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Research Paper

Response Inhibition, Attention and Processing Speed in Male Athlete and Non-athlete Adolescents

Saeideh Ayoubi[1], Nazgol Behgam[2, 3], Dena Sadeghi-Bahmani[4], Hora Heidari[1], Zhila Maghbooli[1], Sharareh Eskandarieh[1*]

1. Neuroscience Institute, Multiple Sclerosis Research Center, Tehran University of Medical Sciences, Tehran, Iran.
2. Department of Nursing, School of Medicine, Tehran University of Medical Sciences, Tehran, Iran.
3. Students' Scientific Research Center (SSRC), Tehran University of Medical Sciences, Tehran, Iran.
4. Department of Epidemiology and Population Health, Stanford University, Stanford, USA.

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ABSTRACT

Background: Executive functions (EFs) are essential in controlling thoughts, emotions, and behavior. Evaluating the effect of athletic activity on the EFs that lead to better quality of life and mental and physical health is essential.

Objectives: This study aimed to compare the components of EFs, including response inhibition, attention, and processing speed among male adolescents.

Materials & Methods: A multi-stage random sampling method was used among 48 athletes and 48 non-athlete male adolescents in Tehran City, Iran. Cognitive functioning was assessed by a series of cognitive measures, including the go/no-go task, integrated visual and auditory test (IVA) and Wechsler intelligence scale for children–the fourth edition.

Results: The results revealed significant differences in response omission and reaction time between the two groups (P=0.01). Nonetheless, no significant discrepancy in response error and the number of response inhibitions was detected (P=0.50). Regarding attention, the differences in visual and auditory attention and most related elements containing vigilance and processing speed were found to be significant (P<0.05). Furthermore, the findings indicate that more athletic activities are associated with better processing speed among athletes (P=0.029).

Conclusion: There is a significant relationship between the amount of regular athletic activities and better EFs in male athlete adolescents. Also, a significant difference was observed between the components of EFs in male athlete and non-athlete adolescents. The difference in reaction time in response inhibition, visual and auditory and vigilance in attention was stronger than other dimensions investigated between our study groups.

Keywords: Executive function, Attention, Processing speed

*** Corresponding Author:**
Sharareh Eskandarieh, PhD.
Address: *Neuroscience Institute, Multiple Sclerosis Research Center, Tehran University of Medical Sciences, Tehran, Iran.*
Tel: *+98 (21) 66348571,* ***Fax:*** *+98 (21) 66348571*
E-mail: *sh_eskandarieh@yahoo.com*

Highlights

• A positive relationship exists between regular athletic activities and enhanced executive functions (EFs) in male adolescent athletes.

• Performing regular athletic activities such as basketball could have a positive effect on improving EFs.

• The most significant difference between male athletes and non-athlete adolescents was observed in reaction time in response inhibition and vigilance in visual and auditory attention.

Introduction

The term "executive functions" (EFs) refers to processes related to the conscious control of thoughts, emotions, and behaviors, which play a pivotal role in daily life management. EFs provide the possibility to respond appropriately to environmental stimuli and adapt to the surrounding environment [1]. As the most complex and highest level of human function, EFs are considered the basis of ordinary behavior that modern humans require to accommodate their purposes. Indeed, EFs, as a cognitive structure, are associated with skills such as problem-solving, attentional control, reasoning, processing speed, organization, planning, working memory, inhibitory control, impulse control and response inhibition [2]. Consequently, the depletion of EFs can give rise to the disruption of daily activities. Overall, the level of EFs varies in people and disorders, and its malfunction could cause or enhance the severity of mental impairment [3, 4].

Previous studies have confirmed the effectiveness of exercise and training in improving an individual's self-concept, especially the physical component of self. Although comparing athletes and non-athletes of different sports has revealed some personality distinctions, the most notable is the higher positive mental health [4, 5]. The studies to date have tended to investigate cognition and EFs and compare their levels in adults and teenagers diagnosed with mental and physical disorders. While some evidence establishes the significant positive impact of EFs on the quality of life of people and academic achievement, data about the influence of physical exercise on parts of EFs are strictly limited and focus only on a specific component [6, 7].

The usage of technological gadgets has rapidly been soaring among adolescents, which may contribute to altering their lifestyle, particularly a decline in athletic activity. Regarding the fundamental role of EFs in the aspects of personal and social life, it is hoped that comparing the EFs between male athlete and non-athlete adolescents contributes to a deeper and more comprehensive understanding of the influence of physical exercise on EFs and makes considerable contributions to arranging educational policy and promoting the adolescent to attend athletic activities [8]. This study aimed to compare the three main variables of EFs, including response inhibition, focus attention, processing speed and their components.

