The Effectiveness of Aerobic Exercises on Components of Executive Functions in Children with Attention Deficit Hyperactivity Disorder

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Abstract

Introduction: It is necessary to investigate the cognitive and behavioral status of children with attention deficit hyperactivity disorder (ADHD) to improve their performance. Therefore, the aim of the present research was to investigate the effect of aerobic exercises on the components of executive functions (cognitive flexibility, impulsivity, response inhibition, and selective attention) in children with ADHD. **Methods**: This was a quasi-experimental study with pretest-posttest design. After performing the Raven screening test and SNAP-4, among the participants, 30 children aged 7-10 years who had IQ scores above 90 and met the ADHD criteria were randomly assigned to experimental (n:15) and control (n:15) groups. Before and after the intervention, both Stroop color and word test and continuous performance test were performed on both groups. Aerobic exercises were performed three sessions per week for three months in the experimental group. Data analysis was carried out using multivariate analysis of covariance. **Results**: The findings showed that aerobic exercise training had a significant increase on cognitive flexibility, response inhibition, and selective attention and significant reduction on the impulsivity in the experimental group compared to the control group. **Conclusion**: Aerobic exercise as a non-pharmacological and non-invasive treatment strategy, free of side effects, seems to be necessary to improve the executive functions of children with ADHD, which emphasizes the need for physical activity.

Keywords: Aerobics; Attention Deficit/Hyperactivity Disorder ;Executive Functions

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Introduction

Attention deficit hyperactivity disorder (ADHD) is one of the most common neurodevelopmental disorders in childhood, which manifests as a persistent pattern of attention deficit or hyperactivity and impulsivity. ADHD is more common among affected children as compared to those who are at the same level and considered as an important issue in community mental health (1). This disorder impairs performance or growth. These symptoms appear before the age of twelve, and the key behaviors of this disorder cause significant impairment in a person's social, occupational, or academic performance, and at least six of the 12 behavioral symptoms are identified in the person (2). An international meta-analysis estimated that global prevalence of this disorder among children was 7.2% (3), and estimates made by some community-based researches were somewhat higher (about 8.7% to 15.5%) (4-6). Ghanizadeh (7) showed that prevalence of symptoms of this disorder is about 10.1% among primary school children, 13.6% among male students, and 6.5% among female students. Half of these children usually have oppositional defiant disorder and a quarter of them suffer from conduct disorder. Specific learning disability disorder also concurrently occurs with this disorder.

One of the main symptoms of ADHD is impaired executive functions (EFs) (8), which is a distinct but essentially interconnected cognitive multi-component structure required to perform difficult or new tasks (9). EFs of prefrontal cortex are voluntary and purposeful behaviors that help integrate goal-oriented management so that people can consider short-term and long-term outcomes simultaneously, evaluate their behavior in real time, and be able to adjust them appropriately. These processes include cognitive flexibility, impulsivity, response inhibition, and selective attention (10). Cognitive flexibility includes person's ability to adapt and change methods for achieving a goal. More generally, it is defined as the ability to review the program when confronting with new barriers, information, or errors. Flexibility includes person's ability to adapt to circumstances. Impulsivity refers to the inability to think about the consequences of behavior (8). Response inhibition involves inhibiting the ability to think before action. This ability helps a person resist the temptation to do something considering his/her prior behavioral assessment. In more general terms, it means the ability to stop or delay an action instead of showing an impulsive (thoughtless) behavior. Selective attention also refers as the ability to focus sources of attention on a particular stimulus and eliminate annoying stimuli. The highest level of attention is selective attention, which includes paying close attention and showing response to the stimulus (11).

One of the theories involved in the etiology of this disorder is low arousal theory, which attributes hyperactivity and inattention to failure to be sufficiently aroused by the stimulus to pay attention to them and regulate the activity level (8). A research showed that major changes made by exercise and physical activity could affect brain function and the nervous system (12). These effects are extensive and range from large structural changes to changes in cell morphology. Smith et al. (9) showed that exercise increased. Vigilance and alertness by increasing alpha and beta brain waves in the cingulate cortex. According to the findings of Alijanpour *et al*., chronic endurance exercise training also increased the electrical activity of alpha and beta brain waves in all brain lobes and leaded to increased alertness, concentration, creativity, and relaxation (10).

