Neurofeedback Effect on Perceptual-Motor Skills of Children with ADHD

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ABSTRACT

Objectives: This study investigates the impact of neurofeedback on perceptual-motor skills of 5 to 12 years old children with Attention Deficit Hyperactive Disorder (ADHD).

Methods: In this clinical study, 40 children between the ages of 5-12 years, who were patients of the Tavanesh Clinic and diagnosed with ADHD, were randomly chosen and divided into two groups of control and test. 20-neurofeedback intervention sessions were performed. The tools utilized in this study included Bruninks–Oseretsky Test of Motor Proficiency and Child behavior checklist (CBCL) survey questionnaire. For evaluation after the intervention, Bruninks–Oseretsky Test of Motor Proficiency scale for children, along with CBCL questionnaire surveys were asked to fill up by the participants' mothers.

Results: After the intervention, the analysis of the scores in all perceptual-motor skills showed significant differences in both groups, but no significant difference was observed in the subtest of strength. The CBCL survey questionnaire revealed that the average scores on attention disorder, aggression, lack of attention and hyperactivity, externalizing and general problems in the test group is significantly less than that of the control group. However, in the confrontational behavior (internalization), there was no statistically significant difference between the test and control groups. There was a correlation between the change of motor skills and change of behavioral patterns in ADHD children.

Discussion: Neurofeedback intervention can have positive effects on improving the perceptual-motor skills of children with ADHD.

1. Introduction

Attention-Deficit with Hyperactivity (ADHD) is a neural-psychiatry disorder. The symptoms of ADHD must appear before the age of 7 years, persist for at least 6 months, expressed both at home and school, and disrupt social and educational functions. In addition, ADHD can be distinguished by behavioral symptoms such as inattention, motor impatience, and impulsivity behaviors [1-3]. Children diagnosed with ADHD are characterized by weak coordination and disorder in the functioning of fine and gross

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motor skills [4]. These children have trouble in the motor process, such as in motor preparation and motor regulation [5-7], and gross motor skills, such as hopping, jumping, romping, walking by side leg, and equilibrium [8, 9].

Improving these skills through various approaches such as sensory and perceptual-motor integration and motor control via occupational therapy interventions and the neural empowerment of related cerebral plexus can have positive effects on both cognitive skills and dimensions of daily living of such children [10-12]. Many studies have focused on the existence of defects in perceptual-motor skills in children diagnosed with ADHD and the relation of behavioral disorders with motor skills [10-13]. The defect in motor abilities in children can result in poor quality of participation in certain areas such as play, homework, and daily activities. It seems that children with motor difficulties are at a higher risk of behavioral and educational difficulties [12-14].

In 2000, the American Psychiatric Association reported that 5% of children of school age have ADHD [2] and about 47–69% of those involve coordination-motor difficulties [15]. The prevalence of this disorder in US is about 7%, and it ranges 2–29% worldwide [16]. A study on students between the ages of 7 to 9 in Tehran, reports the spread of this deficit is about 3% to 6% [17].

Theories based on cognitive neuroscience mention the role of the frontal lobe, basal ganglia, and dopaminergic pathways and indicate that their defective functions can lead to attention difficulties and deficit in behavioral control [18, 19]. Multiple evidences show the functional insufficiency of dopamine in the brain of children with ADHD has an important contribution to the symptoms of ADHD [20, 21]. The findings of new researches reveal that in most children with ADHD, differences in Electroencephalography (EEG) and coordination of electric activities of the brain can be seen when compared with that

