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The effectiveness of physical activity with motor-cognitive approach on executive function in children with Attention Deficit/Hyperactivity Disorder

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Abstract

Background and objective: Psychological studies with behavioral therapy and cognitive therapy approaches seek to discover ways to treat attention deficit / hyperactivity disorder (ADHD). The aim of the present study was to investigate the effectiveness of 12 weeks of physical activity with motor-cognitive approach on response inhibition and sustained attention in children with the symptoms of ADHD.

Material And Method: The present study was a quasi-experimental with a pretest-posttest design. The statistical population of the study consisted of all children aged 9 to 11 years with a history of 1 to 2 years of ADHD symptoms in Kermanshah. 30 children with ADHD voluntarily participated in the study and divided randomly in the experimental and control groups. Participants in the experimental group performed motor-cognitive training with moderate-intensity for 12 weeks (2 sessions in week) and 60 minute per session. The present research instrument was the Wechsler's intelligence scale, the SNAP questionnaire, the stroop test and the continuous performance test. To analyze the data, multivariate and univariate analysis of covariance were used.

Results: The results showed a significant improvement in response inhibition ($F_{1,28}=63.1$, sig=0.001) and sustained attention ($F_{1,28}=32.9$, sig=0.001) scores in children with ADHD in the experimental group following 12 weeks of training ($p \geq 0.001$).

Conclusion: 12 weeks of physical activity with motor-cognitive approach had a positive effect on response inhibition and sustained attention in children with ADHD. Therefore, it is recommended that children with ADHD participate in physical activities with motor-cognitive approach to improve response inhibition and sustained attention.

Keywords: Attention deficit, hyperactivity disorder, Executive functions, physical activity

Introduction

The Attention Deficit / Hyperactivity Disorder (ADHD) is one of the most common psychological and neurodevelopmental disorders of childhood that often lasts until adulthood and it affects various aspects of a person's academic, family and social life (1). Most studies have shown that the prevalence of this disorder in primary school students is about 3 to 5%. An important criterion for diagnosing this disorder is that in addition to the behavioral symptoms, it should last for at least 6 months in the individual (2). In determining the cause of this disorder, genetic risk factors, environmental risk factors and structural and physiological changes in brain function have been mentioned. Most researchers, however, agree that the etiology of ADHD is complex (3). Although the diagnosis of ADHD is based on behavioral cues, research has shown that there are neurological and cognitive underpinnings specific to the disorder (4).

Many studies have shown that ADHD children are weaker than normal children in terms of many components of the executive function such as inhibitory, sustained attention, the working memory, the abstract thinking and planning due to some degree of frontal lobe disorder. Response inhibition is the most important component of executive functions and related to the ability to stop thoughts, actions, and emotions (5). According to this research, it can be also concluded that the most important problem of children's attention with ADHD is the sustained attention deficit disorder (6). Sustained attention means the ability to maintain a purposeful response during a continuous and repetitive activity (1).

Given the findings of various studies, it can be concluded that the deficits in executive functioning is an important theory in the phenomenology of ADHD. Therefore, in the last few decades, special attention has been paid to the executive dysfunctions' effects on the educational and therapeutic planning for this disorder (7). The therapy methods for the children with the symptoms of ADHD are pharmacotherapy, behavioral therapy, and cognitive behavioral therapy. Although some studies have suggested that these therapies are effective, but none of these approaches are able to solve the cognitive difficulties related to this disorder directly (6,8).

In addition to pharmacological and psychological interventions, in recent years, the attention towards using the novel therapeutic approaches for children with the executive dysfunctions has increased (9). One of the newest approaches in field of the treatment of cognitive and motor difficulties in the children with the executive dysfunctions is cognitive rehabilitation using physical activity (10). Some Research have been reported a positive relationship between physical activity and executive functions. Neurologists have considered physical activity as a stimulator of neural pathways in the brain and believe that it affects the growth of brain cells and by stimulating the neurogenesis process, lead to stimulate and cause independent structural and functional changes in the nervous system (6).

