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Transcranial direct current stimulation (tDCS) improves handgrip performance in Brazilian Jiu-jitsu elite male athletes

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Abstract

Background. Brazilian Jiu-Jitsu (BJJ) is a high-intensity martial art whose primary goal is to submit your opponent using joint locks or chokeholds. Investigating different strategies to improve muscular strength and endurance is of primary concern for BJJ practitioners. In the past, Anodic transcranial direct current stimulation (a-tDCS) applied to the left dorsolateral prefrontal cortex (DLPFC) has been shown to improve physical performance.

Problem and aim. However, the effects of tDCS on isometric contraction in BJJ athletes are not known. Thus, the purpose of this study is to investigate the acute effect of tDCS on handgrip strength in elite BJJ athletes.

Material and methods. Ten male BJJ athletes aged 25.5 ± 5.7 years were recruited. Participants completed two experimental conditions (a-tDCS and sham) with an interval of 48 to 72 hours in a randomized manner between sections. Stimulation was applied over the DLPFC (2mA intensity/20 minutes). Immediately after stimulation or sham, participants performed a handgrip MVC test and then sustained a submaximal force to failure at 60% of their MVC. Ratings of perceived exertion (RPE) were collected at the end of the test.

Results. No significant difference was found between a-tDCS and sham conditions for MVC. Time to task failure in the a-tDCS group was statistically higher compared to the sham group. No significant difference was found between a-tDCS and sham groups for RPE.

Conclusions. The a-tDCS promoted performance improvement, increasing the time to task failure in a constant handgrip force task with load at 60% of the maximum.

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Introduction

Brazilian Jiu-Jitsu (BJJ) is a martial art and combat sport in which the main goal is the submission of the opponent based on grappling, sweeps, takedowns, chokeholds, and joint locks [Lima *et al.* 2017; Moller *et al.* 2020]. During BJJ matches/fights, there is an alternation between high and low-intensity movements [Andreato *et al.* 2015]. The high-intensity actions induce a decrease in performance due to muscle fatigue, which causes a reduction in strength and power during the match [Betts *et al.* 2009; Andreato *et al.* 2015].

The duration of the matches in the adult and "master 1" categories (18 to 35 years of age) varies between 5 and 10 minutes. During this time, isometric contraction predominates in small muscle groups, such as forearms and biceps. Furthermore, these isometric contractions are necessary to execute basic movements needed to control the opponent, such as the kimono's footprint [Moller *et al.* 2020; Franchini *et al.* 2005]. Therefore, efficient strategies that can increase isometric strength and resistance to fatigue may help the performance of BJJ athletes.

Several stimulation techniques have been developed to optimize muscular endurance and generate less perception of effort of fatiguing muscle contractions [Hendy, Kidgell 2013]. Among these various techniques, transcranial direct current stimulation (tDCS) has received significant interest from several studies [Vieira *et al.* 2020; Vitor-Costa *et al.* 2015, Lattari *et al.* 2018]. tDCS consists of a non-invasive neural stimulus technique, with the application of a low-intensity electric current, performed using surface electrodes [Nitsche *et al.* 2008].

Anodic tDCS (a-tDCS) applied to the left dorsolateral prefrontal cortex (DLPFC) has been shown to cause improvements in the performance of strength and resistance in dynamic muscle contractions in different tasks [Lattari *et al.* 2018; Victor-Costa *et al.* 2015; Lattari *et al.* 2016]. According to Tanaka *et al.* [2009] there is a close connection between the MC and the cingulate and insular cortex, which are responsible for the perceived effort and may be accountable for delaying muscle fatigue. Therefore, the fact that a-tDCS can reach, through existing neural connections, areas that play an important role in central fatigue may suggest acute adaptations that sustain activity and delay fatigue [Tanaka *et al*. 2009]. The posterior cingulate cortex and the insular cortex are the right DLPFC (Brodmann area 46), which is responsible for activating the areas of sensory-motor function to compensate for central fatigue, contributing to the relationship of agonists and antagonists, stimulating motivation, and decreasing perceived exertion [Tanaka *et al*. 2009; Coggiamanian *et al.* 2007; Liu *et al*. 2003].