In recent years, people have become more inclined to rhythmic exercises such as aerobics. Such exercises not only reduce the feeling of tiredness in people, but also involve the mind in addition to the body, because they coordinate the rhythm with a specific movement, thereby strengthening the intellectual power, memory, and creativity (11). Aerobics has a lot of fans in preschool centers in some countries as mental-motor movements. These centers use rhythmic and simple aerobic exercises to strengthen children's EFs (13). Most studies on exercise science, which have extended exercise to its physiological component, have ignored the potential cause of the coordinated and complex movements incorporated into aerobic exercise sessions. However, performing continuous aerobic movements can provide opportunities to combine and apply cognitive and physical exercise simultaneously (14). Aerobics can increases level of self-efficacy, task orientation, and perceived competence in children (15). A research by Mandolesi et al. (16) demonstrated the effect of physical exercise on cognitive function and psychological well-being in people with different ages. In a review study, Christensen et al. (17) confirmed the effects and long-term stability of physical exercise on cognitive function and mental health in children and adolescents with ADHD.

Considering the foregoing, a previous research has shown that aerobic exercises can play an effective role in improving the quality of psychological, neuro-cerebral, and executive variables in children with ADHD (18). Also, concerning the importance of EFs in a wide range of scales, including mental health, intelligence, and social situations, the aim of the present study was to investigate the effect of aerobic exercise on EFs components in children aged 7 to 10 years with ADHD. Therefore, the question is whether aerobic exercise can be used as a potentially non-pharmacological, motivating, low-cost, and non-stigmatized intervention to improve the components of EFS in children with ADHD?

Methods and Materials

This was a quasi-experimental research with pre-test and post-test design and participants were selected using convenience sampling. The statistical population was all families with ADHD children. At first, all families of these children were invited through a public call (in the offices of pediatricians, psychiatrists, psychologists, and occupational therapy centers) to voluntarily participate in the research. Inclusion criteria were parents of children with ADHD and IQ scores above 30 in children. The exclusion criteria were refusing to continue the research, failure to perform exercises as provided by the experts. All participants signed a consent form to participate in the research, and were assured that they could withdraw from the research process if they were not satisfied. The Raven test and the Swanson, Nolan, and Pelham Rating Scale (SNAP) were then performed on children. Next, 30 children with ADHD and IQ scores above 90 were selected and randomly assigned to two equal groups (aerobics [n:15) and control (n:15)].

Procedure

Prior to the intervention, the pretest was carried out to evaluate the EF components, including response inhibition, selective attention, cognitive flexibility by Stroop Color and Word Test (SCWT) test and impulsivity was also evaluated using continuous performance test in two groups. Then, aerobic exercises were performed three sessions per week for three months in the experimental group. Subjects were exposed to the aerobic exercise three times a week for 60 minutes. The control group attended the gym in the same manner, except that they did not move and only stories were read for them. EF components were measured again 12 weeks later for both groups as posttest.

***Aerobics group training program*:** Elements such as coordination, balance, spatial, temporal, physical awareness, and orientation were utilized in the training program of this research. The program selected in the study included light rhythmic movements with music for 60 minutes. First, 10 warm-up exercises (static stretches, rotational, jumping, and hopping) were performed. The subjects were given a 15-min training on single-beat, double-beat rhythms, etc. at slow speeds according to the rhythm. There were then given 20-min training on chain movements, starting with a single-hand chain, then increasing the chains, doing chain movements in the legs, and finally doing combined hand-legs chain movements (speed and complexity were increased progressively in all these exercises). The movements were performed in a 32- beat chain (8 movements × 4 beats). This chain includes: *1*) march, *2*) toe touch, *3*) easy walk, *4*) step touch, *5*) V step, *6*) mambo, *7*) double step touch, *8*) A step. At the end of each session, dynamic stretching exercises, slow walking, and march were performed for 10 minutes in coordination with rhymes in such a way that the movements were performed by the instructor and the children coordinated their movements with the instructor and the group at the same time (19). These exercises were performed under the supervision of a physiotherapist.

Instruments

Raven IQ Test: This test was developed in the UK and designed to measure Spearman's general intelligence. Respondents need to discover the relationship between geometric shapes. Revised forms of this test are used to measure people's intelligence with different levels of ability (children 5 years and older). This test consists of 36 color images, each with a blank part. There are six options at the bottom of each image, one of which can be inserted in the blank space to complete the incomplete image. The reliability of the Raven test is ranged as 0.80 to 0.90. Correlation coefficient of this test was reported 0.60, 0.70, and 0.58 according to Stanford-Binet test, Wechsler intelligence test, and Wechsler verbal test, respectively (20).

***Swanson, Nolan, and Pelham Rating Scale (SNAP)*:** This scale is used to screen children with ADHD. This scale was first developed in 1980 by three authors named Swanson, Nolan, and Pelham based on the Statistical Diagnostic Guide to Mental Disorders and abbreviated as SNAP representing the initial letters of the names of three above authors (21). As the diagnostic guide was revised and its fifth edition was complied, the above scale was rewritten and published in 2001 by Swanson (22). SNAP consists of 18 items for ADHD, which fall into two sets of symptoms for inattention/hyperactivity/impulsivity. This scale uses a four-point scale (never=0, little=1, somewhat=2, very much=3). The first option states no psychological harm. In Iran, the validity and reliability of the parent form of this rating scale was evaluated on children aged 7 to 12 years in Tehran. The findings of this study showed that criterion validity, test-retest reliability, Cronbach's alpha, and split-half reliability of the test were 0.48, 0.83, 0.90, and 0.76, respectively (21).

