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Anodal transcranial direct current stimulation does not affect 100-meter event performance in sprinters

A estimulação transcraniana anódica por corrente contínua não afeta o desempenho em provas de 100 metros em velocistas

La estimulación transcraneal anódica con corriente continua no afecta el rendimiento en carreras de 100 metros en velocistas

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Resumo
Contexto: Durante a prova de 100 m, a velocidade máxima de sprint e a potência média desenvolvidas ao longo dos 100 m estão fortemente relacionadas ao desempenho nos 100 m. Nesse sentido, a estimulação transcraniana por corrente contínua (ETCC) anódica pode afetar positivamente a velocidade de sprint e a potência. Assim, este estudo analisou os efeitos da ETCC no desempenho em sprint de atletas velocistas. Métodos: Oito velocistas completaram um delineamento duplo-cego cruzado: ETCC anódica e condições simuladas. O estímulo foi aplicado sobre o córtex motor (CM) por 20 minutos, utilizando uma intensidade de corrente de 2 mA na condição ETCC anódica. Imediatamente após as sessões de ETCC, os velocistas realizaram o desempenho máximo de 100 m. A velocidade média foi medida entre 40 e 70 metros [40-70 m], e o tempo durante a prova de 100 m. Resultados: Os resultados não revelaram diferenças significativas entre as condições para a velocidade média de 40-70 m (P = 0,37) e o tempo durante a prova de 100 m (P = 0,47). Durante a prova de 100 m, dois velocistas no teste simulado e mais dois sprints na ETCC anódica apresentaram um tempo atingido menor que o basal. Conclusão: A ETCC anódica não afeta o desempenho de velocistas profissionais. Além disso, as respostas individuais não corroboram um possível efeito benéfico da ETCC anódica em todos os velocistas, apenas em alguns atletas.
Palavras-chave: Estimulação cerebral não invasiva; Velocidade; Atletas

Abstract
Background: During the 100-m event, the maximal sprint velocity and the mean power output developed over 100 m strongly relate to 100-m performance. In this sense, the anodal transcranial direct current stimulation (tDCS) may positively affect sprint velocity and power output. Thus, this study analyzed the effects of tDCS on sprint performance in sprinting athletes. Methods: Eight sprinters completed a double-blind crossover design: anodal tDCS and sham conditions. The stimulus was applied over the motor cortex (MC) for 20 minutes using a 2mA current intensity in the anodal tDCS condition. Immediately after tDCS sessions, sprinters performed the one maximum field 100-m performance. The mean velocity was measured between 40 and 70 meters [40-70m], and the time during the 100-m event. Results: The results did not reveal significant differences between conditions for the mean velocity at 40-70 m (P = 0.37) and time during the 100-m event (P = 0.47). During the 100-m event, two sprinters in the sham and two more sprints in the anodal tDCS showed a lower time reached than baseline. Conclusion: Anodal tDCS does not affect professional sprinters' sprinting performance. Furthermore, individual responses do not support a possible beneficial effect of anodal tDCS across all sprinters, only in some athletes.
Keywords: Noninvasive brain stimulation; Sprint; Athletes

Resumén
Antecedentes: Durante la prueba de 100 m, la velocidad máxima de sprint y la potencia media desarrollada a lo largo de 100 m se relacionan estrechamente con el rendimiento en dicha prueba. En este sentido, la estimulación transcraneal anódica con corriente continua (tDCS) puede afectar positivamente la velocidad de sprint y la potencia de salida. Por lo tanto, este estudio analizó los efectos de la tDCS en el rendimiento de sprint en atletas velocistas. Métodos: Ocho velocistas completaron un diseño cruzado doble ciego: tDCS anódica y condiciones simuladas. El estímulo se aplicó sobre la corteza motora (MC) durante 20 minutos utilizando una intensidad de corriente de 2 mA en la condición de tDCS anódica. Inmediatamente después de las sesiones de tDCS, los velocistas realizaron la prueba máxima de 100 m en un campo. Se midió la velocidad media entre 40 y 70 metros [40-70 m] y el tiempo durante la prueba de 100 m. Resultados: Los resultados no revelaron diferencias significativas entre las condiciones para la velocidad media a 40-70 m (P = 0,37) y el tiempo durante la prueba de 100 m (P = 0,47). Durante la prueba de 100 m, dos velocistas en el grupo simulado y dos más en la prueba de tDCS anódica mostraron un tiempo alcanzado inferior al inicial. Conclusión: La tDCS anódica no afecta el rendimiento de los velocistas profesionales. Además, las respuestas individuales no respaldan un posible efecto beneficioso de la tDCS anódica en todos los velocistas, solo en algunos atletas.
Palabras clave: Estimulación cerebral no invasiva; Sprint; Atletas

