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

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The objective of this study was to evaluate the relations between tDCS by cathodal current and a fatigue indicator in lower limb during isokinetic protocol. In this study was evaluated the results obtained on assessment of isokinetic force of knee extensors and flexors, in concentric muscular action during flexion and extension phases. Seven health volunteers (6 men and 1 woman) participated in the study. The results show significant differences between sham and cathodal conditions only for work/body weight and work fatigue during knee flexion phase. Cathodal tDCS appear to be a valid technique to modulated primary motor cortex activity. The preliminary results suggest that cathodal current polarization appears to be a helpful tool to improve work capacity in human subjects, at least for knee flexion.

KEY WORDS: Transcranial stimulation, Fatigue, Motor performance.

INTRODUCTION: Fatigue can be induced by prolonged or vigorous activities that include physical or mental effort, like severe exercise, prolonged physiological stress and chronic diseases (Afari & Buchwald, 2003; Marcora et al., 2009). Muscular fatigue can be regarded as a reduced muscular work capacity, together with the lost of efficiency, often accompanied by subject feeling of physical and mental fatigue (Marcora et al., 2009), being an crucial factor in limiting the capacity of high-yield athletes. The search for understanding of the physiological processes leading to fatigue is a valuable research area looking for maximum yield. Currently the use of noninvasive technique of cerebral modulation is a promissory tool that may help in training methods and scientific researches. One of those methods is the Transcranial Direct Current Stimulation (tDCS) (Fregni et al., 2005; Fregni & Pascual-Leone, 2007; Priori 2003; Priori et al., 1998; Rosenkranz et al., 2000). The tDCS is usually made by setting of electrodes over the motor cortex region and in supraorbital, shoulders or contralateral cortex regions and, after, applies an electric current continuous (0,4 a 2 mA) for a period of 3 to 20 minutes it modifies the cortical excitability. tDCS can be performed using current cathodal or anodal. The stimulus of anodal current increases the cortical excitability while cathodal current stimulus has an opposite effect (Nitsche et al., 2003; Nitsche et al., 2002; Rosenkranz et al., 2000). Therefore, the objective of this study was to evaluate the relations between tDCS by cathodal current and the fatigue indicator in lower limb during an isokinetic protocol.

METHODS: Seven health right-handed volunteers (6 men and 1 woman) participated in the study (aged 22-32 years). All participants gave their informed consent and the study had the approval of university ethical committee. All volunteers were submitted to the same evaluation isokinetic protocol on dominant lower limb (Biodex System 4 Isokinetic Dynamometer, Biodex Medical Systems, Inc., Shirley, NY). The isokinetic protocol consisted of a concentric muscular action during knee extension and flexion phases, three sets of ten repetitions with one minute interval between sets and an angular velocity of 60^o/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 a cathodal 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, a cathodal 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, 2001). 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 cathode 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 anode was placed over the supraorbital contralateral area (Fp2). In order to perform the sham condition, the electrodes were placed in the opposite position of the cathodal 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., 2003; Fregni et al., 2005; Boggio et al., 2006). After application of Shapiro Wilks test for confirmation of normality, descriptive statistics are presented as mean ± standard error. A paired-samples Student t test was applied to verify significance differences between the two tDCS conditions (Cathodal 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 the cathodal and sham tDCS conditions.

Table 1
Knee extension phase

	Work/body weight (%)	Total work (J)	Work fatigue (%)	AVG PEAK TQ (Nm)
Cathodal	303.33±79.84	2310.65±489.65	23.66±8.21	218.73±41.88
Sham	304.41±81.03	2344.56±510.48	23.13±7.41	218.22±38.66
Student t test (p)	0.892	0.487	0.797	0.894

Results are shown as Mean ± Standard Deviation

Table 2
Knee flexion phase

	Work/body weight (%)	Total work (J)	Work fatigue (%)	AVG PEAK TQ (Nm)
Cathodal	186.70±61.69*	1403.98±425.03	27.23±7.20*	121.02±28.94
Sham	172.93±53.00*	1336.68±381.80	21.82±6.09*	118.15±26.73
Student t test (p)	0.042	0.180	0.010	0.420

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

DISCUSSION: Based on results of Table 2 is possible to observe that the work fatigue was higher in cathodal than sham condition. These differences can be partially explained by changes in work/body weight. Cathodal stimulation obtained a significant higher value in Work/body weight than sham, giving the opportunity to infer that a higher work fatigue was expected. Based on the concept of work fatigue, a higher initial value of work is probably related with a more drastic reduction of the last third of work, that characteristic gives a higher percentage difference in work fatigue (Queiroz et al., 2010). The fact that the total work and average peak torque did not present significant differences shows that the cathodal stimulation preserved both capacities. During knee extension were not found any difference between the two tDCS conditions, these results suggest that cathodal stimulation was able to modulated the motor cortex activity for knee flexion, but not for knee extension. That aspect may be related to the fact that the representation of different regions on primary motor cortex still not completed understood (Nitsche et al., 2003; Ardolino et al., 2005). Other relevant consideration is related to the fact that the modulation effect was in the opposite direction. Was expected a reduction on work capability in almost all indicators, these results shows for knee flexion phase a significant increase of some variables, as work / body weight. Similar results on the effects of cathodal tDCS on peripheral motor axons were obtained by Ardolino et al. (2005), these authors 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: Cathodal tDCS appear to be a valid technique to modulated primary motor cortex activity; the preliminary results of this study suggest that cathodal current polarization appears to be a valuable tool to improve work capacity in human subjects, at least for knee flexion. However, the mechanisms underlying the stimulation of each cortical area are still not clear and warrant future investigation.

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Acknowledgement

This study was partially supported by CNPQ and FAPERJ grants.