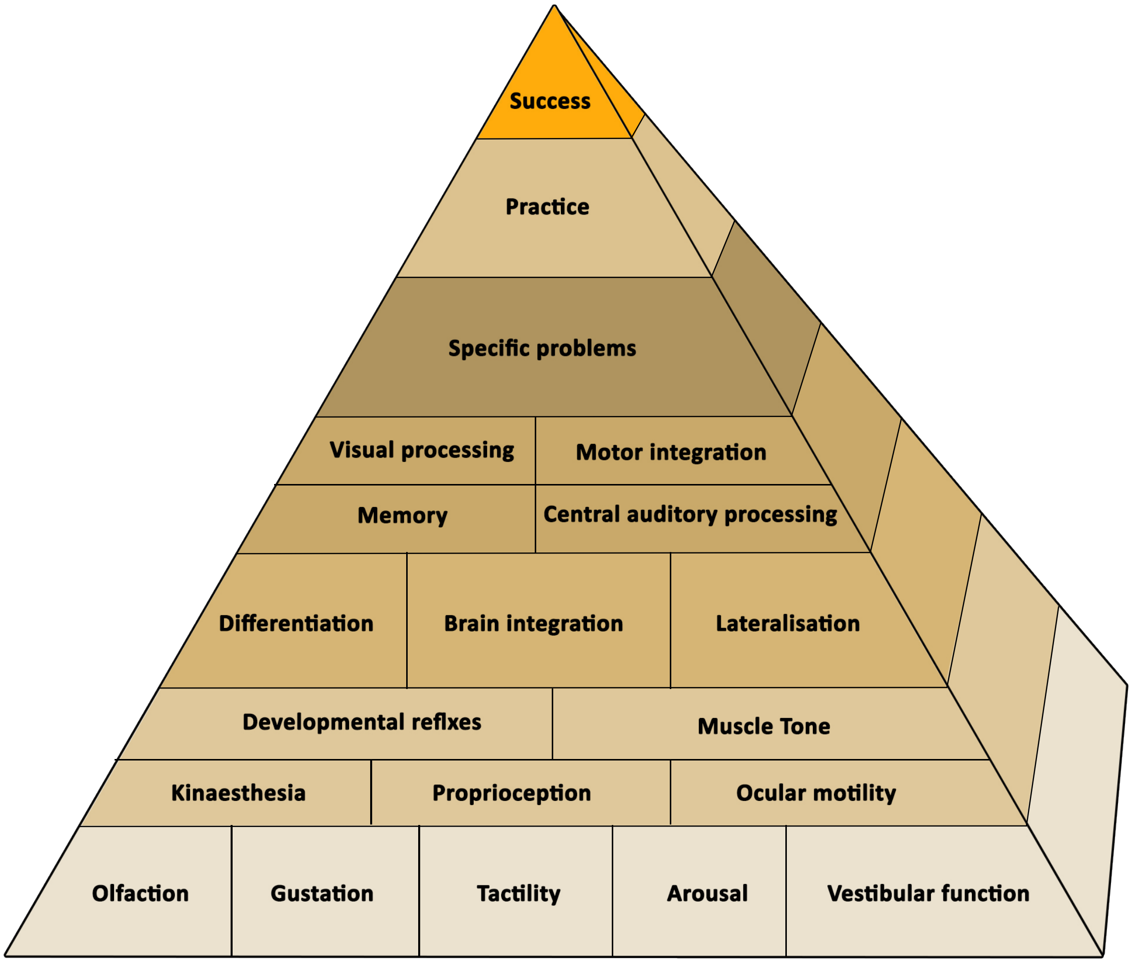

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Figure 1. A leader's guide to the alert program for self-regulation [35].

of normal children. The activity of Theta waves in the frontal and central area that are related to hypoarousal is an index of the decrease in cortical activity. The increase in Theta potency is the most consonant finding in the EEG research documents about ADHD, and it clearly indicates that hypoarousal is a common neuropathological mechanism in children with ADHD [22].

Similarly, the ratio of Theta to Beta, which is related to cortical stimulation, distinguishes between children with ADHD and normal children in a consonant way [23]. The results of Beta activity -that show cortical hyperarousal- are in less consonant. Several studies have reported the decrease in Beta activity in the frontal and central areas, but a few studies have also reported that about 15% of children with ADHD show an increase in Beta activity [22, 24]. In neurofeedback interventions, the alteration of wave's amplitudes originated from the cerebral cortex causes changes in the function of cortex structures that are involved in movements and have influences on the motor efficiency of individuals, considering the changes in the motor cortex.

Neurofeedback is a training process that helps the brain learns self-regulation. Self-regulation means the expansion of personal knowledge and skills in all areas, through individual endeavor and experience of situations and various things [26]. Neurofeedback helps the brain to learn how to regulate itself and obviate its functional defects [27, 30]. The effects of neurofeedback on motor coordination and equilibrium have been mentioned in previous articles [31, 32]. Neurofeedback can increase the efficiency of rehabilitation interventions based on Sensory Integration (SI) and Perceptual Motor (PM) approaches, raise interestedness of children because of the use of visual effects, deepen and stabilize the findings of other interventions, and can fill the vacuum left by the absence of coherent and appropriate protocol for children with ADHD [10, 13].

