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The Effect of Perceptual-Motor Parent-Child Exercises on Executive Functions in Girls with Attention-Deficit/Hyperactivity Disorder: A Randomized Clinical Trial

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Original Article

Abstract

Introduction: Attention-deficit/hyperactivity disorder (ADHD) is an important research topic and a common disorder among children in schools, accompanied by the symptoms of aggression, hyperactivity, anxiety, and attention deficit. Considering the side-effects of medications used to treat this disorder, this study endeavored to investigate the effect of perceptual-motor parent-child exercises on executive functions in children with ADHD.

Materials and Methods: Participants were 36 children with ADHD with age range of 7-10 years with their mothers, randomly divided into two 18-person groups of mother-and-child-together exercises and mother-child-separately exercises. Regarding the above-mentioned groups, the participants practiced perceptual-motor exercises for 8 weeks, three 45-minute sessions per week. Before and after the intervention, data were collected by the Stroop Word Test (computerized version). Data analysis was done through the covariance test at significance level of 0.05.

Results: Higher mean post-test scores in both groups showed that perceptual-motor exercises were effective on executive functions. However, the number of congruent errors (P = 0.006), incongruent errors, congruent correct responses, incongruent correct responses (P = 0.001), congruent reaction time (P = 0.028), incongruent reaction time (P = 0.007), and interference scores were significantly different between the two groups. The mother-and-child-together exercise group performed better than the mother-child-separately exercise group.

Conclusion: Findings reveal that perceptual-motor exercises can improve executive functions of children with ADHD, and mother-and-child-together exercises can be an appropriate method for improving executive functions of children with ADHD.

Keywords: Attention-deficit/hyperactivity disorder; Child-parent exercise; Executive functions; Simultaneous exercise

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Introduction

Attention deficit hyperactivity disorder (ADHD) is one of the most common childhood disorders (1) that often first appears in the early years of primary school (2) and its symptoms continue into adolescence and adulthood (3). ADHD is a chronic neurodevelopmental and biochemical disorder that is characterized by three characteristics: Attention Deficit, Hyperactivity, and Impulsivity. Today, the range of this disorder has become so wide that it is one of the most controversial disorders in childhood and adolescence (4) and the prevalence of this disorder varies from country to country and in different cultures and even gender (5). For this reason, the prevalence of this disorder in different studies has been reported between 2.2 to 17.8% (1), with its prevalence being respectively 7.9 and 5.5% in boys and girls in Iran (7, 6). In addition, 30 to 70% of children show symptoms of this disorder in adulthood (8).

The etiology of ADHD has a strong genetic basis and the role of heredity in people with this complication is estimated at 70 to 80% (9). This disorder also occurs due to structural differences in the junctions between the frontal lobe to the corpus striatum, cerebellum, corpus

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callosum, thalamus, and decreased levels of the neurotransmitters dopamine and norepinephrine (10), and causes adverse consequences on various aspects of life, including executive functions (11). Executive functions are a set of cognitive processes used in the purposeful behavior management (12). From a neuropsychological perspective, executive functions are associated with the pre-frontal cortex of the brain (13) and patients with frontal lobe injuries are unable to perform them well. Various studies have shown that people with ADHD have deficiencies in most of the abilities related to executive functions (14,15). A meta-analysis of 83 studies of executive functions in ADHD found that children and adolescents with the disorder were significantly more defective compared to the general population in assessments of executive functions, including planning, inhibition, verbal and spatial memory, and cognitive flexibility (16). It has been observed that children with ADHD have impaired executive functions (17,18). Executive functions help us keep information about a particular issue in mind, ignore irrelevant information, and block information that prevents us from achieving the goal. Accordingly, these abilities are essential for daily success and are associated with academic achievement, social adjustment, and career success (19). Impaired executive function reduces this success and increases risky behaviors, and these negative effects cause children with ADHD to be rejected by their peers and their relationship with the teacher and family to be disrupted (20).

Given the problems and negative consequences of ADHD, finding an effective treatment for people with this disorder is of particular importance. The National Health Association finds multiple treatments (pharmacotherapy, behavioral therapy, and combination therapy) beneficial for these children (21). Pharmacotherapy is currently most widely used to reduce the risk of this disorder (22), although some researchers believe that drugs do not improve learning in children and cannot improve their cognitive or social skills; In particular, drugs are less effective than social skills and executive function (20). On the other hand, it is reported that 30% of children with ADHD do not respond positively to the drug and are unable to tolerate its side effects. Additionally, the effects of drugs are limited in time and have no long-term benefits (23). Some researchers believe that combination therapy is significantly better than drug therapy (24). On the other hand, parental education is an essential part of behavior therapy interventions and parental education and increasing their ability in parenting affect their children's cognitive skills (25).

