Effect of application of transcranial direct current stimulation during task-related training on gait ability of patients with stroke

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Abstract. [Purpose] The objective of this study was to determine the effect of transcranial direct current stimulation (tDCS) during task-related training (TRT) on the gait ability of patients with chronic stroke. [Subjects and Methods] The participants were 24 patients who were diagnosed with hemiplegia due to stroke. Three groups were created: subjects who performed TRT for general exercise therapy (TRT), subjects who received sham tDCS during TRT for general exercise therapy (TST), and subjects who received tDCS during TRT for general exercise therapy (TT). [Results] The stance phase symmetry profile, the swing phase symmetry profile, and gait velocity all decreased significantly in the TT group compared with the TRT group. However, there was no significant difference in the step length symmetry profile among the groups. [Conclusion] A application of tDCS, that affects the excitatory regulation in the cortical motor area, is an effective rehabilitation method for gait improvement.

Key words: Gait, Hemiplegia, Transcranial direct current stimulation

INTRODUCTION

Forty percent of patients with stroke have moderate functional damage after onset1), and their clinical symptoms are disorder in consciousness, senses, language, cognition, and movement. In particular, their gait abilities are limited because of disorder in movement2). It was reported that task-specific training is more effective than traditional training methods at improving the gait ability of patients with stroke3).

Task-related training (TRT) effectively provides patients with a variety of sensory stimulations and functional activities and consists of tasks that help improve the performance of daily living activities4).

As another alternative to improve functional activities of patients with stroke, invasive and non-invasive nerve-stimulation methods that help regulate the imbalance of excitability in the cerebral cortex of the damaged brain after brain lesions have been actively studied5). Transcranial direct current stimulation (tDCS) is a non-invasive method of brain stimulation, and it has recently been highlighted as a method of rehabilitation after brain lesions6). tDCS increases or decreases activation in the cerebral cortex by applying a weak direct current supplied by two electrodes placed on the scalp7).

Experimental studies of cortical stimulation in stroke models have reported that a combination of tDCS and rehabilitation has a positive effect on the combination of peripheral activities and central stimulation8). Most human studies have investigated the effect of a single stimulation of tDCS on upper extremities, and only a few studies have investigated the combination of a stimulation of excitability in the cerebral cortex and rehabilitation therapy.

Therefore, this study determined the effects of application of tDCS during TRT on the gait ability of patients with chronic stroke, to provide basic data for rehabilitation programs aiming to improve gait ability.

SUBJECTS AND METHODS

From among 267 patients who were admitted to C Rehabilitation Hospital in Gwang-ju City, this study selected 24 patients who were diagnosed with hemiplegia due to stroke. A total of 243 patients were excluded for the following reasons: 66 were not diagnosed with hemiplegia, 36 could not walk, 48 were within six months of onset, 5 wore a pacemaker, 40 had a modified Ashworth scale (MAS) score below 2, 38 had osteoarthritis, and 6 were discharged from the hospital. The characteristics of the study subjects are presented in Table 1. All subjects were informed about the experimental procedures and provided their voluntary consent to participation. This study was ethically permitted by the hospital. The subjects performed 30 minutes of training per day, three times per week for four weeks. The subjects...
were randomly assigned to one of three groups: those who performed TRT for general exercise therapy (TRT), those who received sham tDCS during TRT for general exercise therapy (TST), and those who received tDCS during TRT for general exercise therapy (TT).

A gait analyzer, GAITRite (SMS Technologies Ltd., Elizabeth Way, Harlow Essex, UK), was used to record the temporal and spatial gait characteristics of the subjects. The collected information was processed using GAITRite GOLD, version 3.2b software. Subjects practiced the tasks once before three measurements trial, the results of which were used in the analysis.

The TRT group performed the following six training methods for weight support ability improvement and stepping strategy, as proposed by Carr and Shepherd4) and modified in 2004: (1) lifting and maintaining the lower extremity; (2) lifting the heels; (3) lifting the lower extremity over the footstool followed by lowering; (4) lifting the lower extremity and lowering onto a footstool; (5) walking back and forth over a 3-m distance to a chair; and (6) going back and forth at a constant pace over 10-m distance. The tasks were conducted one-on-one with a physical therapist10).

For tDCS, a direct current stimulator (Phoresor II Auto Model PM850IOMED, Salt Lake City, USA) certified by the U.S. Food and Drug Administration which could be adjusted in 0.1mA increments was used. The electrode attachment followed the international 10–20 system. The anode was installed over Cz area of the left parietal lobe, and the cathode was installed at the right upper orbit. The stimulation current was 2 mA, and the application time was 15 mins during TRT12). The intervention was carried out 12 times for 30 minutes a day and 3 times a week, 4 weeks.

All data of the subjects were quantified and recorded. The symmetry profiles of the stance and swing phases (temporal gait) and the step length symmetry profile (spatial gait) was calculated using data recorded on the GAITRite system. SPSS Version17.0 for Windows® was used to calculate averages and standard deviations and analysis of covariance was used to analyze the differences between groups after the experiment. The statistical significance level was chosen as α = 0.05.