According to the findings of several researches that have elucidated that children with ADHD have an abnormal pattern of EEG, neurofeedback can provide a mechanism to children that normalize themselves by decreasing the slow wave activity and increasing the fast wave activity [33]. According to perceptual-motor standpoints, all human actions originate from movement and motor learning has an important role in the expression of cognitive functions [13, 34]. Thus, it seems that behavioral-motor deficits are a result of inappropriate and uncoordinated information processing from input to the output stage (motor behavior).

Hence, it seems that a change in perceptual processing patterns on brain inputs plays a role in changing the behavioral outputs. As it shown in Figure 1, the pyramid of sensory integration draws the evolution and growth of sensory systems in a systematic and scientific way and explains the processing matrix of sensory input from an unrefined sensory stimulation to becoming a complex behavioral pattern [35]. Interestingly, the deficits and defects in each stage of sensory functions, in cycle and procedure of giving, processing, perceptual, incorporation and recognition, can cause a problem in higher classes of sensory integration pyramid, hampering the growth of sensory stimulations to becoming complex combinational behaviors.

Figure 1 shows that Rehabilitation interventions and perceptual-motor exercises can be effective in decreasing the symptoms of children with ADHD [10, 36]. The American Psychiatric Association has accepted biofeedback or neurofeedback EEG as a supplement therapy [28]. This therapy can also increase the effectiveness and efficiency of other therapeutic interventions. Since cortical waves rise from cortex functions of the nervous system, the children with ADHD have a higher level of Delta and Theta waves, domain increase of cortical Beta in the frontal lobe, and disturbance in Alpha waves balance. The increase in cortical Beta has a strong relation with their disability in stable attention and impulses control [37].

Due to Theta high and Beta low in the frontal lobe of children with ADHD, we have used decreasing Theta and increasing Beta protocol in sensory-motor areas. Several articles have mentioned the effectiveness of neurofeedback therapy on decreasing impulsivity, construction of control, and improving attention [39]. It seems that the major symptoms of inattention are related with motor coordinating [41]. Thus, the motor deficit of children with ADHD is one of the reasons for increasing inattention and defects in occupational memory [42, 43]. In the past, the relation of hyperactivity/impulsivity symptoms with motor coordination has been reported [44, 45].

In this research, one of the input factors is earned at least one year lower than calendar age in the Bruininks-Oseretsky test of motor proficiency. Based on the results of the previous studies on effectiveness of improving perceptual-motor skills, reduction of writing skills, impulsivity, improving working memory and attention span in ADHD children, Studying the improvement of perceptual motor skills in these children is deemed necessary [46].

2. Methods

Children (aged 5 to 12 years) diagnosed with ADHD by a child psychiatrist and referred to the Rehabilitation Center of Tavanesh, located in Tehran, were initially selected for the study. Of them, 40 children who earned at least one year lower than the calendar age [47] in the Bruininks-Oseretsky test of motor proficiency (BOMT) were finally selected for inclusion in the study. The BOMT is a descriptive index for the evaluation of fine and gross motor skills, and it has four subtests for gross motor skills, three subtests for fine motor skills, and one subtest for both fine and gross motor skills. The parents of the selected children were asked to fill the demographic and Child Behavior Checklist (CBCL) survey questionnaires and complete the consent form of conscious participation in research.

The CBCL survey measures a child's competence and behavior through parents or those who know the child well. It includes two wide dimensions (external and internal problems) and eight limited syndromes (Anxiety/Depression, Withdrawal, Physical Complaints, Social Problems, Thought Problems, Attention Problems, Delinquent Behavior and Aggressive Behavior) [14]. The children were then randomly allocated (using simple random method) into two groups (intervention and control groups) of twenty children each. The intervention group received neurofeedback therapy according to decreasing Theta and increasing Beta protocol in the central zone (CZ) area.

All the evaluations were performed by an experienced occupational therapist with three years of experience in occupational therapeutic tests for pediatrics. All interventions and tests, at all levels, were free for the participants. After 8 weeks of the intervention, the BOMT test and CBCL survey questionnaire were retaken. After Kolmogorov–Smirnov, analysis of covariance for checking the effect of the independent variable with the witness of pretest effect, and the Pearson Correlation Coefficient were done.