Overall, adjuvant interventions appear to be needed to improve ADHD. Therefore, behavioral therapy methods such as physical activity and behavioral interventions with the parent-child approach are among the methods whose general benefits have been proven many times. Physical exercise is associated with improved processing speed, memory performance, scheduling, problem solving, executive function, and attention (26). Moreover, physical activity increases the speed and efficiency of neural activity (27), increases the levels of norepinephrine, dopamine, and brain activity, and improves cognitive function (23). On the other hand, parental education is an essential part of behavioral therapy interventions (25). According to some experts, in order to better understand the executive functions of children (28) and their higher mental functions (29), environmental influences and in particular the relationship between parent and child are necessary. A study in the United States found that changes in parenting quality affect the development of executive functions in early childhood (30) and that educating parents and increasing their parenting ability affects their children's cognitive skills (31). Given the results of the above studies (23,31-25), it is possible that physical activity and parent-child interaction can affect the executive functions of children with ADHD. In this regard, the aim of this study was to present two simultaneous interventions in the sports environment and in the parents-and-children physical exercises and to investigate the effect of mother-and-child perceptual-motor exercises on the executive functions of children with ADHD.

Materials and Methods

This study was a randomized clinical trial and the statistical population consisted of 7 to 10 year old female students with ADHD in Shahinshahr, Isfahan Province, Iran. To select the sample group, through the convenience sampling method, the people who obtained a score of higher than 34 in the Conners questionnaire in the parent form, were screened through the calls made in schools, health centers, psychological clinics, and social networks of this city. The study inclusion criteria included children in the age range of 7 to 10 years, signing the consent form by parents of children, and confirmation of ADHD in the children by a psychiatrist based on the Diagnostic and Statistical Manual of Mental Disorders-5th Edition (DSM-5). Besides, the exclusion criteria included not taking medication, no history of cardiovascular diseases (CVDs), and lack of regular attendance of the subject at the training sessions. The eligible students were randomly divided into two

experimental groups 1 (parent-and-child-together practice) and experimental 2 (parent-and-child-separately practice). To compare the mean score of executive functions between the two groups and perform a two-way test at a significance level of 5% ($\alpha = 0.05$), with a test power of 80% ($\beta = 0.2$), and to detect the least difference equal to the amount of standard deviation ($\delta = \sigma$), the sample size was calculated to be 16 subjects in each group using Equation 1. In other words, 16 mothers and 16 children in the mother-and-child-together group and 16 mothers in the mother group and 16 children in the child group had to be placed, which taking into account the 10% extra sample in each group due to distortion or possible loss of subjects, 18 subjects were selected in each group.

Relation 1 $$n = \frac{2\sigma^2(z_{1-\alpha/2}+z_{1-\beta})^2}{\delta^2}$$

In Experimental Group 1, mother-and-child together engaged in perceptual-motor activities with high interaction. In Experimental Group 2, the mother and the child groups performed activities separately and without interaction with each other that were similar in duration and intensity to the perceptual-motor activity of experimental group 1. Two days before and after the exercises, executive functions were measured by the Stroop word test.

The exercises included 24 sessions of 45 minutes (three sessions per week) of perceptual-motor exercises. The training program in each session included 5 minutes of walking and running and warm-up movements, 35 minutes of perceptual-motor exercises (32) and finally, 5 minutes of exercises to return to the initial state (Table 1).

Research tools

In the present study, the parents' form of Conners questionnaire was used to diagnose ADHD and the Stroop word test was used to assess executive functions.

Conners Questionnaire: This questionnaire is used worldwide as the most common tool for screening and diagnosis of ADHD (33,34). The scale was designed by Conners et al. and consists of 26 items that are completed by parents and scored in four-point Likert scale. A score of 0, 1, 2, and 3 indicates no, low, moderate, and high, respectively. Therefore, the total test score will range from 26 to 104. If the child's score is higher than 34, it indicates ADHD, and the higher the score, the greater the degree of disorder in the child, and vice versa (35). In a study conducted in Iran by Abdolkhodaei et al. on 1083 children, the validity of the test was reported to be 90.3 (36).