However, not much is known about the influence of tDCS in responses to isometric contractions in athletes and understanding its potential. As such, the purpose of this article was to verify the acute effects of tDCS on the handgrip forces in elite male athletes from BJJ.

Material and methods

Participants

All participants were initially informed about the procedures and signed an informed consent according to the Norms for Research with Human Beings (Resolution N°. 466/2012 CNS). Anhembi Morumbi University Ethics Committee approved this project under the 3.903.038 protocol number.

The calculations to establish the sample size were done using the software G*Power 3.1.9.7 for t-tests of difference between two dependent means (matched pairs) [Faul *et al.* 2007]. The significance level was set at $\alpha = 0.05$, power at 80 %, and effect size of 1. Partial eta squared ($\eta p2 = 0.04$) was used to determine an effect size f=0.2041. The power analysis resulted in a minimum of 10 individuals (total sample size) was necessary to verify a significant intervention effect with an actual power of 0.803.

The sample consisted of 10 elite Brazilian Jiu-Jitsu male athletes aged between 18 and 35 years (25.5 ± 5.7 years; 77.1 ± 8.6 kg of mass, and 175±6.0 cm of height). Followings were the inclusion criteria: 1) Participate in at least three competitions of the International Federation of Brazilian Jiu-Jitsu (IFBJJ/CBJJ) and/or the United Arab Emirates (UAE) Federation (higher-level competitions compared to other federations) per year; 2) Hold a blue, purple, brown or black belt; 3) Be between 18 and 35 years old, competing in the "adult" and "master 1" categories. Only male subjects were chosen because of greater availability and sample homogeneity. Eligibility requirements were chosen to guarantee participants' current high-level competition. Subjects were instructed not to exercise 24 hours before the tests. Those supplementing were suggested to maintain the supplementation routine during all tests.

Procedures

Subjects performed three visits. At the first visit, the participants signed the informed consent, answered a specific anamnesis to characterize the sample, and their anthropometric variables were measured. In the subsequent two visits, they received either sham or tDCS depending on the randomization. Participants performed 20 minutes of stimulation or sham. In the sequence, they performed the maximal voluntary contraction (MVC) and task failure tests with a load of 60% of the maximum value found in the MVC. The EPR measurement was completed by an independent evaluator and blinded after each condition. Conditions ranged from 48 to 72 hours. Figure 1 shows the study design.

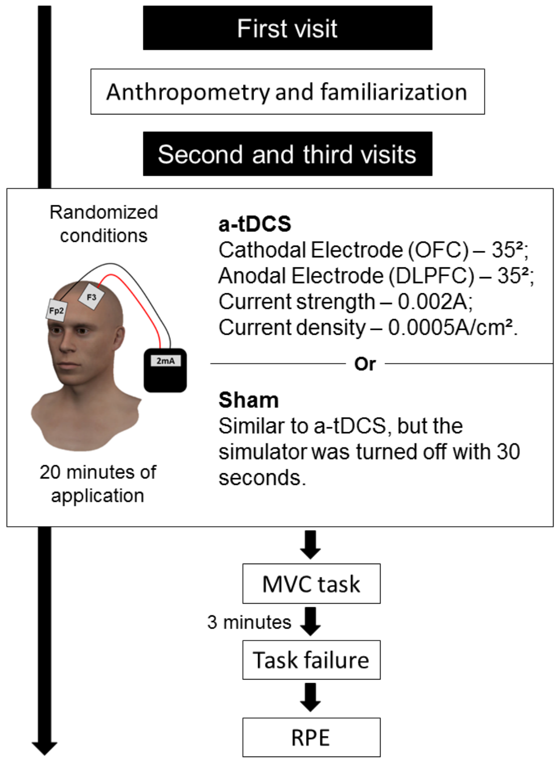

Fig. 1. Study design (Legend: a-tDCS = anodal transcranial direct current stimulation; DLPFC = dorsolateral prefrontal cortex; OFC = orbitofrontal cortex; A = amps; cm = centimeter; mA = milliamps; MVC = maximal voluntary contraction).