3. Results

In terms of demographics variables, no significant difference was observed between the intervention and control groups (Table 1). The scale of the average difference of scores in pretest-posttest shows a significant difference between the two groups in subtests of agility and run's speed, equilibrium, lateral coordination, gross motor skills, coordination of upper limb, speed response, motor-visual speed, upper limp speed, fine motor and perceptual-motor skills ($P<0.001$). However, no significant difference was observed in the strength subtest ($P=0.104$) (Table 2).

The scale of average difference of scores in pretest-posttest shows a significant difference between two groups in subtests of attention problems, aggressive behavior, attention deficit/hyperactivity, externalizing and general problems (P while there is no significant difference in confrontational behavior subscale (P in order to modify the scores effect of the pretest, subtests, and subscales, with posttest scores in both the groups of exami-

Table 1. Comparison evaluation of sex and grade of children with ADHD in the two groups.

Variable	Variable level	Number	Percent	Number	Percent	Statistics	Probability
	Control examination			Chi 2 test/fisher's exact test			
Sex	Boy	13	65	16	80	1.29	0.288
	Girl	7	35	4	20		
	Total	20	100	20	100		
School	Preschool	6	30	6	30	-	-
	Primary	14	70	14	70		
	Total	20	100	20	100		
Grade	Preschool	6	30	6	30	0.95	0.999
	Primary	4	20	4	20		
	Third	7	35	7	35		
	Fourth	1	5	2	10		
	Fifth	2	10	1	5		
	Total	20	100	20	100		

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Table 2. Comparison of the average scores of perceptual-motor skills posttest in the two groups.

Variable	Variable source	Total squares	Mean squares	F	The probability	Size effect
Agility and run's speed	Pretest	266.01	266.01	62.55	<0.001	0.628
	Group	259.85	259.85	61.11	<0.001	0.623
Equilibrium	Pretest	145.69	145.69	64.87	<0.001	0.637
	Group	106.14	106.14	47.25	<0.001	0.561
Lateral coordination	Pretest	180.23	180.23	63.05	<0.001	0.630
	Group	211.31	211.31	73.92	<0.001	0.666
Strength	Pretest	841.83	841.83	179.51	<0.001	0.829
	Group	13.04	13.04	2.78	<0.001	0.070
Gross motor	Pretest	2037.68	2037.68	101.19	<0.001	0.732
	Group	2137.93	2137.93	106.17	<0.001	0.742
Coordination of upper limb	Pretest	104.58	104.58	27.67	<0.001	0.428
	Group	381.72	381.72	101.10	<0.001	0.732
Speed response	Pretest	170.29	170.29	31.56	<0.001	0.460
	group	359.65	359.65	66.66	<0.001	0.643
Motor-visual speed	Pretest	303.16	303.16	81.50	<0.001	0.688
	Group	268.79	268.79	72.26	<0.001	0.661
Upper limp speed	Pretest	236.99	236.99	47.87	<0.001	0.864
	Group	236.37	236.37	47.75	<0.001	0.563
Fine motor	Pretest	1552.26	155.26	52.72	<0.001	0.588
	Group	3087.01	3087.01	104.55	<0.001	0.739
Perceptual-motor skills	Pretest	4493.48	4493.48	61.85	<0.001	0.626
	Group	14614.40	14614.40	201.08	<0.001	0.845

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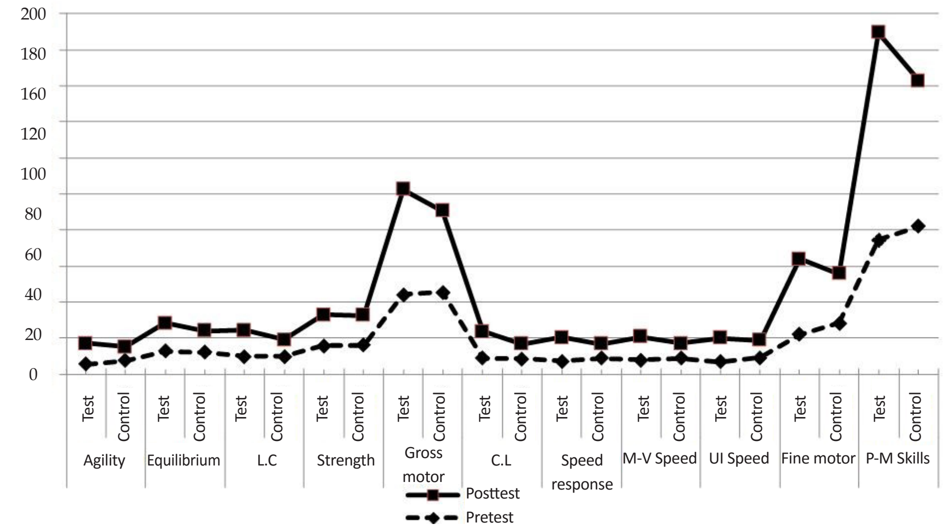

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Figure 2. Average of perceptual-motor skills in posttest and pretest measurement of the two groups.

