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Effect of transcranial direct current stimulation on handgrip strength training in amateur badminton players

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ABSTRACT

Objective. The objective of this study was to explore the effect of transcranial direct current stimulation (tDCS) combined with hand grip strengthening exercises in amateur badminton players.

Materials and methods. This study was a participant-blinded, randomized controlled trial. Thirty amateur badminton players, aged 8–20 years with a minimum playing experience of 6 months, were included. Hand grip strength (HGS) was measured at baseline, Day 1, Day 4, Day 8, and Day 12.

Results. The results of the present study showed no significant difference in hand grip strength between the groups. The overall interaction effect between the groups was found to be insignificant (p = 0.722). However, the overall interaction effect within the group was significant (p = 0.011*). Multiple comparisons revealed the greatest improvement in HGS at Day 12 compared to the baseline value.

Conclusion. The application of anodal tDCS combined with HGS training was ineffective in improving hand grip strength in amateur badminton players.

Keywords: hand strength, non-invasive brain stimulation, racquet sport, exercise

INTRODUCTION

Transcranial direct current stimulation (tDCS) is gaining significant attention in the sports world. Initially developed for clinical applications in various neurological and musculoskeletal conditions, its use has gained traction in the sports community as a potential tool for enhancing athletic performance and recovery [1,2]. tDCS is a non-invasive brain stimulation technique that applies a low electrical current to the scalp, modulating neuronal activity, and potentially enhancing physical performance, cognitive function, and recovery.

The application of tDCS as an ergogenic aid in various sports has also been investigated [3]. The use of anodal tDCS has been reported to be valuable in improving muscle power, endurance, and strength [4,5]. A single session of anodal tDCS over the M1 region in combination with voluntary grip exercises has shown a two-fold increase in motor evoked potentials [6]. Increases in maximal voluntary isometric contraction (MVIC) of the shoulder rotators in handball players and knee extensors in soccer players have also been observed following the application of tDCS [7,8]. A transient increase in maximum leg pinch force has been observed with

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anodal tDCS in healthy individuals [9]. Additionally, anodal tDCS combined with strength training has been shown to improve muscle strength in healthy individuals [4]. The role of tDCS has also been explored in terms of skilled motor performance and motor function, particularly in terms of power and fatigue. Its application has led to improvements in activities of daily living, reflecting enhanced motor activity [10]. Similarly, improvements in upper and lower limb motor performance have been reported in stroke patients following tDCS application [11,12].

While tDCS is considered safe and has the ability to regulate brain activity, it is still unclear whether it can significantly enhance elite sports performance. The application of tDCS offers exciting possibilities for enhancing sports performance, but it should be approached cautiously. Athletes considering its use should consult with professionals to ensure safety and efficacy.

Badminton is a fast-paced racquet sport requiring players to have excellent footwork, rapid changes in direction, and the ability to execute powerful shots. A badminton player uses prehensile grip forces to execute various strokes by altering wrist positions to manipulate the racquet and project the shuttlecock. Grip strength is an important motor skill in badminton, as strong hand musculature influences handgrip strength and enhances the velocity of smashes, impacting overall player performance [13].

Previous research has explored the role of tDCS in motor skills and motor function of the upper and lower limbs in various conditions. However, there is a lack of research examining the impact of tDCS on hand motor function, particularly hand grip strength in sports like badminton, where hand grip strength is crucial. Therefore, this study aims to explore the role of tDCS combined with hand grip strengthening exercises in amateur badminton players.

MATERIALS AND METHODS

Participants

The present study was a participant-blinded, randomized controlled trial conducted at the Shuttle Masters Badminton Academy in Hisar City, Haryana, India. Ethical approval was obtained from the Institutional Ethics Committee (letter no. PTY/2022/155). The trial was registered in the Clinical Trial Registry of India (CTRI/2022/06/043591) and performed according to the Declaration of Helsinki 2013. The inclusion criteria for the study were amateur badminton players aged 8–16 years with a minimum playing experience of 6 months and willingness to participate. The exclusion criteria included players with a history of injury to the elbow, wrist, or hand in the last 3 months, those consuming pain medication, those with a history of epilepsy, and recreational players.

Procedure

A total of 39 players were screened for participation in the study. Thirty participants were selected following the inclusion and exclusion criteria and were randomly allocated to Group A (Active tDCS) and Group B (Sham tDCS) using a lottery method. Written informed consent was obtained from all participants prior to their involvement.

Participants in Group A (Active tDCS) received a single session of tDCS for 20 minutes, along with hand grip strengthening exercises for 4 days per week over 3 weeks. Participants in Group B (Sham tDCS) received sham stimulation for 20 minutes, followed by hand grip strength training 4 days per week for 3 weeks. Figure 1 shows the flow chart of the study. The outcome variable for the study was hand grip strength, measured on Day 1, 4, 8, and 12.