Anthropometric Measurements

'Participants' body mass and height were measured with a weight scale and stadiometer (Sanny BL201PP model). In addition, the skinfold thickness (chest, abdomen, and thigh) was measured using a Slim Guide adipometer (model C-120R) to estimate the body fat percentage using the equations of Siri [1956] and Jackson & Pollock [1978]. All procedures followed the recommendations proposed by the International Society for Advancement of Kinanthropometry.

Application of tDCS

The application of tDCS was carried out with the participants sitting comfortably in a chair. The electrodes (anode and cathode) were connected to a direct current stimulation device (The Brain Driver tDCS v2.1, USA). For the a-tDCS condition, the stimulus was applied in the left DLPFC, ocated on the F3 electrode area, according to the international 10–20 EEG system [Jasper, 1958]. The cathode was positioned over the right orbitofrontal cortex (OFC), located above the Fp2 electrode area. The stimulus had an intensity of 2 mA (current) and a duration of 20 min. The power supply used in tDCS was a 9-volt battery. Previous research [Lattari *et al.* 2016; Victor-Costa *et al.* 2015] has shown that the stimulation of the DLPFC with this dosage (2 mA for 20 min) generated improvements in muscular endurance and strength. A pair of sponges soaked in saline (140 mMol NaCl dissolved in Milli-Q water) was used to wrap the two electrodes (35 cm²) which were fixed by elastics. For sham condition, the electrodes were placed in the same position as the a-tDCS condition, but the device was switched off after 30 seconds, considered an ineffective stimulation. This procedure allows subjects to become 'blind' to the type of stimulus they will receive during the test, thus ensuring a control effect. The correct placement and positioning of the electrodes on the participant can be seen in Figure 2.

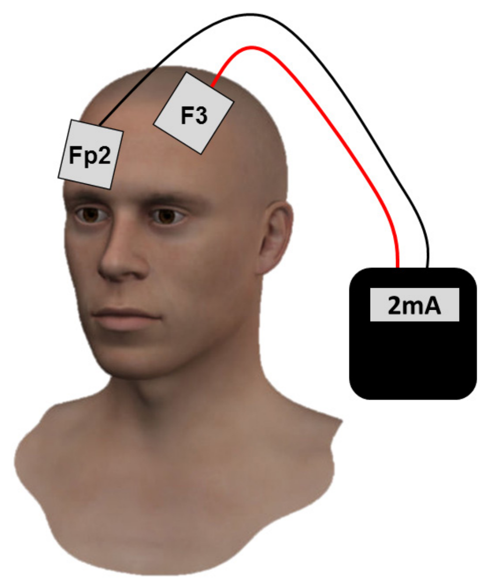

Fig. 2. The experimental montage (F3- the left dorsolateral prefrontal cortex at the electrode area F3 according to the international 10–20; Fp2- the right orbitofrontal cortex at the electrode area Fp2 according to the international 10–20).

Experimental arrangement

Handgrip forces were measured using two force transducers (Vernier, model HD-BTA, USA), one in each hand, connected to software (LoggerPro® version 3.15, USA). The participants were instructed to position their arms at 90° of elbow flexion and with the forearm at a neutral position. Subjects were placed facing a projected screen (0.5 m diagonal) that was located 1 meter away at eye level. The monitor was used to display the handgrip forces, and all subjects affirmed that they could clearly see the display.

MVC task

The participants were instructed to increase the force from baseline to maximum and maintain the maximal force for about 3 seconds. Three such recordings were made. The MVC force was quantified as the average force over 3 seconds (constant part) of the highest trial.

