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Original Article

The Effect of Transcranial Brain Stimulation on the Clinical Symptoms of Attention Deficit Hyperactivity Disorder

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Abstract

Background and Objective: Various psychological, biological and pharmacological interventions are used to treat the attention deficit hyperactivity disorder. Today, Transcranial direct current stimulation (TDCS) is among the biologic therapies that ave attracted the attention of researchers due to its cost-effectiveness and lack of side effects is, which works by stimulating neurons on the surface of the brain. Therefore, the present research aimed to assess the effect of TDCS on improving the clinical symptoms of attention deficit hyperactivity disorder (ADHD).

Materials and Methods: This quasi-experimental research was performed with a pretest-posttest design with a control group and follow-up. This study was performed on children with ADHD in Rafsanjan City, Iran. Among them, 16 people were selected as a sample using convenience sampling method and were randomly assigned to intervention and control groups in equal numbers. For the intervention group, Transcranial direct current stimulation was performed, while the control group received no intervention. Data was collected through the standard Swanson Attention Deficit Hyperactivity Disorder Questionnaire (1980) and repeated measures analysis of variance was employed for data analysis in Amos-24 software.

Results: Based on the findings, in the intervention group, the clinical symptoms of hyperactivity after receiving the intervention, at the posttest stage, were significantly reduced compared to before receiving the intervention ($P<0.01$), while this difference in the Control group was not significant. The findings also revealed that the reduction of clinical symptoms of hyperactivity in the experimental group at the follow-up stage was stable ($p <0.01$).

Conclusions: Based on the results of this study, it can be said that transcranial direct current stimulation is effective in improving the clinical symptoms of ADHD.

Keywords: Attention deficit hyperactivity disorder, Transcranial direct current stimulation, Clinical symptoms

Background

From among the most important and complex common childhood disorders is attention-deficit hyperactivity disorder (ADHD), which has three symptoms, including impulsivity, hyperactivity, and attention deficit, which usually continue into adulthood [1]. Based on the fifth diagnostic and statistical manual of mental disorders, the prevalence of this disorder has been reported to be 5% for children and 5.2% for adults [2]. Also, its prevalence in Iranian children is 3 to 7 percent [3]. The symptoms of this disorder should be observed in all situations of the child's life and cause disruptions in social, academic or extracurricular activities along with the child's development [4]. Children suffering from ADHD experience problems in various fields. From among the educational problems of these children, it can be referred to the problems of attending class and completing long-term assignments, risk of failure in academic years, suspension in education and dropping school [5].

Also, Jones [6] indicate that most of the time, children who suffer from this disorder experience anxiety disorders, problems caused by identity transformation and defects in social communication in adolescence. Researchers have reported various causes related to ADHD, which can be the result of complex interactions between genetics, environment, and biological factors such as brain injuries, neurological diseases, food allergies, and environmental variables, but so far no single factor has been identified as the reason behind it [7]. Neurological reasons are one of the causes of this disorder [8]. Various treatment methods have also been proposed for this disorder. Although pharmacotherapy reduces the main symptoms of ADHD, the results of research indicate that these useful effects do not mean long-term

benefits [9]. Hence, it is crucial to use a method to relieve these symptoms in patients suffering from ADHD with the least side effects, while the most effectiveness [10]. The researches which have been conducted in the recent decades so as to improve rehabilitation techniques have led to the emergence of different strategies to adjust or manipulate the flexibility of the brain. From among these techniques, it can be referred to using brain stimulation techniques such as TDCS, which is a powerful tool in sensory-motor rehabilitation and cognitive functions [11, 12]. TDCS is a non-invasive, cost-effective and safe alternative approach to change the excitability of the cerebral cortex by changing the resting potential of cortical neurons. This weak and direct current stimulates the underlying neurons by connecting two electrodes with different poles (an anode and a cathode) at different points on the surface of the brain skull. Cathodal stimulation decreases brain excitability and anode stimulation decreases brain excitability [13]. Regarding confirming the effectiveness of this therapeutic method, some studies demonstrate that transcranial stimulation of the brain has a significant effect on the response inhibition of children with ADHD. For instance, in a preliminary research, it was stated that stimulating the direct current of brain can lead to higher processing speed, better recognition of stimuli, and an enhanced ability to switch between an ongoing and a new activity [14]. In another study, it was demonstrated that anodic TDCS in the lower right folds of the frontal part of the brain can improve patients suffering from ADHD [15]. Generally speaking, it seems that TDCS is a promising method for improving some of the symptoms of attention deficit hyperactivity disorder. However, more systematic researches are needed. So, the current research aimed to assess the effectiveness of transcranial stimulation of the brain on the clinical symptoms of ADHD.

