

## Cognitive Function in Male Track and Field Iranian National Team Athletes

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### Authors' contributions

*This work was carried out in collaboration between all authors. Authors Hedayat Sahraei and HA designed the study and wrote the protocol. Author Hossein Sepahvand gathered the initial data and performed preliminary data analysis. Authors Hedayat Sahraei and EZ interpreted the data. All authors read and approved the final.*

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### ABSTRACT

**Background:** Cognitive function including decision making and short term memory are affected by environmental factors including physical activity. Data showed that sustained physical activity can improve learning and memory. In the present research, cognitive functions of the Iranian track and field national team were evaluated and compared to the control group using PASAT (Paced Auditory Serial Addition Test) software.

**Materials and Methods:** Ten male members from the athletics team of the Islamic Republic of Iran were selected (age: 26±3 years; weight: 69.2±2.7 kg; height: 178.4±7 cm) and 10 volunteered male students of Allame Tabatabaiee University (age of 25±3 years; weight: 75.42±0.54 kg; height: 169.5±6.2 cm) were evaluated for their cognitive functions including general mental health, sustain attention, reaction time (processing speed), and mental fatigue using PASAT software. In addition, salivary cortisol level was measured in two groups.

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**Results:** Salivary cortisol concentration was higher in the athletes than non-athletes group ( $P<0.001$ ). General cognitive health and sustain attention also was increased in the athletes regarding the non-athletes group ( $P<0.05$ ). Reaction time and mental fatigue was reduced with regard to the non-athletes group but was not statistically significant.

**Conclusion:** It seems that physical activity may increase brain cognitive functions which are manifested by better general cognitive health sustain attention increment, increase in processing speed as well as reduction in mental fatigue.

*Keywords: Exercise; salivary cortisol; cognitive function; sustain attention; processing speed; mental fatigue.*

## 1. INTRODUCTION

Physical activities, sports in particular, are of major factors influencing the psychical wellbeing of people [1]. Much research has shown that physical activities increase the efficiency of respiratory and cardiovascular systems through improving their performance hence; it improves the wellbeing of individuals [2-5]. On the other hand, recent research has proven that physical activities improve the efficiency of brain and its functions. It has also been suggested that physical exercises increase memory capacity in the elderly [3]. Moreover, studies have shown that physical activities can increase emotional intelligence in children. They also improve the cognitive performance of young adult Dwarfs [2].

Animal studies have shown that physical activities can help in increasing synapses reproduction process and dendrite spines in various parts of hippocampus. Moreover, it can increase the volume of dendrites in pyramidal neurons of hippocampus. It also increases cell reproduction in the dentate gyrus of rats' hippocampus [4,5].

PASAT (Paced Auditory Serial Addition Test) is one of the tests that neuropsychologists use to evaluate the processes of consciousness [6]. It is one of the tools for testing immediate memory and attention in which the stimulation is visual rather than auditory [7]. PASAT was first used by Sampson and MacNeilage [8] when they published their studies regarding the effects of brain lesions on information processing in the brain. It has also been used extensively in studies carried out on patients with multiple sclerosis (MS). Moreover, it is exploited in studies concerning the ways in which cognitive-perceptual processing is affected by various neurological disorders, including lesions caused by accidents, chronic fatigue syndrome, tuberculosis, low blood sugar, kidney transplantation, and depression. PASAT is

designed to evaluate the effects of brain lesions on the cognitive performance of the brain in patients with a wide and various ranges of neurological-psychological syndromes. Gronwall and Sampson [9], believed that PASAT measures the speed of information processing. Nowadays, however, PASAT is used to measure multiple functional domains. It is due to the fact that this test requires a successful and perfect performance in a range of cognitive performances, particularly those brain functions that are concerned with attention and consciousness. PASAT has shown good psychometric features, including a high level of internal consistency, and test-retest reliability [9]. Hence it is well established that physical activities can increase cognitive abilities, and with respect to the fact that sports are one of the major regulated and continuous physical activities, we hypothesized that cognitive parameters including general cognitive performance, mental fatigue, speed to response and sustained attention may be better performed in the athletes than others. This hypothesis was examined using the modified form of PASAT software. In addition, since one of the major parameters which can interfere with cognitive function is the stress, salivary cortisol concentration also was detected.

