Galore International Journal of Health Sciences and Research
Vol. 8; Issue: 4; Oct.-Dec. 2023
Website: www.gijhsr.com
Original Research Article *P-ISSN: 2456-9321*

Effect of Transcranial Direct Current Bi-Hemispheric Stimulation on Fine Motor Activity of the Hand in Healthy Adults

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DOI: https://doi.org/10.52403/gijhsr.20230412

ABSTRACT

Background: Evidence states that transcranial direct current stimulation (tDCS) can alter cortical excitability (Cathodal stimulation hyperpolarizes, while anodal stimulation excites). This study compares bihemispheric tDCS to sham stimulation on fine motor activity in healthy adults.
Methods: 24 healthy 18-30-year subjects were recruited at Nizam's Institute of Medical Sciences in Hyderabad, India, and split into experimental (tDCS bihemispheric stimulation) and control (sham) groups. The O'Connor Finger Dexterity Test (OCFDT) and Purdue Pegboard Test (PPBT) results were analysed for hand dexterity before and after stimulation.
Results: Variables like age, height, weight, and BMI of the groups were taken. Significance of differences in Intra- and inter-group hand function dexterity tests (OCFDT, PPBT) test results were done, and a p-value of <0.05 was considered significant.
Conclusion: The study found significant intra-group pre and post-differences in all components of OCFDT and assembly components of PPBT, but inter-group differences in other components of PPBT and OCFDT were insignificant. Results found were limited as tDCS can only stimulate the superficial cortex. In addition, the results in the sham group attributed to some amount of superficial stimulation in sham stimulation. Further research is needed to know the extent of stimulation effects and training effects to understand cortical activity differences in bi-hemispheric and sham stimulation, initial cognitive competence, motor planning, task practice, fine motor function feedback, intensity, electrode size, duration, number of sessions, stimulation site on tDCS effects.

Keywords: Hand function, tDCS, Sham stimulation, Bi-hemispheric stimulation, Transcranial direct current stimulation,

INTRODUCTION

Hand function training following neurological deficit is one of the challenging areas in physiotherapy. The central and peripheral neural systems initiate and regulate the motor activities of skeletal muscles. The human hand is essential in daily functioning and recreational activities. Hand function is broadly categorized into gross and fine motor activities[1,2]. Fine motor activity encompasses the complex coordination of the hand's small muscles, bones, and nerves to execute precise movements. In contrast, gross motor skill relates to broader actions such as arm waving. The M1 (Primary motor area region) is thought to be responsible for manual skill learning and voluntary movements of the hand, particularly fine motor activities[3,4]. There are various methods to enhance hand function, such as repetition of tasks, variability in task training, modification of practice methods, surface EMG feedback, and virtual reality.

These methods influence motor learning and skill development, indirectly influencing the central systems. The cognitive, psychological, and non-physical elements affect fine motor function[5]. The regular practice of motor tasks results in an improvement in the efficiency and learning of movements. The time needed to acquire new skills might vary based on the specific work, ranging from a few days to several weeks or months of focused training[6]. Only some authors have recently published studies on transcranial direct current stimulation and its application on hand function improvement by direct stimulation of brain areas.

Transcranial direct current stimulation (tDCS) is a noninvasive technique employed for neurological stimulation and change the physiological rhythms of neurons, specifically to modify cortical excitability within the brain by delivery of low-amplitude (0-4mA) electrical stimulation through surface scalp electrode[7],[8],[9]. There are two types of stimulation, i.e., anodal and cathodal stimulation. Anodal stimulation causes excitation and cathodal stimulation causes hyperpolarisation[10]. The accurate positioning of electrodes determines the symmetry and distribution of electrical currents and influences the success rate of the therapeutic intervention. It can produce long-lasting and polarity-specific changes in the excitability of the motor cortex[11]. Depending on the current flow, it can increase or decrease neuronal excitability by either membrane depolarization or hyperpolarization[12].

Excitability of the hemispheres occurs based on the stimulation provided to it. Few studies favor applying cathodal or anodal tDCS stimulation on healthy individuals for hand function; these results are used in therapeutic interventions. Studies on Bi-Hemispheric stimulation and its effect on the fine motor activity of the hand in healthy individuals will further help the professionals and fill the lacuna to select a suitable strategy for improving the fine motor activity of the hand following neurological lesions. Studies mentioned using unilateral, sham, anodal, or cathodal stimulation methods. However, they still need further clarity on hand functional skill development by direct bi-hemispheric stimulation. The purpose of the study is to assess the effects of Transcranial direct current stimulation on the fine motor activity of the hand in healthy adults using bi-hemispheric stimulation and compare the results with sham stimulation.

