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EFFECT OF CATHODAL TRANSCRANIAL DIRECT CURRENT STIMULATION OVER AN ANTAGONISTIC CO-ACTIVATION DURING AN ISOKINETIC PROTOCOL

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The objective of this study was to evaluate the effects of cathodal transcranial direct current stimulation (t-DCS) over an antagonistic co-activation of lower limbs muscles during isokinetic exercise. We analyzed the results of isokinetic exercise for dominant leg knee's extensors and flexors muscles during concentric-concentric protocol after cathodal and sham t-DCS. Seven healthy right-handed volunteers took part at the study. The cathodal current is an reducer of motor cortex excitability. Only three of the seven volunteers presented the expected behavior after t-DCS cathodal stimulation, in at least one phase. The findings of this study suggest that the effect of t-DCS cathodal on the muscular co-activation, remains unclear especially because the mechanisms underlying the stimulation of each cortical area are still unknown.

KEY WORDS: Transcranial Direct Current Stimulation, Electromyography, antagonistic co-activation.

INTRODUCTION: The human body has physiological mechanisms to protect the muscles and bones from injury by stretching, muscle weakness and fatigue caused by movements with excessive range and torque (Aquino, 2004; Darainy & Ostry, 2008). The phenomenon of antagonist co-activation is a mechanism of protection against musculoskeletal injuries. On the other hand, excessive co-activation reduces the ability to generate torque of agonist muscles, reducing the performance in sports that require high power output. In order to perform a specified movement, the agonist muscles are quickly activated to provide adequate strength development (Ribeiro et al., 2006), while the antagonic muscles are also activated to prevent muscle overload (Aquino, 2004; Darainy & Ostry, 2008). This mechanism is called co-activation. It is known that this ability can be improved by training, thus, agonist muscles can produce more torque due to a reduced co-activation of antagonistic muscles. This kind of training is commonly used for high-performance athletes who need to improve performance (Liotto, 2008; Ribeiro et al., 2006). It is also known that this agonist-antagonist interaction and force production are both related to the ability of the motor cortex to stimulate the muscles, increasing the capacity of power supply. Basically t-DCS is a noninvasive method of brain activity's modulation, as well as transcranial magnetic stimulation (t-DM), but through direct currents of low amplitude. Currents can be anodal or cathodal, with capacity to, respectively, increase and decrease cortical excitability. With the intention to verify whether the t-DCS can benefit athletic performance by decreasing the antagonist co-activation strength tests were performed on an isokinetic dynamometer. The effect of t–DCS (cathodal and sham) over an antagonist co-activation of the lower limbs during an isokinetic exercise protocol were the aim this study.

METHODS: Seven healthy right-handed volunteers (6 men and 1 woman) were in the study (age between 22-32 years old). All volunteers signed a consent form and the study had the approval of university ethics committee. All volunteers were submitted to the same isokinetics evaluation's protocol on dominant lower limb (Biodex System 4 Isokinetic Dynamometer, Biodex Medical Systems, Inc., Shirley, NY). The isokinetics protocol consisted in knee's extension/flexion in the concentric-concentric mode, with three sets of ten repetitions and angular velocity of 60^{o}/s. One minute interval between sets were observed. The tests were carried out in two sessions (one for each type of stimulation chosen

randomly). On the first sessions, before the isokinetics 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 isokinetics test protocol. During the isokinetic protocol the electromyographyc signal of seven muscles were measured: Rectus Femoris (RF), Vastus lateralis (VL), Vastus Medialis (VM), Biceps Femoris (BF), Semitendineus (ST), Gastrocnemius Lateralis (GL) and Gastrocnemius Medialis (GM). For electromyography were used disposables bipolar Ag/AgCl surfaces electrodes (Meditrace®), with an interelectrodes distance of 20mm. Before place the surface electrodes, skin was shaved, slight abraded with sandpaper and cleaned with alcohol. All procedures for electrodes placement locations and for skin preparation followed recommendations of SENIAM project. The ground electrode was placed at Tibial Tuberosity and the data was acquired with an 8 channels eletromyograph (Noraxon, Myosystem 1400A, EUA). Data was filtered with a band-pass fourth order Butterworth filter, with a cut-off frequency of 20 and 500 Hz. The filtered data was analyzed in time domain, normalized by mean RMS (root mean square) of each channel. Before the isokinetics evaluation, the subjects were submitted to a cathodal or sham tDCS protocol, in different days and in randomized order, with a minimum interval of 48 hours and a maximum of seven days between sessions. During this experiment, subjects were asked to maintain their daily routine. During both sessions, participants initially remained lying 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 lying down for more 10min, until the isokinetics 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 (35cm^2) (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 place 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). The electrodes were placed in opposite position of the cathodal stimulation to perform the sham condition. However, the stimulator was turned off after 5 seconds of stimulation, as described by Siebner et al. (2004) and Boggio et al. (2006). Thus, the subjects reported feeling a tingling or itching sensation coming from the initial electrical stimulation, but they did not received any current in the remaining period of testing. This procedure allowed the subjects to remain "blind" in respect to the type of polarity stimulation 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. Data were analyzed using statistical software (SPSS v.11.5 for Windows).

