J. Phys. Ther. Sci.
26: 363–365, 2014

Original Article

Effect of Transcranial Direct Current Stimulation of Function in Patients with Stroke

Hyun-Kyu Cha, PT, MS[1)], Sang-Goo Ji, PT, PhD[2)], Myoung-Kwon Kim, PT, PhD[3)], Jong-Sung Chang, PT, PhD[4)*]

[1)] *Department of Physical Therapy, College of Natural Science, Daejeon University, Republic of Korea*
[2)] *Department of Physical Therapy, Eulgi University Hospital, Republic of Korea*
[3)] *Department of Physical Therapy, Youngsan University, Republic of Korea*
[4)] *Department of Physical Therapy, Yeungnam College of Science and Technology: 170 Hyeon chung-ro, Namgu, Daegu 705-703, Republic of Korea*

Abstract. [Purpose] The purpose of this study was to determine the effect of transcranial direct current stimulation (tDCS) on the upper limb of function of patients with post-stroke hemiplegia. [Subjects] Twenty subjects were randomly allocated to either the upper tDCS group or the functional training group, with 10 subjects in each group. [Methods] The two groups received functional training for thirty minutes a day, five days a week for four weeks. The tDCS group additionally received tDCS for 20 minutes. The outcome was assessed by the Box and Block test (BBT), grip strength, and the Fugl-Meyer assessment (FMA). [Results] There were significant improvements between pre- and post- intervention in both groups, in the BBT, grip strength, and the upper limb and lower lims sub-items of the FMA. The tDCS group showed significantly greater improvements than the control group in the BBT, and upper limb and lower limb sub-items of the FMA. [Conclusion] These findings suggest that tDCS may be more beneficial than functional training for improving the upper and lower limb functions of chronic stroke patients.
Key words: Stroke, tDCS, Limb function

(This article was submitted Jul. 17, 2013, and was accepted Oct. 2, 2013)

INTRODUCTION

Stroke refers to the lesions and neurologic symptoms resulting from damage to the blood vessels distributed in the brain. Its clinical symptoms include muscle weakening, abnormal muscle tones, somatosensory deficit, decline in physical intelligence, and speech disorders[1)]. These symptoms cause restriction of stroke patients' daily living activities, such as abnormal gait, to the extent that 85% of patients show disorders in upper limb functions six months after the onset of stroke[2)]. Among the upper limb functions of stroke patients, hand functions are the most seriously impaired because Betz cells exist the most densely in the region that is responsible for hand control in the motor cortex[3)]. In stroke patients, the recovery of upper limb motor function is essential for independent performance of daily living activities, because the upper limbs remarkably contribute to most daily living activities and are important for the performance of voluntary movements[4)]. Therefore, the functional recovery of the upper limbs is a primary objective of physical therapy and clinicians should focus on effective plans and treatments for patients' performance of upper limb related activities. Recently, studies have been actively conducted on non-invasive nerve stimulation methods intended to promote the plasticity and reorganization of injured areas of the brain after brain lesions. Schlaug and Renga[5)] reported that when transcranial direct current stimulation (tDCS) and motor learning were implemented in combination, the cerebral cortex was enhanced and functional recovery was promoted. Stefan et al.[6)] reported that cerebral cortex stimulation had positive effects on peripheral activities and centric stimuli.

tDCS is a direct brain stimulation method that can be simply and conveniently used in clinics, and can efficiently activate stroke patients' motor cortexes[7)]. Although many studies have performed peripheral stimulation of cranial nerves using electrical stimulation or functional electrical stimulation, for stroke patients' functional recovery, studies that have performed centric stimulation such as tDCS are lacking. Therefore, the present study investigated the clinical effects of tDCS as rehabilitation therapy for the central nervous system by objectively examining the effect of tDCS on stroke patients' upper and lower limb functions.

*Corresponding author. Jong-Sung Chang (E-mail: jackscjs@hanmail.net)

SUBJECTS AND METHODS

The present study was conducted with those who voluntarily agreed to participate in the experiment after being given sufficient explanation about the purpose and method of the study. The subjects were recruited from patients diagnosed with hemiplegia due to stroke who had gait disturbance. The subjects were participated ten of experimental group (age, 59.8±11.4 years; height, 166.3±5.8 cm; weight, 65.0±8.3 kg; affected side (left/right), 6/4; since onset, 13.8±4.6 months; MMSE-K, 25.6±2.8; Brunnstrom stage, 5.2±0.7), and 10 subjects in the control group (age, 57.8±9.9 years; height, 168.0±8.8 cm; weight, 65.2±7.7 kg; affected side (left/right), 5/5; since onset, 14.5±3.6 months; MMSE-K, 26.7±2.6; Brunnstrom stage, 4.78±0.8). The general characteristics of the subjects were not significantly different between the groups.

The subjects were assigned to the treatment groups by having each of the subjects take out one card from a box containing two types of card representing both of the treatment groups. All the subjects received basic training for functional improvement of the upper and lower extremities for 30 minutes per day, five times per week for four weeks. The experimental group additionally received tDCS for 20 minutes.

