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Reducing symptoms of attention deficit/hyperactivity disorder (ADHD) in elementary students: the effectiveness of neurofeedback

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Introduction and importance: This research was conducted to investigate the effectiveness of neurofeedback on the symptoms of hyperactivity and attention deficit in primary school students with attention deficit/hyperactivity disorder (ADHD) disorder.
Case presentation: The present study utilized a randomized clinical trial with pre-test and post-test measurements and included a control group. The research population included all primary school students with ADHD in 2023; 50 of these children were selected as the experimental group based on the accessible sampling method, and 50 were also included in the control group. Neurofeedback treatment sessions for the experimental group were 30 sessions. Research data were collected in three stages: pre-test and post-test, using a questionnaire based on the Conners rating scale from parents. SPSS-25 analyzed the data.
Clinical discussion: The results showed that neurofeedback is associated with significant effectiveness in the symptoms of attention deficit disorder and hyperactivity of students ($P < 0.05$).
Conclusion: Based on the findings of this research, it can be said that neurofeedback treatment is effective in reducing attention deficit and hyperactivity symptoms of students with ADHD disorder. It is suggested to widely use neurofeedback to reduce the symptoms of attention deficit and hyperactivity disorder.

Keywords: attention deficit, hyperactivity, ADHD, neurofeedback

Introduction

Attention deficit/hyperactivity disorder (ADHD) is the most common childhood disorder[1], which is included in the group of neurodevelopmental disorders, and its symptoms include inattention, impulsivity, and hyperactivity. This disorder often occurs in childhood[2]. Its prevalence is about 7% in children and 5% in adults[3]. This disorder is described based on three subtypes: dominant inattentive type, dominant hyperactive/impulsive type, and combined type[4]. Its prevalence is higher in boys than in girls[5].

HIGHLIGHTS

- Neurofeedback demonstrated significant effectiveness in reducing symptoms of attention deficit disorder and hyperactivity in primary school students with attention deficit/hyperactivity disorder (ADHD).
- The findings of this research support the use of neurofeedback as an effective treatment option for reducing attention deficit and hyperactivity symptoms in students with ADHD.
- The results suggest that widespread implementation of neurofeedback could be beneficial in alleviating symptoms of attention deficit and hyperactivity disorder among students with ADHD.

This disorder has adverse consequences such as academic problems, behavioural disorders, and social and family problems[6]. Children with ADHD face lifelong challenges and need a range of supports to succeed[7].

Different therapeutic approaches are used to help children with ADHD. Pharmacological interventions for ADHD are one of the most common treatments[8]. Although the use of stimulant and non-stimulant drugs in the treatment of ADHD is efficient and widely used, drug treatments also have limitations. Drug treatments may fail to improve the symptoms of the disorder in a subset of children. In addition, they may adversely affect children's sleep, nutrition, growth, and cardiovascular system. Also, there is no strong evidence for the

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long-term effects of drugs[9]. In addition, drugs do not create learning for children and cannot improve their cognitive or social skills[10–14].

Recently, neurofeedback has received a lot of attention as a therapeutic method. Neurofeedback is a type of biofeedback that tries to teach self-regulation by recording electrical responses and providing feedback to the subject[15]. Neurofeedback helps the brain to adjust itself and correct its functional defects[16]. The purpose of neurofeedback training is to correct abnormal brain waves, which improves the child's behavioural and cognitive performance[17]. Neurofeedback affects the activity of brain waves in such a way that activities related to desirable behaviours are produced or continued[18,19].

Brain activity during neurofeedback is monitored through electrodes placed on the head. Then, feedback is given to the person through audio and visual stimuli generated by the computer[20,21]. For ADHD, two common programs are used: theta/beta wave training and slow cortical potentials[22]. Beta waves have decreased in children with ADHD, and on the other hand, theta waves have increased in them[23]. A decrease in beta waves and an increase in theta waves causes a decrease in attention and concentration in children with ADHD. Therefore, one of the neurofeedback programs tries to increase beta waves and decrease theta waves[24,25].

Much research has been conducted to investigate the effect of neurofeedback on improving symptoms of ADHD and some functional components in children with this disorder. For example, Nourizade and colleagues investigated the effect of neurofeedback training on the cognitive processing of children with ADHD. Cognitive processing increased in children after receiving neurofeedback sessions[25]. In another study, Silspor and colleagues showed that neurofeedback could improve the symptoms of ADHD[26–28].

