# ACUTE EFFECTS OF HIGH-DEFINITION TRANSCRANIAL DIRECT CURRENT STIMULATION ON DYNAMIC POSTURAL STABILITY IN A Y-BALANCE TASK

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Purpose: The present study aimed to investigate whether anodal transcranial direct current stimulation (a-tDCS) of the primary motor cortex (M1) could affect dynamic postural stability in healthy young adults. Methods: A randomized, crossover, double-blind experimental design was used in this study. Effects of tDCS on dynamic postural stability were assessed baseline and immediately after tDCS. Results: a-tDCS of M1 significantly decreased the COP of medial-lateral displacement on the posteromedial and posterolateral direction, and path length on the posteromedial direction in the Y-balance, while no significant changes in the sham tDCS (s-tDCS) condition. Conclusion: This study provided evidence that a-tDCS enhanced dynamic postural stability in healthy young adults.

**KEYWORDS:** high-definition transcranial direct current stimulation; dynamic postural stability; center of pressure.

**INTRODUCTION:** The dynamic postural stability will affect the sports performance and increase the probability of injury (M & Puckree, 2014). Dynamic postural stability is a complex mechanism derived from the coordination and synergy between nervous and musculoskeletal systems. Transcranial direct current stimulation (tDCS) which can directly affect the neurophysiological parameters of the central nervous system (i.e., the excitability of the cerebral cortex), has attracted the attention of many researchers and was introduced to the field of sports science. Studies have given evidence that a-tDCS can have a positive effect on improving sports performance, such as postural stability. The primary motor cortex (M1) is important in postural stabilization, which was included in the frontal cortico-basal ganglia network. Neuroimaging studies showed that the motor cortex has strong connectivity with the other brain regions such as the cerebellum via the thalamocortical projections (Lang et al., 2015). At present, the target area of tDCS protocol is mostly concentrated in the cerebellum, and most of the participants are elderly or people with balance dysfunction. So far, the effect of M1 a-tDCS on the dynamic postural stability of healthy adults in the dynamic balance task remains unclear. The Y-balance is considered to better reflect functional activity over other postural control tasks because it combined muscle strength, flexibility, and neuromuscular control while assessing the limits of postural stability (Hoch et al., 2016). Therefore, this study aimed to explore the effect of M1 a-tDCS on the dynamic postural stability in the Y-balance task in healthy adults. We hypothesized the center of pressure displacement was significantly decreased in the Y-balance task after the a-tDCS.

**METHODS:** A total of 12 male adults (age=25.9±1.5 yrs; height=175.6±6.9 cm; weight=72±17.8 kg) were recruited in this study. Inclusion criteria were male adults who without a history of lower limb injuries in the last 6 months and metal in the head, pacemaker (Woods et al., 2016), without the experience of Y-balance task training or assessment. All of them were right-leg dominant as checked by asking participants to kick the ball. Exclusion criteria included