Objectives

The present research aimed to assess the effect of TDCS on improving the clinical symptoms of attention deficit hyperactivity disorder (ADHD).

Materials and Methods

The present semi-experimental study had a pretest-posttest design with a control group and follow-up. This study was performed on all 7-12-year-old children with ADHD, who studied in one of the mainstream schools of Rafsanjan city in 2020-2021. Among them, 16 participants were selected using the convenience sampling method and randomly allocated to two equal groups (intervention and control group). Regarding gender, there were 3 (37.5%) and 4 (50%) female participants in the intervention and control groups, respectively. For the experimental group, direct transcranial electrical stimulation of the brain was performed, while the control group received nothing but pharmaceutical interventions. These children were previously diagnosed by psychiatrists and psychologists as children suffering from attention deficit hyperactivity disorder. The researcher also used Swanson et al.'s ADHD Questionnaire (SNAP-IV) to complete the diagnosis.

It should be mentioned that the collected data were analyzed using ANOVA with repeated measures.

Inclusion criteria were confirming the attention deficit hyperactivity disorder based on DSM-IV diagnostic criteria by a specialist and obtaining a score higher than the average (score 36) in the standard Swanson et al.'s ADHD Questionnaire. Exclusion criteria included: the presence of obvious symptoms of psychosis, intellectual disability, history of brain damage, seizures and epileptic attacks, and the presence of skin problems such as scratches and abrasions on the scalp. These criteria were examined by referring to the children's medical record, psychiatrist's report, clinical interview with the child and parents, and observation.

Measures

Attention Deficit Hyperactivity Disorder Questionnaire

Swanson et al (1980) designed and compiled this questionnaire to measure ADHD in children and is completed by the child's parents. The questionnaire includes 18 questions and 2 components (hyperactivity and attention deficit) and addresses the ADHD in children using a three-point Likert scale (never, very little, a lot, very much) and using questions like (the child often cannot pay attention to details and makes mistakes due to carelessness, etc.). The first 9 questions examine behavioral symptoms of attention deficit and the second 9 questions measure behavioral symptoms of hyperactivity/ impulsivity and are scored in a four-point Likert scale with codes of zero, one, two and three, respectively [16]. In the Iranian population, the reliability coefficient of this test (parent form) has been reported based on the retest method to be .82, .90 based on Cronbach's alpha and .7 based on split half method [17]. In order to ensure the reliability of the test was conducted among thirty parents of the main sample one month after the original test. The resulting correlation coefficient was estimated to be .82 as a reliability index. In order to ensure reliability in terms of internal consistency, Cronbach's alpha coefficient was used, which was equal to .90. Another method used to estimate the reliability coefficient is the method of halving the test, which is based on the equation suggested by Spearman-Brown. The

correlation coefficient between the two halves is equal to .62, which is the same as the reliability coefficient of .76 [17].

The content of the intervention

Stimulation of the brain from the skull via direct electric current is a technology whose applications have been proven in a wide range of diseases and disorders. In the present study, the ACTIVADOSE2 device was used for brain stimulation. Its power source is a 9V battery, with a maximum current of 4 milliamps and a maximum voltage of 82 DC. The study was implementing in such a way that first the sponge pads, which are the outer covering of the electrodes, were soaked in sodium chloride solution and the electrodes were placed inside it. Each of the electrodes were placed on the children's heads according to the operating instructions of the device, i.e., the anode electrode on the right lower frontal gyrus and the cathode electrode on the left lower frontal gyrus and based on the international 10-20 system. During eight sessions in a period of two weeks, treatment was provided with an intensity of two milliamps, each time lasting 20 minutes.

Results

Based on the findings, the mean scores of the clinical symptoms of ADHD in the transcranial brain stimulation group decreased in the intervention stages. However, this component underwent no significant decrease in the control group. So as to check the normality of the data of this research, the Shapiro wilk test was used. The statistics of the Shapiro wilk test were not significant at the level of α=.05 (p<.05). Therefore, the most important assumption of using parametric tests has been met and these tests can be used.

