visits using two-way repeated measures ANOVA. Correlations were evaluated using the Pearson and Spearman correlation analysis for normal distribution and non-normal distribution, respectively. To check the reliability of questionnaires, the Cronbach alpha coefficient was used. The acceptable level for reliability of the study was calculated as 0.80. A *p* value of <0.05 was considered statistically significant with 95% confidence interval (CI).

RESULTS

No side effects were reported in any patient. There was no significant difference between the groups in terms of age, sex, time from cerebrovascular event, type of cerebrovascular disease, and the side of hemiplegic involvement (p>0.05). Demographic and clinical characteristics of the patients are presented in Table 1.

At baseline (Day 0), there was no statistically significant difference in the Brunnstrom recovery stages, FIM motor and total scores, BBS, MI, 6MWT, FAC, and MAS scores between the groups (p>0.05). Reliability of items in the Brunnstrom, FIM motor, FIM total, BBS, MI, 6MWT, FAC, and MAS were high for this sample (Cronbach alpha >0.80 for all).

According to the two-way repeated measures ANOVA for Brunnstrom recovery stages, the main effect for group was statistically significant (F=7.2, p=0.010). The main effect for time was found to be significant (F=67.1, p<0.001). The score showed a significant improvement at all time points (p<0.001). In addition, there was a significant interaction between the group and time points (F=11.6, p<0.001). The results indicated that the main effect of group was statistically significant in the FIM motor and FIM total (F=22.7, p<0.001, and F=24.8, p<0.001; respectively) while the main effect of time was found to be significant (F=109.3, p<0.001, and F=88.7, p<0.001). However, no significant difference was found between Week 4 and Week 12 (p>0.05), while baseline (Day 0) measurement was significantly higher than two measurements (p<0.001 in both scores). The interaction effect between the two factors was significant (F=28.3, p<0.001 and F=18.3, p<0.001). In BBS, there was a significant main effect of group (p<0.001) and main effect of time (p<0.001). No significant difference was found between the other two time points (p>0.05), while baseline (Day 0) measurement was significantly higher than two measurements (p<0.001 and p=0.001, respectively). All effects were statistically significant for MI and 6MWT. The main effect for group yielded an F=9.9, p=0.003 and F=12.7, p=0.001. The main effect for time yielded an F=48.5, p<0.001 and F=26.3, p<0.001, indicating a significance for each time point (p<0.05). Motricity Index and 6MWT measures increased over time for both groups. The interaction effect yielded an F=22.9, p<0.001 and F=12.3 p<0.001. According to analysis results, there was a significant main effect of group (F=13.4, p=0.001) and time (F=61.6, p<0.001) in FAC. The measurements showed an increase over time (p<0.05). The interaction effect was significant between the group and time (F=32.3, p<0.001). However, in MAS, the main effect of group, and interaction effect of group and time were not significant (F=0.1, p>0.05 and F=0.8, p>0.05), while the main effect of time was found to be significant (F=5.0, p<0.05). The measurement of Week 12 was significantly higher than the baseline measurement (Day 0) (p<0.05) (Table 2).

There was no significant correlation between the MAS and the 6MWT, BBS, FIM motor, and FAC scores (p>0.05). However, there was a significant and strong correlation between the FAC measurements on Day 0 and Weeks 4 and 12 and the 6MWT measurements (r=0.88 for Day 0, r=0.75 for Week 4, and r=0.83 for Week 12; p<0.001). In addition, a strong correlation was observed between the BBS and 6MWT, FAC, and FIM motor (p<0.001).

In both groups, the difference between the scores on Day 0 and at Weeks 4 and 12 was determined, and the temporal change (TC) was calculated. The change in time in each parameter was evaluated separately. Accordingly, there were significant differences in all parameters, except for the MAS scores, in all time points (TC0-4, and TC0-12) (p<0.05) (Table 3).

TABLE 3
Temporal changes of the parameters

	TC0-4							TC0-12						
	Mirror therapy group			Control group				Mirror therapy group			Control group			
	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	*p*	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	*p*
Brunnstrom		1.0	0.0-4.0		1.0	0.0-1.0	0.001*†		2.0	1.0-5.0		1.0	0.0-3.0	0.001*†
Functional independence measure motor	34.1±15.9			10.5±9.7			<0.001*‡	36.6±17.0			12.4±11.8			<0.001*‡
Functional independence measure total	35.2±18.6			11.3±11.8			<0.001*‡	37.3±19.7			15.8±12.6			<0.001*‡
The Berg Balance scale		20.0	6.0-52.0		5.0	0.0-27.0	<0.001*†		24.0	6.0-54.0		6.0	0.0-30.0	<0.001*†
Motricity index		26.0	3.0-75.0		0.0	0.0-25.0	<0.001*†		31.0	4.0-75.0		9.0	-19.0-33.0	<0.001*†
Six-minute walking test		55.0	0.0-290.0		0.0	-24.0-48.0	<0.001*†		60.0	10.0-296.0		2.0	-4.0-95.0	0.001*†
Functional ambulation category		2.0	0.0-4.0		0.0	0.0-2.0	<0.001*†		2.0	0.0-5.0		0.0	0.0-2.0	<0.001*†
Modified Ashworth scale		0.0	-1.0-2.0		0.0	-1.0-2.0	0.752†		0.0	-1.0-3.0		0.0	-1.0-3.0	0.281†

TC0-4: Temporal changes between Day 0 and Week 4; TC0-12: Temporal changes between Day 0 and Week 12; SD: Standard deviation; Min: Minimum; Max: Maximum; † Mann Whitney U test; ‡ Independent Samples t test; a *p* value of <0.05 was considered statistically significant (shown with*).