Continuous performance test (CPT): This test is used to assess attention and impulsivity and requires attention retention during a continuous task and inhibition of impulsive responses. This test was developed in 1956 by Rosvold (23). The subject should draw his/her attention to a relatively simple set of visual stimuli and respond by seeing the target stimulus. This test includes three variables of commission, omission response, and reaction time. The validity coefficients of the different parts of the test, which were performed on 3 male elementary school students with a 4-day interval, ranged from 0.59 to 0.93 in a previous study. The results showed significant correlation between coefficients (P<0.001). The test validity was determined by the criterion validity by comparing the normal group and the increased ADHD group, which indicated a significant difference between the two groups in terms of performance score (24).

Stroop test: Stroop color and word test (SCWT) was first developed in 1953 by Ridley Stroop to measure selective attention and cognitive flexibility. SCWT is one of the most important tests used by researchers to measure response inhibition and has been translated in various languages including Chinese, German, Swedish, Japanese and etc. SCWT is a laboratory model for measuring selective attention, cognitive flexibility, and response inhibition, which serves as a baseline test for frontal lobe function. According to Karimi *et al.* (25) the test-retest reliability of SCWT for all three attempts was 0.65, 0.83, and 0.90, respectively (26).

In this study, Shapiro-Wilk test was used to investigate the normality of data distribution. Data analysis was described using mean and standard deviation. The analysis of covariance was applied to determine the effectiveness of aerobic exercises on EFs. All assumptions for the use of analysis of covariance were met, including normality, equality of variance, and the correlation between the covariate and the dependent variables were established.

Table 1. Mean (SD) of descriptive information of executive functions

Variable	Groups	Pretest	Posttest
Selective attention	Experimental	50.40 (6.20)	58.67 (5.38)
	Control	47.20 (6.09)	48.00 (8.00)
Cognitive flexibility	Experimental	50.20 (4.06)	59.67 (8.64)
	Control	48.87 (7.07)	49.93 (9.50)
Response inhibition	Experimental	53.87 (6.74)	59.47 (6.57)
	Control	49.07 (8.21)	47.73 (6.32)
Impulsivity	Experimental	51.73 (3.37)	47.33 (1.88)
	Control	52.27 (4.45)	51.53 (4.29)

Table 2. One-way analysis of covariance in the context of multivariate analysis of covariance

Statistical index/variables	Source of change	SS	df	MS	F	P-value	Eta coefficient
Selective attention	Group	372.11	1.00	372.11	16.93	0.001	0.53
	Error	329.71	15.00	21.98			
Cognitive flexibility	Group	186.77	1.00	186.77	4.02	0.04	0.21
	Error	697.19	15.00	46.48			
Response inhibition	Group	484.25	1.00	484.25	13.81	0.001	0.48
	Error	526.10	15.00	35.07			
Impulsivity	Group	61.53	1.00	61.53	9.10	0.001	0.38
	Error	101.41	15.00	6.76			

Results

Descriptive information of EFs components in experimental and control groups is presented in Table 1 based on pre-test and post-test. Normality results showed that data distribution was normal for all variables.

There was a difference between the mean pre- and post-test scores in the experimental groups. The results of Table 2 confirm the existence of significant differences in the variables of selective attention, cognitive flexibility, response inhibition and impulsivity of ADHD children in the experimental group compared to the control group. Therefore, considering the mean scores obtained and 95% confidence interval, there were a significant increase in selective attention, cognitive flexibility, and response inhibition and a significant reduction in impulsivity for the experimental group compared to the control group ($P<0.05$).

Discussion

The aim of the present study was to investigate the effect of aerobic exercise on EFs components including selective attention, cognitive flexibility, response inhibition, and impulsivity among boys aged 7-10 year. The results of the present study indicated that aerobic exercise significantly increased selective attention, cognitive flexibility, and response inhibition and also reduced impulsivity in the experimental group compared to the control group. The highest and lowest effectiveness in this study was related to the cognitive flexibility and impulsivity scales, respectively.