Levine test was used for equality of variance in the scores of the research variables in the groups. Values of the Levine test for the variable of clinical symptoms of attention deficit-hyperactivity disorder (f=1.025) are insignificant at the level of 0.376. In other words, the null hypothesis of "equal variance of groups" is confirmed.

Table 2. One-way f test (ANOVA) in order to examine the assumption of the equality of the means of groups in the pre-test stage

Source of changes	Sum of squares	DF	Mean of squares	F	Sig
Intragroup	5.083	22	2.542		
Intergroup	48.875	21	2.327	1.092	.354
Total	53.958	23	-		

One-way f test (ANOVA) was used in order to examine the assumption of the equality of the average of groups at the pre-test stage. Table 2 shows no significant difference between the averages of the groups at the pre-test stage of the clinical symptoms of attention deficit-hyperactivity disorder (P<0.05) and the assumption of the equality of the averages in the pre-test stage is confirmed.

The findings of analysis of variance with repeated measures showed a significant difference between the studied groups (P<.001). So as to examine this difference more precisely, Bonferroni post hoc test was employed for pairwise comparison of groups. According to Table 3, no significant difference was observed between the clinical symptoms of ADHD at the pre-test stage in the intervention and control groups (P<.05). However, therewas a significant difference between these two groups at the post-test and follow-up stages. Also, the clinical symptoms of ADHD in the intervention group were significantly lower, compared to the control group (P<.001).

Table 1. Descriptive indicators of clinical symptoms of attention deficit hyperactivity disorder for experimental and control groups during the experimental stages

Group	Pre-test		Post-test		Follow-up	
	Mean	SD	Mean	SD	Mean	SD
transcranial stimulation of the brain	35.50	1.31	27.63	3.72	28.37	3.25
Control	35.00	1.19	34.50	2.00	34.50	1.93

Table 3. Results of the analysis of variance with repeated measures

Effects	Source of changes	Sum of squares	DF	Mean of squares	F	Sig	Effect size	Eta power
Between group	Measurement stage	171.792	2	85.896	32.032	.001	.696	.999
	Measurement stage	131.792	2	65.896	24.574	.001	.637	.999
	Error	75.083	28	2.682	-	-	-	-
Within group	Group	75.083	1	208.333	23.026	.001	.622	.994
	Error	126.667	14	9.084	-	-	-	-

Table 4. The results of pairwise comparison of different stages

Groups	Pre-test			Post-test			Follow-up		
	Mean Difference	SE	Sig	Mean Difference	SE	Sig	Mean Difference	SE	Sig
Experimental	.500	.627	.438	-6.875	1.194	.001	-6.125	1.335	.002

Table 5. The results of Bonferroni post hoc test to compare intervention and control groups at the three stages of pre-test, post-test, and follow-up

Group	Pre-test and post-test		Pre-test and follow-up		Post-test and follow-up	
	Mean Difference	Sig	Mean Difference	Sig	Mean Difference	Sig
Experimental group	7.875	.001	7.125	.001	-.750	.655
Control group	.500	.999	.500	.999	.000	1.000

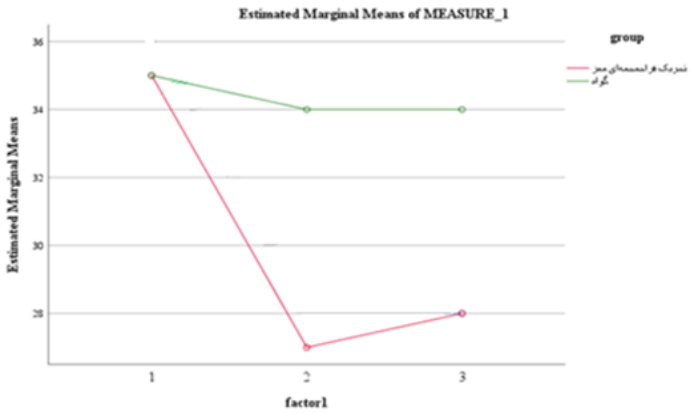

Fig 1. changes scores of the symptoms of attention deficit hyperactivity disorder in the three stages sorted by group

According to the obtained data, in the pre-test stage, there was no significant difference between the studied groups (P<.05). However, at the post-test and follow-up stages, the symptoms of ADHD in the intervention group were significantly lower, compared to the control group (P<.01).

