J. Phys. Ther. Sci.
27: 1045–1047 2015

Original Article

Effect of mirror therapy with tDCS on functional recovery of the upper extremity of stroke patients

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Abstract. [Purpose] This study aimed to determine the effect of mirror therapy (MT) with transcranial direct current stimulation (tDCS) on the recovery of the upper extremity function of chronic stroke patients. [Subjects] Twenty-seven patients at least 6 months after stroke onset were divided randomly into an experimental group (14 patients) and a control group (13 patients). [Methods] All subjects received tDCS for 20 min followed by a 5 min rest. Then the experimental group received MT while the control group conducted the same exercises as the experimental group using a mirror that did not show the non-paretic upper extremity. The groups performed the same exercises for 20 min. All subjects received this intervention for 45-min three times a week for 6 weeks. [Results] After the intervention, the experimental group showed significant improvements in the box and block test (BBT), grip strength, and the Fugl-Meyer assessment (FMA), and a significant decrease in the Jebsen-Taylor test. The control group showed a significant increase in grip strength after the intervention, and a significant decrease in the Jebsen-Taylor test. Comparison of the result after the intervention revealed that the experimental group showed more significant increases in the BBT and grip strength than the control group. [Conclusion] These results show that MT with tDCS has a positive effect on the functional recovery of the upper extremity of stroke patients, through activating motor regions in the brain, and thus plays an important role in recovery of neuroplasticity.
Key words: tDCS, Mirror therapy, Stroke

(This article was submitted Oct. 21, 2014, and was accepted Nov. 28, 2014)

INTRODUCTION

The clinical symptoms of stroke patients are subluxation of the shoulder joint, abnormal muscle tone and decreased motor control ability, decreased coordination ability, associated reaction, pain in the musculoskeletal systems, weakness of muscle strength in the upper extremity, and sensory disorder[1)]. Thus, stroke causes decreased motor control of the upper extremity resulting in disability in independent daily living such as putting on clothes, eating, and personal management[2)]. Physical therapy approaches that aim to improve upper extremity motor function of stroke patients are used in clinical practice. However, with most intervention methods, patients do not achieve full regeneration or activation of the central nervous system[3)]. Recently, scientific advances, have allowed attention to be paid to direct and selective stimulation of the brain using methods based on neuroplasticity of the central nervous system.

Transcranial direct current stimulation (tDCS) activates the brain non-invasively without pain and can change neural structures in the motor cortex, there by inducing neuroplasticity[4)]. Furthermore, tDCS stimulates the damaged area of the brain of stroke patients with 1–2 mA current, resulting in polarization of cranial nerves, which improves motor learning and functions[4)]. Mirror therapy (MT) uses visual feedback to induce recovery of motor functions in the upper extremity. Movements of the non-paretic hand of a stroke patient are reflected in a mirror to create an optical illusion as if the paretic hand moves normally. This means that neuroplasticity can be changed by activating the mirror neuron system involved in motor learning and imitation by observing actions without physical movement[5)].

Studies of tDCS and MT have mainly been conducted with subacute stroke patients within 6 months after stroke onset when neurological recovery can occur quickly after stroke. However, few studies have been conducted of tDCS, a method for stimulating the central nervous system which is effective at eliciting functional recovery in stroke patients, in parallel with MT, which is a simultaneous visual illusion effect. Thus, this study aimed to determine the effect of MT with tDCS on functional motor recovery of the upper extremity of chronic stroke patients.

SUBJECTS AND METHODS

The subjects of this study were 27 stroke patients with hemiplegic symptoms. Subjects were randomly divided into two groups: 14 patients in the experimental group (MT with tDCS) and 13 patients in the control group (without mirror + tDCS). The selection criteria were as follows: a score of 24

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or higher on the Mini Mental State Examination-K (MMSE-K) indicating no cognitive impairment, stroke onset more than 6 months earlier, and no orthopedic or neurological disease history. Participants who met the inclusion criteria and agreed to participate in the study received a general explanation of the trial, and gave their written informed consent. All procedures were reviewed and approved by the Institutional Ethics Committee of Eulji University Hospital. The subjects were randomly divided into an experimental group and a control group. All the subjects received tDCS for 20 min followed by a 5-min rest. Then the experimental group received MT, while the control group performed the same exercise as the experimental group using a mirror that did not show the non-paretic upper extremity. The groups performed the same exercise for 20 min. All subjects received this intervention for 45-min three times a week for 6 weeks. Originally, 30 subjects participated in this study, but one patient with cognitive disability and two patients who complained of headache and during the tDCS application were retired from the study during the experiment.

