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Rapid communication

Transcranial direct current stimulation on the autonomic modulation and exercise time in individuals with spinal cord injury. A case report

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ABSTRACT

Purpose: To report the effect of the transcranial direct current stimulation (tDCS) applied over the primary motor cortex (M1) of an individual, a sedentary male subject with complete chronic spinal cord injury at the T11–T12 levels.
Methods: The individual underwent three experimental sessions: control, sham and anodal tDCS. Before, during and after exercise sessions, the following variables were recorded: heart rate variability, Rating of Perceived Exertion (RPE), power and glucose (this one only before and after the exercise).
Results: The anodal tDCS provided greater exercise time and power, lower perceived exertion, greater reduction in glucose, and an increase in time to reach the threshold of heart rate variability.
Conclusions: tDCS caused an improvement in the exercise tolerance, probably due to the modulation of the autonomic nervous system and the pain, characterized by reduced RPE.

1. Introduction

People with spinal cord injury (SCI) usually experience physiological changes, such as a decrease of muscle mass, a decrease or loss of sensory and motor function, diabetes, cardiovascular disease, obesity, osteoporosis, and arthritis (Gater, 2007), resulting from the injury. Most of these complications could be prevented by means of physical activity not only for SCI chronic level, but also for SCI rehabilitation level (Lugo and Eusse, 2001). In addition to improving functional skills (Giangregorio et al., 2005), the exercise increases quality of life and social integration (Roberton et al., 2011).

A technique that has been shown to be effective in improving motor function in people with stroke using inter-hemispheric modulation is the transcranial direct current stimulation (tDCS) (Lindenberg et al., 2010). In addition to the focus that turned to the improvement of symptoms caused by neuropsychological diseases (Fregni et al., 2006) and neuropathic pain after SCI (Kumru et al., 2013), tDCS has been studied for physical exercise in people without physical disabilities as an ergogenic factor by presenting positive points such as increased performance in trained cyclists on the maximal incremental test (Okano et al., 2013).

Therefore, the aim of this work was to describe a case study of the effects of tDCS on the autonomic modulation and exercise time in a subject with SCI. Our hypothesis is that tDCS can improve exercise tolerance in individuals with SCI by modulation of the primary motor cortex (M1), increasing their motor cortical excitability.

2. Methods

2.1. Subject

An individual male (25 years; 181.5 cm, 65.3 kg) with total chronic SCI (7 years), between T11 and T12 levels, not spastic, sedentary, and right-handed according to the Handedness Inventory of Edinburgh (Oldfield, 1971). The participant was informed of the procedures and risks before signing the informed consent form. The volunteer was instructed to refrain from vigorous activities and ingestion of beverages containing caffeine and alcohol or of using tobacco for 24 h prior to the test. This study was approved by the local ethics committee (Ethics in Research Committee of the Federal University of Rio Grande do Norte, protocol number 750.887).

2.2. Experimental procedures

On the first visit to the laboratory, the individual first rested for 30 min before performing the familiarization. During this time the individual answered some questions concerning the use of medication, time, type and degree of injury, and personal history of chronic

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degenerative diseases. Then, the maximal incremental test, which consisted of the increase, every 1 min, of 0.1 kg·f^{-1} on the arm crank ergometer, was performed. Before each weight increase, the individual was asked about the Rating of Perceived Exertion (RPE) (Borg 1–10). On the arm crank ergometer, the rotation was maintained constant (60 rpm), until exhaustion. Besides that, before and after the maximum incremental test, blood samples for glucose determination (Roche®, Accu-Check Advantage, Brazil) were collected. Heart rate variability (HRV) was recorded continuously throughout the experiment. From the data collected during the maximum incremental test, SD1 was calculated using Poincaré plots. Poincaré plots analyze the HRV representing a diagram in which each R–R interval is plotted against the previous R–R interval (Smith et al., 2007). SD1, which is considered the short-term beat-to-beat R–R variability from the Poincaré plot (Serra-Añó et al., 2014), is the length of the transverse line of the plot data in perpendicular direction (Vanderlei et al., 2009). The analysis of the HRV threshold (HRV_{TH}) was calculated every minute until SD1 reached 3 ms (Lima and Kiss, 2012). In this study, temperature, humidity, and environmental noise were controlled in the laboratory.

In the other three visits, using a lap time of 48 h between each session, the individual performed, randomly, one of the experimental conditions (anodal tDCS, sham tDCS, or control).

2.3. tDCS procedures

Electric current was applied through a portable device containing four main components: electrodes (anode and cathode with an area of 35 cm^2 and 36 cm^2, respectively), multimeter (current intensity electric meter), potentiometer (component that allows the manipulation of the intensity of the current), and 3 batteries (9 V) to generate the applied current. The electrodes were wrapped in a sponge soaked with saline solution (NaCl 150 mM).

