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ORIGINAL ARTICLE

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Electromyography Investigation of Eccentric and Concentric Phases of the Biceps Dumbbell Curl Movement after Four Weeks of Transcranial Direct Current Stimulation in Healthy Men

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ABSTRACT

Background: Transcranial direct current stimulation is a safe method that employs a low-intensity current to induce stimulation in the brain. The utilization of tDCS has the potential to enhance both muscular strength and performance. This study investigated the effects of tDCS on the electromyographic activity of the biceps during concentric and eccentric contractions.

Methods: Twenty-two healthy subjects were randomly assigned to transcranial direct current stimulation or control groups. The tDCS group received anodal stimulation over the primary motor cortex for 15 minutes, while the control group received nothing. The subjects performed the maximum voluntary isometric contraction and concentric and eccentric contractions of the biceps, with 80% of their one-repetition maximum. After preliminary tests, a covariance analysis was conducted.

Results: Results showed that the one-repetition maximum in the tDCS group was significantly higher than the control group ($P < 0.05$). After 4 weeks of tDCS interventions in full range of motion and the concentric phase of movement, the tDCS group showed a significant decrease in the normalized root-mean-square of biceps brachii ($P< 0.05$). The data illustrates a reduction of 22% during the concentric phase and 18% during the eccentric phase.

Conclusions: Our findings indicate that tDCS improves muscular strength and neuromuscular efficiency. Nevertheless, it is important to use caution when interpreting the findings of this study, given its limited period and the small sample size of the group.

KEYWORDS

Concentric, Eccentric, Electromyography, tDCS, Strength

How to cite

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Introduction

Human neuroscience studies have widely used transcranial direct current stimulation (tDCS), a non-invasive method of brain stimulation, over the past decade. Transcranial direct current stimulation sends a weak direct current (up to 2 mA) through the scalp and creates a steady electric field in the brain. This field can change the resting membrane potentials of neurons to make them more or less excitable. Depending on the polarity and location of the electrodes, tDCS can target specific areas in the cerebral cortex [1, 2]. A single session of tDCS can induce neurophysiological aftereffects that may last for more than an hour after stimulation. Repeated sessions of tDCS can achieve more durable effects [1]. Therefore, this technique allows us to investigate the reversible neuroplasticity of the human brain [1], and its impact on changes in neural activity and motor performance in both healthy and clinical populations.

Dynamic muscle contractions during resistance exercises are divided into concentric and eccentric phases. Concentric contraction is when the muscle shortens under tension, whereas eccentric contraction is when the muscle lengthens under tension. Eccentric contractions occur when the external load surpasses the force that the muscle generates. The principle of specificity in strength training suggests that concentric and eccentric movements trigger distinct stimuli in the muscle, leading to distinct adaptations [3, 4]. The type of muscle contractions in resistance training influences neural adaptation. The central nervous system uses a different neural strategy to control skeletal muscles during eccentric versus isometric or concentric muscle contractions, such as the selective activation of fast-twitch motor units during eccentric contractions [5, 6]. Studies using neuroimaging have also shown that there is more activity in the cortex during eccentric actions compared to concentric actions. This could be because eccentric actions rely on more complex motor skills or reflexes that help control the muscle as it lengthens [7]. Studies have also shown that eccentric activity results in an inversion of the motor unit recruitment pattern (beginning with a larger motor unit) [8], faster neural adaptation after resistance training [9], and a decrease in EMG amplitude at similar force levels [10, 11].