For tDCS (Phoresor II Auto model PM 700, IOMED, Salt Lake City, USA), 7×5 cm^2 (area; 24 cm^2) sized sponge electrodes (Daeyang medical Co., Ltd, Korea) were used. The anode of the electrode was attached to the precentral sulcus (10–20 international electroencephalography system C3 or C4), which is the primary motor area on the same side as the lesion, and the cathode was attached to the forehead on the other side. The electrodes were soaked in water and fixed in maximal tight contact with the relevant areas using bands. The intensity and time of the stimulation applied were 1 mA and 20 minutes, respectively. These conditions were sufficient to generate large amounts of motor evoked potential without causing adverse effects or inconvenience within the range of safety indicated by previous studies[8, 9].

The box and block test can be used as a measure of manual dexterity and can provide one indication of hand dominance. The box and block test consists of a wooden box 53.7 cm by 25.4 cm which is divided into two equal compartments by a 15.4 cm-high partition. Subjects were instructed to transfer as many 2.5 cm cubes as possible from one compartment to the other in one minute. Subjects' scores were the number of cubes transferred in one minute[10].

Grip strength was evaluated by a dynamometer (JAMAR hand dynamometer, Sammons Preston Rolyan, Ilinois, USA). For measurement, subjects sat with their arms at their sides with the elbow joint in 90° flexion and the wrist joint in the neutral position. The subjects were asked to squeeze the dynamometer with as much force as possible, being careful to squeeze only once for each measurement. Three trials were made with a rest of about one minute between each[11]. The FMA is a stroke-specific, performance-based impairment index. It is designed to assess motor function, balance, sensation and joint function of patients with post-stroke hemiplegia. It is used clinically and in research to determine disease severity, describe motor recovery, and to plan and assess treatment[12]. The maximum score for the motor performance is divided into 66 points for the upper extremity and 34 for the lower extremity[13].

The experimental results were statistically analyzed using SPSS 12.0 KO (SPSS, Chicago, IL, USA). After the general characteristics of the subjects were determined, the paired t-test was used to compare the changes occurring between pre-test and post-test in each group. The differences between the two groups were tested using the independent t-test. The statistical significance level, α, was chosen as 0.05

Table 1. Pre- and post-intervention values of the BBT, grip strength, FMA

		EG (n=10)	CG (n=10)
BBT*	pre	23.0±12.9[a]	17.50±7.3
(unit)	post	49.3±15.5	26.60±8.8
Grip strength	pre	15.5±7.8	12.00±7.9
(kg)	post	21.8±4.5	20.30±6.4
FMA-U*	pre	20.5±6.0	22.60±12.3
(score)	post	48.7±12.5	29.70±9.2
FMA-L*	pre	18.5±8.1	13.60±7.1
(score)	post	27.8±3.6	22.50±6.4
FMA-B*	pre	10.5±2.8	8.60±4.9
(score)	post	13.0±1.7	9.30±5.0

[a]mean±SD. FMA, Fugl-Meyer assessment; FMA-U, upper extremity; FMA-L, lower extremity; FMA-B, balance

RESULTS

There were significant improvements after the intervention in both groups, in the BBT, grip strength, and the upper limb and lower limb sub-items of the FMA ($p<0.05$). The experimental group showed significantly greater improvement than the control group in the BBT, and the upper limb and lower limb sub-items of the FMA ($p<0.05$) (Table 1).

DISCUSSION

It is difficult for patients with stroke to recover the function of the upper extremity. Stimulation of the brain by non-invasive technique such as tDCS, regulates the function of non-specific neural structures, and improves corticomotor excitability and motor function enhancement[14]. tDCS is a comfortable and painless corticomotor stimulation technique that induces functional changes dependent on the parameters, intensity, duration, and location of stimulation[9]. This study evaluated the effect of tDCS training with conventional physical therapy on function of the upper and lower limbs and activities of daily living (ADL) of stroke patient with activity limitations. The main findings of our study were significant improvements in upper limb and lower limb motor function and ADL in the experimental group compared to the control group.

This is similar to findings that the application of tDCS improves activation of the premotor cortex and hand function[15]. Fregni et al.[16] reported that tDCS could improve of impaired lower limb function and ADL, such as independent and voluntary motor performance. Hummel et al.[17] showed that tDCS for ten days of the primary motor cortex shortened reaction times by 11.75% in the Jebsen-Taylor hand function test. In addition, regarding a study applying tDCS to the hand and leg areas of the motor cortex reported improved activation of the corticospinal tract, enhanced recovery level, and a shortened recovery time among stroke patients[18]. This means that application of tDCS improves the walking ability of stroke patients.