## 2. MATERIALS AND METHODS

Ten male members from the athletics team of the Islamic Republic of Iran were selected (age:  $26\pm 3$  years; weight:  $69.2\pm 2.7$  kg; height:  $178.4\pm 7$  cm) and 10 volunteered male students of Allame Tabatabaai University (age of  $25\pm 3$  years; weight:  $75.42\pm 0.54$  kg; height:  $169.5\pm 6.2$  cm) were selected after being examined by a psychiatrist and neurologist. All the participants were tested for having any kind of underlying disease in the auditory system, problems in speech, and taking specific medications, except for acetaminophen. Their educational background varied from diploma to BSc for athletes and MSC or PhD for

control group. All of the subjects were provided with free insurance during the study. Moreover, their nutrition was similar. Having been given the instructions, they were tested with PASAT software (Pazhoheshpouya Cogno-Soft Co., Tehran, Iran) on April 30<sup>th</sup>, 2013 from 17:00 to 19:00. In order to determine their salivary cortisol, their saliva sample was also taken. Experiments were conducted in accordance with ethical guidelines and approved by the local ethics committee (The Baqiyatallah (a.s.) University of Medical Committee). The test used in this study, PASAT, is, in short, as follows: totally 61 numbers from 1 to 9 were given to the subjects randomly with an interval of 3 seconds. The subject must add up the two last numbers in the series and give the answer before being given the next number. For instance, if numbers 2 and 6 were given to the subject, the correct answer would be 8. The number of correct answers for every subject is called the accuracy of responses. The experimental and control group were compared in terms of the accuracy of responses. Moreover, the average responding time (response speed), the longest series of correct responses (continuous attentiveness), and the longest series of wrong responses (mental exhaustion) were also investigated. Cortisol ELISA kit was used for measuring salivary cortisol (Cortisol ELISA kit, Diagnostics Biochem Canada Inc, dbc). In order to carry out this test, saliva samples were collected and kept in 10 mm falcon tubes before PASAT, and then they were conserved in a freezer at a temperature of -20°C. On the experiment day, the samples were liquefied in room temperature. Then, having been centrifuged for 5 minutes at a spinning speed of 3000 per minute, 20 micro liter of each sample was separated for the test [10,11]. The protocol for PASAT test was described in detail elsewhere with modifications [12]. The subject was trained two times (3 min each) before the main test. Each time the subject was rest on a suitable chair and a headphone was fixed over his head. Then the PASAT software was started by the user. The software is able to recognize the correct or incorrect response. After training completion, the subject completed the test.

Data was analyzed by SPSS software version 16. Results were expressed as mean±SEM. At first, data distribution was analyzed using the Komolgorov-Smirnov test for determining its normal distribution. To assess the relationships between variables, Pearson correlations were used. In order to determine the significance of

the difference between the groups, independent t-Test was used. The significance level was  $p < 0.05$ .

### 3. RESULTS

#### 3.1 General Mental Health in Athletes and Non-athletes Based on Pasat Software

The result of general mental health is shown in Fig. 1. As it is indicated in the figure, PASAT software test showed that the general mental health (the number of correct responses) in athletes was significantly higher than that of non-athletes, ( $t_{18}=8.73$ ,  $P < 0.05$ , Fig 1). Pearson correlation test revealed that the  $r^2$  for athletes was 0.9 and for non-athletes was 0.76.

