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EFFECT OF ANODAL TRANSCRANIAL DIRECT CURRENT STIMULATION ON LOWER LIMBS MUSCULAR FATIGUE DURING ISOKINETIC PROTOCOL

Rebecca Cantreva, Jonas Gurgel, Gabriela Moreira, Flávia Porto, Rafael Montenegro, Gabriel Espinosa, Alex Itaborahy and Paulo Farinatti

Biomechanics Research Group, Federal Fluminense University – GPBIO; Laboratory of Physical Activity and Health Promotion, Rio de Janeiro State University – LABSAU – Brasil

The objective of this study was to evaluate the relations between Transcranial direct current stimulation (tDCS) by anodal current and the work fatigue in lower limb during isokinetic protocol. In this study was evaluated the knee extensors and flexors resulting torques, from an isokinetic assessment, in concentric / concentric muscular action, after tDCS by anodal and sham current. Results showed significant differences between anodal and sham conditions for average peak torque during knee extension phase and work fatigue during knee flexion phase. Anodal tDCS showed not to be a suitable technique to modulated primary motor cortex activity. The preliminary results indicate a negative effect on work fatigue (knee flexion phase) and average peak torque (knee extension phase).

KEY WORDS: Transcranial Direct Current Stimulation; muscular fatigue; motor performance.

INTRODUCTION: In recent years, new techniques for modulating brain function have emerged, among them is the transcranial direct current stimulation (tDCS). Depending on the positioning of the cathode or anode electrode, the nature of tDCS is different. Anodic current stimulation increases cortical excitability, while the cathode current stimulus has the opposite effect (Rosenkranz et al., 2000, Nitsche et al., 2002, Nitsche et al., 2003). Some studies have shown that it is possible to manipulate the brain excitability by transcranial direct current stimulation (tDCS) modulating neuromuscular fatigue sensation. Priori et al. (2007) have evaluated the effect of anodal polarization on the areas of the cerebral cortex assessing the muscular fatigue by using an isokinetic dynamometer protocol. The isokinetic dynamometer determines the resistance and measures the torque exerted counter resistance by the muscle (Dvir, 1995). To limit the movement execution velocity, the equipment generates an accommodative resistance always proportional to the torque produced by the individual (Kawabata, 2000). The aim of this study was to assess the effect of anodal tDCS on indicators of neuromuscular fatigue induced by an isokinetic protocol.

METHODS: Seven health right-handed volunteers (6 men and 1 woman) participated in the study (aged 22-32 years). All participants signed their informed consent and the study had the approval of university ethical committee. All volunteers underwent to the same isokinetic protocol on dominant lower limb (Biodex System 4 Isokinetic Dynamometer, Biodex Medical Systems, Inc., Shirley, NY). The isokinetic protocol consisted of a concentric-concentric knee extension/flexion, three sets of ten repetitions with one minute interval between sets and angular velocity of 60º/s. On the first test day, before the isokinetic evaluation, subjects were allowed to practice the movement pattern as many times as they preferred to become familiar with the task. A two-minute interval was used between practice trials and the isokinetic test protocol. During the isokinetic protocol was evaluated the average peak torque, total work, work / body weight and work fatigue, the last one can be defined as the difference of first and last third of work (DVIR, 2002). Before the isokinetic evaluation, the subjects were submitted to an anodal or sham tDCS protocol, in alternated days and randomized order, with a minimum interval of 48 hours and a maximum of seven days. During this experiment, subjects were asked to maintain their daily routine. During both sessions, participants initially remained laid down in resting condition for 15min, then, an anodal or sham tDCS was applied over the participant's left scalp targeting the insular cortex (LIC). The current intensity was 2mA with 20min duration. Soon after the stimulus ending, participants remained laid down for more 10min, and only after the isokinetic protocol was started. The electric current was passed through a pair of sponges soaked in a saline solution (150 mMols of NaCl dissolved in water Milli-Q) involving both the electrodes (35cm2) (Nitsche & Paulus, 2000). The electrodes (anodal and cathodal) were connected to a constant current stimulation equipment with three power batteries connected in series (9V) presenting a maximal output of 10mA. The batteries were regulated by a professional digital multimeter (EZA EZ 984, USA) with a standard error of ±1.5%. For cathodal stimulation polarity over the left insular cortex (LIC), the anode was placed over the C3 area which is more precisely located at 5cm of the far left side of the midpoint of the subject's skull (Cz) according to the international EEG 10-20 system. This method of neuronavigation has been used previously in studies of transcranial magnetic stimulation and transcranial electrical stimulation (Gerloff et al.,1997; Fregni et al., 2005; Boggio et al.,2006; Fecteau et. al, 2007). The cathode was placed over the supraorbital contralateral area (Fp2). In order to perform the sham condition, the electrodes were placed in the same position of the anodal stimulation. However, the stimulator was turned off after 5 seconds of stimulation, as described by Siebner et al.(2004) and Boggio (2006). This procedure allowed the subjects to remain "blind" in respect to the polarity stimulation type received during the test (Nitsche et al.,2003a; Fregni et al.,2005, Boggio et al., 2006). After application of Shapiro Wilks test for confirmation of normality, descriptive statistics are presented as mean and ± standard error. A paired-samples Student t test was applied to verify significance differences between the two tDCS conditions (anodal and Sham). The significance level was set at α=0.05. The data were analyzed using statistical software (SPSS v.11.5 for Windows).