any history of neurological diseases and psychological illnesses; receipt of electrotherapy that might affect the nervous system in the two weeks before the study; the use of any sedative medicines in the two days before the study. The study procedures were approved by the Institutional Review Board of the Shanghai University of Sport (No.102772021RT035).
A randomized, crossover, double-blind experimental design was used in this study. Participants were allocated to either a-tDCS or sham tDCS (s-tDCS) conditions with a randomization list that was prepared before testing. This study consisted of two visit sessions that were at least separated by 3 days. On the first visit session, participants were either received 20 min of a-tDCS or s-tDCS according to the randomization list. Participants were asked to perform a Y-balance task after 20 minutes of tDCS. On the second visit session, another type of stimulation (a-tDCS or s-tDCS) was applied, and a Y-balance test was performed. None of the participants knew whether a-tDCS or s-tDCS was applied. The tDCS was delivered by an electrical stimulator (Starstim, Spain) through a constant-current unit connected to the electrodes (3.14 $cm^2$ electrodes), an anodal electrode on the scalp over the Cz and the return electrode on the C3、C4、Fz、Pz (10/20 EEG system), respectively. During a-tDCS, a continuous current (2 mA) was applied for 20 min. The s-tDCS consisted of 60 s of current at 2 mA. In both a-tDCS and s-tDCS, the current was ramped up and down over 30s at the start and end of the stimulation to prevent electrical transients (Nitsche et al., 2008). The participants were asked to wear the same shorts provided by the experimenters. After the warm-up for 5 min, participants were shown a video that illustrated the goals and requirements of the Y-balance task (Roberto et al., 2016). All participants were positioned in the middle of the force platform with barefoot and verbally instructed to push the “reach indicator” block as far as possible with the left limb in the anterior, posterolateral, and posteromedial directions while maintaining a single limb stance with their hands on their hips. Then, they were instructed to perform 3 trials on the force plate, 1-min resting periods were provided between trials. The ground reaction force (GRF) was measured using one 3D force plate (9287C, Kistler Corporation, Switzerland) at a sampling rate of 1000 Hz.
Descriptive statistics including mean and standard deviation were calculated for all dependent variables. Shapiro–Wilk test was used to examine if the outcomes were normally distributed. A 2 (stimulation condition: sham, anodal) x 2 (time: pre, post) repeated measures ANOVA (Version 22.0; SPSS, Inc., Chicago, IL, USA) examined the effect of tDCS on maximum reaching distance, COP displacement and average velocity, and kinematic and kinetic variables (to determine the main effect of stimulation condition, time, and interaction of stimulation condition × time). We applied the least significant difference (LSD) for multiple comparisons when the significant interaction effects were observed. The significance level was set as α = 0.05.

**RESULTS:** The two-way ANOVA revealed no significant interaction for reaching distance in the anterior, posteromedial, and posterolateral directions. In addition, no significant main effects of time and stimulation conditions were observed for the above outcomes in the three directions (Table 2).

**Table 2 The distance and movement-phase in different directions of the Y-balance task**

| Variable | | | a-tDCS | s-tDCS | Interaction (intervention × time) | Time (pre vs. post) | Intervention (a-tDCS vs. s-tDCS) |
|---|---|---|---|---|---|---|---|
| Reaching distance (%) | ANT | pre | 76.3±4.7 | 76.1±4.9 | 0.460 | 0.656 | 0.835 |
| | | post | 76.1±3.1 | 76.9±5.6 | | | |
| | PM | pre | 118.1±8.9 | 118.9±9.1 | 0.468 | 0.628 | 0.969 |
| | | post | 118.4±11.5 | 117.2±11.8 | | | |
| | PL | pre | 130.8±7.2 | 132.2±7.8 | 0.207 | 0.854 | 0.988 |
| | | post | 132.1±6.2 | 130.6±7.1 | | | |

Note: a-tDCS, anodal transcranial direct current stimulation; s-tDCS, sham transcranial direct current stimulation; ANT, anterior direction; PM, posteromedial direction; PL, posterolateral direction.

Anterior direction: No significant interaction was observed on the $COP_{AP}$ (COP of anterior-posterior) displacement, $COP_{ML}$ (COP of medial-lateral) displacement, and path length. Two-way ANOVA reported that $COP_{AP}$ displacement, $COP_{ML}$ displacement, and path length were significantly decreased after tDCS, regardless of the type of stimulation.
Posteromedial direction: No significant interaction was observed on the $COP_{AP}$ displacement. Two-way ANOVA indicated a significant interaction effect on $COP_{ML}$ displacement and path length. Post-hoc analysis demonstrated a-tDCS significantly decreased the COPML displacement ($p$=0.001) and path length ($p$=0.002), s-tDCS did not significantly change the $COP_{ML}$ displacement and path length (Fig 1A&B).
Posterolateral direction: No significant interaction was observed on the $COP_{AP}$ displacement and path length. A significant interaction effect was observed on $COP_{ML}$ displacement. Post-hoc analysis demonstrated that compared with baseline the $COP_{ML}$ displacement was significantly decreased after a-tDCS ($p$=0.001), there was no significantly changed on $COP_{ML}$ displacement after s-tDCS ($p$=0.455, Fig 1C).