Subjects were seated on a chair in a comfortable position with both arms on the armrest in a relaxed position. A sponge electrode of 7×5 cm^2 (area; 24 cm^2) for tDCS (Phoresor II Auto model PM 700, IOMED, Salt Lake City, USA) was soaked in 0.9% physiological saline and applied to the head of the patient using as tight a band as possible without creating discomfort. The anode electrode was attached to C3 and C4, the primary motor cortex (M1), while the cathode electrode was attached to the supraorbital area of the non-paretic side according to the International 10/20 system. Stimulation was applied with 2 mA stimulus intensity for 20 min[6)]. The paretic hand was hidden behind a 35×35 cm mirror, and the non-paretic hand was put in front of the mirror. Subjects looked at the upper extremity of the non-paretic side reflected in the mirror and observed the movement. The MT program consisted of pronation, supination, flexion, and extension of both wrists, flexion and extension of the fingers, and flexion and extension of the elbows. One set consisted of 20 repetitions of each motion. Subjects performed 10 sets and rested for 2 min between sets. To help the subjects concentrate, every time a set was completed, a verbal compliment was given once. The total program time was 20 min[5)]. The box and block test (BBT), which measures the manual dexterity of stroke patients, counts the number of blocks that can be moved from one box to another box in 1 min. Each block is a 1 inch cube. Subjects were requested to move the blocks as quickly as they could with motivational compliments. The wooden blocks were moved one at a time. The test-retest reliability is very high r=0.96 for: the right hand, and r=0.94 for the left hand[7)]. To measure hand grip strength, a JAMAR hand dynamometer (Sammons Preston Rolyan, Illinois, USA) was used. The measurement was conducted while the subjects were seated on a chair with their upper arms close to the body, their elbows flexed at 90°, and the wrist in the neutral position. The mean value of three measurements was used in the analysis. The reliability of grip strength measurement has been reported as r=0.99, which is very high[8)]. The Jebsen-Taylor test is an objective assessment tool that measures the functional hand tasks that are most widely used in daily living. Each test consists of writing, turning over a card, stacking checkers, picking up small common object, simulated feeding, picking up a large light tin can, and picking up a large heavy tin can. The assessment measure the time (seconds) taken to perform each task. The reliability of this assessment tool has been reported as r=0.99, which is very high[9)]. The Fugl-Meyer assessment (FMA) assesses the motor functions, balance, and senses of stroke patients. In this study, detailed items of the upper extremity function were used as the main assessment index, without functional assessment of the lower extremity, and the coordination ability among the shoulder, elbow, forearm, wrist, and hand was examined. The reliability of this assessment tool has been reported as r=0.94, which is very high[10)]. For statistical analysis in this study, SPSS 18.0 was used to calculate the mean and standard deviation. The data are expressed as mean ±standard deviation Within-group and between-group comparisons for all variables were performed by using TwoWay ANOVA. A statistical significance level of α=0.05 was used in all analyses.

Table 1. General and medical characteristics of subjects (N: 27)

	EG (n=14)	CG (n=13)
Gender (male/female)	8/6	7/6
Age (years)	58.29±10.67[a]	60.38±10.19
Height (cm)	168.86±6.10	167.08±8.52
Weight (kg)	62.86±8.10	64.46±7.11
Causes (infarction/hemorrhage)	9/5	8/5
Affected side (right/left)	6/8	7/6
Since onset (month)	13.2±5.1	15.5±7.8
Modified Ashworth Scale (G0/G1/G1+)	5/6/3	7/6/0

[a]mean±SD, EG: experimental group, CG: control group

RESULTS

The homogeneity test of age, height, weight, and disease history between the experimental and control groups found no significant differences between the two groups (Table 1).