### RESULTS

All groups showed improvements in gait velocity, stance phase symmetry profile, and swing phase symmetry profile, with the TRT group and TT group showing significant improvements (p<0.05) for all items. All groups also showed a decrease in the step length symmetry profile, but there were no significant differences among the groups (p=0.43) (Table 2).

### Table 1. Characteristics of the subjects

| Characteristic                  | TRT group (n = 8) | TST group (n = 8) | TT group (n = 8) |
|---------------------------------|-------------------|------------------|-----------------|
| Age (years)                     | 61.6 (15.8)a      | 57.7 (10.0)      | 59.0 (6.0)      |
| Height (cm)                     | 162.1 (9.4)       | 165.4 (7.0)      | 167.6 (8.9)     |
| Weight (kg)                     | 63.9 (8.4)        | 65.8 (10.7)      | 67.1 (8.7)      |
| Prevalence (months)             | 15.3 (8.4)        | 22.5 (14.5)      | 23.8 (16.2)     |
| Paretic side (Rt/Lt)            | 5/3               | 4/4              | 3/5             |
| Etiology (hemorrhage/infarction)| 1/7               | 3/5              | 4/4             |

*a Means (SD)  
TRT: Task-related training group, TST: Task-related training + sham transcranial direct current stimulation group, TT: Task-related training + transcranial direct current stimulation group

### Table 2. Gait parameters of the subjects

|                          | TRT group (n = 8) | TST group (n = 8) | TT group (n = 8) |
|--------------------------|-------------------|------------------|-----------------|
|                          | Pre-test          | Post-test        | Pre-test        | Post-test    | Pre-test | Post-test |
| **Temporal gait parameters** |                   |                  |                 |             |         |           |
| Velocity (cm/s)*         | 68.3 (27.8)a      | 64.7 (26.8)      | 55.3 (23.7)     | 47.6 (19.2)  | 59.3 (25.2) | 48.7 (22.8) |
| **Spatial gait parameters** |                   |                  |                 |             |         |           |
| Stance phase symmetry profile (%)* | 0.2 (0.1)     | 0.2 (0.1)        | 0.2 (0.1)       | 0.2 (0.08)  | 0.2 (0.1) | 0.1 (0.1) |
| Swing phase symmetry profile (%)* | 0.4 (0.2)        | 0.4 (0.2)        | 0.4 (0.2)       | 0.4 (0.2)   | 0.4 (0.2) | 0.4 (0.1) |
| Step length symmetry profile (%) | 0.2 (0.2)       | 0.2 (0.2)        | 0.2 (0.1)       | 0.2 (0.1)   | 0.2 (0.2) | 0.1 (0.2) |

*a Means (SD)  
** Significant difference between TT group and TRT group (p<0.05)
TRT: Task-related training group, TST: Task-related training + sham transcranial direct current stimulation group, TT: Task-related training + transcranial direct current stimulation group
This study aimed to determine the effect of tDCS during TRT on the gait ability of patients with stroke, to establish its applicability in rehabilitation programs for gait ability improvement.

Various exercise conditions are presented to patients with stroke to help them use the optimal strategy for solving motion problems and achieving functional proficiency. In addition, active learning is meaningful for solving problems assigned as functional tasks, with practical tasks being more useful than abstract tasks.

Theilmann et al. emphasized the importance of providing goal-directed training, which consists of meaningful functional tasks which involve functional motions. Their study results are consistent with the results if our present study, and they showed that performing functional tasks rather than simple muscle strengthening led to significant improvements in gait. Hummel et al. used tDCS to stimulate the M1 receptor of patients with chronic stroke twice per day for 10 days and reported that the performance time was improved (11.75% + 3.61%). Also, when normal persons received the same treatment, they showed an improved performance time (10.96% + 2.75%) too, indicating that repeated tDCS for a short time during TRT can elicit behavioral effects because of the efficiency of the training.

The recovery of symmetry in gait elements of patients with stroke is very important for the success of the physical therapy. A general problem found with gait abilities of stroke patients is the asymmetric and rapid transfer of the center of gravity to the non-paralyzed side because of the instability of the paralyzed lower extremity. As a result, the stance phase of the paralyzed side and the swing phase of the non-paralyzed side become shorter, reducing the step length. Furthermore, gait velocity becomes slower. In this study, reductions in the swing phase symmetry profile, the stance phase symmetry profile, and velocity were found in the TT group which were significant when compared with the TRT group (p<0.05). These results indicate that both the paralyzed and non-paralyzed sides showed improvements in the time and ratio of the gait cycle together with an increase in gait velocity, thus improving the swing and stance phase symmetry profiles, as suggested by previous studies. Therefore, the improvement in velocity was due to improvement in the symmetry of gait of the subjects’ paralyzed and non-paralyzed sides, indicating that tDCS during TRT is effective at improving the gait ability of patients with stroke.

Based on this result, the application of iDCS during TRT is an effective rehabilitation training method, and this study has provided basic data to support such a conclusion. However, the number of subjects, 24 was small; therefore, the results cannot be generalized to all patients with hemiplegia due to stroke. In addition, the consistency of the effect of the training was not verified. Therefore, these two limitations should be addressed in future studies.

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