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Original Article

The effects of exercise training using transcranial direct current stimulation (tDCS) on breathing in patients with chronic stroke patients

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Abstract. [Purpose] This study was conducted to investigate the effect of exercise training using transcranial direct current stimulation (tDCS) on breathing in patients with chronic stroke patients. [Subjects and Methods] Thirty chronic stroke patients who do not show abnormal response to electric stimulation were enrolled in this study and each 15 subjects were randomized either into the study group and the sham-controlled group. The subjects performed diaphragmatic breathing exercise for 20 minutes while tDCS device was attached to them (for study group, the device was on while for the sham-controlled group, the device was turned off 30 seconds later) [Results] The results of FVC, FEF1 and FEV1/FVC in the study group and those of FVC and FEV1 in the sham-controlled group were significantly increased after the breathing exercise. The independent comparison result between the groups showed that the breathing performance of study group significantly improved based on the results of FVC and FEV1. [Conclusion] In conclusion, the results of this study confirmed that breathing exercise effectively improved FVC and FEV1 in chronic stroke patients. Also, the breathing exercise using tDCS was more effective in improving FVC and FEV1.

Key words: Chronic stroke, Transcranial direct current stimulation (tDCS), Diaphragmatic breathing exercise

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INTRODUCTION

Hemi-paralysis caused by stroke has damaged central nerve system, in particular, cerebral cortex, premotor cortex and motor track in cerebrum[1)]. Patients with hemi-paralysis suffer various functional disorder depending on location of lesions, limited daily activities and cognitive function disorders, difficulties to exercise or change positions. Their changed muscle tone deteriorates voluntary exercise functions and causes abnormal functions of entire body[2)].

Abnormal position control and changed muscle tone negatively affects necessary exercise control that coordinates all muscles involving breathing and circulation of body and breathing muscles themselves and position control that controls the movement of thorax and maintains the strength of breathing muscles[3)]. Long-term damaged breathing functions causes functional disorders of body trunk posture and weakens breathing muscles[4)]. Decreased up-down movement of diaphragm during voluntary breathing and hyperpnea increases the strength of breathing muscles. Chronic hemi-paralysis patients have deceased vital capacity due to the weakening of breathing muscles during inhaling/exhaling and increased remaining amount of airs in the lung that lead to decreased maximum breath pressure. Moreover, the muscles involving in positions and breath-

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ings are reported to be closely related[5].

The demands for rehabilitation of patients and their families have rapidly increased and various physiotherapeutic approach have used so far. Most of central nerve system regeneration and activation methods do not result in complete regeneration but only limited[6]. Among recent physiotherapeutic approaches, many therapeutic methods based on nerve plasticity in related to regeneration ability of central nerve system started to appear with the development of science. Transcranial direct current stimulation (tDCS) is a therapeutic method to change the excitability of local area in brain by applying a 1-2mA of current on the scalp[7]. There were several previous studies including studies on the brain activation for exercise training in healthy subjects[8, 9], and spinal network stimulations[10]. And its efficacy and safety has been proved in various studies on cardiovascular system, automatic functions and safety and efficacy using a tDCS[11, 12]. Most of studies, however, have been limited to limb or cognitive functions. As such, this study was conducted to investigate the effect of tDCS on breathing, a primary concern of the recovery for stroke patients.

SUBJECTS AND METHODS

Thirty patients who had stroke more than six months before and currently are hospitalized were enrolled between June to July 2016. They had no abnormality in pulmonary, cardiovascular system or adverse reaction to electric stimulation before their brain injury. The study methods were sufficiently explained to all patients based on Declaration of Helsinki before the participation. Those who understood the contents and purpose of this study and voluntarily agreed to participate in this study were enrolled. The subjects were randomized into either the study or sham-controlled group (15 subjects in each group).

For the application of tDCS, a Phoresor II Auto PM850 (IOMED®, Salt Lake City, USA) was used. To stimulate primary motor cortex of damaged side, anode was attached to C3 and C4 based on international 10–20 system and cathode was placed supraorbital area of other side. A 5 × 7 (35 cm^2) sized sponge electrodes were used to attached on the scalp. The electrodes were soaked in 0.9% normal saline beforehand and were closely attached to the skin as possible using a band to give comfortable feelings to patients[13]. A spirometer (MicroQuark Italy Cosmed) was used to measure forced vital capacity (FVC), forced expiratory volume at one second (FEV1) and forced expiratory ratio (FEV1/FVC). The results of this study were analyzed using a SPSS 18.0 for windows for statistical analysis. An independent t-test was used to evaluate the efficacy analysis before and after the treatment and a paired t-test was performed to compare the difference between the groups. The significant level was 0.05.