In this study, limb motor function and ADL assesment significantly improved in the experimental group, which indicats that tDCS had a beneficial effct for these subjects. This result agrees with previous reports that tDCS increased motor performance assessments of the shoulder, elbow, and wrist, and lower limb assessments of stroke patients[15, 19]. Together, these results suggest that conventional physical therapy with tDCS provides non-specific input to the motor cortex, facilitating changes in neural activation and synaptic plasticity which promote functional recovery, and enhance voluntary activities such as ADL by increasing the activity of the cerebral cortex in damaged brain areas[20]. Therefore, the application of tDCS could facilitate cortical repair by brain reorganization, and have great clinical benefits through improvements of impaired cortex and motor dysfunction of stroke patients. A variety of stimuli delivered to the cerebral cortex may enhance neural plasticity and motor learning. Application of tDCS combined with physical therapy may be more beneficial than functional training for improving the limb functions and activities of daily living of patients with chronic stroke. Further studies are needed to generalize these findings, to investigate a variety of physical therapies with concurrent tDCS, and to consider patients' quality of life as well as independence of ADL.

REFERENCES

1) Kautz SA, Patten C: Interlimb influences on paretic leg function in post stroke hemiparesis. J Neurophysiol, 2005, 93: 2460. [Medline] [CrossRef]
2) Dobkin BH: Clnical practice. Rehabilitation after stroke. N Engl J Med, 2005, 352: 1677–1684. [Medline] [CrossRef]
3) Prange GB, Jannink MJ, Groothuis-Oudshoorn CG: Systematic review of the effect of robot-aided therapy on recovery of the hemiparetic arm after stroke. J Rehabil Res Dev, 2006, 43: 171–184. [Medline] [CrossRef]
4) Harris JE, Eng JJ: Paretic upper-limb strength best explains arm activity in people with stroke. Phys Ther, 2007, 87: 88–97. [Medline] [CrossRef]
5) Schlaug G, Renga V, Nair D: Transcranial direct current stimulation in stroke recovery. Arch Neurol, 2008, 65: 1571–1576. [Medline]
6) Stefan K, Kunesch E, Cohen LG: Induction of plasticity in the human motor cortex by paired associative stimulation. Brain, 2000, 123: 572. [Medline] [CrossRef]
7) Kwon YH, Ko MH, Ahn SH, et al.: Primary motor cortex activation by transcranial direct current stimulation in the human brain. Neurosci Lett, 2008, 435: 56–59. [Medline] [CrossRef]
8) Iyer MB, Mattu U, Grafman JM, et al.: Safety and cognitive effect of frontal DC brain polarization in healthy individuals. Neurology, 2005, 64: 872–875. [Medline] [CrossRef]
9) Boggio PS, Castro LO, Savagim EA, et al.: Enhancement of non-dominant hand motor function by anodal transcranial direct current stimulation. Neurosci Lett, 2006, 404: 232–236. [Medline] [CrossRef]
10) Mathiowetz V, Volland G, Kashman N, et al.: Adult norms for the box and block test of manual dexterity. Am J Occup Ther, 1985, 39: 386–391. [Medline] [CrossRef]
11) Lee DC, Jang KP: An analysis of grip strength for Korean adults. J Ergo Soc Korea, 1997, 16: 565–572.
12) Fugl-Meyer AR, Jaasko L, Leyman I: The post-stroke hemiplegic patient. 1. A method for evaluation of physical performance. Scand J Rehabil Med, 1975, 7: 13–31. [Medline]
13) Duncan PW, Goldstein L, Horner R, et al.: Similar motor recovery of upper and lower extremities after stroke. Stroke, 1994, 25: 1181–1188. [Medline] [CrossRef]
14) Berlim MT, Neto VD, Turecki G: Transcranial direct current stimulation: a promising alternative for the treatment of major depression? Rev Bras Psiquiatr, 2009, 31: 34–38. [Medline] [CrossRef]
15) Nitsche MA, Doemkes S, Karakose T, et al.: Shaping the effects of transcranial direct current stimulation of the human motor cortex. J Neurophysiol, 2007, 97: 3109–3117. [Medline] [CrossRef]
16) Fregni F, Boggio PS, Mansur CG, et al.: Transcranial direct current stimulation of the unaffected hemisphere in stroke patients. Neuroreport, 2005, 16: 1551–1555. [Medline] [CrossRef]
17) Hummel F, Wu CW, Floel A: Improvement of skilled motor functions in elderly healthy volunteers by cortical stimulation. Neuroimage, 2004, 22: S29.
18) Hummel F, Celnik P, Giraux P, et al.: Effects of non-invasive cortical stimulation on skilled motor function in chronic stroke. Brain, 2005, 128: 490–499. [Medline] [CrossRef]
19) Hummel FC, Voller B, Celnik P: Effects of brain polarization on reaction times and pinch force in chronic stroke. BMC Neurosci, 2006, 7: 73. [Medline] [CrossRef]
20) Tanaka S, Takashi H, Manabu H: Enhancement o fpinch force in the lower leg by anodal transcranial direct current stimulation. Exp Brain Res, 2009, 196: 459–465. [Medline] [CrossRef]