#### 3.2 Reaction Time in Athletes and Non-athletes

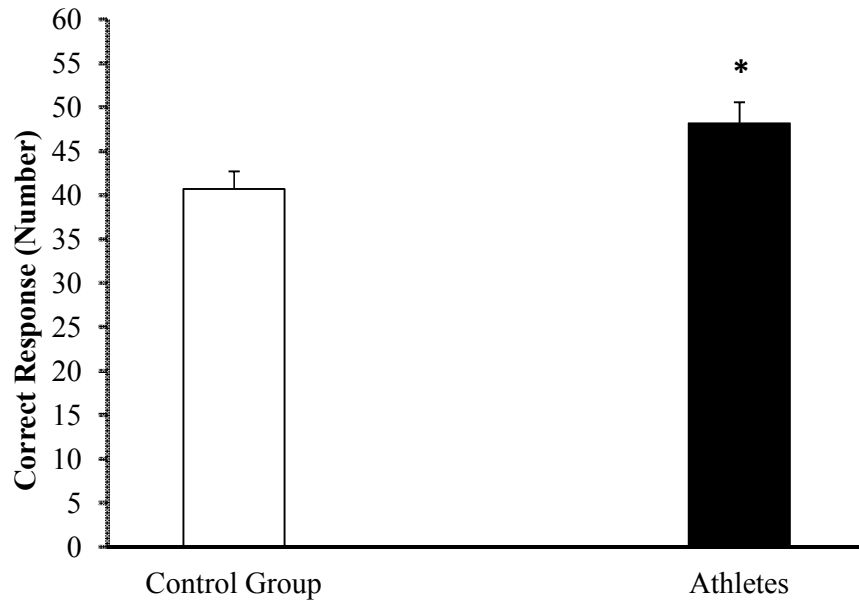
Fig. 2 indicated the results obtained from PASAT software test on reaction time between athletes and non-athletes. The results indicated that reaction time in athletes was lower than that of non-athletes. However, it was not statistically significant, ( $t_{18}=1.009$ ,  $P > 0.05$ , Fig. 2). Pearson correlation test revealed that the  $r^2$  for athletes was 0.83 and for non-athletes was 0.812.

#### 3.3 Sustained Attention in Athletes and Non-athletes

As mentioned in the method section, in PASAT software test, the longest series of correct responses is a criterion for measuring sustained attention. Fig. 3 indicated that this item was better in the athletes which was statistically significant, ( $t_{18}=2.84$ ,  $P < 0.05$ , Fig. 3). Pearson correlation test revealed that the  $r^2$  for athletes was 0.751 and for non-athletes was 0.615.

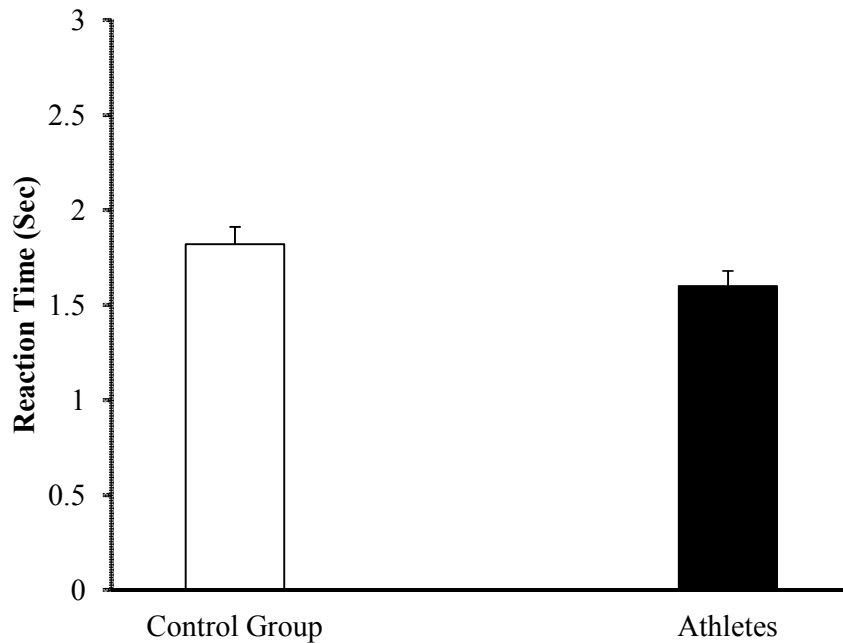
#### 3.4 Mental Fatigue in Athletes and Non-athletes

Investigation that used PASAT software for cognitive evaluations, considering the longest series of wrong responses for measuring mental fatigue. Our results showed that there was no significant difference between athletes and non-athletes in this respects, ( $t_{18}=0.6012$ ,  $P > 0.05$ , Fig. 4). Pearson correlation test revealed that the  $r^2$  for athletes was 0.720 and for non-athletes was 0.63.