Introduction

There is considerable debate in the literature about the ergogenic potential of various dietary supplements regarding their effectiveness in improving physical performance in athletes (Porrini & Del Bo, 2016). Given this, transcranial direct current stimulation (tDCS) emerged as a neuroscience technology associated with performance-enhancing in sports (Angius, Hopker, & Mauger, 2017; Angius, Pascual-Leone, & Santarnecchi, 2018; Davis, 2013; Edwards et al., 2017). tDCS is a neuromodulatory technique in which a low-intensity direct electrical current is applied to the scalp over different regions of the cerebral cortex (Nitsche & Paulus, 2000). The application of anodal tDCS over the motor cortex (MC) causes an increase in cortical excitability (Nitsche & Paulus, 2000), and this mechanism has been suggested as responsible for enhancements found in physical performance (Angius et al., 2017).

Few studies investigated the effects of anodal tDCS on sprinting performance (Alix-Fages et al., 2021; Chen et al., 2021). A recent finding shows that anodal tDCS applied over the MC does not seem to improve the 150-meter initials during a repeated sprinting task in trained basketball players (Chen et al., 2021). In addition, no change was observed for the 30-meter sprint when anodal tDCS was previously applied to the cerebral cortex of healthy subjects (Alix-Fages et al., 2021). In turn, these results are limited regarding the effects of anodal tDCS on 100-m sprint performance in sprinting athletes.

During the 100-m event, the maximal sprint velocity [Vmax] and the mean power output developed over 100 m strongly relate to 100-m performance (Slawinski et al., 2017). In this scenario, plausible hypotheses support a positive effect of anodal tDCS on 100-m sprint performance in professional sprinters. First, anodal tDCS increases cortical excitability, which is associated with improved power performance (Grospretre et al., 2021). Second, anodal tDCS has also been shown to increase countermovement jump (CMJ) performance (Codella, Alongi, Filipas, & Luzi, 2021; Grospretre et al., 2021; Lattari et al., 2020). Moreover, variables related to CMJ have shown a positive association with sprint performance (Morris, Weber, & Netto, 2022). These hypotheses could support the ergogenic potential of anodal tDCS on 100-m sprint performance in sprinters. However, the effect of anodal tDCS on 100-m sprint performance in sprinters remains unclear.

Therefore, this study analyzed the effects of tDCS on sprint performance in sprinting athletes. We hypothesized that no differences would exist between anodal tDCS and placebo for sprint performance (Alix-Fages et al., 2021; Chen et al., 2021). On the other hand, estimates of performance enhancement in field tests may not apply to sprinting athletes (W. G. Hopkins, Hawley, & Burke, 1999). In this case, a change of ~1% could benefit sprinters (Will G Hopkins, 2004). Thus, individual improvements in sprinting performance are expected only for the anodal tDCS.

Materials and methods

Participants

Initially, we invited the 16 sprinters registered with the Brazilian Athletics Confederation of the state of Rio de Janeiro (https://www.cbat.org.br/novo/). However, eight athletes did not agree to participate in the research. Thus, eight sprinters, aged between 19 and 29 years [age = 21.8 ± 3.6 years, body mass = 72.5 ± 8.1 kg, height = 1.80 ± 0.1 m] and registered at the Brazilian Athletics Confederation participated in this study. They trained between 3 and 6 times a week (M ± SD = 5.0 ± 0.9) and reported their best time recorded in an official 100-m event (M ± SD = 11.5 ± 0.5 s; Minimum = 10.7 s; Maximum = 12.3 s). Eligibility criteria included: (a) sprinting athletes; (b) not having any neuropsychiatric, cardiovascular, or osteoarticular diseases; and (c) not using any medication. The exclusion criteria were as follows: (a) epilepsy history, (b) stroke history, (c) smokers, (d) use of any metallic implants, (e) use of cardiac pacemaker (Bikson et al., 2016), (f) use of caffeinated or alcoholic beverages two days before each experimental session; and (g) involvement with strenuous exercise two days before each visit. This research was conducted following CNS Resolutions No. 510/2016 and 466/2012. The experiment was approved by the Institutional Ethics Committee from the University of Salgado de Oliveira (protocol number 4.393.282).