Table 1. Perceptual-motor exercises

Exercise sessions	Exercise program	
First	Static and dynamic balance (by balance board)	Spatial perception, vision, and shape perception exercises
Second	Type of movement (animal walking)	Game of finding objects in the sand
Third	Moving through the obstacles in different ways	Carrying objects over the obstacles and the Keep Away play
Fourth	Hopscotch game	Throwing rings inside a special area
Fifth	Aerobics	Two-people sprint training
Sixth	Dodgeball game	Hitting the balloon in the air
Seventh	Mouse game toy for cats	Jumping in specific directions by foot shapes
Eighth	Flexible movements	Ring and ball game
Ninth	Agility exercises	Jumping in squares in a coordinated and group manner
Tenth	Delicate movement practice	Receiving and throwing skills
Eleventh	Trampoline	Strengthening the memory of finding the mother with eyes closed
Twelfth	Zumba	Musical chairs game
Thirteenth	Step training	Reaction speed games
Fourteenth	Standing on the tube	Exercise with a stretcher and carrying the ball with a stick
Fifteenth	Training with a bench and a ball	Number puzzle with eyes closed
Sixteenth	Passing through the ring from different directions	Game of spatial perception and coordination and combined exercises
Seventeenth	Balance training with balls and cones	Exercises with balls and cones
Eighteenth	Hitting the ball to a specific area	Training on the Swedish bars and shadow game
Nineteenth	Review of exercises	Smart kid match
Twentieth	Trampoline	Training for middle muscle strength
Twenty-first	Game with balls and rings	Cognitive exercises
Twenty-second	Bilateral coordination training	Circular exercises
Twenty-third	Pilates exercise	Wolf and lamb game
Twenty-fourth	Skills of moving and manipulating	Strength exercises

Stroop Word Test: This test was first designed by Stroop to measure selective attention and cognitive flexibility through visual processing (37). The Stroop word test has been used in various studies in various clinical groups to measure response inhibition, selective attention, cognitive variability, and cognitive flexibility (38-42). The implementation and scoring of this tool is as follows.

Preliminary stage: In this stage, a circle in four colors red, blue, yellow, and green is displayed on the screen. The subject is asked to respond by pressing a button that matches the color of the circle they see.

Experimental stage: This stage is exactly according to the method of the main stage. The purpose of this step is just to practice and get acquainted with the method of answering and the place of the keys on the keyboard, and has no effect on the final result.

Execution stage: In this stage, 48 congruent colored words and 48 incongruent colored words with red, blue, yellow, and green colors are displayed to the subject randomly and consecutively. Congruent words mean that the color of the word is the same as the meaning of the word, for example, the word green, which is indicated by green. Incongruent words mean that the color of the word differs from the meaning of the word, for example, the word green, which is indicated by red, blue, or yellow. The subject's task is to determine only the apparent color of the words, regardless of its meaning. Researchers believe that the color-word task measures mental flexibility and response inhibition. In studies, the test-retest validity of this has been reported in the range from 0.80 to 0.91 (43).

First, the hypotheses were examined (following the data distribution from the normal distribution, equality of variance of the research data, and the homogeneity of the regression line slope) and finally, the study hypotheses were tested using the covariance test. Finally, the data were analyzed in SPSS software (version 22, IBM Corporation, Armonk, NY, USA). $P < 0.05$ was considered as the level of significance of the data.

Results

Based on descriptive findings, each group consisted of 18 people. The mean age index of children in experimental group 1 and experimental 2 was 8.44 ± 1.44 and 8.66 ± 1.37 years, respectively. Before performing data analysis, its assumptions were tested using analysis of covariance (ANCOVA). The Shapiro-Wilk test results were not significant for any of the variables in the pre-test and post-test stages ($P > 0.05$). Therefore, the hypothesis that the data followed the normal distribution was established. Additionally, the results of Levene's test and homogeneity of regression slope showed that the assumption of equality of covariance matrices and the assumption of equality of variances for the task related to executive functions have been observed. Therefore, the conditions for using ANCOVA were available. The ANCOVA results in evaluating the effectiveness of parent-child perceptual-motor exercises on executive functions are presented in table 2.

Based on the data in presented table 2, the parent-and-child perceptual-motor exercises had a significant effect on executive functions ($P = 0.001$). The results showed that parent-child perceptual-motor exercises reduced the number of errors in both groups and increased the number of correct answers in both groups, in addition to improving the reaction time and interference score of both groups. Other results showed that there was a significant difference in intergroup comparisons and the perceptual-motor exercises had a greater effect on experimental group 1 (parent-and-child-together exercises) compared to experimental group 2 (parent-and-child-separately exercises) on the variables of the number of congruent errors, the number of incongruent errors, the number of correct congruent responses, the number of correct incongruent responses, the congruent reaction time, the incongruent reaction time, and the interference score.