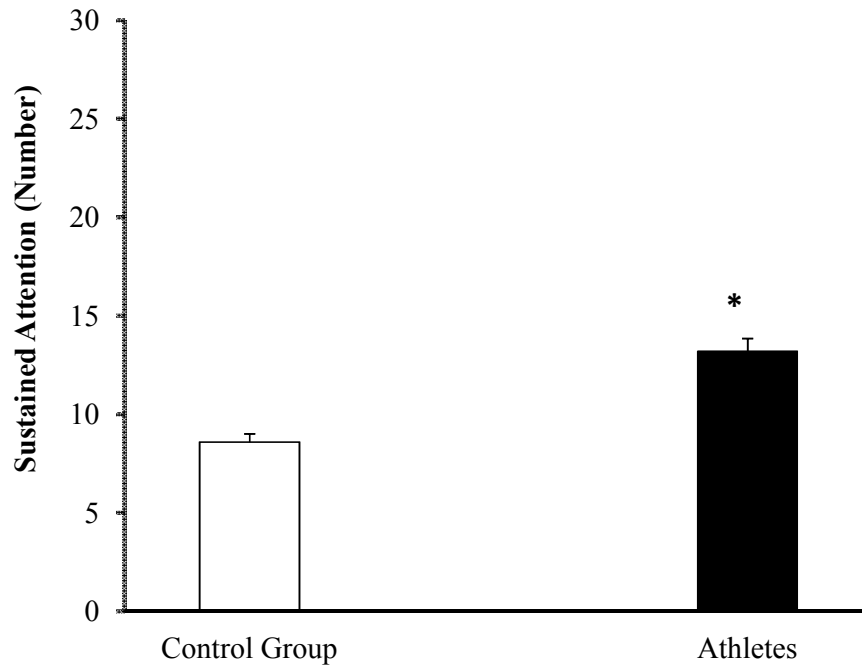
**Fig. 1. Global mental health differences in athletes and non-athletes (control). Global mental health (the number of correct responses) in athletes was significantly higher than that of non-athletes**

*Data is shown as mean±SEM of global mental health, \*P<0.05 different between the groups*

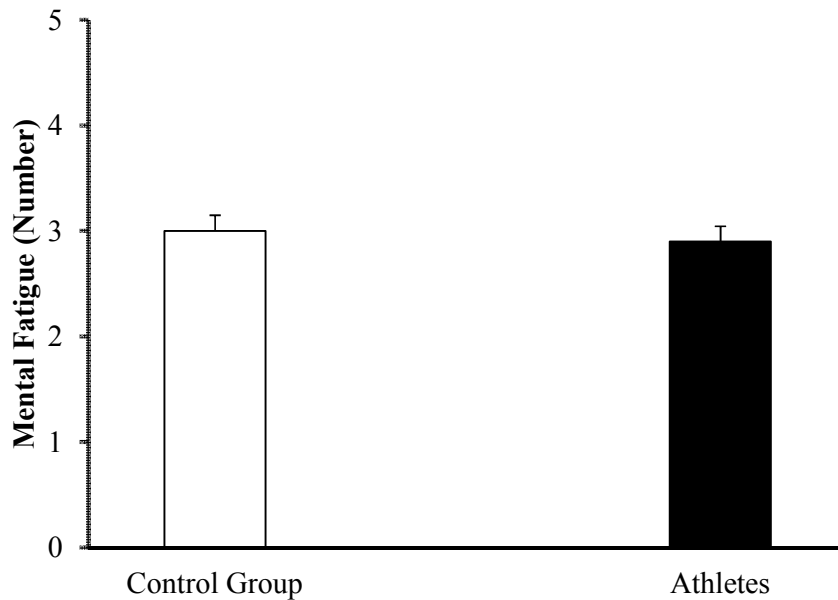


**Fig. 2. Reaction time changes between the athletes and non-athletes. Reaction time in athletes was lower than that of non-athletes**

*Data is shown as mean±SEM of reaction time; there was no significant difference between the groups*



**Fig. 3. Sustained attention differences between the athletes and non-athletes. Sustained attention in athletes was significantly higher than that of non-athletes**  
*Data is shown as mean±SEM of sustained attention, \*P<0.05 different between the groups*



**Fig. 4. Comparison of mental fatigue between athletes and non-athletes. There was no significant difference between athletes and non-athletes in this respect**  
*Data is shown as mean±SEM of mental fatigue*