Failure task

Subjects were instructed to accurately match a target force at 60% of their handgrip maximal isometric force (MVC task). The subjects were asked to gradually push against a force transducer and increase their force to match the target force within 3–4 seconds. When the target was reached, subjects were instructed to maintain their force on the mark as accurately and as consistently as possible until muscle failure. Failure was defined when the participant was unable to sustain the force for more than 3 seconds.

Ratings of perceived exertion (RPE)

The ratings of perceived exertion (RPE) were measured using the Borg 0-10 Scale with scores ranging from 0 (Nothing at all) and 10 (absolute maximum) [Borg 1998].

Statistical analysis

Descriptive statistics with mean and minimum, and maximum values data were calculated for age and anthropometric variables. The normality of the data was performed using the Shapiro-Wilk test. A paired t-test analysis was used to compare MVC task, Task failure, and RPE results between experimental conditions (a-t-DCS and sham). Inferential statistics were performed using the GraphPad Prism 5.0. The level of significance was set at $p \leq 0.05$.

Results

The anthropometric data of the sample can be seen in mean, minimum, and maximum values in table 1.

Table 1. Anthropometric characteristics of the sample.

	Media	Min.	Max.
Age (years)	25.5	18	35
Weight (kg)	77.2	66	98
Height (m)	1.75	1.65	1.8
BMI (kg/m²)	25.3	21.7	34.7
Body fat (%)	10.4	5	29.4

BMI = Body mass index; kg = kg; m = meters

Data referring to information about the athletes' belt level and fight category are identified in table 2 in percentage values.

Table 2. Belt level and weight category information of the sample.

Graduation	N	%
Blue belt	3	30%
Purple belt	3	30%
Brown belt	2	20%
Black belt	2	20%
Weight category	**N**	**%**
Light feather	1	10%
Feather	2	20%
Light	4	40%
Middle	2	20%
Super heavy	1	10%

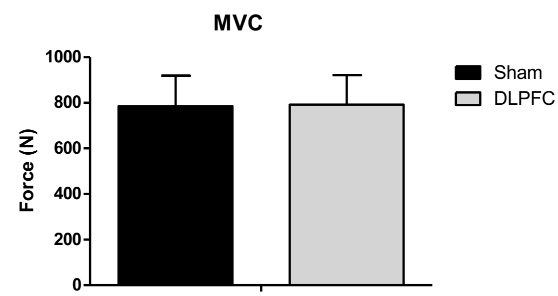

Fig. 3. Responses in MVC task in sham and a-tDCS (DLPFC).

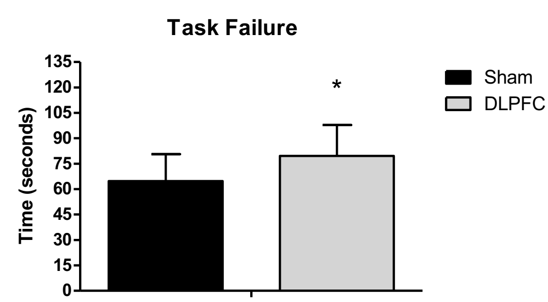

Fig. 4. Responses in task failure in sham and a-tDCS (DLPFC). Legend: *a-tDCS (DLPFC) > sham (t = 4.422; p = 0.001).

Table 3. Mean and standard deviation data for the task failure and ratings of perceived exertion.

Outcomes	Sham (M ± SD)	a-tDCS (M ± SD)	T	p
RPE	7.9 ± 0.4	7.5 ± 0.8	1.809	0.10
Task failure (s)	64.7 ± 15.9	79.6 ± 18.2	4.422	0.001

Legend: RPE = Ratings of Perceived Exertion; M = Mean; SD = standard deviation; s = s.

No significant difference was found between a-tDCS ($M = 792.4 \pm 128.8$) and sham groups ($M = 785.4 \pm 133.3$) for MVC ($t = -0.3813$; $p = 0.71$) (Figure 3).

The time in task failure in a-tDCS (DLPFC) group ($M = 79.6 \pm 18.2$ s) was higher compared to sham ($M = 64.7 \pm 15.9$ s) ($t = 4.422$; $p = 0.001$) as presented in Figure 4 and Table 3.