Discussion

The aim of this study was to determine the effect of the mother-and-child-together perceptual-motor exercises on the executive functions of children with ADHD. The results suggested that the mother-and-child-together cognitive-motor exercises had a significant positive effect on the executive functions of children with ADHD. This finding was consistent with the results of previous studies (41,44-47) regarding the effect of physical activity on the executive functions of children with ADHD and research findings regarding the effect of parent-child relationship on the executive functions of these children (28,30). The set of activities used in the present project and the total duration of the study (24 sessions) had the necessary minimum to affect these sports activities (47). Attention deficit is the most characteristic and serious problem of children with ADHD and selective attention is a cognitive process focused on one dimension of the environment and ignoring other cases (48). Perhaps the reason for these favorable effects is the positive effect of sports activities on the brain function, which increases the levels of epinephrine and dopamine transmitters; These neurotransmitters can regulate brain processes for cognitive responses (23) and increase attention and concentration, making a person more susceptible to controlling inappropriate behaviors (47).

Table 2. Intra-group and inter-group changes of executive functions

Variable	Group	Pre-test	Post-test	Intra-group differences	Inter-group differences				
					Pre-test		Post-test (covariance)		
					t	P	F	P	Eta squared
Number of congruent errors	Experimental 1	12.38 ± 6.06	6.27 ± 1.48	0.001 ⁂	-0.394	0.696	8.824	0.006	0.211
	Experimental 2	13.22 ± 6.60	8.72 ± 3.06	0.011 ⁂					
Number of incongruent errors	Experimental 1	15.33 ± 3.23	8.61 ± 2.35	0.001 ⁂	-0.095	0.925	14.438	0.001	0.304
	Experimental 2	15.44 ± 3.77	11.27 ± 3.77	0.001 ⁂					
Number of correct congruent responses	Experimental 1	27.05 ± 3.78	35.50 ± 2.95	0.001 ⁂	-0180	0.859	22.597	0.001	0.406
	Experimental 2	27.27 ± 3.64	30.77 ± 2.96	0.006 ⁂					
Number of correct incongruent responses	Experimental 1	22.00 ± 3.78	32.11 ± 2.63	0.001 ⁂	-0.953	0.347	17.541	0.001	0.347
	Experimental 2	23.16 ± 3.55	27.27 ± 2.67	0.001 ⁂					
Congruent reaction time (ms)	Experimental 1	137.90 ± 99.09	1085.30 ± 48.07	0.038 ⁂	-0.860	0.396	5.249	0.028	0.137
	Experimental 2	1168.90 ± 116.02	1136.40 ± 75.23	0.048 ⁂					
Incongruent reaction time (ms)	Experimental 1	1247.30 ± 93.28	1143.70 ± 71.53	0.001 ⁂	-0.180	0.858	8.324	0.007	0.201
	Experimental 2	1253.10 ± 99.51	1206.90 ± 57.27	0.032 ⁂					
Interference score	Experimental 1	-109.33 ± 103.29	-58.38 ± 86.31	0.019 ⁂	0.483	0.633	2.288	0.041	0.118
	Experimental 2	-84.16 ± 177.38	70.50 ± 82.58	0.048 ⁂					

Tantillo et al. concluded that exercise could be beneficial for children with ADHD by increasing dopamine (49).

On the basis of the neurophysiological hypothesis, physical exercise increases the levels of epinephrine and norepinephrine, dopamine, and serotonin in the pre-frontal, hippocampus, and corpus striatum areas. This increase acts similar to drug stimulants, positively affecting nerve function and attention (23). Furthermore, given the theory of arousal mechanism (50), ADHD is due to abnormalities in the arousal mechanisms of the brain of people with this disorder. Studies have examined the arousal mechanisms from two aspects: "hyper-arousal" and "hypo-arousal". The "hyper-arousal" approach states that the confusion and overload of data does not allow the child to refine and select stimuli. In contrast, the "hypo-arousal perspective" believes that low arousal and insufficient activity of inhibitory control mechanisms cause distraction and, consequently, cognitive problems in children with ADHD (51). Therefore, it is said that exercise balances the arousal in children by balancing the secretion of epinephrine in the area of brainstem arousal, and thus, reduces the level of irritability in children (49). Therefore, it can be expected that participating in regular exercise increases concentration and ability to maintain attention. One of the applications in motion therapy is perceptual-motor programs. Perceptual-motor training programs are valid physical training programs that are based on the level of development and include many of the same elements (52). All voluntary movements require an element of perception, and there is an important link between the perceptual and motor processes (52). In perceptual-motor programs, factors such as physical awareness, spatial awareness, temporal awareness, and directional awareness are emphasized and these programs have been used to treat various disorders of childhood (53). The mechanism of action of perceptual-motor activities is such that these activities are performed through stimulus identification, information processing, sensory integration, decision making, response selection, planning, sending command, movement execution, and receiving feedback (54). Additionally, neuroimaging studies have shown that children with ADHD have difficulty with cerebellar and frontal lobe function, which play a key role in executive functions (planning, organizing, decision-making, time perception, inhibition, and thinking) (10). Decreased brain activity in these areas in these children may be due to the smaller size of these areas in the brain and less chemical activity in these areas (1). Accordingly, recent studies point to the improvement of the structure and function of the frontal lobe as a result of physical activity and, consequently, the improvement of cognitive functions (55,56). In their study, Kim et al. demonstrated the effect of physical activity on brain cell