Oraki and colleagues investigated the effect of neurofeedback on improving working memory in children with ADHD. The results of their research showed that increasing alpha waves as a result of neurofeedback can increase working memory in children[29]. Bakhshayesh *et al.*[30] concluded that neurofeedback can reduce the initial symptoms of ADHD. Alvarez and colleagues investigated the effectiveness of neurofeedback in reducing cognitive damage caused by cancer. The data of this study showed that neurofeedback can reduce cognitive damage in these patients[31]. Therefore, according to the above-mentioned materials, the present study aims to investigate the effectiveness of neurofeedback in reducing the symptoms of hyperactivity and attention deficit in elementary school students.

Method

The present study utilized a randomized clinical trial with pre-test and post-test measurements and included a control group and follow-up stage. The research population included all elementary school students in Tehran with ADHD in 2023. By referring to ADHD treatment centres with neurofeedback devices, the researcher did a sampling of 7–12-year-old children referring to these centres. Initially, 65 of these children were selected as the experimental group based on the available sampling method, which was finally reduced to 50 according to the entry and exit criteria. The number of neurofeedback treatment sessions for them was 20 sessions (90 min), and 2 sessions were held every week. A few days before the implementation of the first therapeutic-educational session of neurofeedback, the Conners hyperactivity and attention deficit questionnaire was completed by the child's parents, and the pre-test data was collected in this way and also, at the end of the therapeutic-educational sessions with an interval of one or several days, the same questionnaire was completed by the parents, and in this way, the post-test data of the experimental group was collected.

The students of the control group (children who did not receive neurofeedback treatment) were selected from 5 elementary schools in Tehran, and 50 students with ADHD were assigned to the control group. It should be noted that these people were recognized by the doctor as hyperactive children and were recorded in their files. The control group's data was also collected in parallel with the experimental group.

The inclusion criteria were age 7 to 12 years, absence of other psychiatric disorders such as learning disorder, oppositional defiant disorder, epilepsy, or mental retardation; not using medicine during research; Written consent of parents regarding their agreement for their child's participation in the research. Also, non-cooperation in the complete treatment process or incomplete questionnaire information were exclusion criteria.

Neurofeedback treatment protocol

Beta training

Neurofeedback therapy was implemented in this research using the monopolar protocol. In this way, it increased on the FCz point of beta[15–18]. Theta[4–8] was reduced. If the range of high beta was greater than beta, the high beta would be reduced; otherwise, no intervention would be done.

Smr training

This method was used for times when children were more hyperactive and impulsive. The biopolar protocol on points C1 and C5, here Smr[12–15] was increased. Theta and High beta[22–26] were reduced. Therefore, if high beta was decreased from the beginning, it should have been reduced here as well. In some people, monopolar protein on C3 responds better to Smr changes than bipolar on C1. To know which assembly has the best efficiency, a baseline was taken on C3 in unipolar form, and a baseline was taken on C1 and C5 in bipolar form, in each of which the ratio of beta to theta was higher than the same assembly for Smr reinforcement was used.

In the mixed and balanced state of ADD and ADHD, 15 min of Smr training and 15 min of Beta training (with a change range of two minutes) were performed. If ADD was greater, more beta (by a ratio of two to one) than Smr training would be applied.

Data collection tool

Short and Revised Questionnaire of Conner's Rating Scale for Parents: This questionnaire has 26 questions that were completed by mothers and has 4 subscales: (1) Atmospheric opposition, (2) Cognitive problems/inattention, (3) Impulsivity, and (4) ADHD index. The subject's raw score in each subscale is calculated from the sum of the parents' ratings from 1 to 4 in terms of that subscale, and then, based on the patient's age and gender, the scores are converted to the standard t score. A criterion score equal to or greater than 65 usually indicates significant clinical problems in that subscale. The age range used in Conner's scales is 3–17 years,

Table 1

Comparison of the mean and standard deviation of symptoms of attention deficit, hyperactivity, and deficit along with hyperactivity

		Minimum score		Maximum score		Mean		SD	
Variable	Group	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Attention deficit	Experimental	17	6	2	10	18.25	9	1.25	2.16
	Control	18	17	21	21	19	18.25	1.41	1.89
Hyperactivity	Experimental	18	6	25	14	20.75	10.25	3.40	3.30
	Control	17	17	24	25	19.75	20	3.06	3.55
Attention deficit hyperactivity disorder	Experimental	43	12	44	33	43.25	21.75	0.95	10.87
	Control	40	41	44	43	42	42	1.82	0.81

and a separate age norm with 3-year age intervals has been prepared for boys and girls. Completing this questionnaire takes 5–10 min. For evaluation in this test, it can be said that obtaining an average score of 1.5 or higher indicates the presence of attention deficit hyperactivity disorder. In other words, this questionnaire has 26 questions, and therefore, the total test score will range from 26 to 104. If the child's score is higher than 34, it indicates attention deficit disorder. The higher the score, the greater the child's impairment. Conners *et al.*[32] reported the reliability of this scale as 0.90. The validity of this questionnaire has been reported as 0.85 by the Institute of Cognitive Sciences[33]. Internal reliability coefficients have been reported to range from 0.75 to 0.90. The validity of Conner's form was obtained using the factor analysis method, and their differential validity was confirmed by statistically examining the ability of the questionnaire to distinguish people with ADHD from normal people and other clinical groups[34].