Numerous trials have shown that tDCS improves muscle strength and performance [12, 13]. When the anodal tDCS stimulates target neurons, the resting potentials in the cell body and axon membrane show a small depolarization. This makes it more likely for neurons to fire and become excitable in the target region [1, 14]. Research demonstrates that bilateral tDCS of the M1 can considerably boost the muscle strength and explosive force of the knee extensor and flexor [12]. Additionally, studies suggest that anodal tDCS could serve as a useful instrument for boosting muscle power [13]. The biceps dumbbell curl movement, which consists of concentric and eccentric phases of muscle contraction, was implemented in this study. One of the methods that can assess neuromuscular adaptations is measuring the electrical activity of the muscles. Measuring the electrical activity of the biceps muscle in each phase separately can provide a more precise evaluation of tDCS's effect on muscle activity. To the best of our knowledge, no study has examined the effect of tDCS on the electrical activity of the concentric and eccentric phases of the biceps dumbbell curl movement. Since tDCS enhances neural adaptations, we aim to investigate whether four weeks of tDCS can increase strength and improve muscle electrical activity. We hypothesize that tDCS alone can induce changes in the electrical activity and strength of the biceps muscle during both concentric and eccentric contractions.

Material and Methods

Study design and Subjects

This was a simple, randomized study. Random sequences created with the SPSS version (SPSS Inc., USA) were placed in numbered and sealed, unreadable packets. We randomly assigned eleven participants to the tDCS group and another eleven to the control group. After verifying that each person matched the inclusion and exclusion criteria, the packets were opened sequentially, and the participants were divided into the respective groups.

We included twenty-two healthy young men who engaged in recreational activities for two to three hours per week (e.g., sports or aerobic exercise) and had no history of regular resistance training and no upper body injuries participated in this study. They underwent physical health and sports risk assessments using the PAR-Q test. The sample was selected from the University of Mazandaran. However, four of them dropped out of the intervention sessions due to personal issues: tDCS (n = 10) and control (n = 8) (Figure 2). All subjects visited the health laboratory of the University of Mazandaran one week before the test to become familiar with tDCS, EMG, MVC recording, and biceps dumbbell curl movement. We provided them with specific guidelines to maintain their regular daily routine, refrain from taking supplements, and abstain from participating in other exercise programs during the study period. Additionally, we instructed them not to drink beverages containing caffeine or alcohol and to stop exercising forty-eight hours prior to the testing sessions. All participants provided written informed consent, and the study was approved by the research ethics committee of the University of Mazandaran (IR.UMZ.REC.1403.001).

Interventions and Groups

For 15 minutes, transcranial stimulation of 1.5 mA was applied to the tDCS group (group T).The stimulation was delivered to the primary motor cortex via the anode electrode over the C3 region and the cathode electrode over the C4 region [15]. The group T participated in three stimulation sessions per week on alternating days at the health laboratory of Mazandaran University for four weeks, from 16:00 to 19:00. Physical activity was abstained from by this group throughout the assessment and intervention sessions. The control group (group C) participated exclusively in the pre-test and post-test, with no additional stimulation or training provided in between (Figure 1).