RESULTS

The general characteristics results of the subjects did not show any significant difference between the groups (Age: tDCS group 57.1 ± 13.7 years, Sham-tDCS group 56.4 ± 14.7 years; Height: tDCS group 163.9 ± 8.9 cm, Sham-tDCS group 165.2 ± 8.8 cm; Weight: tDCS group 68.2 ± 8.5 kg, Sham-tDCS group 67.40 ± 9.6 kg).

The vital cavity results of FVC, FEV1 and FEV1/FVC showed effective results in the study group while those of FVC and FEV1 showed effective in the sham-controlled group when the figures before and after the breathing exercise with tDCS were compared (Table 1). The results of FVC and FEV1 showed significantly higher in the study group than that of sham-controlled group when the groups were compared (Table 1).

DISCUSSION

Previous studies have been focused on the activation of cerebrum cortex in stroke. Schlaug et al.[14] reported that conventional methods to activate cerebrum cortex with the use of tDCS bring synergic therapeutic effect and repetitive movement training is required[15]. This study investigated the breathing performance when tDCS was applied with breathing exercise out of clinical methods for cerebrum cortex activation in many recent studies.

In general, chronic stroke patients have lower maximum breath pressure than healthy people by 21%. Decreased breathing ability causes much fatigue when a patient performs daily activities or functional movement[4], The fatigue, in turn, causes imbalanced breathing and changed breathing control pattern due to increased sensitivity to carbon dioxide and decreased

Table 1. Comparison of the respiratory effects before and after the experiment

	tDCS group (n=15)			Sham-tDCS group (n=15)		
	Before	After		Before	After	
FVC (L)	2.3 ± 0.6	2.6 ± 0.6*	0.3 ± 0.1	2.5 ± 0.6	2.6 ± 0.6*	0.1 ± 0.0¥
FEV1 (L)	2.1 ± 0.5	2.3 ± 0.6*	0.2 ± 0.2	2.2 ± 0.6	2.2 ± 0.6*	0.0 ± 0.0¥
FEF (L)	5.5 ± 2.1	6.0 ± 2.3	0.4 ± 1.1	5.7 ± 2.6	5.8 ± 0.5	0.1 ± 0.6
FEV1/FVC (%)	92.5 ± 5.7	89.8 ± 6.0*	2.6 ± 5.3	87.2 ± 5.5	86.2 ± 5.7	0.9 ± 3.3

Value are Mean ± SD. Paired t-test: *$p<0.05$, Independent t-test: ¥$p<0.05$

voluntary breathing in the paralyzed side[16]. Adequate maintenance of pulmonary volume and capacity as well as enlargement of thoracic wall and ventilations should be used to resolve this[17].

J. Kim et al. reported that thoracic resistance exercise, diaphragmatic breathing exercise through thoracic mobility exercise and proprioceptive neuromuscular palpitation resulted in significant change in FVC, FEV1 and MVV results in their study[18]. Britto et al. reported in their study on the strength of breathing muscles that resistant breathing exercise using a device significantly strengthened the breathing muscles and endurance[19]. Sartori et al. reported that feedback breathing exercise significantly increased the result of FEV1 in patients with fibrous cysts[20]. Other studies also reported that breathing exercise effectively strengthened diaphragms and involving breathing muscles and improved posture control and daily activities[21]. These positive results of previous studies are in line with the result of this study that showed the breathing exercise improved FVC and FEV1 results as in breathing abilities in both study and sham-controlled groups in patients with chronic stroke.

Jeffry et al. (2007) reported that tDCS activated motor evoked potentials from the activation of the motor cortex of lower limbs in the brain in patients with stroke[22]. Madhavan et al. also reported that tDCS could stimulate primary motor cortex to increase the excitability of corticospinal tract[23]. Nitche et al., however, reported that tDCS could activate cerebrum cortex one hour or more while no change on corticospinal tract that connects to the peripheral areas[24]. The result of this study confirmed that the study group more effectively improved the results of FVC and FEV1 than sham-controlled group did when the results were compared before and after the use of tDCS.

The positive exercise training process observed in this study was considered from effective activation of brain by tDCS. Many previous studies, however, have reported that the activation via tDCS is limited up to one hour and because of that, treatment program may need to be modified in various ways. The breathing exercise with the use of tDCS is expected to be effective in posture control not only limited to breathing performance and more studies should be performed in the future.

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