The present study set out to compare the three main variables of EFs: Response inhibition, focus attention, processing speed, and their components (i.e. "response error", "response omission", "response inhibition", "response time", "listening attention", and "visual attention"). Also, each component of visual and auditory attention, as well as three sub-components of "vigilance", "focus", and "speed", were investigated in athletes and non-athletes.

Materials and Methods

Study participants

This cross-sectional study was conducted on 96 male adolescents aged 12 to 16 from 2020 to 2021. A multistage random sample of 48 non-athletic adolescents was recruited from different high schools of 1, 14 and 22 regional municipalities in Tehran City, Iran. Three different areas of the municipality have been chosen to prevent selection bias and recruit people with various socioeconomic statuses [9]. Initially, the school principal and parents received a thorough explanation of the project. With the cooperation of the committee of the basketball board of Tehran Province and sports clubs, 48 adolescent basketball players who have played basketball for at least the last two years were recruited randomly.

Study measures

We applied the go/no-go task to evaluate the participants' response inhibition. At the go stage, presenting a stimulus, a subject provides a consistent response as quickly as possible. In the other situation (inhibition stage), another stimulus is presented following the introduction of the first stimulus, and the person must refrain from responding when the second one appears. A person's ability to curb the response in the second situation indicates inhibitory control. The results are divided into three main category scores: the percentage of committed errors, inappropriate inhibition, and reaction time. Obtaining a high score in committing an error, inappropriate inhibition, and reaction time imply a person's inability to constrain the response. In other words, the higher a person's score in the test components, the more deficient in response Inhibition. Previous studies reported validity and reliability at 0.6 and 0.8 with the Cronbach α method, respectively [10, 11].

The integrated visual and auditory continuous performance test (IVA test) was applied to evaluate participant's attention [12]. The test chiefly assesses attention, response control, credit, and quality. The response or not response of participants to 500 stimuli, which were presented for only one and a half seconds, was recorded. Therefore, the test requires sustained attention, measures 50 visual and auditory features and points out how the brain processes related information and motor response. The most prominent characteristics that are determined are caution, stability, endurance, regulation of fine movements, the scale of attention (concentration, vigilance, speed, or alertness), perception, sensory-motor, and types of attention (focused, continuous, selective, alternating and divided attention). This study used the IVA test to measure visual and auditory attention and most related elements, including vigilance and speed. In the research of Moreno-García et al., this test has a suitable sensitivity of 92% and a predictive power of 90% in the investigation of attention and accuracy and diagnosis of ADHD [13, 14]. The findings proved that this test is acceptably valid in assessing concentration and accuracy [15].

Wechsler intelligence scale- the fourth edition (WAIS-IV) is an IQ test designed to measure intelligence and processing speed for children ages 6-16 years 11 months 30 days. To evaluate the participants' processing speed, we applied the subtests of WAIS-IV, including "coding" and "symbol search" [16]. The WISC-IV has 15 subtests; 10 core subtests are applied to measure the four index scores and full-scale IQ. The other five are supplementary subtests that can be used in case a core subtest cannot be used or is not appropriate for a particular child. These are verbal comprehension, perceptual reasoning, working memory, processing speed and full-scale IQ.

Statistical analysis

We collected data sets using descriptive statistics, including central tendency, frequency distribution, and standard deviation. The Skewness and Kurtosis coefficients were used to normalize the data. The independent samples t-test compared the means of two research groups. According to coefficients and the negligible difference between mean and median, the distribution of the attention and its components, response inhibition components and processing speed were considered to have Gaussian distribution, so the mean as an indicator of central tendency and parametric statistics models as well as two-group t-test was applied.

Significance levels were set at 0.05 and all analyses were carried out using SPSS software, version 23.

Results

The 48 male athlete adolescents and 48 non-athletes matched in gender, age and city of residence were selected. The mean age of the athlete group was 14.04±1.383 years and that of the non-athlete group was 14.02±1.422 years.

As shown in Table 1 and according to the independent t-test and Levene's test, a significant difference between the two groups was evident in the response omission and the response time and both decreased in the athlete adolescents (P=0.045, 0.01, respectively). Nevertheless, no significant difference was observed between the response error and response inhibition (P=0.50, 0.62, respectively). Another finding indicated a statistically notable increment in attention quotient in the athletic compared to non-athletic groups (P<0.01). Levene's test showed a positive correlation between auditory and visual attention, which is higher in athletes. Moreover, vigilance and speed related to visual and auditory attention were remarkably higher. The last finding demonstrated a substantially higher processing speed in athletic ones than in other groups.

Discussion

The present study evaluated whether the EFs of male athlete adolescents differed from those of male non-athlete adolescents.

