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Research paper

Effects of transcranial direct current stimulation over the supplementary motor area body weight-supported treadmill gait training in hemiparetic patients after stroke

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ABSTRACT

Transcranial direct current stimulation (tDCS) is used in a variety of disorders after stroke including upper limb motor dysfunctions, hemispatial neglect, aphasia, and apraxia, and its effectiveness has been demonstrated. Although gait ability is important for daily living, there were few reports of the use of tDCS to improve balance and gait ability. The supplementary motor area (SMA) was reported to play a potentially important role in balance recovery after stroke. We aimed to investigate the effect of combined therapy body weight-supported treadmill training (BWSTT) and tDCS on gait function recovery of stroke patients. Thirty stroke inpatients participated in this study. The two BWSTT periods of 1 weeks each, with real tDCS (anode: front of Cz, cathode: inion, 1 mA, 20 min) on SMA and sham stimulation, were randomized in a double-blind crossover design. We measured the time required for the 10 m Walk Test (10MWT) and Timed Up and Go (TUG) test before and after each period. We found that the real tDCS with BWSTT significantly improved gait speed (10MWT) and applicative walking ability (TUG), compared with BWSTT + sham stimulation periods ($p < 0.05$). Our findings demonstrated the feasibility and efficacy of tDCS in gait training after stroke. The facilitative effects of tDCS on SMA possibly improved postural control during BWSTT. The results indicated the implications for the use of tDCS in balance and gait training rehabilitation after stroke.

1. Introduction

Noninvasive brain stimulation (NIBS) such as transcranial direct current stimulation (tDCS) is reportedly effective for the treatment of paralysis after stroke [1]. tDCS is used in a variety of disorders including upper limb paralysis [2], hemispatial neglect [3], aphasia [4], and apraxia [5], and its effectiveness has been demonstrated. However, there are few reports on the use of tDCS in improving balance and gait ability after stroke [6,7], which are important for activities of daily living [8].

Some intervention studies used tDCS to improve lower limb functions and to treat balance and gait disorders. The use of anodal tDCS on the lower leg motor area enhanced knee extension force [6], postural stability, and lower extremity strength [7] of stroke patients and promoted positive changes in static balance and gait velocity in children with cerebral palsy [9] and patients with Parkinson disease [10]. In these studies, tDCS was applied over the lower limb region of the primary motor area (M1) to examine the effects on lower limb motor function and gait ability. The M1 area in the cerebral cortex plays a role in voluntary movement of the lower limbs, and therefore, balance and gait. Meanwhile, the premotor area and supplementary motor area (SMA) play a role in planning and adjustment of gait movement [11]. Specifically, the SMA plays an important role in the recovery of balance and walking ability and anticipatory postural adjustment, which is important for maintaining balance during walking [11].

tDCS is also reportedly effective in combination with other therapies [10]. Studies in post-stroke patients have combined therapy with tDCS stimulation over the upper limb region of the M1 and constraint-

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induced movement therapy as well as robotic training for upper limb paralysis [12]. tDCS stimulation over the inferior parietal gyrus has also been combined with prism adaptation therapy for hemispatial neglect [13] and speech therapy for aphasia [14]. Robotic gait training in combination with tDCS was used and investigated as therapy to improve the walking ability of stroke patients [15].

Body weight–supported treadmill training (BWSTT), a new method for treatment of gait disturbance after stroke has been also used and has been effective for improving walking speed and asymmetrical posture during walking [16].

Thus, we surmised that the combined use of BWSTT and tDCS over the SMA would enhance the improvement in gait recovery after stroke. This study aimed to clarify the effects of combined therapy with tDCS and BWSTT in hemiparetic patients after stroke on improvement in walking ability.

2. Materials and methods

This is a double-blind, randomized crossover comparative study of post-stroke hemiparetic patients in a rehabilitation hospital. The inclusion criteria were new-onset supratentorial lesion and a gait disorder, ability to walk 20 m with supervision or slight assistance, and ability to undergo BWSTT. The exclusion criteria were orthopedic/systemic diseases that limit exercise therapy, severe dementia/higher brain dysfunction with difficulty understanding directions, implanted metal in the head or implanted cardiac pacemaker, and difficulty undergoing BWSTT, as judged by the physician in charge.