Discussion

The purpose of this study was to verify the acute effects of tDCS on the handgrip strength of Brazilian jiu-jítsu athletes. The results showed that a-tDCS effectively increased the time before task failure in an isometric grip strength exercise, but no change was observed in the MVC and RPE tests. The tests performed by the athletes in the study contained visual information for the motor responses of the handgrip. A study by Cynarski *et al.* [2021] could observe that jujutsu athletes (martial art with characteristics similar to Jiu-Jitsu) had good reaction time for handgrip strength, based on visual information, having better results than when compared to judokas. This information corroborates the choice and specificity of the tests performed by the BJJ athlete.

In the present study, applying a-tDCS over the DLPFC promoted an improvement of 14.9 seconds (79.6 ± 18.2 seconds) in the time to failure in an isometric handgrip test compared to the sham (64.7 ± 15.9). Although these results are the first carried out with this task and in this specific population, previous studies have also shown that a-tDCS was effective in improving physical performance during dynamic strength exercises [Vieira *et al.* 2020; Lattari *et al.* 2019; Lattari *et al.* 2016], tolerance in strenuous activity [Lattari *et al.* 2018; Victor-Costa *et al.* 2015] and even during a maximal incremental cardiorespiratory test [Okano *et al.* 2015].

The positive results found in this study were thought to be through the application of a-tDCS on DLPFC; however, there are still gaps in the literature about the best area to be stimulated, especially in specific populations. A study developed by Cogiamanian *et al.* [2007] with healthy individuals reported that a-tDCS (-21%) was able to significantly reduce the resistance time when compared to placebo conditions (-35%) or without stimulation (-39%), demonstrating that the application of a-tDCS over motor areas of the cerebral cortex increased the muscular resistance of the flexors of the left elbow in an intensity corresponding to 35% of the MVC. However, studies diverge on the application of tDCS directly under the CM in some populations [Kan *et al.* 2013; Williams et al. 2013; Montenegro *et al.* 2015].

According to Kan *et al.* [2013], a-tDCS may not affect the performance of muscle function due to the ceiling effect of neural capacity, where stimulation could not further improve this function since it was already at its maximum capacity. This ceiling effect may suggest that in specific populations, such as athletes and perhaps healthy and active people, stimulation under the CM directly might not be the best strategy. Moreover, this may also be one of the hypotheses to try to explain some controversies in the findings with tDCS. In a study by Williams *et al.* [2013], no significant differences were found in the application of a-tDCS (2mA for 20 minutes) in a healthy population during elbow flexor task failure performed at a load of 20% of the MVC, yet the a-tDCS condition generated greater fatigue and greater perceived exertion when compared to the sham. Another study carried out by Montenegro *et al.* [2015], performed with a dynamic strength test, also found no significant difference for the application of tDCS directly under the CM.

Contrary to its initial hypothesis, the present study did not find any significant differences in RPE. However, studies performed with strength and aerobic exercises diverged on the results of RPE in their findings [Lattari *et al.* 2018]. One of the possibilities for this finding in the current study may be the questionable sensitivity of the scale used to measure RPE [Borg, 1998].

In the current study, a-tDCS might have the ability to generate greater recruitment and increase the rate of triggering of the motor units by sending a significant number of sensory inputs to the sensorimotor and motor cortex [Cafarelli *et al.* 1979]. Another theory would be the possibility of modulating feedback inhibitor systems, which limit cortical information to the motor system in order to protect it during a high workload, and consequently an increased risk to this system [Cogiamanian *et al.* 2007; Noakes *et al.* 2004]. Furthermore, we cannot fail to mention that the sensation and perception of pain may be associated with muscle fatigue [Gandevia 2001; Noakes *et al.* 2004], and a-tDCS could reduce pain, delaying fatigue during a sustained voluntary contraction and prolonged [Fregni *et al.* 2006], even though no differences were found in the RPE in the present study.

