OS7- Neuromotor Facilitation

Anodal Transcranial Direct Current Stimulation over the Lower Limb Motor Cortex Increases the Cortical Excitability with Extracephalic Reference Electrodes*

Tsuyoshi Tatemoto[1], Tomofumi Yamaguchi[2], Yohei Otaka[1], Kunitsugu Kondo[1], and Satoshi Tanaka[3,**]

[1] Tokyo Bay Rehabilitation Hospital, Narashino, Chiba, Japan
[2] Keio University, Shinanomachi, Japan
[3] Nagoya Institute of Technology, Nagoya, Japan
tanaka.satoshi@nitech.ac.jp

Abstract. The aim of the present study was to investigate whether anodal transcranial direct-current stimulation (tDCS) of lower-limb primary motor cortex (M1) could increase cortical excitability when reference electrodes were placed at extracephalic positions. Ten healthy volunteers participated in this study. Anodal electrodes were placed over the left lower-limb M1, whereas reference electrodes were placed on the contralateral forehead (cephalic condition) or contralateral upper arm (extracephalic condition). Motor evoked potentials (MEPs) were recorded as a measure of cortical excitability before and after tDCS (2 mA, 10 minutes). Compared with a sham condition, MEPs significantly increased for both cephalic and extracephalic conditions, and this increase was maintained for approximately 60 minutes after stimulation. No side effects were reported. We conclude that tDCS over lower-limb M1 in conjunction with extracephalic reference electrodes can increase cortical excitability without any side effects.

1 Introduction

Transcranial direct-current stimulation (tDCS) is a non-invasive means of cortical stimulation in which weak direct current polarizes target brain regions [1]. Recently, tDCS has been shown to modify cognitive and motor functions in both healthy volunteers and neurological patients [2]. Thus, tDCS is potentially a new rehabilitation strategy for cognitive and motor deficits. However, optimal parameters of tDCS remain unclear.

One important tDCS parameter is the location of the reference electrode. When upper-limb primary motor cortex (M1) was targeted for tDCS, anodal electrodes

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** Corresponding author.

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were placed over upper-limb M1 and reference electrodes (cathodal) were placed over the contralateral forehead [1]. This arrangement increased upper limb cortical excitability [1]. However, this arrangement potentially creates unwanted changes in frontal cortex excitability under the reference electrode [3, 4]. Recently, excitability in upper-limb M1 has also been shown to increase when reference electrodes are placed over the contralateral upper arm [4]. However, whether anodal tDCS of lower-limb M1 with extracephalic reference electrodes can produce similar changes in excitability is still unknown. Resolving this issue is necessary before this method can be used to improve lower limb impairments in neurological patients.

The purpose of the present study was to investigate whether tDCS over lower-limb M1 increases cortical excitability when reference electrodes are placed on the upper arm of healthy volunteers. This study was approved by the local ethics committee of Tokyo Bay Rehabilitation Hospital.

2 Material and Methods

Ten healthy volunteers participated in three different experimental conditions. All volunteers provided written informed consent before inclusion. Conditions were performed on different days. In all conditions, the stimulation (anodal) electrode (surface area 5×7 cm^2) was always placed over left lower-limb M1. The reference electrode (surface area 5×10 cm^2) was placed on the contralateral forehead (cephalic) or upper arm (extracephalic). tDCS (2 mA) was applied for 10 minutes using a DC STIMULATOR PLUS (NeuroConn, Germany). In sham conditions, the reference electrode was placed on the contralateral forehead and tDCS (2 mA) was applied for only the first 15 seconds.

Motor evoked potentials (MEPs) of the tibialis anterior (TA) muscle were recorded as a measure of cortical excitability before and 0, 10, 30 or 60 minutes after the tDCS. MEPs were elicited using a Magstim 200 magnetic stimulator (Magstim Company, UK). At the beginning of each condition, we determined the resting motor threshold (rMT) for the right TA muscle. rMT was defined as the lowest stimulation intensity required to elicit MEPs of 100-μV peak-to-peak amplitude in five of ten trials. During test stimulation, the stimulation intensity was adjusted systematically in 10% steps of the subject's rMT, between 100% and 130% of rMT. Each stimulation intensity-level was applied 10 times.

For data analysis, a mean MEP-amplitude for each stimulation intensity-level was calculated from average peak-to-peak MEP responses. The data were normalized with respect to the MEP amplitude before tDCS. For each intensity-level, normalized data were subjected to a one-way repeated measure ANOVA with experimental condition (cephalic, extracephalic, and sham) as a factor. Post hoc tests were performed with Bonferroni correction for multiple comparisons. Significance was set at $p < 0.05$.