Transcranial direct current stimulation (tDCS)

tDCS was administered using a battery-powered device. A current of 2 mA was delivered via a pair of circular sponge electrodes soaked in normal saline. The anode was placed on the primary motor cortex (M1, C3 or C4) on the left side of the brain, and the cathode was placed on the right supraorbital area. For sham stimulation, the electrodes were placed in the same positions, but the current was applied for only 30 seconds and then turned off.

Hand grip strengthening

All participants performed a 5-minute warm-up session, including gentle stretching of the upper limbs, followed by hand grip strengthening exercises as outlined in Table 1.

Hand grip strength evaluation

Hand grip strength was measured using a handheld dynamometer (Jamar). Participants were seated with their shoulder adducted, elbow flexed at 90°,

TABLE 1. Hand grip strengthening training protocol

Exercises	Weeks		
	Week 1	Week 2	Week 3
Ball squeezing	2 sets (20 reps)	3 sets (20 reps)	4 sets(20 reps)
Hand grippers	2 sets (15 reps)	3 sets (15 reps)	4 sets(15 reps)
Wrist flexion with dumbbells	2 sets (20 reps)	3 sets (20 reps)	4 sets(20 reps)
Wrist extension with dumbbells	2 sets (15 reps)	3 sets (20 reps)	4 sets(20 reps)

reps=repetitions

TABLE 2. Demographic characteristic of the study participants

		N	Mean	Std. Deviation	t-value	p-value
Height (cm)	**Group A**	15	164.13	6.47	.328	.745
	Group B	15	163.40	5.75		
Weight (kg)	**Group A**	15	59.73	6.89	.956	.347
	Group B	15	57.73	4.27		
BMI	**Group A**	15	21.82	1.29	.499	.621
	Group B	15	21.59	1.30		
Weekly Training (hours)	**Group A**	15	19.13	3.20	1.890	.069
	Group B	15	16.80	3.55		

**reps=repetitions*

TABLE 3. Between group comparison of the handgrip strength

Hand grip strength		N	Mean	Std. Deviation	t-value	p-value
Baseline	**Group A**	15	41.18	14.70	.348	.730
	Group B	15	39.23	16.03		
Day 1	**Group A**	15	41.55	14.87	.274	.786
	Group B	15	40.01	15.92		
Day 4	**Group A**	15	41.93	14.93	.275	.785
	Group B	15	40.37	15.93		
Day 8	**Group A**	15	42.55	15.03	.364	.718
	Group B	15	40.46	16.37		
Day 12	**Group A**	15	43.04	14.91	.441	.663
	Group B	15	40.55	15.94		

TABLE 4. Multiple comparison of the outcome variable at various time points using Repeated measure ANOVA

Pairwise Comparisons						
Hand Grip Strength		**Mean Difference**	**Std. Error**	**p-value**	**Std. Deviation t-value**	
					Lower Bound	**Upper Bound**
Baseline	Day 1	-0.580*	.127	.002**	-1.006	-.154
	Day 4	-0.945*	.145	.0001**	-1.429	-.461
	Day 8	-1.301*	.162	.0001**	-1.842	-.761
	Day 12	-1.591*	.163	.0001**	-2.135	-1.047
Day 1	Day 4	-0.365	.151	.475	-.871	.140
	Day 8	-0.721*	.152	.001**	-1.229	-.213
	Day 12	-1.011*	.142	.0001**	-1.486	-.537
Day 4	Day 8	-0.356	.153	.581	-.868	.156
	Day 12	-0.646*	.152	.005**	-1.155	-.137
Day 8	Day 12	-0.290	.111	.306	-.662	.082

forearm in neutral position, wrist in 30˚ dorsiflexion, and 15˚ ulnar deviation. They were instructed to squeeze the dynamometer three times, and the average of the three readings was recorded. Hand grip strength was evaluated at baseline and on Days 1, 4, 8, and 12 post-stimulation.

Data analysis

The data were analyzed using SPSS (version 21.0). Descriptive statistics (mean and standard deviation) were used for data presentation. Unpaired t-tests were used for between-group comparisons, and paired t-tests were used for within-group comparisons of outcome variables. Repeated measures ANOVA was applied to assess the overall interaction effect of the intervention between and within the groups at various time points. A significance level of $p < 0.05$ was set.

RESULTS

The demographic characteristics of all participants are summarized in Table 2. The study included 80% male and 20% female participants, aged between 15 and 20 years. The mean age of participants was 18.43 ± 1.68 years, with an average playing experience of 12.30 ± 5.17 months and mean weekly training hours of 19.13 ± 3.20 hours. The results showed no significant improvement in hand grip strength at any time point when comparing between groups. Table 3 presents the between-group comparison of hand grip strength.

Repeated measures ANOVA revealed no significant interaction effect of the intervention at any time points between the groups ($p = 0.722$). However, within-group analysis showed significant improvements ($p = 0.011$**). Post-hoc comparisons for within-group effects demonstrated maximum improvement in hand grip strength at Day 12 (MD = -1.591, 95% CI: -2.135, -1.047) compared to baseline, indicating that repeated application of tDCS improved hand grip strength. Paired t-tests for within-group analysis showed improvements in hand grip strength in both groups, regardless of the type of tDCS applied, suggesting that the hand grip strength exercises were primarily responsible for the improvement.