DISCUSSION

In the present study, we attempted to examine the effect of MT on lower extremity motor function and ambulation using certain parameters of motor recovery, disability, balance, motor function, walking speed, ambulation, and degree of spasticity, which have not been investigated as combined in previous studies. Our study results showed that MT in addition to the conventional rehabilitation program had a positive effect on motor recovery, disability status, ambulation, balance, motor function, and walking speed. This positive effect sustained for a short interval (eight weeks) after the treatment. However, the MT was not seen to have any effect on the degree of ankle plantar flexor spasticity. To the best of our knowledge, this is the first study to evaluate lower extremity motor function and ambulation using these many parameters.

Although the exact mechanism is still unknown, two theories have been suggested to explain the effect of MT.[20] The first is the mirror neuron system mechanism in which the mirror neurons are activated while watching or performing an activity. Therefore, it is thought that watching the unaffected extremity in the mirror activates the mirror neurons in the brain.[7] The other theory is the primary motor cortex mechanism, in which the primary motor cortex is activated during the ipsilateral extremity movement and while watching contralateral extremity movements in the mirror.[8] Both of these conditions facilitate neuroplasticity and functional recovery. To date, a few studies have been conducted to evaluate the effects of MT on lower extremity motor function and ambulation, and the results have demonstrated that MT may be an effective modality.

In a study by Sütbeyaz et al.,[9] a total of 40 patients with hemiparesis after stroke during the previous 12 months were divided into two groups, both of which received a conventional rehabilitation program of two to five hours per day for five days a week for a total of four weeks. The MT group received MT including dorsiflexion of the non-paretic ankle for 30 min in each session and the control group received the same therapy during the same time period without using the mirror's reflective side. The patients were evaluated before therapy and, then, one and six months after therapy. During follow-up, the Brunnstrom stages and FIM motor scores of the MT group patients were significantly higher, although there was no significant difference in the FAC and MAS scores. The lack of a significant difference in the MAS scores can be explained by the complex pathophysiology of spasticity and that visual feedback is not adequate to control spasticity. The lack of difference in the FAC between the groups was attributed to an insufficient duration of MT and the multifactorial structure pattern of walking.[9] Similarly, in the current study, the beneficial effects of MT on lower extremity motor recovery stage and disability were demonstrated. However, unlike the previous study, MT was also seen to have a positive effect on ambulation. The beneficial effects of MT were observed on balance, motor function, and walking speed which affected ambulation, as well. Therefore, a period of four weeks of MT can be considered sufficient to have positive effects on the factors affecting the gait ability. Similar to the study of Sütbeyaz et al.,[9] no effect on the degree of ankle plantar flexor spasticity was observed in our study. This can be due to the complex pathophysiology of spasticity, and the lack of a single method of evaluation spasticity in all aspects. In the current study, only the MAS was used to evaluate spasticity. The use of more than one method together may yield stronger evidence in the evaluation of the effect of MT on spasticity.

In a study by Mohan et al.,[10] 22 acute post-stroke patients were divided into two groups, and both groups received a conventional rehabilitation program for 90 min a day for six days a week for a total of two weeks. The MT group received additional MT for 30 min per day. All patients were evaluated before therapy and at the end of two weeks of treatment. A significant change was determined in the FAC, although no significant difference was observed in the Fugl-Meyer Assessment of motor recovery or the Brunel Balance Assessment. In the current study, a positive effect was seen on both motor recovery and balance level. In the previous study, although the positive effect on the level of ambulation was determined, the positive effect of motor recovery and balance levels affecting ambulation in a positive way were not observed. This may be due to the multifactorial nature of walking. In addition, a two-week intervention may not be adequate to determine significant changes in motor recovery and balance levels. However, it should be considered that other medical conditions in the acute period may affect the study results.

The main limitations of this study include relatively small sample size and short follow-up time. Furthermore, there was no use of radiological techniques which could have shown the radiographic effects of the MT on the primary motor cortex and mirror neuron system mechanisms.

In conclusion, MT which is a simple and inexpensive method without requiring any assistance can be applied in addition to conventional rehabilitation program, yielding a greater improvement in the lower extremity motor function and ambulation with sustained effects for a short period of time after the treatment. Using MT combined with conventional therapy may be beneficial for post-stroke patients. Nonetheless, there is a need for further studies of MT with larger populations and longer follow-up periods to confirm these beneficial effects for post-stroke patients.

Acknowledgments

The authors would like to thank Füruzan Köktürk, PhD. for contributions in the statistical analyses of the data.

Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding

The authors received no financial support for the research and/or authorship of this article.

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