The anthropometric values with the considerable variation found in the sample of this study can be explained by the fact that jiu-jitsu is classified by age group, gender, and weight categories. According to the IBJJF [2021] the weight categories for adults and male masters are rooster (57.50 kg), light feather (64.00 kg), feather (70.00 kg), light (76.00 kg), middle (82.30 kg), medium-heavy (88.30 kg), heavy (94.30 kg), super-heavy (100.50 kg) and ultra-heavy (no maximum weight). Forty percent of the participants were over the weight they reported fighting; this was expected, given that BJJ athletes usually lose weight for the competitive period. An essential piece of information to consider is that according to Cynarski *et al.* [2021], the bodyweight of grappling athletes (judo and jujutsu) influences handgrip strength.

As far as we know, this is the first study to investigate the effects of a-tDCS applied to DLPFC on the performance of isometric strength (specific task) in elite Brazilian jiu-jitsu athletes. However, the study is not without its limitations, such as the absence of a control group, the low sample size, and the lack of quantifying variables that could investigate the mechanisms of action of tDCS. In addition, stimulating other cortical areas, including female athletes, and assessing cortical excitability during the tasks, should be investigated in future studies.

Conclusions

Stimulation of DLPFC by application of a-tDCS to a small sample size of male adult and master 1 level BJJ athletes resulted in statistically significant improvement of handgrip strength at 60% of MVC compared to sham. The results may indicate an ergogenic aid of a-tDCS on handgrip strength. However, there was no change in MVC and RPE between the two groups.

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Transkranialna stymulacja prądem stałym (tDCS) poprawia wydajność chwytu ręki u zawodników elity brazylijskiego Jiu-jitsu

Słowa kluczowe: neuromodulacja, mózg, wytrzymałość mięśniowa, nieinwazyjna stymulacja mózgu, środki ergogeniczne, zapasy, walka

Streszczenie

Wprowadzenie. Brazylijskie Jiu-Jitsu (BJJ) to sztuka walki o wysokim natężeniu, której głównym celem jest zmuszenie przeciwnika do poddania się przy użyciu dźwigni stawowych lub duszenia. Badanie różnych strategii poprawy siły mięśniowej i wytrzymałości ma kluczowe znaczenie dla praktykujacych BJJ. W przeszłości wykazano, że anodowa przezczaszkowa stymulacja prądem stałym (a-tDCS) stosowana do lewej grzbietowo-bocznej kory przedczołowej (DLPFC) poprawia wydolność fizyczną.

Problem i cel. Jednakże, nie jest znany wpływ tDCS na izometryczne skurcze u zawodników BJJ. Celem tego badania było zbadanie ostrego wpływu tDCS na siłę chwytu ręki u elity zawodników BJJ.

Materiał i metody. Do badania zakwalifikowano dziesięciu mężczyzn, zawodników BJJ w wieku 25,5 ± 5,7 lat. Uczestnicy przeszli dwa warunki eksperymentalne (a-tDCS i warunki pozorowane) w odstępie 48-72 godzin w sposób losowy między sekcjami. Stymulację przeprowadzano na DLPFC (intensywność 2 mA/20 minut). Bezpośrednio po stymulacji lub w warunkach pozorowanych przeprowadzono test MVC chwytu ręki, a następnie utrzymano submaksymalne obciążenie do momentu wyczerpania przy 60% MVC. Po zakończeniu testu zebrano dane dotyczące odczuwanego wysiłku (RPE).

Wyniki. Nie stwierdzono znaczącej różnicy między a-tDCS a warunkami pozorowanymi dla MVC.

a-tDCS promował poprawę wydajności, wydłużając czas do niepowodzenia zadania w zadaniu ze stałą siłą chwytu z obciążeniem na poziomie 60% maksimum.

Wnioski. A-tDCS promował poprawę wydajności, wydłużając czas do niepowodzenia zadania w zadaniu ze stałą siłą chwytu z obciążeniem na poziomie 60% maksimum.