DISCUSSION

The present study aimed to investigate the effects of tDCS along with hand grip strength training on hand grip strength in amateur badminton players. The result of the study showed no improvements in hand grip strength when compared between the groups. However, the improvements in hand grip strength (HGS) were found to improve when within-group comparisons were done. The post hoc comparisons showed maximal improvement in HGS at Day 12 from the baseline value.

The insignificant improvement in hand grip strength observed in the present study can be attributed to the incongruous stimulation site and the arrangement of electrodes used in the study. The present study used anodal stimulation of the left side of the brain and the cathode on the right supraorbital area. This arrangement of electrodes might not have been able to induce changes in the cerebral cortex or facilitate the left M1 motor pathway. In contrast, findings from a study also suggest that tDCS stimulation over the right cathode and left anode (RcLa) area produced significant improvement in unimanual and bimanual grip strength compared to the right anode and left cathode (RaLc) and sham stimulation [14]. This suggests that the stimulation site used in our study might have been inappropriate.

In addition to this, another possible reason for no improvements in HGS could be the stimulation intensity used in the study. The present study used a stimulation intensity of 2 mA, which might not have been effective in inducing changes in hand grip strength. A study also suggested that the application of tDCS at higher intensities, i.e., more than 1.5 mA, may not necessarily increase the excitability of the cortex and recommends using lower intensity to attain the desired effect of the stimulation [15].

There are various studies that suggest cathodal tDCS over M1 produces changes in the excitability of the cortex, regardless of the polarity [16,17]. An improvement in time to exhaustion was reported in knee extensors when the anode was placed over the left motor cortex and the cathode above the shoulder compared to the anode on the left motor cortex and the cathode on the contralateral forehead [18]. Bilateral anodal tDCS also increases corticospinal excitability regardless of the side stimulated, suggesting the role of polarity of electrodes [19]. Therefore, the site, polarity of electrodes, and intensity of stimulation in the present study may not have been appropriate to produce changes in hand grip strength.

Similar to the findings of the present study, there are studies that showed no improvement in hand grip strength in cerebellar disorder patients and patients with unilateral cerebral palsy [20,21]. A review also suggested that the application of tDCS had no significant effect on upper limb strength but showed improvement in endurance in healthy individuals [22]. Another study in post-stroke hemiplegia patients also suggested improvement in motor function but no improvement in hand grip strength [12]. In contrast, other studies have shown the positive effect of tDCS on motor function of the hand and displayed the motor learning effect of the intervention. The application of anodal tDCS has been shown to produce greater improvement in metronome-assisted tasks and the speed-accuracy tradeoff function of the hand in healthy individuals, displaying a motor learning effect [23]. The application of dual tDCS has also shown improvement in precision hand grip and digital dexterity in the paretic hand after stroke [24]. The application of bilateral tDCS produces greater improvement in grip strength and supports its use in sports requiring bilateral coordination of the upper limbs [26]. Similar findings were suggested by another study, which also showed improvement in grip forces with the application of tDCS in healthy older adults [25]. A positive effect was also displayed by the use of anodal tDCS with strength training on muscle power [26]. It was also reported that anodal tDCS applied over the primary motor cortex enhances precise movement of the hand in healthy participants [27].

Various studies have explored the role of tDCS on stroke and cerebellar patients and have shown improvement in the motor performance of the upper and lower limbs. It sequences the modulation in neural activation and plasticity of synapses, increasing the activity of the cerebral cortex and thereby promoting functional recovery in these patients [9-12]. Thus, the results of these studies reflect the varying results on the motor learning effect induced by tDCS. Therefore, it can be interpreted from the results that the application of tDCS is effective in improving motor skills but has no influence on hand grip strength.

In addition, the small sample size of the present study could have restricted the statistical ability to detect minor or modest effects, which might be the prime cause for the insignificant results. There could also be gender-based differences in the present study, as 80% of participants were male and only 20% were female. A review published in 2019 indicated that two studies, out of three studies that included only female participants, showed improvement in hand grip strength (HGS), whereas only one study with male participants showed similar effects, reflecting the influence of gender on HGS [28]. Along with this, there could be anthropometric differences in muscle thickness that affect HGS [29].

The present study encounters some limitations, such as small sample size and the single-blinded nature of the study. Thus, future research on larger sample sizes, gender-based differences, and double-blinded randomized controlled trials using different stimulation sites, intensities, and polarities can be conducted to further explore the effect of tDCS on hand grip strength in badminton players.

CONCLUSION

Transcranial direct current stimulation applied to the primary motor cortex (M1, C3 or C4) combined with hand grip strength training was ineffective in improving hand grip strength in amateur badminton players. However, gender-based differences and anthropometric differences in muscle thickness warrant further exploration to better understand the effects of tDCS on hand grip strength.

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