Study design

In this counterbalanced randomized, sham-controlled, and double-blind study, subjects participated in two baselines and two experimental visits on four occasions interspaced by one week. On the first visit, the sprinters underwent anthropometric assessments [body mass and height] and the maximum field 100-m performance. For the second visit, the 100-m performance was repeated. After baseline assessments, subjects completed two counterbalanced randomized experimental conditions (1:1): anodal tDCS and sham. The MC was stimulated for 20 min at a 2-mA current (~ 0.06mA/cm^2). The mean velocity of the sprint was measured between 40 to 70 meters [40-70m]). The excerpt between 40 and 70-m was chosen due to its relationship with the achievement of Vmax (Slawinski et al., 2017) (Fig.1). the time reached during the 100-m event was also measured. The experimental conditions were performed at the same time of the day for each participant (9 am to 11 am) to avoid circadian rhythm effects. All experimental visits took place on a standard synthetic track. The subjects were evaluated on the same days under the following temperature and relative humidity: Day 1: 29º-32°C and 55%–62%; Day 2: 28º-31°C and 56%–60%; Day 3: 29º-32°C and 63%–68%; Day 4: 31º-33°C and 51%–54%.

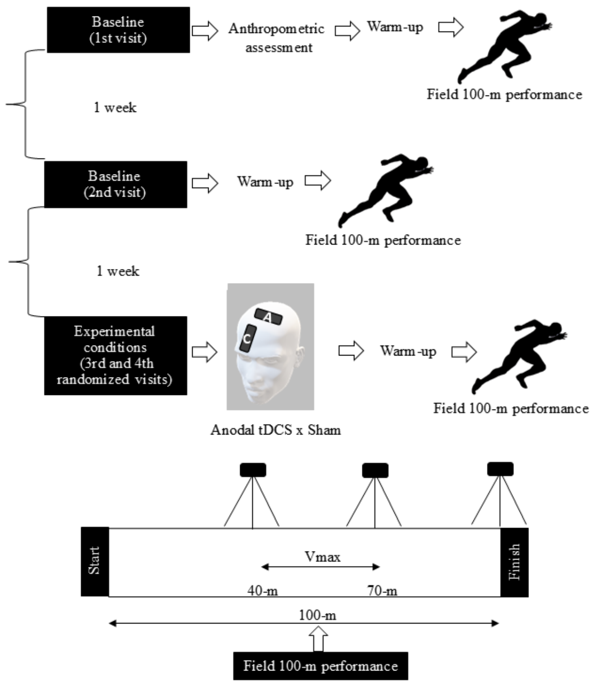

Fig. 1- Study overview.

Legend: A = anodal electrode; C = cathodal electrode CMJ = countermovement jump. Vmax = maximal sprint velocity

tDCS protocol

The tDCS was applied using two pads soaked in a saline solution (0.8% NaCl), with the two electrodes inside (5.0 x 7.0 cm) connected to a direct current stimulation device (TCT - Shanghai, China). In both conditions, the anode electrode was placed over the MC and the cathode over the right orbitofrontal cortex (OBF). Electrode placement according to the international 10–20 electroencephalography system (Herwig, Satrapi, & Schonfeldt-Lecuona, 2003). The subjects were stimulated for 20 min at a 2-mA current (~ 0.06mA/cm^2) in the anodal tDCS condition (Codella et al., 2021; Lattari et al., 2020). However, the stimulator was switched off after 60 s in the sham (Gandiga, Hummel, & Cohen, 2006). The intensity ramp-up and ramp-down functions of the TCT device were used at the beginning and the end of tDCS for 1 minute (impedance levels < 5 k ohms). The researcher who applied the tDCS was absent during the physical measurements (field 100-m performance) to follow a double-blind design.

Warm-up

After the tDCS protocol, the subjects performed a specific warm-up consisting of 5 minutes of continuous running at a self-selected pace and another 5 minutes of specific movements (i.e., skipping, dribbling, and anfersen).