METHODS

The study was conducted at Nizam's Institute of Medical Sciences, Hyderabad, and Telangana, India. After obtaining ethical clearance and written informed consent, 24 samples, aged between 18 to 30 years healthy individuals, were taken into the study. Subjects with a history of seizers, accidents, sensory impairments, visual field defects, subjects on psychiatry medication, elbow flexion, and hand function deficit because of any other clinical and non-clinical reasons, which affect hand function and Dermatitis, and any metal near the zone of treatment were excluded. Subjects were randomized into two groups, i.e., Group 1: Experimental = tDCS (Bi-hemispheric stimulation) and Group 2: Control = sham Bi-hemispheric stimulation. Subjects' demographic data was taken. Motor activity of Hand (Manual dexterity) evaluation was done using the O'Connor finger dexterity test and Purdue Pegboard test at the study's beginning and after the stimulation application for two weeks.

tDCS - Bi-hemispheric stimulation method: Subjects are seated in a comfortable chair with head and armrests. Sponge electrodes soaked in isotonic sodium chloride solution were placed under the anode and cathode. Electrodes secured on the scalp region with a strap. The anode electrode is placed over the primary motor cortex on the left hemisphere primary motor area (Left M1; C3 or C4, according to EEG 10/20 system), and the cathode is placed over the Primary motor cortex on the right hemisphere (Right

M1; C3 or C4, according to EEG 10/20 system). 2mA for 20 min current applied on both areas for anode to cause excitability and cathode to cause inhibition, five times a week for two consecutive weeks

Figure 1: tDCS application

tDCS - sham stimulation method: During TDCS, the sham stimulation method, subjects were positioned, and electrodes were placed in a similar bi-hemispheric stimulation. However, the TDCS current delivery turned off after 30 seconds. Subjects experienced a brief tingling sensation under the electrode for 30 seconds after being turned on, so there was no difference in initial sensory experience in either group.

Perdue pegboard test (PPBT) is a psychomotor test of manual dexterity and bimanual coordination. The examination covers two skills: fine motor dexterity, commonly known as "fingerprint" dexterity, and gross motions of the arms, hands, and fingers. The Purdue Pegboard is a rectangular board with two sets of twenty-five vertically aligned holes and four concave containers at the top with three types of small pegs placed in it. Subjects were advised to Remove the pegs and place them vertically in the holes as rapidly as possible, as many as possible, with right (Rt) hand and left (Lt) hand within 30 seconds. Next, assembled pins (combined pins, washers, and collars) were placed in the vertical rows using both hands. Pegs inserted in 30 seconds are counted and graded(13)(Figure 2: Perdue pegboard test (PPBT) a: left b: right c: both d: assembly).

Figure 2: Perdue pegboard test (PPBT) a: left b: right c: both d: assembly

O'Connor Finger Dexterity Test (OCFDT) evaluates fine motor skills. The subject was seated comfortably at a table measuring approximately 30 inches tall. Place the test (pins in the well) before the subject. The board has 100 holes, each of which can accommodate three pins. Subjects were instructed to insert three pins into each hole as quickly as possible by picking up three at a time with a single hand. Please. The subject starts from the farthest corner from them and moves left to right only when using the left hand and right to left when using the right hand. Before going to the next row, each row is filled. Enough pins are provided on the board so that they have enough, even if they drop one or two on the ground without any pause to get them. The subject starts at the command of the therapist, "BEGIN, " and continues until the entire board is filled. The subject's performance in terms of time required to fill the board was measured in seconds using a stopwatch. Time documented for first fifty holes and the second fifty[14]

Figure 3: O'Connor Finger Dexterity Test (OCFDT)

RESULTS

The data were analysed using IBM SPSS version 25. All the continuous variables are presented as mean ± standard deviation and percentages, respectively. The inter-group comparison of the continuous variables age, height, weight, and BMI was done using an unpaired t-test. The intra-group comparison for the pre-post values of the Perdue pegboard and O'Conner finger dexterity test was done using a paired t-test.

Table 1:Intra-group comparison within the two groups for OCFDT

Test	Side	Variables		Experimental mean±sd	P value	Sham mean±sd	P value
OCFDT	Right	Right 1st half	Pre	227.63±31.39	0.01	211.43±18.31	0.001
			Post	216.2±28.62		204.52±21.64	
		Right 2nd half	Pre	222.8±28.93	0.003	214.06±22.12	0.05
			Post	211.58±26.94		208.23±23.33	
		Right raw score	Pre	236.36±31.28	0.01	223.45±20.76	0.005
			Post	224.47±28.4		216.79±23.49	
	Left	Left 1st half	Pre	255.01±29.47	0.001	235.24±19.48	0.001
			Post	244.55±25.18		226.15±21.07	
		Left 2nd half	Pre	248.54±25.52	0.024	239.05±20.84	0.01
			Post	243.45±23.04		228.82±19.48	
		Left raw score	Pre	375.54±40.5	0.001	351.35±30.05	0.01
			Post	36.83±35.83		338.82±30.83	