proliferation (57). It seems that perceptual-motor exercises through facilitating neural plasticity, creating new synaptic structures, increasing information processing performance (58), increasing the efficiency of neurotransmitters, neural adaptation, restoring behavioral function, and emotion regulation (59), improve the brain development and increases the function of the nervous system and cognitive function.

On the other hand, the results of studies on the parent-child relationship have shown that children with ADHD problems have a direct impact on the parent-child interaction (60-64). Excessively supportive parenting probably causes the processes of organization and inhibition, which are key components of executive functions, to not grow properly (65). Thus, parental guidance may be able to assist the executive functions of these children (66). In concurrent parent-child classes, changing punishing style, the principle of parental encouragement to children, and how to establish a positive relationship between parent and child can affect children's executive functions (67); In such a way that parents, instead of giving orders to their children or surrendering to them, give them the opportunity to make decisions and choices, and this makes the child aware of his strengths and possessions and make better cognitive decisions (68). It also increases the self-esteem and self-confidence of parents and children, improves their interaction, and ultimately improves the child's executive functions by improving the parent-child relationship.

According to what stated above, the parent-and-child-together perceptual-motor exercises were more effective than the parent-and-child-separately perceptual-motor exercises. Explaining this finding, it can be said that learning the correct ways of interacting with children reduces the existing stress and tension and improves the parent-child relationship, and by creating a bridge between parents and children through participation in educational programs, leads to recognizing the strengths and weaknesses of parents in communicating with their child. The results of some studies suggest that by participating in educational programs, parents acquire the necessary knowledge and skills to improve the quality of parent-child interaction (69,70), which was consistent with the findings of the present study. In families with children with special needs and problems, it is important to pay attention to the parents' relationship with the child and to participate in intervention programs. Therefore, it can be concluded that exercise therapy based on the parent-child relationship is a technique by which the family environment and the quality of parenting are influenced and the executive functions are developed in these children.

Limitations

The limitations of the present study included the difficulty in completing the sample size for various reasons such as lack of parental cooperation to attend meetings and lack of the same ability of parents to perform activities and differences in mothers' goals to participate in physical activity with their children; Because some mothers focused on their physical activity to achieve fitness, and some mothers aimed to improve their children's health,

Recommendations

It is suggested that in future studies, the effect of perceptual-motor exercises with other family members and in other gender groups such as father-son, mother-son, and father-daughter and in different age groups be investigated. In addition, the intervention should be evaluated at longer intervals.

Conclusion

Overall, simultaneous parent-child cognitive-motor exercises can have a positive effect on executive functions of children with ADHD. The parent-child education method is economically viable and lacks the side effects of medication. Teaching child control skills to parents is very important; Because they spend more time with the child and have the power and authority to apply incentives and punishments, and can reduce the cost of treatment, in addition to increasing the effectiveness of behavioral therapy in the treatment of children.

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Authors' Contribution

Study design and ideation: Rokhsareh Badami, Marziyeh Jafari
Attracting financial resources for the study: Marziyeh Jafari
Support, executive, and scientific services of the study: Rokhsareh Badami, Marziyeh Jafari, Zohreh Meshkati
Providing study equipment and samples: Rokhsareh Badami, Marziyeh Jafari
Data collection: Marziyeh Jafari
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Specialized evaluation of the manuscript in terms of scientific concepts: Rokhsareh Badami, Marziyeh Jafari, Zohreh Meshkati
Confirmation of the final manuscript to be submitted to the journal office: Rakhsareh Badami, Marzieh Jafari, Zohreh Meshkati
Responsibility for maintaining the integrity of the study process from the beginning to the publication and responding to the opinions of the judges: Rokhsareh Badami, Marziyeh Jafari, Zohreh Meshkati

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Conflict of Interest

The authors have no conflict of interest.

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