Field 100-m performance

After the warm-up (i.e., ~ 1 minute), sprinters performed one maximum field 100-m performance test. The test was carried out similarly to a 100-m race, using the same commands: "On your marks,"; "Ready," and starting Shot. The following field 100-m performance procedures were adopted: a) the 100-m sprints were performed individually; b) all sprinters used a standard crouched position start, similar to that used for the 100-m race; c) the pair of photo-cells and a chronometer were triggered by a standard audio signal similar to those of typical competitions (i.e., "fuze starting pistol"); d) An experienced researcher visually inspected for proper technique, and "burnt match" attempt was invalid. The mean velocity of the maximal sprint was measured between 40 and 70 meters [40-70m] and during the entire 100-m event using three pairs of photoelectrical cells and starting blocks (MultiSprint Full, Minas Gerais, Brazil). Assuming an athlete's relative acceleration ability (t) is constant in a certain race period, the sprinter will reach the Vmax after attaining the maximal relative acceleration (Healy, Kenny, & Harrison, 2022). Thus, lower values of t indicate the ability to reach a higher percentage of Vmax, which generally occurs between 40 and 70 meters on the position-velocity curve during the 100-m event. In this sense, the use of mean velocity is representative of Vmax. In addition, there is a near-perfect negative correlation of the Vmax with 40-60 m (r = - 0.98) and 60-80 m (r = - 0.96) split time (Healy et al., 2022). Moreover, the time reached during the 100-m event also was measured. These devices were connected to a program that allowed measuring time with an accuracy of 0.001 seconds (MultiSprint Full, Minas Gerais, Brazil).

Statistical analyses

Previously, the intra-class correlation coefficient (ICC, model 3.1) with $CI_{95\%}$ (ICC [$CI_{95\%}$], and standard error of measurement (SEM = SD/√n) were calculated for the mean velocity between 40-70m and time reached during the 100-m event. After the normal distribution of the variables (Shapiro-Wilk test) was confirmed ($P > 0.05$). A one-way repeated-measures ANOVA with Bonferroni post-hoc corrections was used to investigate the effect of the tDCS conditions (Baseline, anodal tDCS, and sham) over the dependent variables (i.e., mean velocity for 40-70m, and time reached during the 100-m event). The Greenhouse-Geisser correction was applied when the assumption of sphericity was violated ($P < 0.05$). Statistical significance was set at $P < 0.05$. Statistical analyses were performed using the software package SPSS (IBM SPSS version 25.0, Chicago, IL, USA). In addition, due to the small number of athletes utilized (n = 8), the power analysis also was determined for each dependent variable. In this case, the power analysis was calculated using G*Power software (version 3.1). Moreover, each dependent variable's smallest worthwhile change (SWC = 0,3*CV%) was used to provide information about individual responsiveness to the tDCS protocol.

Results

Reliability for the mean velocity between 40-70 m and time reached during 100-m event.

In the section 40-70 m, the mean velocity presented the following values for test (M = 9.304 m•s^{-1} and SEM = 0.142 m•s^{-1}] and retest [M = 9.388 m•s^{-1} and SEM = 0.122 m•s^{-1}), with ICC (0.96 [0.80 to 0.99]). In the 100-m event, the time reached presented the following values for the test (M = 11.68 s and SEM = 0.15 s) and retest (M = 11.65 s and SEM = 0.16 s), with ICC (0.94 [0.72 to 0.99]).

Comparisons between the conditions for mean velocity [40-70m] and time [100-m]

No significant differences were found between the conditions for mean velocity 40-70m ($F_{2,14}$ = 1.086; P = 0.37) and time reached during the 100-m event ($F_{2,14}$ = 0.799; P = 0.47) (Table 1).

Table 1- Analyses of dependent variables.

Mean velocity (m•s^{-1})	Baseline (M ± SD)	Anodal tDCS (M ± SD)	Sham (M ± SD)
40-70m	9.346 ± 0.367	9.360 ± 0.268	9.426 ± 0.288
Time (s)			
100-m	11.67 ± 0.43	11.65 ± 0.37	11.59 ± 0.35

Legend: M = mean; SD = standard deviation; m•s^{-1} = meters per second; s = seconds

In the race stretch between 40 and 70 meters, only sprinter 5 showed positive changes in the anodal tDCS compared to baseline (+0.7%). In addition, sprinter 5 showed worsened performance in the sham compared to baseline (-1.8%). On the other hand, two sprinters also improved their performance in the sham compared to the baseline (sprinter 1 = +2.5%; sprinter 6 = +1.1%) (Figure 2).