RESULTS: Table 1 (knee flexion phase) and Table 2 (knee extension phase) shows the percentage of RMS, the mean and SD per type of stimulation per each muscle.

DISCUSSION: Generally when the agonist activation is increased, the co-activations also increases, however it is not expected when the subject is underwent to a cathodal stimulus (Nitsche et al., 2003; Nitsche et al., 2000; Rosenkranz et al., 2000). In the present study the expected reduction of the excitability was not detected, that was also showed by Ardolino et al. (2005) in experiments with electroencephalographic analysing the influence of direct current on the spontaneous central nervous activity.

Table 1
Knee flexion phase – antagonists muscles - RMS percentage

	VM (%) Mean±SD	RF (%) Mean±SD	VL (%) Mean±SD
Cathodic	41.57±9.33*	31.56±24.93*	45.82±15.06
Sham	28.49±11.97*	33.47±25.04*	43.01±12.39
Student t test (p)	0.000	0. 050	0.053

* Significant difference (p≤0.05)

Table 2
Knee flexion phase - agonists muscles - RMS percentage

	BF (%) Mean±SD	ST (%) Mean±SD	GM (%) Mean±SD	GL (%) Mean±SD
Cathodic	209.10±66.01	243.19±59.29*	233.02±73.79	197.23±76.42*
Sham	205.63±44.99	228.20±45.86*	233.78±26.96	180.05±58.75*
Student t test (p)	0.505	0.004	0.906	0.002

* Significant difference (p≤0.05)

Table 3
Knee extension phase – agonists muscles - RMS percentage

	VM (%) Mean±SD	RF (%) Mean±SD	VL (%) Mean±SD
Cathodic	249.87±45.43	252.99±66.30*	226.53±56.02
Sham	249.27±29.80	235.72±61.34*	235.30±30.60
Student t test (p)	0.882	0.000	0.144

* Significant difference (p≤0.05)

Table 4
Knee extension phase – antagonists muscles - RMS percentage

	BF (%) Mean±SD	ST (%) Mean±SD	GM (%) Mean±SD	GL (%) Mean±SD
Cathodic	69.50±22.66*	38.94±12.03*	47.26±26.54*	70.53±24.88*
Sham	65.65±20.83*	41.65±16.33*	41.38±13.30*	76.29±33.46*
Student t test (p)	0.003	0.024	0.004	0.004

* Significant difference (p≤0.05)

During knee flexion phase, two of three antagonistic muscles were activated in a different way in sham and cathodal conditions. VM was more activated and VL was less activated in cathodal stimulation. Related to flexion agonistic muscles, ST and GL were more activated in cathodal stimulation.

In extension phase, only RF showed significant difference among the agonistics muscles, this difference was caused by an increase of activation with cathodal current. Regarding the antagonistic muscles, as happened in the flexion phase, data showed different way of activity in sham and cathodal conditions. BF and GM were more activated and ST and GL were less activated in cathodal stimulation.

Another aspect that was expected is that the effect caused by cathodal current would be the same, for the muscles with similar function, whether it is positive or negative. Nevertheless this relation also was not demonstrated, and else, opposite behavior was found. This fact might be justified by the lack of understanding about mechanisms underlying the stimulation of each cortical area are still not clear and warrant future investigation.

CONCLUSION: Among the seven analyzed muscles, only three have shown the expected behavior, in at least one phase, which were RF as muscle antagonistic on the flexion and ST and GL as muscle antagonistic on the extension. The findings of this study suggest that the effects of tDCS cathodal on the muscular co-activation, remains unclear and especially because the mechanisms underlying the stimulation of each cortical area are still unknown. Further studies with a bigger sample are suggested to provide more consistent data.

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