Data analysis

This research used descriptive statistics indicators and analytical statistics methods, including multivariate covariance analysis, to describe and analyze data using SPSS-25.

Results

The results of Table 1 show that the mean scores in the control group in the pre-test and post-test stages (attention deficit hyperactivity disorder and attention deficit hyperactivity disorder) did not differ much from each other. However, the average scores in the experimental group in the post-test phase have decreased compared to the pre-test (attention deficit hyperactivity disorder and attention deficit hyperactivity disorder).

Table 2

Results of the Kolmogorov–Smirnov test scores for attention deficit, hyperactivity, and attention deficit with hyperactivity

Variable	Group	F	Significance
Attention deficit hyperactivity disorder	Experimental	0.199	0.002
	Control	0.166	0.002
Attention deficit	Experimental	0.141	0.002
	Control	0.131	0.002
Hyperactivity	Experimental	0.126	0.002
	Control	0.175	0.002
Total	Experimental	0.136	0.002
	Control	0.186	0.002

The results of Table 2 show that the score of attention deficit with hyperactivity, attention deficit, and hyperactivity is normal according to the significant level.

The results of Table 3 show that in the scores of attention deficit along with hyperactivity, attention deficit, and hyperactivity according to the significant level, there is no homogeneity of variances in the two groups. However, due to the equality of the subjects in the two experimental and control groups and the normality of the data in the scores of attention deficit along with hyperactivity, attention deficit, and hyperactivity, it is possible to use parametric tests.

As Table 4 shows, there is a significant difference between the experimental and control groups in the symptoms of ADHD in the post-test stage. Because the mean scores in the symptoms of ADHD in the post-test phase were lower in the experimental group than in the control group, therefore, it can be concluded that the neurofeedback treatment method is effective in reducing the symptoms of ADHD in students.

As Table 5 shows, there is a significant difference between the experimental and control groups in the severity of symptoms of attention deficit along with hyperactivity in the post-test stage. Because the mean scores in the severity of symptoms of attention deficit with hyperactivity in the post-test phase in the experimental group were lower than the control group. Therefore, it can be concluded that the neurofeedback treatment method is effective in reducing the symptoms of attention deficit along with hyperactivity of students.

As Table 6 shows, there is a significant difference between the experimental and control groups in the severity of symptoms of attention deficit in the post-test stage. Considering that the mean scores in the severity of symptoms of attention deficit in the post-test stage in the experimental group were lower than the control group. Therefore, it can be concluded that the neurofeedback treatment method is effective in reducing the symptoms of attention deficit in students.

As Table 7 shows, there is a significant difference between the experimental and control groups in the severity of hyperactivity

Table 3

The results of Levin's test scores for attention deficit hyperactivity disorder and attention deficit hyperactivity disorder

Variable	F	Significance
Attention deficit hyperactivity disorder	12.402	0.002
Attention deficit	9.964	0.005
Hyperactivity	6.647	0.017
Total	5.132	0.025

Table 4

The results of the covariance analysis table comparing the mean of attention deficit/hyperactivity disorder (ADHD) symptoms in the post-test stage

Source	Sum of squares	df	Mean square	F	Significance	Eta	Test power
Pre-test	487.403	1	487.403	22.094	0.001	0.513	0.994
Group	1913.130	1	1913.130	86.723	0.001	0.805	1.000
Error	463.264	21	22.069				

symptoms in the post-test phase. Considering that the mean scores in the severity of hyperactivity symptoms in the post-test phase in the experimental group were lower than in the control group. Therefore, it can be concluded that the neurofeedback treatment method is effective in reducing the severity of students' hyperactivity symptoms.

Discussion and conclusion

Considering that in ADHD, the symptoms (attention deficit, hyperactivity, and their simultaneous presence) have common underlying mechanisms, and most of the time in a combined form, that is both attention deficit and hyperactivity are together, in presenting the results. We will explain at the same time.

The findings of the research showed that the neurofeedback treatment method was able to significantly reduce the symptoms of attention deficit and hyperactivity in the case group compared to the control group. These results were consistent with the findings of Roy and colleagues, Farid and colleagues, Nemati and colleagues, Sudnawa and colleagues, Schönenberg and colleagues) and Fauzan and Nazaruddin[7,10,15,19,20,24].