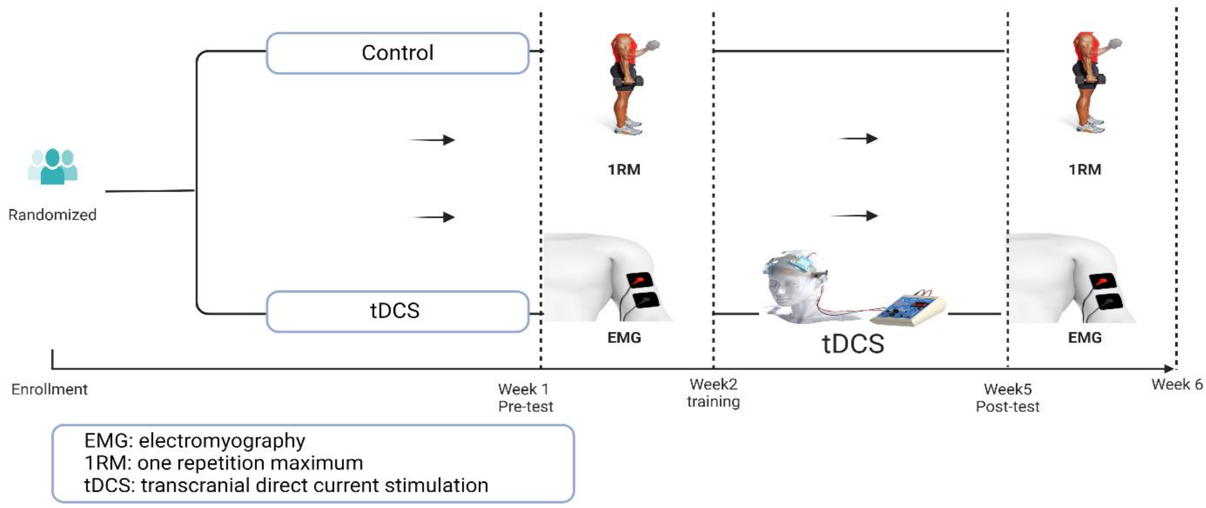

Figure 1. the timeline of the entire experimental interventions. three days per week, for a duration of four weeks.