Of the 262 patients recruited, 224 were excluded. Of the 38 remaining subjects, 30 consented to participate. The subjects (age, 45–79 years) included 21 men and 9 women and were divided into two groups (groups A and B, n = 15 in each group). Two intervention periods were set, and the pre- and post-intervention periods were determined in each group for evaluation. The interval between intervention periods was 3 days, and evaluations were carried out the day after each final intervention day. During each intervention period, real or sham tDCS stimulation was performed. In group A, tDCS (real stimulation) and BWSTT were performed during the first period, whereas sham stimulation and BWSTT were performed during the second period. In group B, the intervention was performed by switching the order of stimulation (real/sham) combined with BWSTT (Fig. 1).

In the intervention periods, tDCS was applied using a DC stimulator (NeuroConn GmBH, Ilmenau, Germany) and two saline-soaked electrodes (5 × 5 cm). The anode electrodes was positioned 3.5 cm anterior to Cz according to the International 10/20 EEG System [17]. The cathode was positioned over the inion [18,19]. Stimulation was performed at 1.0 mA for 20 min during BWSTT. The real/sham stimulation was set by entering a password, which prevents the subjects/persons performing the intervention from knowing the type of stimulation applied. BWSTT was performed once a day for 20 min for a period of 1 week. Subjects walked on a treadmill with 20% body weight support. The walking speed was gradually increased by setting it at 80%–90% of the subject's maximum on the treadmill, which was determined based on the difficulty in walking continuously, self-estimation, and foot dragging. Physical assistance was avoided during BWSTT.

The 10 m Walk Test (10MWT) and Timed Up and Go Test (TUG) were the primary evaluation items. Measurements were performed twice and we used the average score as the representative value for the statistical analysis. The secondary evaluation items were the Fugl-Meyer Assessment of the Lower Extremity, Performance Oriented Mobility Assessment, and Trunk Impairment Scale. The differences in basic and clinical characteristics in each group were analyzed using the *t*-test, Mann-Whitney test, and chi-square test. Two-way repeated measures analysis of variance (ANOVA) was performed, using time required for the walk tests (10MWT and TUG) and scores of evaluation items during the pre- and post-intervention periods as dependent variables after confirming normality of variables by Shapiro-Wilk test. Groups and intervention periods were the factors used to test the presence or absence of the main effect as well as interactions among factors. When a main effect and interaction were present, a simple main effects test was performed using Bonferroni's post hoc analysis. p Values < 0.05 were considered statistically significant. Statistical analyses were carried out using SPSS statistics 23 (IBM Inc., Armonk, NY, USA).

This study was approved after ethics review by Tokyo Metropolitan University and Saitama Misato Sogo Rehabilitation Hospital. We explained the study details to the subjects orally and in writing and they provided signed consent. We performed tDCS according to safety standards and guidelines.

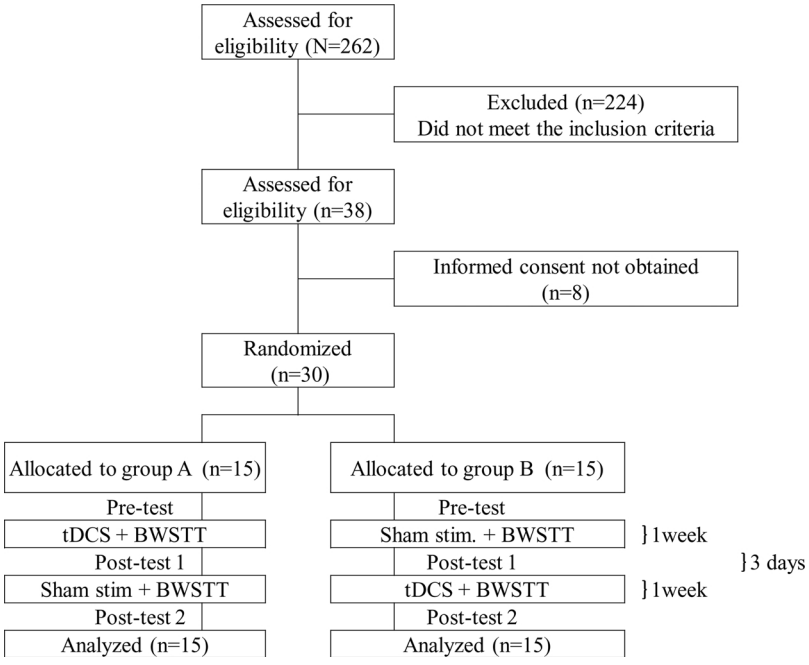

Fig. 1. Flowchart of patient participation and study.