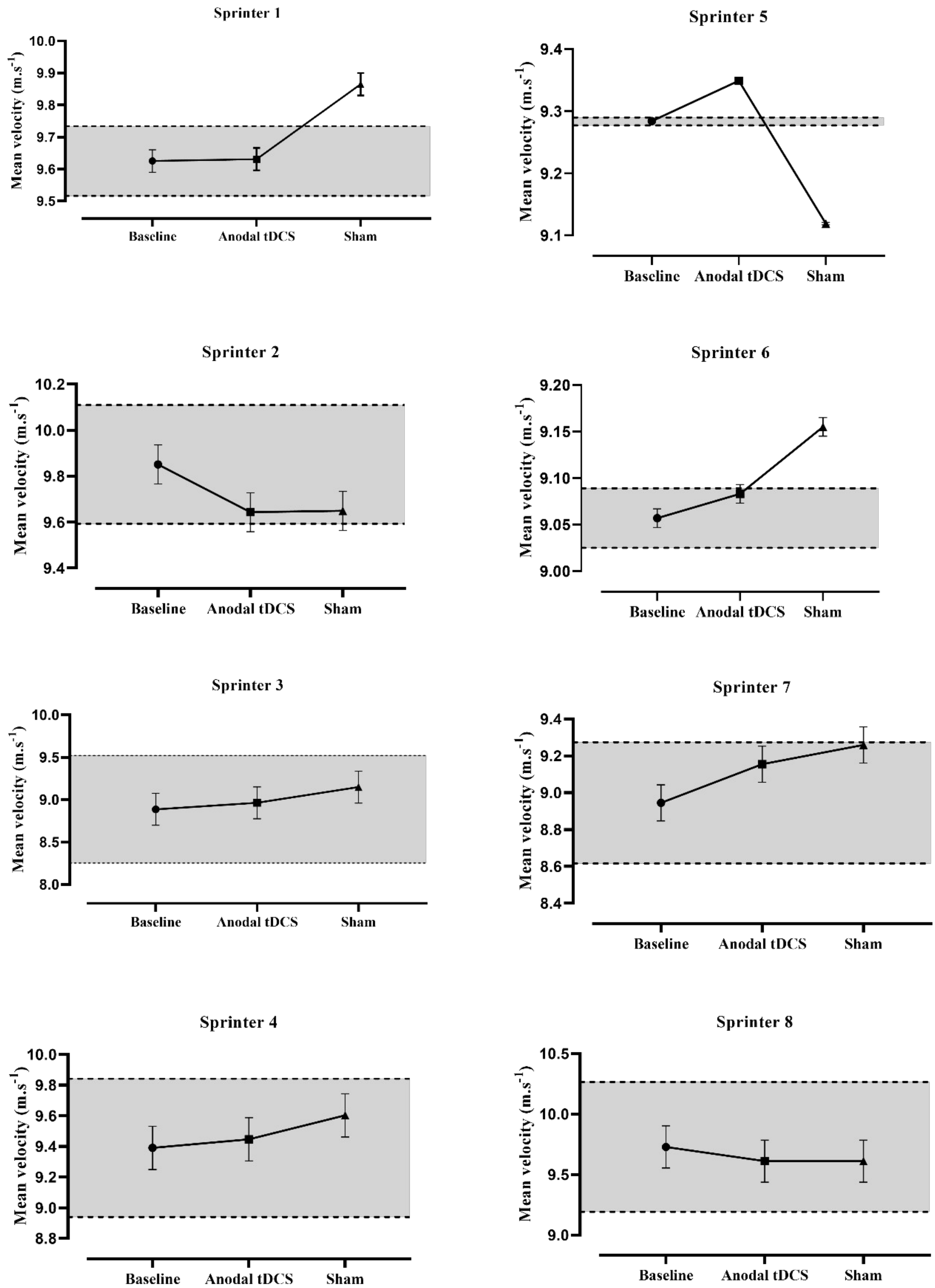

Fig. 2- Individual responses related to anodal tDCS and sham conditions for mean velocity between 40 and 70 meters. The area demarcated by gray color corresponds to the SWM. The black dots, squares, and triangles correspond to the athlete's experimental conditions, and the error bars correspond to the SEM.

Regarding the time reached during the 100-m event, two sprinters showed a lower time reached in the sham than baseline (sprinter 1 = -1.3%; and sprinter 7= -2.2%). On the other hand, sprinter 5 showed a greater time reached in the sham than baseline (+1.2%). Moreover, two sprinters showed a lower time reached in the anodal tDCS than baseline (sprinter 5 = -0.8% and sprinter 7 = -1.6%) (Figure 3).