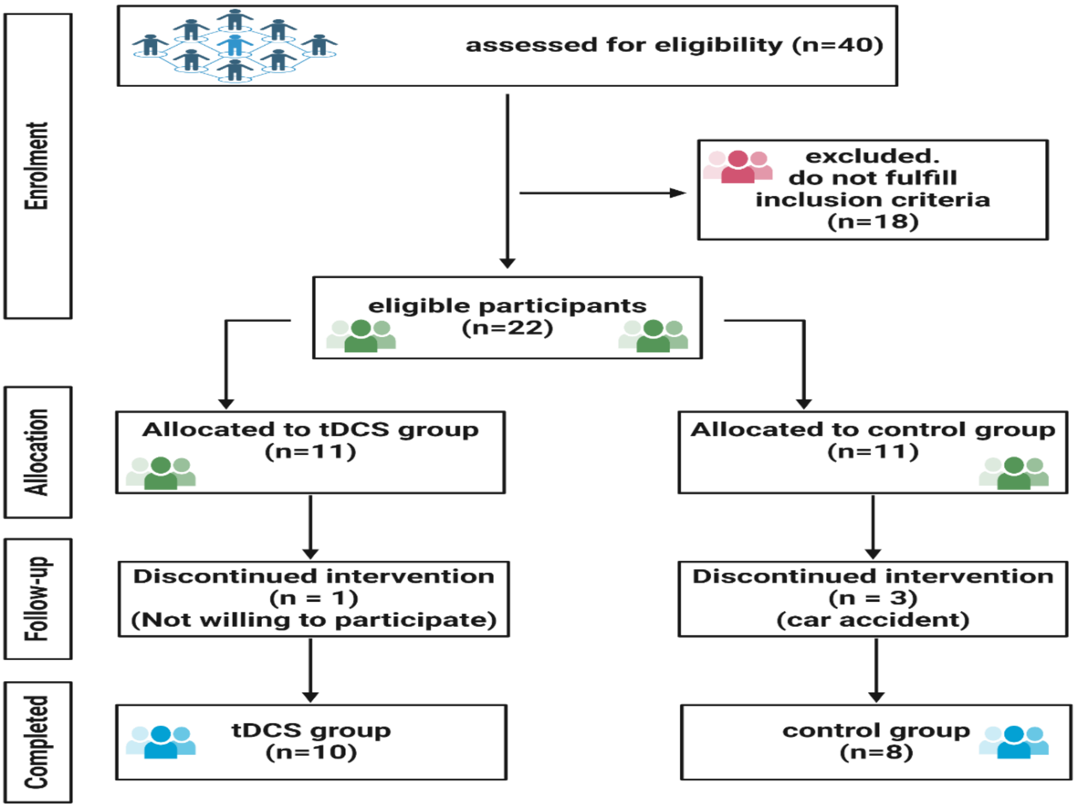

Figure 2. Study flow chart

Electromyography

The electromyography data was recorded using the MegaWin Muscle Tester ME 6000 (Mega Electronics Ltd., Finland). Electromyographic data was obtained from the biceps brachii muscle using skintact surface electrodes (Skintact, Innsbruck, Austria). In order to reduce noise interference, adhesive tape was utilized to secure the electrodes. EMG data was acquired using Megawin software version 3.1 with a 2000 Hz sampling rate. The electrode placement was determined and designated in accordance with the Surface Electromyography for Non-Invasive Assessment of Muscles (SENIAM) guidelines [16]. The data was filtered with a high-pass and a low-pass filter (10–500 Hz) and a notch filter to remove noise from electrical devices [17]. In order to mitigate the influence of various factors, including electrode placement in the pre-test and post-test, on the root-mean-square (RMS) of the test participants, the maximal voluntary isometric contraction (MVIC) was used for normalizing the RMS values. A window size of 750 milliseconds was utilized for analyzing [18].

1RM (dynamic strength)

We calculated the 1RM value using the Brzycki (1993) method. This protocol requires participants to perform repetitions at a suitable speed and range of motion until they reach failure or lose the proper form. After a general warm-up, the subjects selected a weight and completed ten repetitions of a set as a specific warm-up. Following this, we increased the weight to limit the subject to a maximum of 4-6 repetitions, terminated the test at this point, and calculated 1RM using Brzycki's formula [19].

Transcranial Direct Current Stimulation (tDCS)

Transcranial direct current stimulation (tDCS) was utilized by the Neurostim 2 device (MedinaTeb, Iran), which has a maximal output voltage of ±30 V and can deliver direct currents ranging from 0.1

to 2 mA. The anode electrode was positioned over C3 (according to the international 10-20 system) on the primary motor cortex [20], and the cathode electrode was located over C4 on the contralateral hemisphere [21]. A current of 1.5 mA was delivered to the scalp through a 5*5 cm carbon pad saturated in conductive gel for a duration of 15 minutes. A researcher who abstained from data analysis conducted tDCS just for group T for four weeks and three sessions each week. (Figure 3).

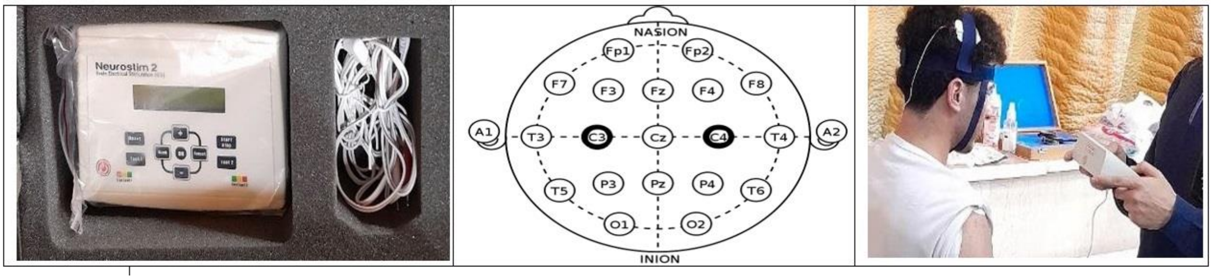

Figure 3. anodal tDCS stimulation for 15 minutes using a 5cm x 5cm carbon pad dipped in conductive gel. anode electrode was placed over C3. cathode electrode was placed on the C4.

Pre-Test and Post-Test

Following height, weight, and arm circumference measurements, participants performed a general and specific warm-up during the pre-test session. The electromyographic (EMG) activity of their biceps during MVIC was recorded. After three minutes of rest, the EMG activity of their biceps during the dumbbell curl with 80% 1RM was recorded. This task was done in three consecutive repetitions with a movement tempo of 20 BPM, which was set by a metronome. Their 1RM was recalculated following twelve sessions of interventions over the course of four weeks. The same assessments were performed again in the post-test session, following a 48-hour rest period.

