Effects of Transcranial Direct Current Stimulation over the Motor Cortex on Isometric Rate of Force Development in Healthy Adults

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Abstract

Previous studies have demonstrated that transcranial electrical stimulation can modulate motor performance with regards to peak force and acceleration. However, no study has yet explored the effects of tES on peak rate of force development.

In the present randomized, double-blind, sham-controlled study, 33 right-handed participants completed isometric lateral pinches during and after receiving 15 minutes of real or sham stimulation to the primary motor cortex. Use of real tDCS significantly improved peak rate of force development both during and after stimulation compared to sham. However, neither peak force nor EMG amplitude were similarly modulated by tDCS. These results provide support for tDCS modulating the coordination of neural output to increase peak rate of force development in healthy individuals.

1. Introduction

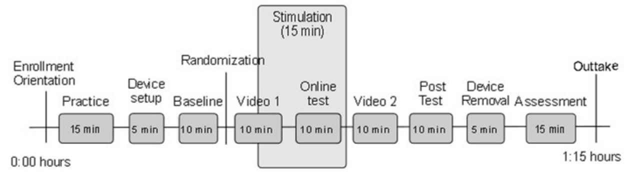
Efficient motor function is crucial for both everyday tasks and athletic performance. While research into motor performance has traditionally focused on biomechanics, it is equally important for optimal motor performance that the central nervous system provides appropriately strong and well-coordinated neural signals to the muscles [1]. These signals, known as the neural drive, control the recruitment of motor units and therefore have a fundamental role in force production.

Transcranial electrical stimulation has been shown to modulate motor performance, both behaviorally and biologically, particularly with regards to peak force (pF) and acceleration [2]. However, relatively little research has examined the possible effects of tES on peak rate of force production (pRFD).

Peak rate of force development is reliant on neural drive, quantifies what many athletes would call explosiveness, and is thought to predict success in athletic and real-world muscular tasks better than peak force or acceleration on their own [3]. As such, pRFD offers a metric that may be both a valuable outcome outside of the lab environment, as well as a sensitive target for neuromodulation.

In this work, we explore the possible benefits of a single session of transcranial direct current stimulation (tDCS) on pRFD and pF in a double-blinded, randomized, sham-controlled study.

2. Methods



Timeline of events Following enrollment and a practice period of 3 maximum voluntary contraction (MVC) pinches, to familiarize subjects with the task, the neurostimulation headset was set up and participants completed baseline measurements consisting of 5 MVC pinches. Adaptive randomization was then used to balance baseline performance across groups. Online test and post-test as shown above consisted of 5 MVC pinches each.

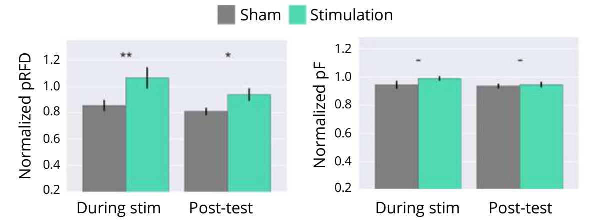
Data acquisition Left-hand pinches were recorded using a Biometrics Precision Pinch Meter P200 in lateral pinch orientation, with participant's forearm resting on the table. Participants were shown real-time feedback of their pinch force. Participants were instructed to complete each isometric lateral pinch by "pinching as hard and as fast" as they could.

EMG measurements were recorded from the left flexor pollicis longus muscle, using a Biometrics SX230 surface EMG sensor and were time-aligned with pinch force data.

Neurostimulation tDCS was provided using the Halo Sport Neurostimulation System. The stimulation group (n = 14, mean 33yo, 12/2 M/F) received 15 minutes of 2 mA stimulation with an additional 30-second ramp at the beginning and end of the stimulation session. The Sham group (n = 17, mean 37yo, 14/3 M/F) received a 30-second ramp up to 2mA followed immediately by a 30-second ramp down. In both cases, the anode was placed over the right motor cortex (C4) and the cathode was placed over the left motor cortex (C3). Electrodes were foam nibs backed by carbon

Data Analysis A Python script was used to identify pinch events and extract pF and pRFD, defined as the peak slope in the force time curve over any 10-millisecond interval in the pinch, as well as RMS power of EMG. Two participants who did not complete all pinches were excluded from further analysis. Results were aggregated and normalized to each participant's baseline performance, and were compared between and within groups using a conservative, non-parametric test (Mann-Whitney U).

3. Results



Peak rate of force development (left figure) was significantly higher in the stimulation group compared to the sham group both during stimulation (p = 0.009) and after stimulation (p = 0.03). Error bars show SEM.

Peak force (right figure) and **EMG** RMS amplitude (not shown), however, were not significantly different either during or after stimulation. Error bars show SEM.

4. Discussion and Conclusions

Results of the present study support the use of tDCS to improve peak rate of force development (pRFD).

The fact that this improvement in pRFD was seen in isolation, without simultaneous improvement in peak force (pF), might be explained by an acceleration in muscle fiber recruitment. Increased neural drive due to the tDCS intervention would recruit all motor units sooner, increasing pRFD.

However, the fact that EMG RMS amplitude also remained unchanged suggests that the increase in pRFD in this study **may have been caused by increased *coordination* of neural drive**, rather than by increased *magnitude* of neural drive.

Continued work will focus on elucidating the mechanisms behind these behavioral and biological results.

References
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