As can be seen, a significant difference was found between the pretest and posttest stages, as well as between pretest and follow-up stages in the intervention group (P<0.001), but these differences were not significant in the control group (P<.05). Also, the difference between posttest and follow-up stages was not significant in neither group (P<.05).

Discussion

The results demonstrated that transcranial stimulation of the brain affected the clinical symptoms of ADHD. This result is consistent with those of previous research, indicating that electrical stimulation of the brain is effective in improving the symptoms of attention deficit and hyperactivity [18, 19].

Transcranial direct electrical stimulation improves control interference in patients suffering from ADHD [20]. The results of the research conducted with ADHD children and adolescents was that TDCS improves processing speed, stimulus recognition and ability to move in a new and continuous activity [14]. In explaining the effect of extracranial brain stimulation on the left posterior lateral prefrontal cortex, it can be stated that providing stimulation by changing the excitability of neurons and shifting the membrane potential of surface neurons, in the direction of depolarization or hyperpolarization, causes brain cells to fire more or less [21]. In the present study, the left posterolateral prefrontal cortex was non-invasively stimulated through a weak electric current to change the cortical excitability. According to the reports, TDCS current to the dorsal prefrontal cortex (DLPFC) can modulate cognitive functions that are considered as functions of the frontal cortex, particularly attention control and executive function. Many evidences also emphasize the influence of the dopamine system, which helps to stimulate the brain. In a clinical-genetic study of COMT (the enzyme that breaks down dopamine released in the synaptic cleft); it was demonstrated that COMT genotypes are significantly related to the effects of TDCS. Recently, it has been shown that TDCS in the DLPFC causes dopamine release in the striatum [22].

Generally, it can be concluded that although pharmacotherapy is one of the most common treatments, due to the adverse effect of chemical substances on the natural processes of systematic development of the central nervous system, as well as the lack of a stable and lasting effect on the improvement of this disorder, this method is highly criticized. Therefore, psychological/biological treatments are emphasized along with pharma-cotherapy. On the other hand, one of the problems of these children is lack of attention, which causes problems in doing homework especially for children in primary school. Therefore, since it has been proven that inattention is improved by increasing dopamine activity, transcranial stimulation of the brain in the DLPFC area reduces the clinical symptoms of this disorder, by its mechanism of action on increasing dopamine. From among the limitations of this study, it can be referred to the limited number of subjects and answering the questionnaire by one of the parents. However, according to the findings of the present research, it is suggested that medical centers and clinical therapists use transcranial brain stimulation along with psychotherapy and pharmacotherapy for greater effectiveness. It is also suggested to the researchers to conduct other similar studies by considering the role of gender and age of the subjects. Also, the subjects can be divided into groups based on the type of ADHD and then, the effect of these interventions on types of hyperactivity may be examined. According to the results of this research, it can be concluded that transcranial direct electrical

stimulation of the brain is effective on the clinical symptoms of ADHD.

Conclusions

In conclusion, this study demonstrated that transcranial direct current stimulation (TDCS) is effective in reducing the clinical symptoms of attention deficit hyperactivity disorder (ADHD), particularly in improving hyperactivity and maintaining these improvements over time. The findings align with previous research, highlighting the role of TDCS in modulating brain excitability, particularly in the left dorsolateral prefrontal cortex, leading to enhanced attention control and executive function. Given its non-invasive nature and lack of significant side effects, TDCS can be a valuable complementary treatment to pharmacotherapy, especially for addressing the limitations of medication-based interventions. Further research is recommended to explore the influence of age, gender, and ADHD subtypes on treatment efficacy.

Compliance with ethical guidelines

Before execution of the study, the ethics ID of (IR.YAZD.REC.1399.018) was received from the Research Ethics Committee of Yazd University and the exact working method of the device was explained completely and separately for the child and the parents. Besides, the necessary explanations were provided regarding the absence of side effects and no costs were imposed on the subjects. Also, consent of the parents as the legal guardians of the children was obtained in the form of a consent form.

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Authors' contributions

All authors made equally contributions to this study.

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Conflicts of Interest

The authors declared no conflict of interest.

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