Statistical Analyses

To examine the research hypotheses, the Shapiro-Wilk test was employed to assess the normality of the data. The results, which were not statistically significant ($P < 0.05$), suggested that the data adhered to a normal distribution. Levene's test was employed to examine the homogeneity of variances; the results of this test did not indicate that group variances were equal ($P < 0.05$). Following these initial assessments, a covariance analysis was performed. The analysis of the data was conducted utilizing SPSS 27. At 0.05, a significant level was determined.

Results

The descriptive characteristics of the 18 participants who completed the entire 4-week intervention are presented in Table 1. The two groups were comparable before the intervention, as there was no significant difference in their age ($p = 0.364$), height ($p = 0.121$), weight ($p = 0.197$), or body mass index ($p = 0.562$). Analysis of the research parameters using covariance is demonstrated in Table 2. In 1RM, full range and concentric phase of motion, significant changes are observed.

Table 1. Descriptive characteristics of the participants

Items	T (n=10)	C (n=8)	p-value
Age (years)	20.4±1.1	21±1.3	0.364
Height (cm)	179.4±8	173.2±4.7	0.121
Weight (kg)	75.5±11.4	69.1±10.4	0.197

BMI (kg/m2)	23.3±2.2	23±2.5	0.562

Table 2. Analysis of the research parameters using covariance

Groups	T	C	p-value	Effect size	Observed Power
1RM (Kg)	14.6 ± 2.22	11.75± 1.66	0.001*	0.454	0.99
Full range of motion (%MVIC)	51.62±16.81	70.15±32.23	0.008*	0.292	0.84
Concentric phase (%MVIC)	63.5±20.9	73.3±15.9	0.037*	0.124	0.55
eccentric phase (%MVIC)	39.7±13.5	41.1±12.9	0.124	0.167	0.509

The parameters tested demonstrated significant effects or interactions. The data is presented as Mean ± Sd; * indicates a significant group difference at P<0.05. T tDCS, C control. 1RM one repetition maximum. MVIC maximum voluntary isometric contraction.

Electrical Activity of full range of motion[1]: After 4 weeks, group T showed a significant decrease in the normalized root-mean-square of biceps brachii, as shown in Figure 4a. (P < 0.05).

Concentric phase: After 4 weeks, as shown in Figure 4b, a significant decrease in the normalized root-mean-square of the biceps brachii was observed in group T compared to group C (P < 0.05).

Eccentric phase: After 4 weeks of interventions, the difference in electrical activity normalized by MVIC in the pre-test and post-test is shown in Figure 4c. There is no significant difference in the normalized root-mean-square of the biceps brachii muscle in group T compared to group C (P = 0.125).

Muscle strength: One repetition maximum (1RM) strength results for the biceps muscle are shown in Figure 4d. Statistical analysis showed that 1RM in group T after the test was significantly higher than in group C compared to the pre-test (p < 0.05).

In Figure 4e, pre-to-post differences in concentric and eccentric phases induced by tDCS are displayed as a percentage. An 18% reduction in the eccentric phase and a 22% reduction in the concentric phase were observed.

[1] Concentric + Eccentric

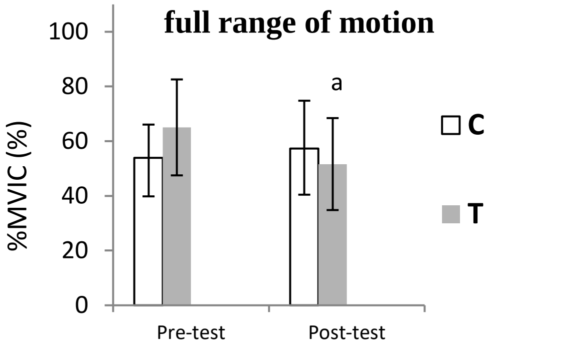

Figure 4a. Pre- and post-trial group scores for biceps normalized RMS. Letters “a” represent a comparison between groups. Significant Difference from C a $p< 0.05$.

