Brain Stimulation 12 (2019) 1309–1311

Contents lists available at ScienceDirect

Brain Stimulation

journal homepage: http://www.journals.elsevier.com/brain-stimulation

A single session of bihemispheric transcranial direct current stimulation does not improve quadriceps muscle spasticity in people with chronic stroke

Cerebral lesions following stroke cause an interhemispheric competition in the brain where the excitability of the affected hemisphere decreases and that of the unaffected hemisphere increases. This leads to a reduction of inhibitory control of spinal networks by the corticospinal tract of the affected side which in turn lead to the phenomenon of spasticity [1]. It has been found that i) bihemispheric-transcranial direct current stimulation (bi-tDCS) may reduce the interhemispheric imbalance in chronic stroke people (CSP) [2], and ii) anodal-tDCS applied over the affected leg motor cortex can alter the excitability of some spinal circuits involved in spasticity [3]. Although two studies have evaluated the acute effects of tDCS on spasticity of the upper limb [4,5], the effects of a single session of bi-tDCS on spasticity of lower limb remain to be clarified. Accordingly, we examined whether a single session of bi-tDCS could improve quadriceps spasticity in CSP.

Thirteen CSP (57 ± 12 years) were included in this study. Inclusion and exclusion criteria as well as characteristics of the patients are shown in the Supplemental Material.

This study used a randomized, sham-controlled and single-blind crossover experimental method. Each participant attended two experimental sessions one week apart: i) effective bi-tDCS, and ii) sham bi-tDCS. At the beginning of each session, participants performed 3 maximal isometric voluntary contractions (MVC). Then, an instrumental assessment of quadriceps spasticity was performed before effective/sham bi-tDCS, 10 minutes after the beginning of the effective/sham bi-tDCS (During), and immediately after the end of the effective/sham bi-tDCS.

For both bi-tDCS protocols the anode (7 × 5 cm) was placed over the leg motor cortex of the affected side with the medial border of the electrode placed laterally to Cz of the international electroencephalogram 10–20 system [6] (Fig. 1A). The cathode was placed in the same position over the leg motor cortex of the unaffected side. For the effective bi-tDCS, current (intensity: 2 mA) was delivered for 20 minutes using a constant-current electrical stimulator (Eldith DC-Stimulator, Germany). For the sham bi-tDCS, the same current was only delivered during the first 2 minutes (18 minutes without stimulation).

As recommended, spasticity was assessed using an "objective" instrumental evaluation [7,8]. Each set of instrumental evaluations of spasticity consisted of 5 fast passive quadriceps stretches at an acceleration of ~$500^{\circ}.s^{-2}$ (maximum speed of $240^{\circ}.s^{-2}$).

An isokinetic dynamometer (Biodex, Shirley Corporation, USA) was used to generate quadriceps stretches and to measure quadriceps torque of the affected limb. Participants were seated in the dynamometer chair with an 85° hip angle and the lower legs hanging over the edge of the seat. The knee angle was set at 90° for the MVCs. Passive pain-free range of motion was determined for each participant at the beginning of the first session and was used to set the limits of motion for both sessions. EMG activity of the rectus femoris (RF) and the vastus lateralis (VL) of the affected limb was recorded during both MVCs and quadriceps stretches. Bipolar surface electrodes linked to their amplifier (Bagnoli-4, Delsys Inc., USA) were placed on the skin, according to the SENIAM recommendations [9] (Fig. 1B).

For each quadriceps stretching test, maximum resistive peak torque (MRPT, Nm) produced was recorded, and work (J) was calculated by summing the area under the torque curve (torque multiplied by angular displacement in radians). Then, the MRPT was expressed as a percentage of the MVC torque to obtain the relative MRPT (rMRPT, %). The work was normalized by the MVC torque to obtain the relative work ($J.Nm^{-1}$). For each quadriceps stretching test and muscle a root mean square (RMS) for the entire EMG signal during the stretching phase was calculated and normalized to the RMS value obtained over a 0.5-s window around the MVC peak torque (relative EMG, %). For each spasticity parameter (rMRPT, relative work, and RF and VL relative EMG) and assessment (before, during and after effective/sham bi-tDCS), a mean of the 5 quadriceps stretching tests was used in the analysis.