Considering the importance of the relationship between physical activity and cognitive function (10), physical activity-based interventions have been used in related with ADHD and their effectiveness on motor and cognitive function (8), improving executive functions, motor skills, academic performance, psychological processes, and reducing the symptoms of hyperactivity have been confirmed by research (11). For example, Chou et al. (2017) showed the

positive effect of yoga exercise on the executive functions of children with ADHD (12). Jarraya et al. (2019) also showed in their study that 12 weeks of kindergarten-based yoga practice improved inattention behavior, visual attention parameters and visual-motor accuracy in 5-year-old children with ADHD (13). However, Mahon et al. (2013) in their study did not observe a significant effect on sustained attention of ADHD children following one intermittent exercise session (14). Also, in the research of Banikarimi et al. (2018), fundamental motor training had no significant effect on continuous attention and cognitive impulsivity in children with ADHD (11).

Researches show that not all types of physical activity interventions are effective on promote executive functions of children with cognitive dysfunction, and the rate of progress in cognitive function through physical activity may be related to the characteristics of the activities performed (16). Also, despite much research over the past few decades in the field of etiology and determination of prevalence of ADHD, no strong and comprehensive model has been drawn to solve the numerous problems for the children with this disorder and therefore needs more research. Given the problems of children with ADHD in executive functions and due to the enjoyable nature of physical activity for children and children's natural desire for physical activity and using the motor activities which are symptoms of hyperactivity, if ADHD children practice executive functions purposefully with physical activity, they will be able to enjoy motor and coordination benefits while improving their executive functions.

The aim of the present study was to investigate the effect of 12 weeks of table tennis training with emphasis on teaching executive functions on response inhibition and sustained attention in children with ADHD.

Materials and Methods

The methodology of the present study was quasi-experimental study with the pre-test-post-test design. The statistical population of the research consisted of children 9 to 11 years old with ADHD in Kermanshah, who referred to psychological education centers. The SNAP-IV questionnaire was used to ensure that these individuals had ADHD.

The inclusion criteria of the study included psychiatrist confirmation for ADHD, age 9 to 11 years, the lack of the other disorders such as mental retardation and learning disorder, not use of medication at the time of intervention, having history of 1 to 2 years of ADHD symptoms, IQ 90 to 110 using the completion of IQ test and conscious consent to participate. The exclusion criteria of the study included absence of more than two times in training sessions and visual-auditory and physical-motor skills difficulties. After selecting qualified individuals, 30 children voluntarily participated in the present study and randomly assigned to two control and experimental groups (n=15). Due to the use of semi-experimental research method, the optimal number of samples for each group was 15 (4,6).

At the beginning of the experiment, after obtaining the consent of the parents and communicating with the subjects and explaining the goals and process of the sessions, response inhibition and continuous performance test were taken from both groups. Participants in the experimental group performed motor-cognitive training with moderate-intensity for 12 weeks (2 sessions in week) and 60 minute per session. The training sessions included warming up (5 minutes),

motor-cognitive training through table tennis playing (50 minutes) and cooling down (5 minutes). The focus of the main part of the exercise was based on presenting assignments with different complexities based on training on the components of attention and response inhibition. Some examples of exercises included the following: Catching orange balls with both hands and not catching white balls, catching orange balls with the right hand and white balls with the left hand, responding to the white balls with forehand and responding to the orange balls with backhand and so on. The complexity of the exercises depended on each child's needs and motor skills (17-19). The training protocol was adapted from previous studies and its content validity was confirmed by 10 sports psychologists. Evaluation and training sessions were conducted by researchers and clinical experts. Data were collected using the following tools:

Personal Profile Questionnaire

In order to collect general information, the questionnaires made by researchers were given to the parents of the subjects, which includes the name, gender, age, grade, history of referring to a psychiatrist and the name of the drug used, illness and physical difficulties of the subject.

Intelligence Quotient test

To assess children's intelligence Wechsler's intelligence scale (2014) was used. According to Atadokht et al. report, the validity and reliability of this test were 74% and 94%, respectively (20).

SNAP-IV Questionnaire

The Swanson's et al. SNAP-IV questionnaire (1980) was used to measure the ADHD. The SNAP-IV questionnaire is an 18 items scale which is completed by parents and teachers. Sadr al-Sadat et al. reported that the reliability coefficient of this test was 82% based on the test-retest method and 90% based on Cronbach's alpha method (21).