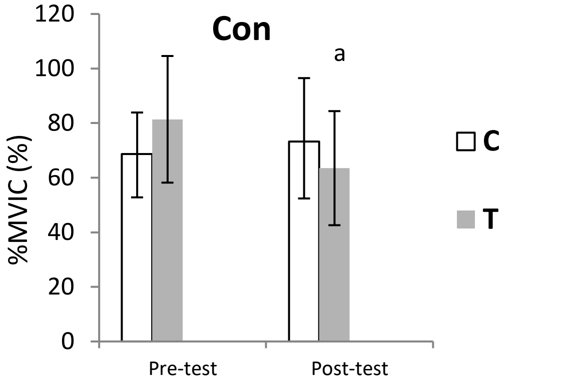

Figure 4b. Pre- and post-trial group scores for concentric phase of dumbbell curl movement. Letters “a” represent comparisons between groups. Significant Difference from C a $p<0.05$

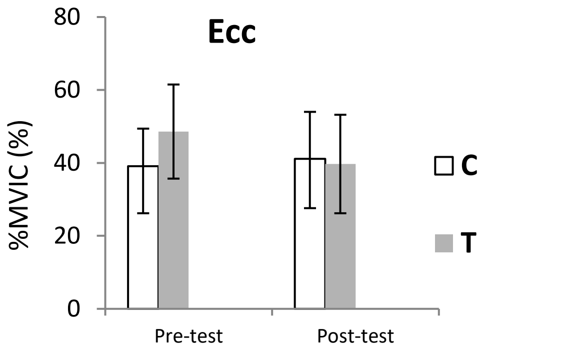

Figure 4c. Pre- and post-trial group scores for eccentric phase of dumbbell curl movement.

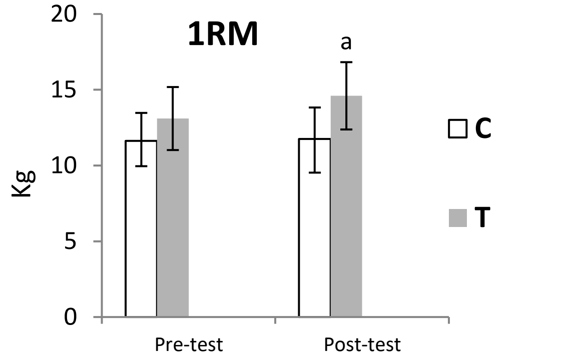

Figure 4d. Pre- and post-trial group scores for biceps 1RM. Letter “a” represents comparisons between groups. 1RM one repetition maximum. Significant Difference from C a $p< 0.05$

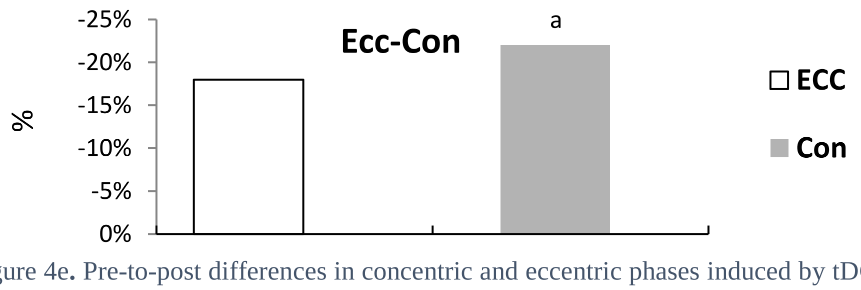

Figure 4e. Pre-to-post differences in concentric and eccentric phases induced by tDCS. 18% reduction in eccentric phase and 22% reduction in concentric phase were observed.

Figure 4. Data expressed as mean ± Sd. according to Bonferroni. T tDCS, C control, Con concentric phase. Ecc eccentric phase. MVIC maximum voluntary isometric contraction. 1RM, one repetition maximum.