After the intervention, the experimental group showed significant improvements in the BBT, grip strength, and the FMA ($p<0.05$), and a significant decrease in the Jebsen-Taylor test ($p<0.05$). The control group showed a significant increase in grip strength after the intervention ($p<0.05$), and a significant decrease in the Jebsen-Taylor test ($p<0.05$). Comparison of the results after the intervention revealed that the experimental group showed more significant increases in the BBT and grip strength than the control group ($p<0.05$) (Table 2).

DISCUSSION

Within 6 months after stroke onset, motor function can be recovered naturally. After 6 months, neurological function has recovered; therefore, the physical therapeutic approach is the focus during this period[11)]. This study aimed to determine the effect of MT with tDCS on functional motor recovery in the upper extremity of chronic stroke patients. The results show that the interventions had positive effects.

Table 2. Comparison of the experimental group and the control group results

		EG (n=14)	CG (n=13)
Box and block test (unit)**	pre	25.29±11.81[a]	23.00±9.16
	post	37.21±9.62**	25.62±9.03
Grip strength (kg)**	pre	12.00±3.53	9.92±3.38
	post	15.29±2.16**	12.31±2.72*
Jebsen-Taylor (sec)	pre	122.93±33.99	120.00±25.34
	post	93.36±28.03*	103.92±12.33*
Fugl-Meyer assessment (score)	pre	36.50±11.04	39.15±9.00
	post	45.57±8.76*	41.85±15.78

[a]mean±SD, *p<0.05, **p<0.01, EG: experimental group, CG: control group

Although many studies have been conducted of recovery of motor function of the upper extremity, stroke patients with decreased physical function have difficulty performing tasks as well as decreased motivation for rehabilitation. Therefore, a cognitive intervention that increases the motivation of stroke patients is necessary. As a cognitive intervention method, MT activates the frontal or parietal lobe in the corresponding motor region only observing the behavior of others, and this area is called the mirror neurons. Therefore, MT could play an important role in learning a new skill or understanding others' behavior, which can be used to motivate stroke patients[12)]. In addition, tDCS, which performs non-invasive stimulation in the brain of stroke patients, can elicit structural changes in neuroplasticity, thereby helping stroke patients recover motor function in the upper extremity. The neurological mechanism of tDCS is hyperpolarization of neurons in the brain by cathode stimulation, which reduces the excitatory response in the cerebral cortex, while anode stimulation elicits depolarization increasing the excitatory response[13)].

After the main intervention of this study, the experimental group showed a more significant increase in BBT and grip strength than the control group did. This result is consistent with the results of another study in which MT application improved stroke patients motor function and senses in the two limbs of the paretic side[12)]. Another study reported that MT improved functional recovery in the upper extremity and performance of daily living activities of subacute stroke patients[14)]. This result was attributed to the optical illusion of movement of the non-paretic side activating mirror neurons through mirror reflection, thereby improving the movement of the paretic side.

It was also reported that when 1mA anode direct current stimulation was applied to the primary motor region of the brains of chronic stroke patients for 20 min, hand motor functions improved in the Jebsen-Tayler test[15)]. Another study reported that tDCS activated the damaged cerebral cortex, thus helping positive functional recovery of the upper extremity[16)]. These results are similar to those of our study indicating that depolarization of cell membranes is induced when the microcurrent of tDCS is applied to cortical areas, changing the NMDA receptors and activating the cerebral cortex[17)].

This study demonstrated that, applying tDCS has a positive effect on the motor function recovery of stroke patients in addition to the effect of MT. The visual illusion effect of MT activated the damaged cerebral cortex directly, but selective stimulation of the central nervous system helped activate the corticospinal tract of stroke patients.

This study had several limitations. First, due to the small number of subjects, it is difficult to generalize the results to all stroke patients. Second, we could not control therapy duration other than the intervention duration. Third, we did not separate subjects by functional performance level and performed only simple tasks. Therefore, these limitations should be addressed in the future by including more subjects and studying tDCS and MT simultaneously for a longer duration.

ACKNOWLEDGEMENT

This study was supported by Wonkwang Health Science University in 2015.

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