Stroop test

The Stroop test was designed in 1935 by Ridley Stroop and is one of the most usable tests for the response inhibition. In this test, the names of the four main colors, each with the same color (congruous words) and different from the color of their own ink (incongruous words), appear randomly on a monitor screen and the participant is asked to press the corresponding key on the keyboard as soon as possible based on the color of the word. The validity and reliability of this test have been confirmed in previous research in our country (4,22).

Continuous performance test

Continuous performance test of Rosvold et al. (1956) was used to measure sustained attention. This test consists of two sets of stimuli (numbers and letters), each of which consists of 150 stimuli. Among the stimuli, 30 stimuli are target stimuli that the subject is expected to respond to by observing them (pressing a key). The validity and reliability of this test have been confirmed in previous research (23).

To ensure the normality of the data and the homogeneity of variances, Shapiro-Wilk test and Levin test were used, and to test the research hypotheses, multivariate and univariate analysis of covariance were used in SPSS 23 software. Significance level was considered 0.05 at all stages ($p < 0.05$).

Results

The mean of response inhibition and sustained attention in pre-test and posttest are presented in figure 1.

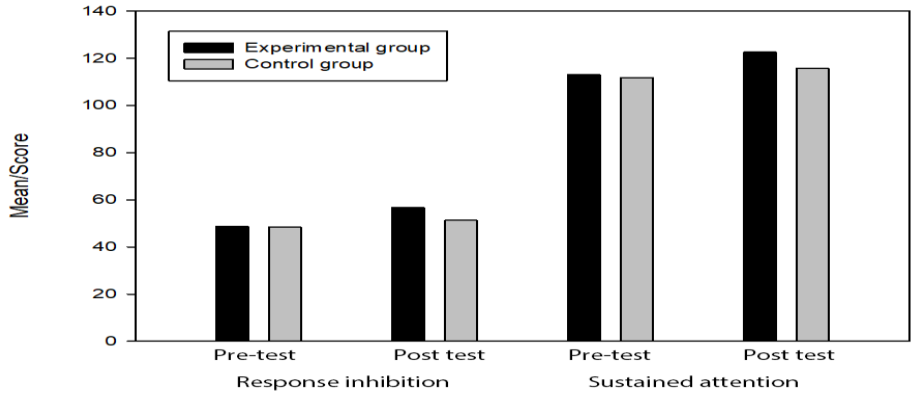

Figure 1. mean of response inhibition and sustained attention in control and experimental groups.

As shown in figure 1, the average of response inhibition and sustained attention in the experimental group have increased from pre-test to post-test dramatically in comparison with the control group. According to the results of Shapiro Wilk and Levin tests, the assumptions of analysis of covariance were confirmed (P≥0.05). To investigate the effect of independent variable on the dependent variables of research, the multivariate analysis of covariance was used, the results of which are shown in Table 1.

Table 1. the results of multivariate analysis of covariance test (MANCOVA) based on the Hotelling's trace

Value	F	Hypothesis df	Error df	sig	η2
2.68	33.52	2	25	0.001	0.728

*P value <0.05, df= Degree of freedom; sig= Level of significance; η2= Eta-squared.

According to the results of multivariate analysis of covariance, the independent variable had a significant effect at least on one of the variables of sustained attention and response inhibition. (F = 33.52 and P = 0.001). Therefore, univariate analysis of covariance was used to determine the differences between two groups in the dependent variables, the results of which are presented in Table 2.

Table 2. the results of univariate analysis of covariance (ANCOVA) to compare response inhibition and sustained attention in groups

Source	The dependent variable	MS	df	F	sig	η2
Group	Response inhibition (strop)	294.4	1	63.1	0.001	0.708
Group	Sustainable attention (CPT)	205.4	1	32.9	0.001	0.559

*P value <0.05, df= Degree of freedom; MS= Mean squares; sig= Level of significance; η2= Eta-squared.

According to analysis of covariance in Table 3, after eliminating pre-test effect, a significant difference was observed in the mean scores of post-tests of sustained attention ($P < 0.001$) and response inhibition ($P < 0.001$) in the two groups. According to the results of Eta-squares, it can be said that 70% of the changes in the scores of sustained attention and 55% of the changes in the scores of inhibition were due to the effect of the training program.

