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Original Article

The Effect of Mirror Therapy Integrating Functional Electrical Stimulation on the Gait of Stroke Patients

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Abstract. [Purpose] The aim of the present study was to examine whether mirror therapy in conjunction with FES in stroke patients can improve gait ability. [Subjects] This study was conducted with 30 subjects who were diagnosed with hemiparesis due to stroke. [Methods] Experimental group I contained 10 subjects who received mirror therapy in conjunction with functional electrical stimulation, experimental group II contained 10 subjects who received mirror therapy, and the control group contained 10 subjects who received a sham therapy. A gait analysis was performed using a three-dimensional motion capture system, which was a real-time tracking device that delivers data in an infrared mode via reflective markers using six cameras. [Results] The results showed a significant difference in gait velocity between groups after the experiment, and post hoc analysis revealed significant differences between experimental group I and the control group and between experimental group II and the control group, respectively. There were also significant differences in step length and stride length between the groups after the experiment, and post hoc analysis revealed significant differences between experimental group I and control group. [Conclusion] The present study showed that mirror therapy in conjunction with FES is more effective for improving gait ability than mirror therapy alone.

Key words: Mirror therapy, Functional electrical stimulation, Gait analysis

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INTRODUCTION

Mirror therapy is a form of mental practice, and it excites the primary motor cortex and evokes movement of the paralyzed side as patients confirmed movement of the non-paralyzed side visually[1)]. A mirror neuron is neuron that responds to observation of a person's movement as if in response to real movement and can be activated through mirror therapy[2)].

Yayuzer et al.[3)] reported that subacute stroke patients who received mirror therapy showed improved function of upper and lower extremities, and Stevens and Stoykov[4)] reported that visual information of sound side movement was conveyed and that movement of the affected side was improved. Functional electrical stimulation is a method used for inducing improvement of functional movement such as strength and gait ability with electrical stimulation in patients who suffer from upper motor neuron diseases such as stroke, multiple sclerosis, and spinal cord injury[5)]. Sullivan and Hedman[6)] reported that muscle strength, range of motion, and functional movement are more improved after applying both functional task performance and FES than after applying functional task performance alone. Peurala et al.[7)] also reported that a group that received both gait training and FES show better improvement of gait ability than another group that only received gait training.

The effect of functional task performance in conjunction with FES has been demonstrated in stroke patients, but the effect of application of both mirror therapy and FES to stroke patients is not yet known. The aim of the present study was to examine whether mirror therapy in conjunction with FES in stroke patients can improve gait ability.

SUBJECTS AND METHODS

This study was conducted with 30 subjects who were diagnosed with hemiparesis due to stroke. Sufficient explanation of this study's intent and the overall purpose was given, and voluntary consent to participation in this study was obtained from all of the subjects. All procedures were reviewed and approved by the Institutional Ethics Committee of Eulji University Hospital. Subjects were randomly divided into 3 groups. Experimental group I contained 10 subjects who received mirror therapy in conjunction with FES, experimental group II contained 10 subjects who received mirror therapy, and the control group contained

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Table 1. General and medical characteristics of the subjects (n=30)

	EG I (n=10)	EG II (n=10)	CG (n=10)
Age (years)	52.9±9.9[a]	48.6±8.5	54.6±9.2
Since onset (months)	7.1±3.4	7.3±2.9	6.7±2.3
Weight (kg)	63.4±8.6	63.1±9.5	65.5±7.3
Height (cm)	167.7±7.0	166.1±8.1	168.0±7.4
Gender (male/female)	6/4	7/3	6/4
Affected side (left/right)	3/7	4/6	4/6
Causes (infarction/hemorrhage)	6/4	7/3	7/3

[a]Mean±SD, EG I: Mirror therapy + FES group, EG II: Mirror therapy group, CG: Sham therapy group