To verify the effect of bi-tDCS on spasticity parameters, separate ANOVAs with factors of time (× 3: before/during/after) and stimulation (× 2: effective/sham bi-tDCS) were used. *Post-hoc* analyses were performed using the Tukey-HSD comparisons.

Statistical analysis revealed no main effect of "stimulation" on any spasticity parameter but a main effect of "time" for rMRPT ($F_{(2,24)} = 4.7$; $P < 0.05$; Fig.1Ci) and relative work ($F_{(2,24)} = 4.4$; $P < 0.05$; Fig.1Cii). No significant "time" effect was found for the RF ($F_{(2,24)} = 2.5$; $P = 0.14$; Fig.1Cii) and VL ($F_{(2,24)} = 1.2$; $P = 0.31$, Fig.1Civ) relative EMG. The lack of interaction between the factors "stimulation" and "time" (All P-value>0.35) showed that the time effects were not attributed to the effective bi-tDCS.

Discussion

The results showed that a single session of bi-tDCS does not alter quadriceps spasticity either during or immediately after application.

Other than one case study [4], only Bradnam et al. [5] investigated the effects of a single session of tDCS on upper limb spasticity.

https://doi.org/10.1016/j.brs.2019.06.027

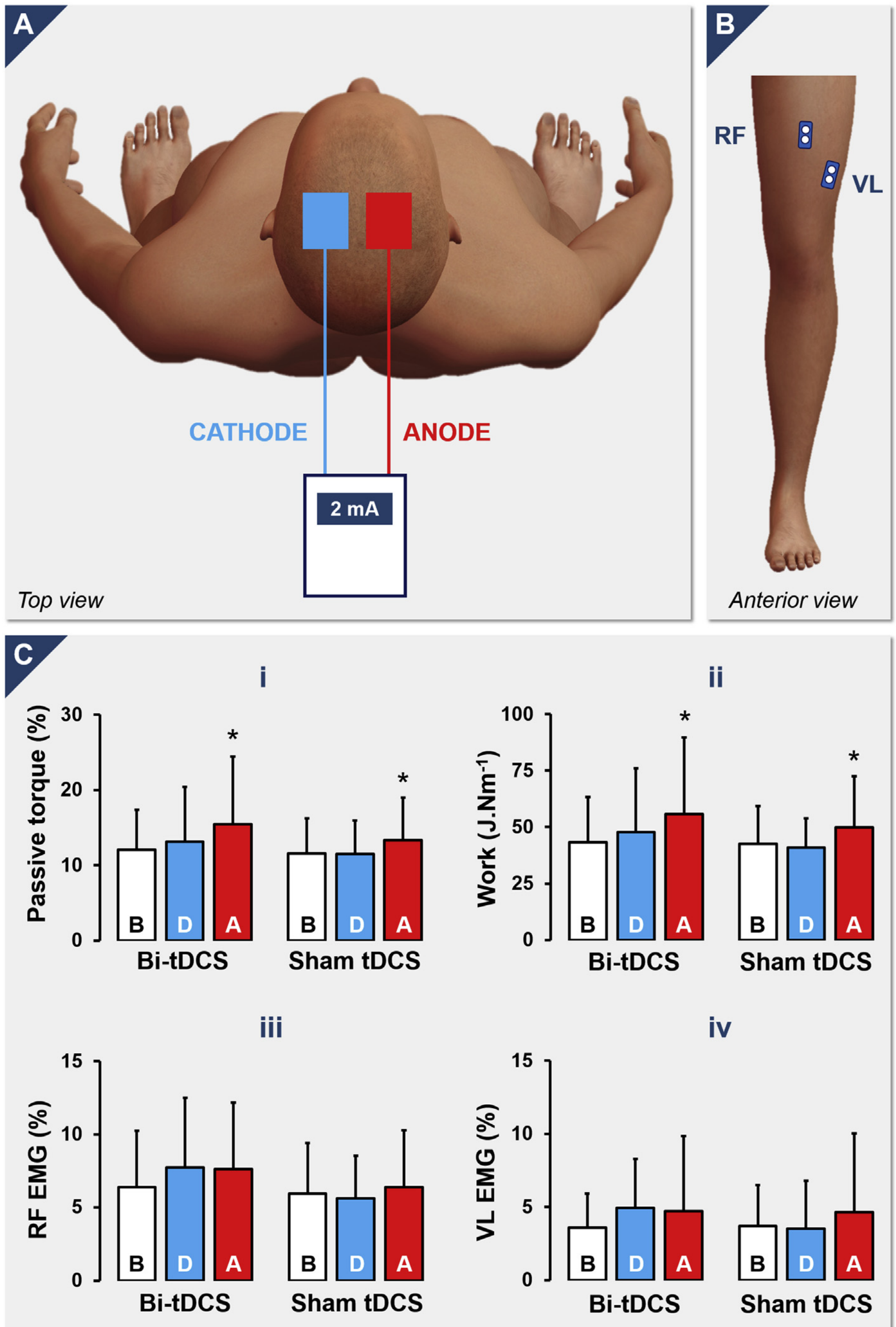

Fig. 1. A. Schematic view of electrode placement for effective and sham bihemispheric-transcranial direct current stimulation (bi-tDCS). The right brain hemisphere and the left leg represent the affected sides while the left brain hemisphere and the right leg represent the unaffected sides. **B.** Schematic view of electrode placement for rectus femoris (RF) and vastus lateralis (VL) EMG recordings. **C.** Mean and standard deviation of the normalized torque (i), normalized work (ii), and normalized EMG of RF (iii) and VL (iv) signals during fast passive quadriceps stretches before ('B', white histograms), during ('D', blue histograms), and after ('A', red histograms) effective bi-tDCS ('bi-tDCS') and sham bi-tDCS ('sham tDCS'). * indicates significant difference with baseline assessment (before effective or sham bi-tDCS measurements). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