### 3.5 Salivary Cortisol Concentration in Athletes and Non-athletes

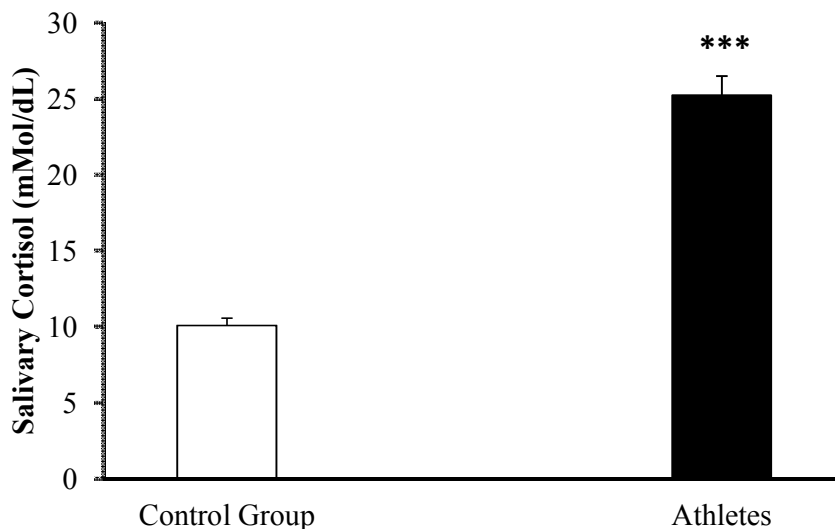
Salivary cortisol concentration of the samples was measured using ELISA kit. The results showed that the cortisol level in athletes was significantly higher than non-athletes, ( $t_{18}=8.73$ ,  $P<0.001$ , Fig. 5). Pearson correlation test revealed that the  $r_2$  for athletes was 0.92 and for non-athletes was 0.78.

### 4. DISCUSSION

This experiment aimed at determining the effect of physical activity (sport) on mental and cognitive functioning criteria of athletes. It compared them to a control group comprised of the students of MSc. and PhD. One of the major problems in the present study, however, is that the sample size of both experimental and control groups was low ( $n=10$  in each group). One may question that the results would change if the sample size became greater. The response may be in three notions: first of all, the parameters in which were measured in the present study were quantitative and therefore, the small sample size would not influence the results. Second, the sensitivity of the methods which were used in this study-PASAT software and ELISA method- were high enough to identify minor differences in the experiments. Third, the experimental group was

just the 10 and we prefer to select equal sample for the control group. It was found that major measured criteria, such as general well-being (general functioning), continuous attention, mental fatigue, and response time (information processing speed) were significantly higher, compared to the non-athlete group. The results show the effect of physical activity on mental performance. Moreover, the cortisol level in the saliva of the athletes was higher than those of the other group. Since the athletes were tested 6 hours after the matches had ended, their higher cortisol level could indicate the effect of stress they went through because of the matches which did not decrease until that time.

Mental performance is the best criterion for determining brain's power in adapting behaviors with external changes [3,9]. Experiments showed that the frontal as a summarizer of the information is critically important in processing and determining the type and intensity of behavior in response to external stimuli. The fact that there is a relationship between the frontal lobe and Broca's area, which is known as the motor part of speech, makes it possible to find ways for examining its performance. It means if the summarizing capacity of the frontal lobe is higher, the verbal response would be also faster. On the other hand, the sensory part of speech, Wernicke's area, is located in a part that is



**Fig. 5. Salivary cortisol concentration in athlete and non-athlete (control) groups. Salivary cortisol level was significantly higher in athletes than non-athletes**

*Data is shown as mean±SEM of salivary cortisol, \*\*\* $P<0.001$  different between the groups*

closely related to hearing system. Hence auditory stimuli can serve as appropriate stimuli for evaluating sensory-motor performance and the summarizing capacity of the cortex, since their responses are a kind of speech intermingled with summarizing and thinking [13].