Discussion

The results showed that there was a significant improvement in the sustained attention and response inhibition in children with the symptoms of the ADHD following 12 weeks of motor-cognitive training. The findings are consistent with the results of research by Chou et al (12) and Jarraya et al (13). For example, the results of Chou et al.'s research (2017) showed a positive effect of a yoga training course on response inhibition, vigilance, and Impulse-control disorder (ICD) in children with the symptoms of ADHD (19). Also, Jarraya et al (2019) demonstrated the effectiveness of yoga practice on the parameters of the visual attention and visual-motor acuity, and fine motor skills, and decrease of the behavior of the inattention and hyperactivity in children with ADHD (9). However, the results are inconsistent with the research of Mahon et al. (2013) and Banikarimi et al. (2018). Mahon et al. (2013) did not observe a positive effect on the continuous attention of children with ADHD following their one-session exercise program. Also, Banikarimi et al. (2018) did not report a significant effect on the executive functions of ADHD children following their fundamental movement training. The differences observed in the results may be due to the nature of the intervention and the type of program used, duration of the program, the type of tool used, severity of the symptoms of the disorder and so on (11). It should be noted that Mahon et al.'s (2018) study consisted of 20 minutes of intermittent exercise (30 sec exercise/30 sec rest) at 90% of peak aerobic work rate. They noted that the intensity and duration of the exercise program could guarantee the neurological and behavioral function of ADHD children. It is also possible that the difference between the type of program and the duration of the intervention of the present study and the study of Banikarimi will clarify the difference between the findings. The research program of Banikarimi et al (2018) was only 10 sessions of 30 minutes and included simple fundamental skills, while the present research exercise was designed for 24 one-hour sessions based on the improvement of executive functions. In addition, the results of recent studies have shown that a combination of physical and cognitive training may increase the effectiveness of interventions (6). In the present study, a combined program of motor and cognitive training was used, and perhaps for this reason, it was more effective than Banikarimi et al's research.

Studies on the neurology of motor activity confirm that movement and exercise affect brain cells as well as stimulate and make independent structural and functional changes in the nervous system by affecting the neurogenesis process. These changes include the release of growth factors such as the Brain-derived neurotrophic factor (BDNF), which is active in the brain's hippocampus, cerebral cortex and pre-brain as important areas for learning, memory and thinking (24,25). In addition, physical activity leads to increase in levels of neurotransmitters, such serotonin, noradrenaline and acetylcholine, which play an important role in cognitive

function. Motor activity can affect brain function and lead to the activation of limbic areas and the frontoparietal of the brain (25).

Another possible mechanism that leads to the development of cognitive functions as a result of physical exercise is the increase in cerebral blood flow in areas of motor control as well as areas of the hippocampus. Increased cerebral blood flow due to motor training may provide more oxygen and fuel for neural functions and have a significant effect on excitability in neuronal cells and nerve impulse conduction speed, thereby improving cognitive function (6, 26). The children with the symptoms of attention deficit/hyperactivity disorder (ADHD) have difficulty in visual pursuit and visual convergence (27). There is also a close relationship between eye function and the systems responsible for executive functions in the brain (28). In this regard, it can be said that table tennis due to the needs of predictive control and smooth pursuit movement of vision, as well as planning various movements during the game can improves the function of the brain areas involved in executive functions (29).

The most important limitation of this research was the use of available sampling method and lack of the follow-up stage. Therefore, it is recommended to use random sampling methods in future research, and in addition, short-term and long-term follow-up should be used to examine the effectiveness of the results more accurately. Also, comparing this method with other methods such as pharmaceutical, behavioral, cognitive, metacognitive, etc. in other groups of children with special needs can have interesting results.

Conclusion

The results of the present study showed that 12 weeks physical activity with motor-cognitive approach (table tennis practice) was very effective on response inhibition and sustained attention in children with ADHD. Based on the results of the present study, it is recommended that these children participate in table tennis training and at the same time benefit from its cognitive and motor benefits.

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Informed Consent

All tests completed the consent form before participating in the study.

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