Discussion

The purpose of this study was to perform a biceps dumbbell curl movement with a weight equal to 80% of 1RM in the pre-test and post-test sessions. The assessment of the adaptations induced by tDCS was conducted through electromyographic activity. The results of our experiments revealed that, at a constant weight, the electrical activity of the biceps brachii muscle throughout the full range of motion was significantly decreased in group T compared to group C. These significant changes suggest that the main cause of the alterations in group T was the transcranial direct current stimulation of the primary motor cortex of the brain. This finding suggests that the muscle achieved better efficiency in the recruitment of muscle fibers at the same load, which is consistent with the results reported by Cadore et al. (2010), who discovered that a period of strength training decreased muscle activity [22]. Based on these findings, it is possible that tDCS could improve the neuromuscular economy with regard to motor unit recruitment for a specific load (80% 1RM). Neuromuscular economy is a phenomenon characterized by electrical myographic activity variations that indicate the minimum amount of muscle activation necessary to complete a given task [22, 23]. At a similar weight, Cadore et al. discovered that strength training reduces muscle activity. They suggested that subjects require fewer motor units, particularly those of the fast contraction type, to lift the same weight; consequently, the electromyography amplitude reduces. The data presented in Figure 4e illustrates a reduction of 22% during the concentric phase and 18% during the eccentric phase. These findings suggest that tDCS improves neuromuscular efficacy and economy in muscle fiber recruitment. This is a remarkable finding that demonstrates the potential benefits of applying this intervention. However, more research is required to fully comprehend these mechanisms and their implications for exercise and rehabilitation. In this study, by analyzing the electrical activity of the concentric and eccentric phases of the movement separately, we found that the normalized electrical activity of the muscle decreased significantly in the concentric phase, while this change was not significant in the eccentric phase. This may be due to the fact that the central nervous system regulates skeletal muscles using a distinct neural strategy during eccentric contractions [5], and the eccentric phase of the movement involves a greater degree of motor complexity and stretch-induced reflexes to control the lengthening muscle [7]. Transcranial direct current stimulation induces subthreshold alterations in the neuronal membrane potential of the outer cortex but has no direct impact on the deep layers and control levels responsible for eccentric movement and reflexes [24]. Consequently, it has been incapable of effecting significant changes during this phase of motion. As a result, due to the uniqueness and complexity of the eccentric phase's neural mechanism, the application of tDCS alone was insufficient to significantly alter muscle electrical activity. To the best of our knowledge, no study has examined the effect of tDCS on the motor phases separately, so we are unable to compare our findings with those of other research in this area.

Numerous studies [21, 25, 26] have supported the ability of tDCS to increase muscle strength, either alone or in combination with other exercises. According to our findings, four weeks of anodal tDCS stimulation for 15 minutes per session at an intensity of 1.5 mA over the primary motor cortex significantly increased biceps muscle strength as measured by 1RM tests. The observed enhancement in muscular strength can be primarily attributed to the improved neural facilitation induced by tDCS. Muscle strength is dependent not only on muscle mass but also on motor unit recruitment. Anodal tDCS may improve the innervation of the central nervous system by inducing a minor depolarization of the resting membrane potential of the cell membrane and the axon of the target neurons, which in turn increases the likelihood of neuronal firing rate and excitability in the target area [1]. These changes in neural plasticity caused by tDCS are expected to increase the excitability of primary motor cortex neurons and, thus, the recruitment of motor units. The effects of tDCS were investigated by Hikosaka et al., who discovered that it enhanced handgrip strength [21]. Likewise, Lattari et al. examined the acute effects of tDCS on muscle strength in a review study. They proposed that tDCS could enhance maximal voluntary isometric contraction [26]. Yi et al. examined the immediate effect of tDCS on walking speed, lower-limb functional strength, and balance in healthy elderly subjects. They reported that tDCS improved walking and lower-limb functional strength in older adults. They recommended tDCS as a safe and effective method for improving physical and motor performance, including walking and lower limb functional strength, in older adults [27]. It has also been shown that tDCS significantly increases the strength and explosive force of the extensor and flexor muscles in the non-dominant leg [13]. Consistent with these studies, our findings demonstrated that tDCS alone increased dynamic strength in the group T and also improved neural adaptations by enhancing neuromuscular efficiency at a constant weight.