Comparison of the mean impulsivity scale scores in the pre-test (51.73) in comparison to the post-test (47.33) in the experimental group showed that aerobic exercise reduced the impulsivity level. Archer *et al.* (26) and Abramovich *et al.* (27) also showed that exercises effectively reduced the impulsivity symptoms of children with ADHD, and also affected their risk of development. Thus, it can be concluded that aerobic exercise can be effective in reducing the impulsivity symptoms. Considering exercise may prevent cognitive impairment through various extra molecular mechanisms such as neurogenesis, synaptogenesis, and angiogenesis by interaction with hormones, secondary neurotransmitters and nerve growth factors, physical activity, especially aerobic exercise, can have many positive effects on various aspects of brain function, including a reduction in impulsivity rate (28).

Comparison of the mean selective attention scale scores in the pre-test (50.40) in comparison to the post-test (58.67) in the experimental group showed that aerobic exercise increased the selective attention level. Medina et al. (29), and Chou et al. (30) investigated the effectiveness of aerobic exercise on selective attention and showed that regular 3-month aerobic exercises could increase selective attention in children with ADHD. Therefore, aerobic exercises may be effective in increasing the selective attention of ADHD children. Moreover, since the increase in slow brain waves in its different areas is associated with brain fog, slowness of reaction time, dyscalculia, poor judgment, lack of impulse control, and decreased attention and arousal in individuals, therefore decreased selective attention in these individuals can be explained due to abnormal brain waves. Numerous studies showed that aerobic exercise had beneficial effects on cognitive functions, especially types of attention (31). Aerobic exercises can affect brain waves by increasing alpha and beta and reducing theta and delta waves, which in turn improve the attention function of these children.

Comparison of the mean cognitive flexibility scores in the pre-test (50.20) in comparison to the post-test (59.69) in the experimental group showed that aerobic exercise increased cognitive flexibility. Smith et al. (9) showed that voluntary aerobic exercise improved memory and cognitive processes, which is consistent with the results of the present study suggesting a significant increase in cognitive flexibility of the experimental group compared to the control group. Therefore, it can be said that aerobic exercise can improve cognitive processes (22). Since moderate-and vigorous-intensity aerobic exercise may increase a variety of neurochemicals such as lactate, cortisol, neurotrophins, neurotransmitters, and neuromodulators, it thus improves children's cognitive flexibility.

Comparison of the mean response inhibition scores in the pre-test (53.87) in comparison to the post-test (59.47) in the experimental group showed that aerobic exercise increased response inhibition. Mehren *et al.* (24) showed that aerobic exercise was effective in increasing response inhibition in children with ADHD. Since aerobic exercises may lead to structural and chemical changes such as increased brain-derived neurotrophic factor (BDNF), which plays an important role in synaptic plasticity and neurogenesis, those produce sustained changes that improve response inhibition among children with ADHD.

The finding of the present study is consistent with Archer *et al.*, Abramovich *et al.*, Medina *et al.*, Chou *et al.*, Smith *et al.* and Mehren *et al.* (9, 24, 26, 27, 29, 30). However, while focusing on the physical exercises, the present study had two major differences from the above studies. First, aerobic exercises were concurrently performed with rhythmic music of a special beat. A thirty-two-beat aerobic chain exercise is a cognitive exercise because it requires coordination of hands and legs and the movements must be in harmony with the rhythm. Second, our training sessions lasted about 60 minutes and while those lased for less than 30 minutes in other researches. Although the effects of increased physical activity on executive and cognitive functions have been proven, there is interesting evidence suggesting that physical activity with a cognitive nature (aerobics) has a greater impact on cognitive function, especially EFs (32, 33). In the present study, aerobic exercises had the greatest effect on cognitive flexibility.

One of the limitations of the present study is type of subjects' defining characteristics (their predominantly inattentive, hyperactive, combined morphology) were not considered. Therefore, the results of the present study cannot explain which type of ADHD children can benefit from aerobic therapy approach. Also, the findings of the present study can be generalized just to children aged 7 to 10 years with ADHD and generalization to other hyperactive children should be conducted with caution and sufficient knowledge. Further studies are also needed to understand the effect of combining such interventions with traditional mental health treatment. In the present study, moreover, only one instrument was used in order to measure each of the dimensions of EFs; so, it is suggested to use multiple measurement approach for each dimension of EFs in future research.

Conclusion

The results showed that 60-min moderate-to-vigorous intensity rhythmic exercise had a positive and significant effect on executive functions (selective attention, cognitive flexibility, response inhibition, and impulsivity) in ADHD children. In addition, we concluded that exercises, that are cognitive in nature, are among the best options for improving the structural and functional problems of the nervous system, mental health, and well-being. Therefore, mental health service providers can provide evidence-based exercise interventions for people with severe mental illness.

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Ethical considerations
The article is taken from the doctoral dissertation of psychology with the code 1544813756398381398162290624 approved by the Ethics Committee of the Islamic Azad University of Qom, Iran.

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