Table 2: Intra-group comparison within the two groups for PPBT

Test		Experimental mean±sd	P value	Sham mean±sd	P value
Assembly PPBT	Pre	44.67±7.50	0.007	46.53±6.84	0.036
	Post	45.91±7.49		47.63±6.98	
Both PPBT	Pre	30.75±2.58	0.116	29.33±2.86	0.01
	Post	31.12±2.57		30.43±2.65	
Sum PPBT	Pre	68.92±5.27	0.119	66.67±5.58	0.342
	Post	68.66±5.17		67.54±5.24	

The inter-group comparison for pre - and post-values of the Perdue pegboard and O'Conner finger dexterity test was done using an unpaired t-test. A p-value of <0.05 was considered significant for all analyses. (Sig = significant; NS = Not significant). To study the effect of transcranial direct current, 24 subjects were randomised into experimental (n=12, 8 Female, 4 Male) and sham groups (n=12, 8 Female, 4 Male). Both groups are homogenous; the range of age in both groups is between 20 and 25 years, height 152 to 172 cm, and BMI 19 to 24. The differences between pre and post-test scores of all components of OCFDT within the group showed statistical significance in control and experimental groups (p=<0.05), whereas between-group differences were insignificant. Within group pre and post-Assembly task results on PPBT in control and experimental groups were statistically significant (p=<0.05), whereas between-group differences of all components of PPBT were insignificant.

DISCUSSION AND CONCLUSION

According to the literature, tDCS applied over the motor cortex (M1) affects motor learning[15]. Transcranial Direct Current stimulation (tDCS) has many significant benefits compared to alternative noninvasive brain stimulation treatments. These include its inherent user-friendly characteristics, use of large electrodes, incorporation of a sham mode, and its portable nature [16]. During stimulation, a few subjects experienced minimal discomfort and a tingling sensation, mild itching, and erythema; however, these symptoms are typically of a mild form and are transient in duration[17]. However, inter-individual variation in conductivity may alter the passage of electrical currents. Possible processes behind the effects of cathodal and anodal stimulation on brain cell membrane function include changes in local ionic concentrations, modifications to transmembrane proteins, and changes in hydrogen ion concentration resulting from electrolysis[18]. The extended duration of motor learning results associated with bi-hemispheric transcranial direct current stimulation (tDCS)[19],[20]. The transmembrane potential of neurons can be altered by applying current, which affects the level of excitability[21],[22]. According to existing knowledge, it is believed that transcranial direct current stimulation (tDCS) enhances the expression of the brain-derived neurotrophic factor gene (BDNF)[23],[24], which subsequently affects the induction of NMDAR-dependent long-term potentiation (LTP), which helps in the promotion of neural function. As several areas of the brain also impact motor skills and coordination, our study mainly focused on the primary motor area(M1) which might have had a minimal effect on the subject's fine motor function based on accuracy and speed. Sara et al. 2020 found that bi-hemispheric tDCS is better than Uni-tDCS in improving motor learning. Doyon et al. 2009 stated that early learning primarily involves M1, whereas early consolidation heavily relies on the striatum; tDCS cannot reach that deep to work on the striatum[25].

PPBT test is considered a measure of manual dexterity and bimanual coordination components of finger dexterity; assembly component results within groups may be attributed to the effects of tDCS. On the other hand, OCFDT results differed significantly within the group rather than between the groups. Comparable results were obtained in control and experimental groups, possibly because training effects superimposed on Bi hemispheric tDCS. The Sham group showed results similar to those of the experimental group. The study duration was only five days a week, two weeks, and 20 minutes in a session in the experimental group. Initially, sham treatment with similar electrode placement with 30 sec on time contributed to some level of excitability and motor learning. Further research is needed to understand cortical activity differences with tDCS bi-hemispheric, sham stimulation, and training effects, initial cognitive competence, motor planning, task practice, fine motor function feedback, intensity, electrode size, duration, number of sessions, stimulation site on tDCS effects.

Data availability: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declaration by Authors

Ethical Approval: This research was reviewed and approved by NIMS Institutional Ethics Committee: Committee Review Letter no: EC/NIMS/2945/2022, 59TH ESGS No:1316/2022. Informed consent was obtained from all participants

Acknowledgement: None

Source of Funding: None

Conflict of Interest: The authors declare no conflict of interest.

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How to cite this article: Naveen Kumar Balne, Bestha Vinitha, S. Afshan Jabeen, Lakshmana Prasad G, Sireesha Yareeda. Effect of transcranial direct current bi-hemispheric stimulation on fine motor activity of the hand in healthy adults. *Gal Int J Health Sci Res*. 2023; 8(4): 91-96. *DOI: 10.52403/gijhsr.20230412*

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