The neurofeedback training process is based on the principle of active conditioning, which is based on the two concepts of reinforcement and reinforcement. In the neurofeedback process, operant conditioning is when the patient receives a reward for finding a suitable mental state. In this way, when the power of a certain rhythm of the patient's brain signal reaches the threshold, in return, he receives auditory or visual feedback that is usually similar to a game. Therefore, the person tries to adjust his mental state to receive the desired stimulus (visual or auditory feedback), and this increases the desired behaviour (putting the person in the desired mental state) and increases the probability of the occurrence of that particular rhythm[33].

During training, brain activity is controlled by the conscious and unconscious management of attention. Conscious learning happens when a person learns how the feedback signal relates to his mental state. The major part of learning happens at the unconscious level, where the brain gradually becomes able to directly and automatically control the feedback signal. New skills acquired consciously and unconsciously are internalized during training and are automatically transferred to the daily activities of the person. This is just like learning to drive. Just as driving becomes a series of automatic actions after complete learning and is never forgotten, the inhibitions that the brain learns during neurofeedback training will be permanent. Therefore, neurofeedback helps the brain to learn how to regulate itself and correct its functional deficiencies. Therefore, there is no manipulation or foreign substance intervention that has side effects or creates dependence[15]. In addition to what was said, Narimani and colleagues cite that neurofeedback provides a mechanism for the individual to balance his cortical profile by reducing slow-wave activity and increasing fast-wave activity[17]. Therefore, it is expected that by compensating for the EEG abnormality, the person will show more attention and focus and have a higher level of arousal and, as a result, can improve his performance. Studies have shown that the increase of slow brain waves (less than 10 Hz) in different brain areas is associated with foggy thinking, slow reaction time, arithmetic failure, poor judgment, lack of impulse control, and decreased attention and arousal in people. Therefore, it is expected that by suppressing or reducing the amplitude of theta wave in the central region of the skull (CZ), one would witness a behaviour change, especially an increase in arousal and attention in people. Therefore, it can be concluded that neurofeedback training can help people with hyperactivity disorder regulate their brain wave activity and, in this way, improve their attention problems.

Therefore, it can be concluded that this treatment method can be effective in sustainably reducing this disorder. The result of the present study supports the value and effectiveness of the treatment of hyperactivity disorder with neurofeedback training. In general, it can be concluded that neurofeedback can help people with hyperactivity disorder regulate the activity of brain waves and, in this way, improve their impulsivity and inattention problems. It is expected that this method of treatment can be effective along with other methods of treatment in the country.

Table 5

The results of the covariance analysis table comparing the mean intensity of attention deficit symptoms with hyperactivity in the post-test stage

Source	Sum of squares	df	Mean square	F	Significance	Eta	Test power
Pre-test	67.103	1	67.103	1.158	0.331	0.188	0.143
Group	858.447	1	858.447	14.819	0.012	0.748	0.864
Error	289.647	5	57.929				

Table 6

The results of the covariance analysis table comparing the mean severity of attention deficit symptoms in the post-test stage

Source	Sum of squares	df	Mean square	F	Significance	Eta	Test power
Pre-test	11.256	1	11.256	4.171	0.097	0.455	0.381
Group	130.274	1	130.274	48.271	0.001	0.906	1.000
Error	13.494	5	2.699				

Table 7

The results of the covariance analysis table comparing the average intensity of hyperactivity symptoms in the post-test stage

Source	Sum of squares	df	Mean square	F	Significance	Eta	Test power
Pre-test	61.025	1	61.025	31.374	0.003	0.863	0.992
Group	223.248	1	223.248	114.776	0.001	0.958	1.000
Error	9.725	5	1.945				

Limitations

Some of the most important limitations of this research include the following. Among these limitations is the lack of control of some disturbing and intervening variables in the internal validity of the research, such as the type of family environment and the society around the ADHD child under treatment with neurofeedback and educational methods and the type of schools, and their staff. Another limitation of his research that the time limit was limited.

Ethical approval

This study was approved by the research ethics committee of Research Ethics Committees of Babol University of Medical Sciences (ethical code: IR.BABOL.REC.1399.1503).

Consent

Written informed consent was obtained from the patients' parents/legal guardians for publication and any accompanying images. A copy of the written consent is available for review by the Editor-in- Chief of this journal on request.

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Author contribution

All authors contributed to the design and implementation of the study.

Conflicts of interest disclosure

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Guarantor

All authors accept full responsibility for the study.

Data availability

Data are available from authors on request.

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