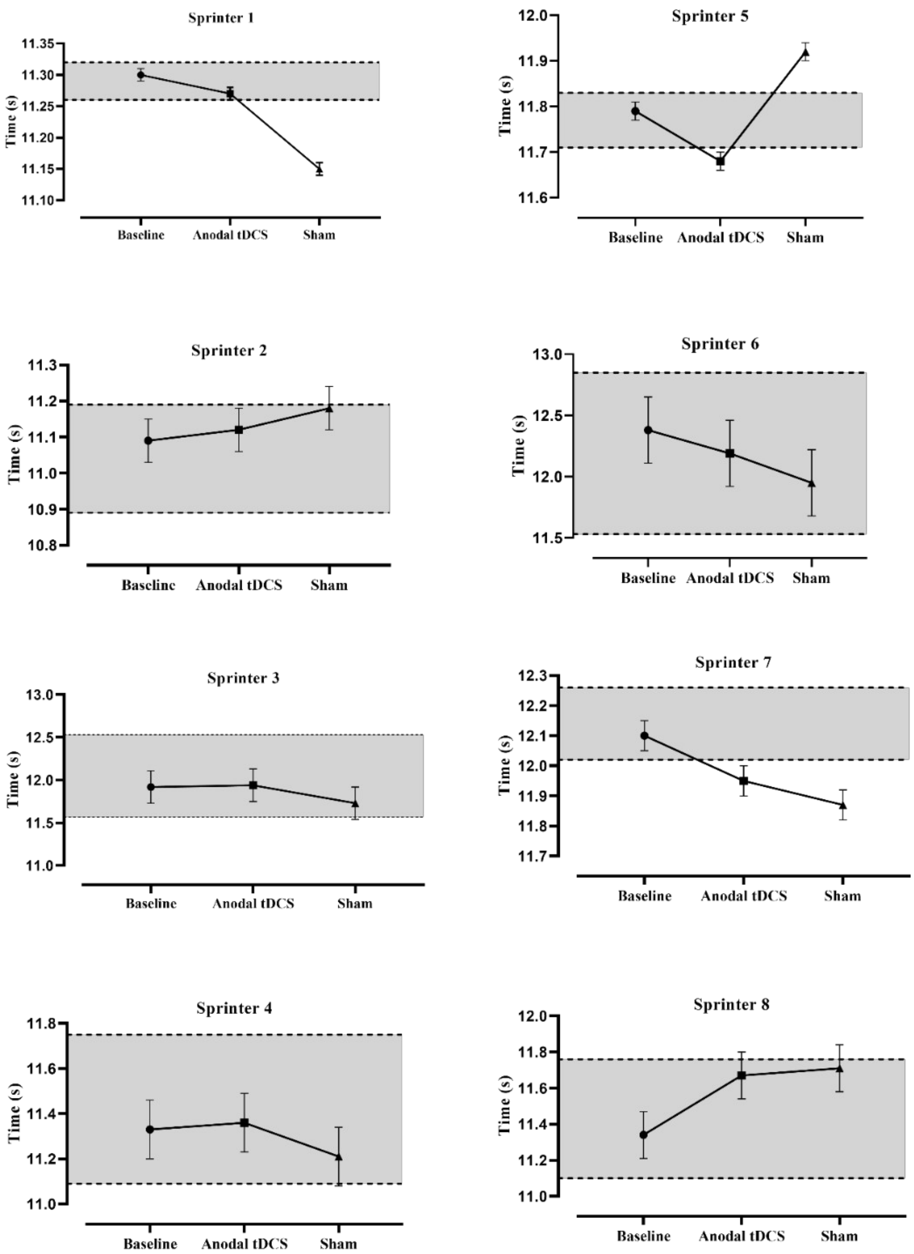

Fig. 3 - Individual responses related to anodal tDCS and sham conditions for a time reached during the 100-m event. The area demarcated by gray color corresponds to the SWM. The black dots, squares, and triangles correspond to the athlete's experimental conditions, and the error bars correspond to the SEM.