RESULTS: Table 1 (knee extension phase) and Table 2 (knee flexion phase) shows the work/body weight (%), total work (J), work fatigue (%) and average peak torque (Nm) in anodal and sham tDCS conditions.

Table 1
Knee extension phase

	Work/body weight (%)	Total work (J)	Work fatigue (%)	AVG PEAK TQ (Nm)
	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Anodal	304.87±82.22	2302.95±413.87	23.74±7.19	209.16±37.33*
Sham	304.41±81.03	2344.56±510.48	23.13±7.41	218.22±38.66*
Student t test (p)	0.958	0.418	0.736	0.015

Results are shown as Mean ± Standard Deviation. * Significant Difference (p≤0.05)

Table 2
Knee flexion phase

	Work/body weight (%)	Total work (J)	Work fatigue (%)	AVG PEAK TQ (Nm)
	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Anodal	181.26±52.26	1358.12±257.01	26.87±6.82*	116.28±24.18
Sham	172.93±53.00	1336.68±381.80	21.82±6.09*	118.15±26.73
Student t test (p)	0.269	0.667	0.003	0.514

Results are shown as Mean ± Standard Deviation. * Significant Difference (p≤0.05)

DISCUSSION: Table 1 (knee extension phase) shows a statistical significant reduction on average peak torque and unchanged results for all other variables (work/body weight, total work and work fatigue) during anodal tDCS condition compared to sham. These results appear to be partially explained by a better torque distribution over amplitude range during anodal current stimulation. Analyzing the data of table 2 (knee flexion phase) is possible to observe that work fatigue result was higher in anodal tDCS condition than sham. Despite the fact that there was no statistical differences in all other variables (work/body weight, total work and average peak torque), is possible that the second third of work was higher in anodal tDCS condition than sham. This argument appears to be plausible once work fatigue can be defined as the difference of first and last third of work (Dvir, 2002; Kawabata, 2000). Was expected that anodal tDCS condition would be able to facilitate motor-evoked potential (Nitsche & Paulus, 2000; Ardolino et al., 2005). Surprisingly, however, the results show that the changes were in opposite direction: after anodal stimulation the work fatigue during knee flexion phase suffered a significant increase and the average peak torque had the opposite behavior during the knee extension phase. These results differs from others studies (Merzagora et al., 2010; Fregni & Pascual-Leone, 2007), where the anodal tDCS condition promoted an increase on exercise execution capability, showing at least a reduction on rated of perceived exertion. The suggested explanation in these cases is the stimulation of cortical areas responsible for pain modulation as the thalamic nucleus. Otherwise, Ardolino et al. (2005) alert to the fact that no data are available about the after-effect of human peripheral nerve polarization. Yet, increased or decreased neuronal excitability depend on the orientation of the excitable tissue with respect to the electric field, and the distance from the polarizing electrodes (Ardolino et al., 2005). A possible explanation is based on the fact that small differences in electrode placement over the scalp can result in diametrically opposite effects on motor evoked potentials by tDCS (Priori, 2003).

CONCLUSION: Anodal tDCS showed not to be a suitable technique to modulated primary motor cortex activity, since the preliminary results indicate a negative effect on work fatigue (during knee flexion phase) and average peak torque (during knee extension phase). These effects are not desirable for sports science, searching for new performance improvement methods. However, the mechanisms underlying the stimulation of each cortical area are still not clear and warrant future investigation, as well the effects of anodal tDCS on others populations.

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