They found a reduction in spasticity according to the modified Ashworth scale. Although their tDCS protocol (cathodal-tDCS over the unaffected hemisphere) differed from the present study, our stimulation set-up also included the application of a cathodal current over the unaffected hemisphere, thus should have had similar effects to that of Bradnam et al. [5]. The differences in results suggest that neural structures involved in lower limb spasticity do not respond to tDCS in the same way as those involved in upper limb spasticity. Further studies are required to determine whether i) a single session of bi-tDCS can modulate spinal networks excitability in spastic CSP, and ii) the lack of acute effect of bi-tDCS on the spasticity of CSP is specific to the quadriceps or consistent for other leg muscles (e.g. triceps surae). In addition, in contrast with studies reporting spasticity improvement in CSP following a tDCS session and using a subjective spasticity assessment (manual testing) [4,5], we used an objective instrumental spasticity assessment, which is more sensitive to the degree of spasticity and is not operator-dependent [7,8].

The results of this study do not support the use of a single session of bi-tDCS to improve quadriceps spasticity in CSP.

Conflict/declaration of interest

None.

Acknowledgements

This work was supported by the « Fondation Garches ». The authors would like to thank the « Centre d'Investigation Clinique et Technologique 805 » for its monitoring of the study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brs.2019.06.027.

References

[1] Li S, Francisco GE. New insights into the pathophysiology of post-stroke spasticity. Front Hum Neurosci 2015;9:192. https://doi.org/10.3389/fnhum.2015.00192.

[2] Nowak DA, Grefkes C, Ameli M, Fink GR. Interhemispheric competition after stroke: brain stimulation to enhance recovery of function of the affected hand. Neurorehabilitation Neural Repair 2009. https://doi.org/10.1177/1545968309336661.