Table 3. Comparison of posttest average scores of behavioral problems of test and control group with statistic control of post-test effect, through covariance analysis test.

Variable	Variable source	Total squares	Mean squares	F	The probability	Size effect
Attention problems	Pretest	2684.77	2684.77	149.55	<0.001	0.802
	Group	386.93	386.93	21.55	<0.001	0.368
Aggressive behavior	Pretest	1183.47	1183.47	84.09	<0.001	0.694
	Group	2124.35	2124.35	150.95	<0.001	0.803
Attention deficit/hyperactivity	Pretest	66.297	66.297	54.27	<0.001	0.595
	Group	2374.18	2374.18	194.35	<0.001	0.840
Confrontational behavior	Pretest	1514.38	1514.38	218.20	<0.001	0.855
	Group	2.97	2.97	0.430	<0.056	0.011
Externalizing	Pretest	1387.37	1387.37	321.17	<0.001	0.897
	Group	397.51	397.51	92.02	<0.001	0.713
General problems	Pretest	914.65	914.65	95.68	<0.001	0.721
	Group	2363.74	2363.74	247.27	<0.001	0.870

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nation and control, data analyzed in terms of compare average and all results show that there is no significant effect of the pretest, subtests, and subscales, on posttest scores (Table 3).

4. Discussion

Both intervention and control groups reported significant improvement in all subtests and subscales, considering eight weeks break between pretest and posttest. However, the results that earned by using neurofeedback intervention according to decreasing Theta and increasing Beta protocol showed a significant rate of improvement in the intervention group compared with the control group. This is about subtests of Bruininks-Oseretsky motor test: agility and run's speed, equilibrium, lateral coordination, gross motor skills, coordination of upper limb, speed response, motor-visual speed, upper limp speed, fine motor and perceptual-motor skills, and subscales of CBCL behavioral questionnaire: attention problems, aggressive behavior, attention deficit/hyperactivity, externalizing and general problems. There was no significant improvement in two groups in the strength subtest of Bruininks-Oseretsky motor, test and confrontational behavior subscale of CBCL behavioral questionnaire. The findings of this study are consonant to the findings of another research done by Dehghan et al. (2010), in which they investigated the effects of using perceptual-motor practices on ADHD children aged 5 to 8 years. They showed that the improvement in motor skills results in the improvement in behavioral problems in ADHD children [10].

Similarly, our findings with respect to neurofeedback with decreasing Theta and increasing Beta protocol on ADHD children are in agreement with the findings of another clinical research done by Beauregard and Colleagues in 2006. In this research, they showed that FMRI enhanced the activities of some brains areas: right anterior cingulate, left caudate and lateral prefrontal cortex. It also exposed that the neurofeedback intervention with decreasing Theta protocol [4-7] and increasing Beta domain [13-16] and Beta 1 [16-19] improved attention in children with ADHD [49]. It can be expressed that children with ADHD have motor coordination problems because of weakness in attention [44]. Motor weakness because of attention deficit must not be ignored [49]. High level of attention deficit along with motor coordination indicates a common neurological mechanism [40]. Attentional and sensory-motor functions are dependent on each other. Therefore, low attention is required for doing automatic motor actions, and high attention is required for doing complex motor assignments [40]. It seems that the major symptoms of inattention have relation with motor coordinating [41].

Thus, the motor deficit of children with ADHD is not only a motor problem; rather it is one of the reasons for increasing inattention and defects in occupational memory [42, 43]. Future studies should focus on daily living perceptual-motor activities and stable attention. This inquiry consists of some limitations such as differences in age, symptoms, and cultural context of children, and lack of control over their diets that increased the deficit symptoms.

5. Conclusion

The present study shows that neurofeedback intervention can have a positive effect on improving the perceptual-motor skills of children with ADHD. This intervention can also decrease attention problems, aggressive behavior, attention deficit/hyperactivity, externalizing, and other general problems.

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Conflict of Interests

The authors declared no conflict of interests.

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