10 subjects who received a sham therapy. All subjects performed a PNF neurodevelopment technique for 30 minutes a day, 5 times a week for 6 weeks. The subjects in experimental groups I and II were instructed to sit on a table for therapeutic purposes based on the mirror therapy program proposed by Sütbeyaz et al.[8], and to use a 60 × 90 cm mirror designed such that its angle could be adjusted. After placing the mirror between the non-affected and affected lower limbs, the affected lower limb was positioned behind the mirror. The mirror's angle was then controlled according to the patient's sitting height so that the movement of the non-affected lower limb could be seen in the mirror. For functional electrical stimulation (FES) equipment, this study used a Microstim, which consisted of one pair of surface electrodes (50 × 50 mm), a stimulator, and a foot switch. The foot switch was attached to the bottom of the forefoot on the patient's affected side and set to activate FES as soon as the forefoot on the affected side came off the ground. In addition, the patients were taught to create simultaneous active movements for dorsiflexion of the foot on the affected side when dorsiflexion of the foot on the non-affected side was seen in the mirror. The patients had to repeat maintenance of dorsiflexion for 10 seconds and then rested for 5 seconds. Experimental group II was instructed to perform the same training without application of FES. The control group did not receive FES, and performed the same training after covering the mirror with a white cloth. Each group performed additional exercise for 20 minutes. A gait analysis was performed using a three-dimensional motion capture system, which was a real-time tracking device that delivers data in an infrared mode via reflective markers using six cameras. The reflective markers were attached to the left and right anterior superior iliac spines (ASISs), left and right posterior superior iliac spines (PSISs), left and right femoral regions, lateral epicondyles of the left and right knees, left and right tibial regions, left and right lateral malleoli, heads of the left and right second metatarsal bones, and left and right posterior calcaneal bones. The Eva Real-Time (EvaRT) were used for data processing. To measure gaits, each subject was instructed to walk inside a 7 m capture area from the starting to end points three times at a comfortable speed. The average of the measurement values after excluding 1 m from each of the starting and end points was adopted for a gait analysis. In addition, temporal gait characteristics of velocity and cadence and spatial gait characteristics of step length and stride length were recorded. Paired t-tests were used to verify statistical significance in performances before and after the experiment. To make comparisons between the groups, a one-way ANOVA was conducted. In addition, a post hoc test was performed using Fisher's Least Significance Difference (LSD) test. The statistical significance level was set at α=0.05.

RESULTS

General characteristics and results of the homogeneity test of the subjects are shown in Table 1. Velocity, cadence, step length and stride length of all groups were significantly improved after the experiment ($p<0.05$). The results showed a significant difference in gait velocity ($p<0.01$) between groups after the experiment, and post hoc analysis revealed significant differences between experimental group I and the control group and between experimental group II and the control group, respectively. There were also significant differences in step length and stride length ($p<0.01$) between the groups after the experiment, and post hoc analysis revealed significant differences between experimental group I and control group ($p<0.05$) (Table 2).

DISCUSSION

According to the results of this study, velocity, step length, and stride length in experimental group I were improved after the experiment compared with experimental group II and the control group. This showed that mirror therapy in conjunction with FES is more effective for improving gait ability than mirror therapy alone. FES increased activation of the sensory-motor cortex area of stroke patients and the influence on functional movement. It is known to improve treatment effects and to have a positive effect on motor learning[9]. We thought that this may be due to brain reorganization in response to mirror therapy occurring at the same time as recovery of muscle function due to FES.

Sütbeyaz et al.[8] randomly assigned 40 stroke patients to a mirror therapy group and a control group. The subjects repeatedly performed dorsiflexion of the ankles with the non-affected lower limb placed in front of a mirror. Measurement of their functional ambulation categories (FAC) during exercise showed that the mirror therapy group

Table 2. Comparison of gait ability between groups (n=30)

		EG I (n=10)	EG II (n=10)	CG (n=10)	Post hoc
Velocity (cm/s)	Pre	47.3±4.6[a]	45.3±6.2	46.6±5.3	/
	Post	63.3±6.4**	60.5±8.4**	53.4±5.6*	a,b>c
Cadence (steps/min)	Pre	71.5±12.1	70.5±10.1	69.2±10.3	/
	Post	84.6±14.0**	78.0±8.7*	75.0±10.5*	/
Step length (cm)	Pre	30.1±6.1	30.4±2.8	30.2±3.4	/
	Post	38.5±4.7**	35.9±3.6*	33.4±4.6*	a>c
Stride length (cm)	Pre	64.6±11.6	60.3±7.9	57.4±5.0	/
	Post	77.0±9.1**	72.4±6.7**	67.3±9.6**	a>c

[a]Mean±SD, *p<0.05, **p<0.01, EG I: Mirror therapy + FES group, EG II: Mirror therapy group, CG: Sham therapy group

achieved a statistically significant higher level of improvement in gait ability than the control group. This result was similar to that of the present study. FES increases the activity of the cerebral sensory-motor cortex in stroke patients and has an effect on functional movement, and it has a positive effect on motor learning and improves the effect of treatment[9]. We suspect that the gait abilities were improved due to synergistic effects of FES and mirror therapy. In a cross-sectional study in which FES was applied to the ankle dorsiflexors of stroke patients, Sabut et al.[10] reported that statistically significant increases were found in gait velocity, cadence, and stride length. Kesar et al.[11] noted that application of FES to the tibialis anterior muscle of stroke patients during walking improved gait ability by correcting foot drop. Limitations of this study include its small sample size, the difficulty in generalizing its results, and the fact that we did not confirm the durability of the effects through follow-up. Future studies should employ larger sample sizes, and compare the effects of mirror therapy with those of other interventions.

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