Table 1. Components of the EFs, including response inhibition, attention and processing speed

Variables	Component	Mean±SD		t-statistic	df	P
		Athlete	Non-athlete			
Response inhibition	Response omission	1.10±1.97*	2.33±2.86*	-2.44	94.00	0.045
	Response time	331.73±57.71**	360.02±81.03**	-1.97	84.92	0.01
	Response error	2.71±1.18*	2.65±1.81*	0.15	94.00	0.509
	Response inhibition	36.19±3.34*	35.02±3.77*	1.60	94.00	0.62
Attention	Attention quotient	107.81±9.86	83.65±18.75	7.90	71.16	0.001
	Auditory attention	104.06±12.40	81.88±17.54	7.15	94.00	0.10
	Visual attention	110.69±8.89	86.38±23.02	6.82	60.70	0.001
Visual attention	Vigilance	105.69±8.25	83.33±31.21	4.79	53.54	0.001
	Focus	109.65±13.63	99.33±12.01	3.93	94.00	0.31
	Speed	106.85±14.81	89.48±9.49	6.83	80.03	0.01
Auditory attention	Vigilance	100.92±14.88	78.69±28.95	4.73	70.20	0.001
	Focus	89.73±18.43	78.73±14.64	3.23	94.00	0.33
	Speed	118.35±14.53	105.81±8.73	5.12	77.01	0.21
Processing speed	Processing speed	93.83±9.07*	83.06±6.39*	6.72	84.44	0.029

*Mean based on variable score; **Mean based on time.

The main findings of this study are as follows. First, there is a significant relationship between the amount of regular athletic activities and better EFs in male athlete adolescents. Also, a significant difference was observed between the components of the EFs in male athletes and non-athlete adolescents that align with those obtained from other studies [2, 3, 4, 7].

This study has identified a significant difference in response omission and reaction time between the study groups, whereas no notable difference has been observed in response error and response inhibition. Since the average response time to the stimuli in athletes was significantly lower compared to non-athletes, it can be implied that athletes perform better in reacting to the stimuli. These results are consistent with a study indicating that athletes show shorter stop-signal reaction times than non-athletes [17]. Following previous studies, these results highlight the importance of consistent athletic activity and workouts to promote reaction speed, reaction time, and response processing [18-21].

In the current study, comparing all dimensions of the attention variable with two groups demonstrated the higher privilege in athletic ones, which seems consistent with earlier reports [2, 7, 22, 23]. However, this outcome is contrary to findings by Denny et al. This discrepancy could be due to the studied community and the tools used [24].

Another evident finding from the analysis is that the visual and auditory vigilance related to the attention variable and the response time dimension in the response inhibition variable was significantly higher in the athlete group. Therefore, it is suggested that more emphasis be placed on attending athletic activities as a part of the daily life of teenagers because improving the dimensions of attention can be helpful in people's learning rate in different fields.

A significant difference in favor of athletic adolescents was detected concerning processing speed. Though the results of Aghayari et al. and Azami et al. were inconsistent with ours [25, 26], most previous studies have confirmed the association between processing speed and sport [27, 28].

Further research should be carried out to establish the factors that deter teenagers from attending athletic activities and assess the long-term impact of sports on EF. An identical investigation of the female population is intriguing and could be usefully explored in future research. More broadly, research is also needed to determine whether individual or team activities will bring the same or different results.

Conclusion

In conclusion, this approach has proved helpful in expanding our understanding of how athletic activities lead to better brain performance in adolescents. Undoubtedly, fostering healthy and cheerful teenagers has a decisive influence on future advancement and social development. The more advanced the grade and level of intelligence, brain functions, and skills, the higher would be the physical and mental strengths that lead to more capable individuals serving profitably to themselves, family, organizations, and society. A reasonable approach to this aim could be providing sustainable conditions and favorable facilities for extended athletic activities. To access the public population from all financial and social classes, it is necessary to establish well-equipped sports clubs and pieces of equipment in schools. It enlightens teenagers with the concept of active leisure time and advises them to use their spare time productively to maximize the benefits of recreational athletic activities. Regarding the prevention of sports injuries, it is noteworthy to employ expert and committed coaches. Therefore, it is recommended that authorities place great importance on athletic activities in educational plans and encourage teenagers to attend mentioned activities to escalate physical and mental health levels.

Study limitations

First, this study was limited to 12-16 years old male adolescents in Tehran City. Therefore, the generalizability of results to other cities' populations and age ranges could be problematic. Second, this research was limited to basketball; to generalize the results to other sports, the studied variables must be investigated separately in individual and team sports.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of Tehran University of Medical Sciences (Code: IR.TUMS.NI.REC.1401.055).

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Authors contributions

Supervision: Sharareh Eskandarieh; Funding administration and methodology: Sharareh Eskandarieh; Data analysis: Saeideh Ayoubi; Investigation: Saeideh Ayoubi and Sharareh Eskandarieh; Conceptualization, writing the original draft, review and editing: All authors.

Conflict of interest

The authors declared no conflict of interest.

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