3 Results

No volunteers reported side effects in any experimental condition. Fig. 1 shows the change in MEP amplitude for each stimulation intensity-level. MEP amplitude increased after tDCS in both the cephalic and extracephalic reference conditions (Fig 1A-D), and was significantly larger compared to sham conditions at stimulation intensities of 120% and 130% of rMT (120%, $F(2,18) = 68.72$, $p < 0.001$; 130%, $F(2,18) = 5.78$, $p < 0.05$). Fig 2 shows the time course of changes in mean MEPs at stimulation intensities of 120% and 130% of rMT. Mean MEPs transiently increased after tDCS in both experimental reference conditions and after-effects lasted almost 60 minutes.

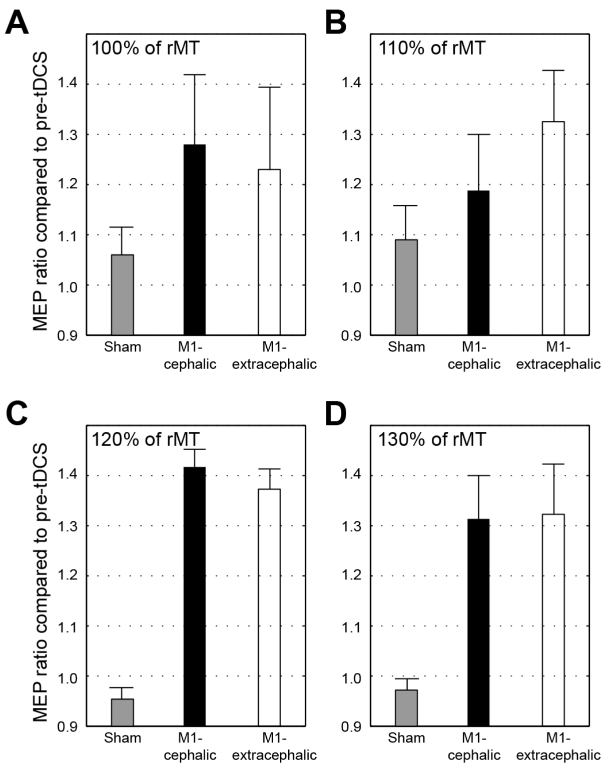

Fig. 1 Change in MEP amplitude after tDCS for each stimulation intensity. The bar graphs show the mean MEP-value 0–60 minutes after tDCS, averaged over 10 volunteers. Data were normalized with respect to the MEP amplitude before tDCS. Error bars indicate standard error.

4 Discussion

In the present study, anodal tDCS of lower-limb M1 significantly increased cortical excitability when reference electrodes were placed on the contralateral forehead. This result replicated previous findings [5]. Here, we newly show increased cortical activity without side effects after tDCS while using a reference electrode located away from the brain. Potential changes in activity under the reference electrode [3, 4] were avoided. Extracephalic reference electrodes might therefore be a more optimal arrangement for inducing changes in cortical excitability of lower-limb M1.

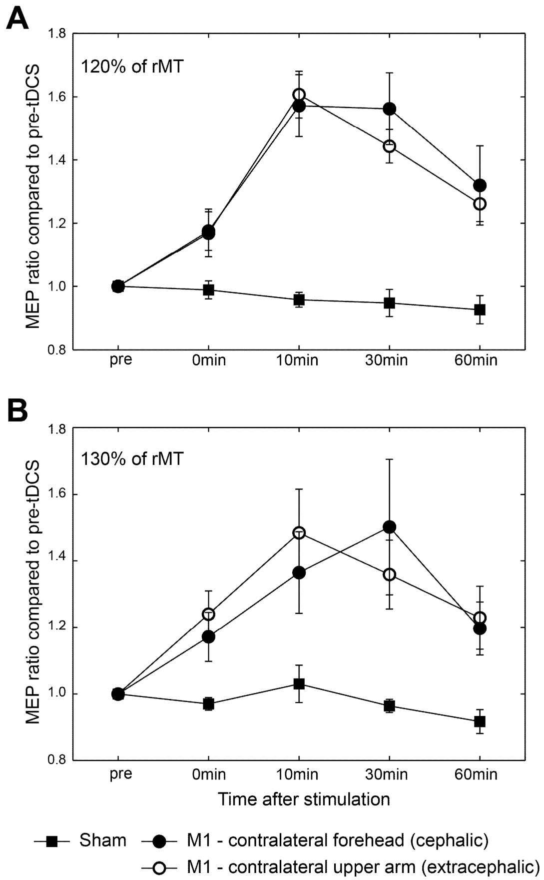

Fig. 2 Time course of increased MEP amplitudes after tDCS at stimulus intensity-levels of 120% (A) and 130% (B) of rMT. Data show the mean MEP-value at each time point, averaged over 10 volunteers. Error bars indicate standard error.

Future studies should investigate whether tDCS with extracephalic reference electrodes can change lower limb function in addition to cortical excitability.

5 Conclusion

Effective tDCS over lower-limb M1 can be performed with extracephalic reference electrodes without any side effects.

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