For the data collection during the anodal tDCS, the international EEG 10–20 system was used for positioning the electrodes. The anodal was placed in the Cz (central zero) bilaterally at 4.5 cm on the left hemisphere and 4.5 cm on the right hemisphere. The reference electrode was placed on the occipital protuberance in order to avoid inhibitory effects on the supra-orbital contralateral area (Fp2), to avoid any interference on HRV results (Clancy et al., 2014). A constant current of 2 mA was applied for 12 min, with a ramp procedure in the first and the last 30 s (gradual increase and reduction of the applied current until reaching 2 mA and 0 mA, respectively), for a total time of 13 min.

For the sham stimulation, the electrodes were placed at the same position as for the anodal one. However, the stimulator was turned off after the ramp procedure, which was held for only the first 30 s (gradual increase of the applied current until reaching 2 mA) (Gandiga et al., 2006).

3. Statistics

For the data of power and the exercise time, the percentage differences between the three conditions (control, sham, and anodal tDCS) were calculated. Descriptive statistics were used for the other results.

4. Results

Table 1 shows the maximum power (MAX-P), exercise time (ET), percentual ratio between anodal and sham (A/S%), percentual ratio between anodal and control (A/C%), and percentual ratio between sham and control (S/C%) during the test with control, anodal, and sham tDCS, respectively. The ET for the anodal tDCS was, in all cases, higher than that found for the sham and control conditions. The same profile was observed for the absolute MAX-P, since this variable was greater (7.4%) for the anodal tDCS when compared to the sham and control tDCS (14.8%).

Table 1
Maximum power (MAX-P), exercise time (ET), percentual ratio between anodic and sham (A/S%), percentual ratio between anodic and control (A/C%) and percentual ratio between sham and control (S/C%) during the test with control, anodic and sham tDCS, respectively.

	Anodic	Sham	Control	A/S (%)	A/C (%)	S/C (%)
MAX-P (W)	87.75	81.25	74.75	7.4%	14.8	8%
ET (s)	703	622	591	10.6	15.97	5

W = watts; s = seconds.

The power (W) and the RPE in function of the time are shown in Fig. 1(A) and (B), respectively. The results indicate that, after 5 min, the W for the sham tDCS and the control condition were slightly higher than the W for the anodal condition (Fig. 1(A)). The RPE during the maximal incremental test (Fig. 1(B)) indicates that, after 5 min, the RPE for the sham tDCS and the RPE for the control condition were higher than that for the anodal tDCS.

The calculated SD1 using the Poincaré plots for every minute during the maximal incremental test for anodal tDCS, sham tDCS, and control, are presented in Fig. 2. HRV_{TH} for sham tDCS and control reached 45 W and 35 W, respectively. For the anodal tDCS, this value was approximately 55 W.

Fig. 3 shows the glucose values (mg·dL^{-1}) before and after exercise. In all conditions it can be observed that after the exercise, the percentage of glucose was reduced. For the anodal tDCS (11.12%) the reduction was slightly higher when compared to the sham tDCS (5.6%) and to the control condition (9.8%).

5. Discussion

This study revealed that anodal tDCS applied over the M1 bilaterally before exercise improved the exercise tolerance 15.97% in a sedentary

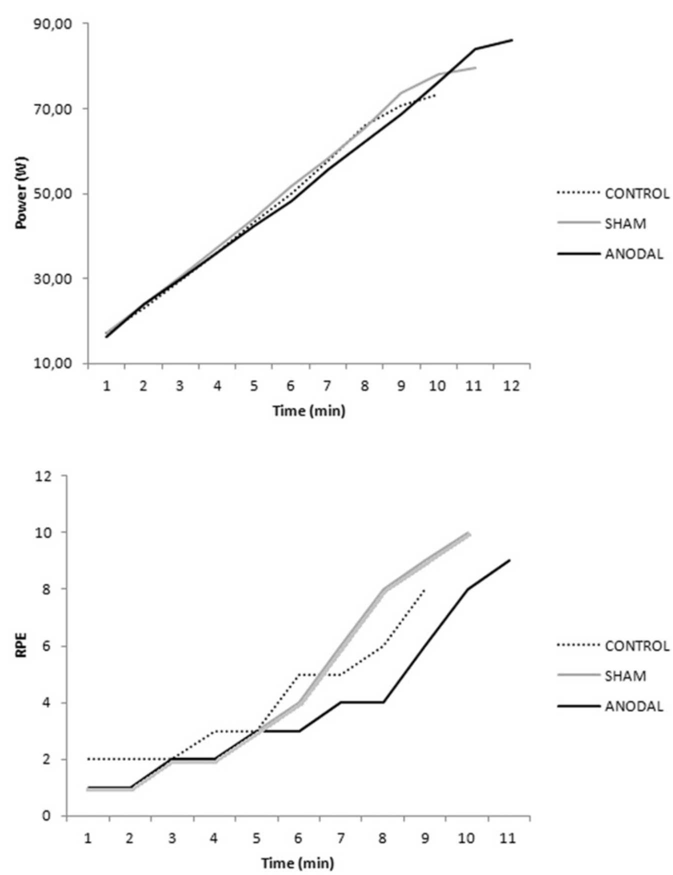

Fig. 1. Power (W) (A) and RPE (B) in function of the time during the maximal incremental test for anodal tDCS, sham tDCS, and control conditions.