Discussion

This study analyzed the effects of tDCS on sprint performance with sprinting athletes, and no change was shown over the mean velocity between 40 and 70 meters and the time reached during the 100-meter event. However, the power analysis determined for mean velocity between 40-70m and time reached during the 100-m event suggests caution related to the results found. Our findings showed individual responsiveness to the tDCS protocol in some sprinters. Collectively, these data demonstrated that I) the anodal tDCS showed no ergogenic effect on performance in the 100-meter event, and II) the individual responsiveness to the tDCS protocol may generate both positive and negative effects on sprint performance. To our knowledge, this is the first study investigating the ergogenic effects of anodal tDCS on 100-meter performance in athletes of the modality, the flagship event in track and field (Slawinski et al., 2017).

A previous meta-analysis showed no effect of anodal tDCS on sprint tasks (Shyamali Kaushalya, Romero-Arenas, Garcia-Ramos, Colomer-Poveda, & Marquez, 2022), corroborating our initial hypothesis. A similar finding was demonstrated concerning the sprinting time in the 150-m initials with trained basketball players (Chen et al., 2021) and the 30-m sprint performance in healthy subjects (Alix-Fages et al., 2021). However, the mechanisms involved in enhancing sprint performance using anodal tDCS still need to be explored. It is plausible to assume that the anodal tDCS mechanism (i.e., modifying the neuronal transmembrane potential) may not be responsible for possible improvements in sprint performance. However, this hypothesis needs further elucidation.

Concerning the 100-meter event performance, minimal differences would be expected between the sprinters. The results of our study did not find differences between the anodal tDCS and placebo for sprint performance. However, the power analysis found in the research may be incurred in the type II error, which limits an external validation of the results for athletes in the modality. In turn, this is the first study that individually explored the effects of tDCS on sprint performance with sprinters. In this context, an improvement of ~1% is already considered beneficial for sprinters, and our findings showed some interesting results.

Remarkably, two athletes showed positive effects in the sham condition compared to baseline on mean velocity in the 40-70-meter stretches (+ 2.5% and + 1.1%). In turn, only one sprinter showed positive changes in the anodal tDCS compared to baseline (+ 0.7%). For the time reached during the 100-m event, two sprinters showed a lower time in the sham (-1.3% and -2.2%) and anodal tDCS (- 0.8% and -1.6%) compared to baseline. Concerning results found in the sham condition, these findings can be explained by the possibility of a placebo effect of sham on physical performance. However, this hypothesis still lacks further clarification from the literature. For the anodal tDCS, these positive findings could be explained by inter-individual variability concerning the cortical excitability effects (Jamil et al., 2017). The cortical excitability effects did not linearly correlate with increasing intensity direct current in all subjects (Jamil et al., 2017). In this case, sprinters 5 and 7 benefited from the increased cortical excitability. However, this hypothesis has not yet been investigated. On the other hand, most athletes responded with lower intensities of direct intensity current, being that greater intensities reached the ceiling effect with no change in cortical excitability. This hypothesis is corroborated by homeostatic plasticity mechanisms, where the neural activity is stabilized within a physiologically reasonable dynamic range (Karabanov et al., 2015).

Strength and limitations

The present study does have some limitations. The first limitation is the study's small sample (n = 8), and more sprinters must be included to increase the power analysis of findings. On the other hand, the athletes used in the study had very similar speed performances in the 100 meters (CV < 1%). That said, the smallest worthwhile change can be much more useful, as it provides more accurate and reliable information regarding changes in the specific performance of a given athlete over different conditions. This prerogative highlights one of the strengths of this study. Another limitation of the study was performing the field 100-m performance. Somehow, environmental factors can influence the results found. On the other hand, this study showed good ecological validity. In practical terms, the 100-meter race held indoors is not of great value in terms of the performance marks obtained.

Given the above, we suggest further investigations on the effects of tDCS in 100-m event performance with sprinters. tDCS is a noninvasive cortical stimulation technique with the potential to alter cortical excitability and modulate motor performance in healthy adults (Buch et al., 2017; Reis & Fritsch, 2011). For instance, tDCS has a promising impact on motor reaction time (Carlsen, Eagles, & MacKinnon, 2015), an essential phase in the 100-m sprint (Slawinski et al., 2017). Thus, tDCS may present ergogenic effects on other parameters related to the 100-m event, which requires further investigation.

Conclusion

Anodal tDCS has no ergogenic effects on 100-m sprint performance in sprinting athletes. Furthermore, individual responses do not support a possible beneficial effect of anodal tDCS across all sprinters, only in some athletes. Coaches and athletes should consider the task performed when the goal is acute performance improvement after using anodal tDCS.

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