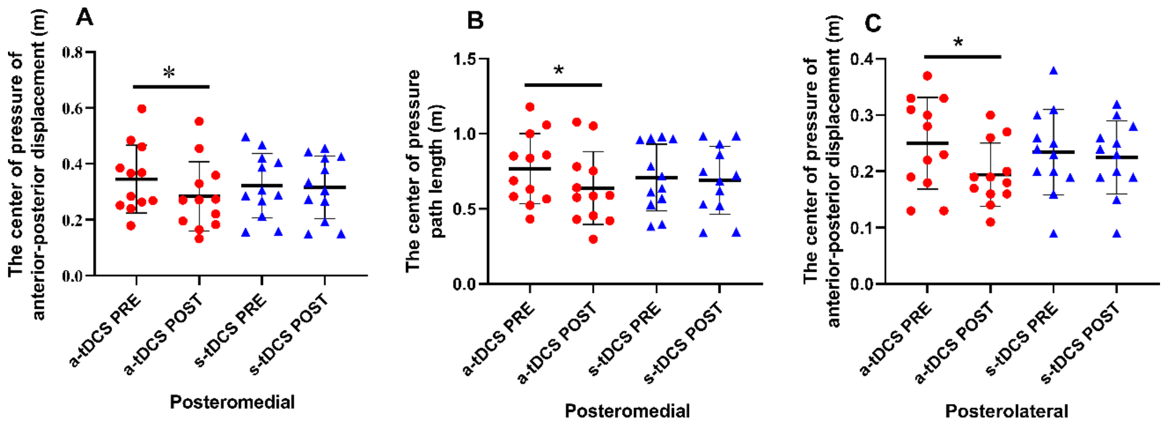


**Figure 1 The center of pressure sway on the posteromedial direction (A&B) and posterolateral direction (C). a-tDCS, anodal transcranial direct current stimulation; s-tDCS, sham transcranial direct current stimulation; *$p$ < 0.05.**

## DISCUSSION:

COP represents a weighted average of all the pressures over the surface of the area in contact with the ground, which reflects the result of the neuromuscular control. The reduction in the COP displacement after a-tDCS may help reduce the cost of postural control and the risk of imbalance. Kaminski et al. (2016) reported that M1 a-tDCS promotes balance (longer time in balance and smaller error scores) performance in a dynamic balance task. Meanwhile, Sohn et al. (2013) found a-tDCS could significantly improve the dynamic stability index with eyes opened and closed. With similar results, this study found that the $COP_{ML}$ displacement and path length was significantly reduced after a-tDCS. The reduction of the COP displacement reflects the improvement of the dynamic postural control ability. Previous studies have shown that postural control involves several brain structures, in particular, the cortico-basal ganglia network which includes the M1. In addition, better postural control was correlated with the larger volume of the primary and secondary motor cortices, olfactory bulb, medulla, and frontal association cortex (Surgent et al., 2019). As a-tDCS in the M1 area could increase the excitability of the cortex and improve the functional connectivity of the cortico-basal ganglia network. Moreover, a-tDCS can improve the connectivity between M1 and supplementary motor area (Polanía et al., 2012), functional coupling between the left thalamus and the ipsilateral primary motor cortex (Machado et al., 2019). It would logically follow that a-tDCS improved the efficiency of these circuits which is associated with postural stability. However, we did not observe the phenomenon that the reach distance of Y-balance after a-tDCS. The Y-balance task was developed from the star balance test and evaluates the dynamic stability while performing movements in the anterior, posterolateral, and posteromedial directions. The performance of Y-balance was influenced by a combination of the range of motion, flexibility, neuromuscular control, and muscle strength (Fullam et al., 2014). Moreover, as reported in previous studies, “ceiling effects” may have been present in young and healthy adults who have the good muscle strength and proprioceptive function. This may be the reason why no significant change in the reach distance of the Y-balance has been observed. In brief, the improvement of dynamic postural stability might improve the sports performance of athletes. This study has found that a-tDCS could significantly improve postural stability in healthy young adults, and it could be applied to athletes in the future to explore the effect of a-tDCS on athletes' dynamic postural stability and sports performance.

**CONCLUSION:** The present study demonstrated that a-tDCS of M1 significantly decreased the COP displacement on the posteromedial and posterolateral direction in the Y-balance task, while no significant changes in the s-tDCS condition. This study provides preliminary evidence that a-tDCS could enhance dynamic postural stability in healthy male adults.

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