Conclusion

We conducted a study to examine the impact of four weeks of tDCS on the C3 and C4 regions of M1 on the biceps dumbbell curl movement. These findings show that using tDCS with the anode on the left M1 (C3) and the cathode on the right M1 (C4) made the biceps brachii muscle stronger and more efficient. These studies suggest that anodal tDCS induces neuromodulation, leading to brain states that can generate greater strength.

Therefore, applying a-tDCS to the motor cortex for a duration of 15 minutes can be an effective method to promote performance in muscle strength training. These findings hold significant relevance to sports performance, playing a crucial role in athletes' success across various sports fields. We can use tDCS as a supplementary tool to optimize training efficiency.

Ethical Considerations:

Compliance with ethical guidelines

All of the study participants provided written informed consent

Funding

The authors state no funding is involved.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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«مقاله پژوهشی»

بررسی الکترومیوگرافی فازهای اکسنتریک و کانسنتریک حرکت جلو بازو دمبل پس از چهار هفته تحریک فراجمجمه ای با جریان مستقیم در مردان سالم

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چکیده

هدف: تحریک فراجمجمه ای با جریان مستقیم یک روش بی‌خطر است که از یک جریان با شدت کم برای القای تحریک در مغز استفاده‌می‌کند. استفاده از تحریک فراجمجمه‌ای با جریان مستقیم پتانسیل افزایش قدرت و بهبود عملکرد عضلانی را دارد. این مطالعه به بررسی اثر تحریک فراجمجمه ای با جریان مستقیم بر فعالیت الکترومیوگرافی عضله دوسر بازویی در طول انقباضات درونگرا و برونگرا پرداخت.

روش شناسی: بیست و دو فرد سالم به طور تصادفی در گروه تحریک فراجمجمه‌ای با جریان مستقیم یا گروه کنترل قرارگرفتند. گروه مداخله تحریک فراجمجمه‌ای با جریان مستقیم را روی قشرحرکتی‌اولیه به مدت ۱۵ دقیقه دریافت‌کرد، در حالی که گروه کنترل تحت هیچ مداخله‌ای نبود. آزمودنی‌ها حداکثر انقباضات ارادی ایزومتریک و همچنین انقباضات درونگرا و برونگرا عضله دوسربازویی را با ۸۰ درصد یک–تکرار–بیشینه خود انجام‌دادند. جهت تحلیل‌آماری پس از انجام آزمون‌های اولیه، تحلیل کوواریانس انجام‌شد.

نتایج: یافته‌ها نشان‌داد که یک–تکرار–بیشینه در گروه تحریک فراجمجمه‌ای با جریان مستقیم به طور معنی‌داری بیشتر از گروه کنترل بود ($P<0/05$). پس از چهار هفته تحریک فراجمجمه‌ای با جریان مستقیم در دامنه‌حرکتی کامل و در فاز حرکتی درونگرا، گروه تحریک فراجمجمه‌ای با جریان مستقیم کاهش معنی‌داری در فعالیت الکتریکی نرمال‌شده دوسر بازویی نشان‌داد ($P<0/05$). داده‌ها کاهش ۲۲درصدی در طول فاز درونگرا و ۱۸درصدی در طول فاز برونگرا را نشان می‌دهند.

نتیجه گیری: نتایج نشان‌می‌دهد که تحریک فراجمجمه‌ای با جریان مستقیم قدرت‌عضلانی و کارایی عصبی عضلانی را بهبود می‌بخشد. بااین‌وجود، با توجه به بازه زمانی محدود مداخله و حجم نمونه کوچک گروه، توصیه می‌شود تفسیر یافته‌های این مطالعه با احتیاط انجام‌شود.

واژه‌های کلیدی
الکترومیوگرافی، برونگرا، تحریک فراجمجمه‌ای با جریان مستقیم، درونگرا، قدرت

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