[3] Roche N, Lackmy A, Achache V, Bussel B, Katz R. Effects of anodal transcranial direct current stimulation over the leg motor area on lumbar spinal network excitability in healthy subjects. J Physiol (Camb) 2011;589:2813–26. https://doi.org/10.1113/jphysiol.2011.205161.

[4] Vandermeeren Y, Lefebvre S, Desfontaines P, Laloux P. Could dual-hemisphere transcranial direct current stimulation (tDCS) reduce spasticity after stroke? Acta Neurol Belg 2013;113:87–9. https://doi.org/10.1007/s13760-012-0163-5.

[5] Bradnam LV, Stinear CM, Barber PA, Byblow WD. Contralesional hemisphere control of the proximal paretic upper limb following stroke. Cerebr Cortex 2012;22:2662–71. https://doi.org/10.1093/cercor/bhr344.

[6] Klem GH, Lüders HO, Jasper HH, Elger C. The ten-twenty electrode system of the international federation. The international federation of clinical neurophysiology. Electroencephalogr Clin Neurophysiol Suppl 1999;52:3–6.

[7] Kim DY, Park C, Chon JS, Ohn SH, Park TH, Bang IK. Biomechanical assessment with electromyography of post-stroke ankle plantar flexor spasticity. Yonsei Med J 2005;46:546–54. https://doi.org/10.3349/ymj.2005.46.4.546.

[8] Fleuren JFM, Voerman GE, Erren-Wolters CV, Snoek GJ, Rietman JS, Hermens HJ, et al. Stop using the Ashworth Scale for the assessment of spasticity. J Neurol Neurosurg Psychiatry 2010;81:46–52. https://doi.org/10.1136/jnnp.2009.177071.

[9] Hermens HJ, Freriks B, Disselhorst-Klug C, Rau G. Development of recommendations for SEMG sensors and sensor placement procedures. J Electromyogr Kinesiol 2000;10:361–74.

Thomas Cattagni*
Inserm Unit 1179, Team 3: Technologies and Innovative Therapies Applied to Neuromuscular diseases, UVSQ, CIC 805, Physiology-Functional Testing Ward, AP-HP, Raymond Poincaré Teaching Hospital, Garches, France

Nantes Université, Movement - Interactions - Performance, MIP, EA 4334, F-44000 Nantes, France

Maxime Geiger
Inserm Unit 1179, Team 3: Technologies and Innovative Therapies Applied to Neuromuscular diseases, UVSQ, CIC 805, Physiology-Functional Testing Ward, AP-HP, Raymond Poincaré Teaching Hospital, Garches, France

CIAMS, Univ. Paris-Sud, Université Paris-Saclay, 91405, Orsay, Cedex, France

CIAMS, Université d'Orléans, 45067, Orléans, France

Anthony Supiot
Inserm Unit 1179, Team 3: Technologies and Innovative Therapies Applied to Neuromuscular diseases, UVSQ, CIC 805, Physiology-Functional Testing Ward, AP-HP, Raymond Poincaré Teaching Hospital, Garches, France

Raphaël Zory
Laboratory of Human Motricity, Sport, Education and Health (EA 6312), University of Nice Sophia Antipolis, France

Didier Pradon, Nicolas Roche
Inserm Unit 1179, Team 3: Technologies and Innovative Therapies Applied to Neuromuscular diseases, UVSQ, CIC 805, Physiology-Functional Testing Ward, AP-HP, Raymond Poincaré Teaching Hospital, Garches, France

* Corresponding author. UFR STAPS, Université de Nantes, Laboratoire "Motricité, Interactions, Performance" EA 4334, 25 bis Boulevard Guy Mollet - BP 72206, 44 322, Nantes, cedex 3, France.
E-mail address: thomas.cattagni@univ-nantes.fr (T. Cattagni).

30 May 2019
Available online 28 June 2019