In PASAT, auditory stimuli lead into a verbal response, which is resulted from an analysis carried out in the frontal lobe [9]. This reaction depends on brain's capacity to memorize previous stimuli for a short time (short-term memory). Therefore, hippocampus is also involved in the process. On the other hand, the frontal lobe is capable of omitting repetitive stimuli and tracing a specific one so that the brain is capable of focusing on a specific target. Any type of interference in major subcortical parts, such as amygdala or hypothalamus, or other lobes, such as the visual lobe, sensory lobe can lead into decreasing the summarizing capability of the frontal lobe [13]. This problem arises when one has an underlying hyperactive amygdala or hypothalamus. It is triggered by chronic stress [14]. Compared to non-athletes, the general functioning was found to be higher in athletes. It should be noted that the results did not imply that non-athletes did not have a high level of mental health. In fact, compared to the average in the society, it was shown that athletes had a higher level of general functioning. With respect to what was said previously, a higher mental general well-being signifies that speech and summarizer parts of the cortex have a higher functioning. On the other hand, it signifies a higher level performance in hippocampus. Previous study showed that physical activities lead into an increase in the neurons in dendrites in the hippocampus [15]. Moreover, they showed that physical activities in animals increased the number and size of the synapses in mossy fiber of CA3 hippocampus [15]. It is expected that the same is the case with the brain of the athletes in this study. Therefore, the responses observed among athletes could be due to this factor. On the other hand, studies showed that compared to non-athletes, athletes had a bigger hippocampus. This signifies that the athletes in the study showed higher responses due to having a bigger hippocampus. McEwen et al. showed that hippocampus shows the highest level of sensitivity to stressing hormones and that it has a higher number of glucocorticoid receptors for cortisol hormone. They showed that a long-term increase in plasma cortisol can decrease the number and size of the synapses in hippocampus CA3. Therefore, chronic stress

decreases the size of hippocampus [13]. On the other hand, in agreement with other studies, these results showed that plasma cortisol highly increased due to exercising [15]. It is the reason why a phenomenon, called hypercortisolemia, emerges during exercising and physical activities. It should be noted, however, that during exercise the Hypothalamus-Pituitary-Adrenal (HPA) axis gets activated, brain neurohormones, adrenal glands increase due to the activation of the sympatho adrenal axis. The locus coeruleus in the brain stem secretes norepinephrine during exercise can strengthen the relationship between the frontal lobe and hippocampus [16]. Therefore, due to the fact that the activity of Norepinephrine is higher than cortisol, not only there is no decrease in the hippocampus size and memory and learning activities, but also due to the strengthening of the path of the hippocampus to the cortex, the cognitive capabilities of the brain increase. It needs to be mentioned that only the types of stress that increase the secretion of adrenal hormones, cortisol in humans and corticosterone in rodents, instigate damage to the hippocampus. However, the types of stress that both increase cortisol and norepinephrine, as with group exercises and physical activities, increase cognitive performances in humans and animals.

The next part of the study dealt with the tests carried out on athletes with respect to their response time. Compared to the control group, their results did not differ significantly. It must be stated that this variable requires verbal skills. Since verbal skills are formed gradually and are not dependent on one's stress condition, they are affected less by the changes in environment. However, the observed insignificant decrease may not be due to exercising. It may become more explicit with a higher number of subjects. With respect to this part of the study, it appears that the well-being of hearing transference paths was observed in both groups and there were no significant differences.

In this regard, athletes showed a higher attention, compared to the control group [17]. It must be noted that paying attention to the target and not diverting attention from it is one of the functions of the cortex that increases the capability to show behavior appropriate to the variable. In this paper, this capability was higher in athletes, compared to the control group, that is, physical exercise may lead into an improvement in the frontal lobe's capabilities. As we know, it happens due to various factors, including norepinephrine

function in the hippocampus and the frontal lobe. In short, it is concluded that exercise increases brain's ability to follow one target.

In the other part of the study, data showed that mental fatigue in both groups was almost equal and mental fatigue was observed in both groups. Mental fatigue was observed by counting the number of wrong answers. An increase in the number of wrong answers shows brain's incapability in summing up precise and accurate responses. One of the reasons for this incapability could be the underlying stress that decreases brain's capability based on the performance of the hippocampus. These types of stress are caused due to various reasons. Previous studies showed that stress decreases brain's decision making ability among humans and animals and impairs various memories [12,13,16,17,18]. Although both athlete and control group scored low, their mental fatigue was not very high.

The last part of the study showed that the cortisol level in athlete's saliva was significantly higher than that of the control group. It signifies that exercise is a type of stress which is added to the stress of the match. Therefore, an increase in athlete's cortisol level is inevitable. However, since the perceptual-cognitive activities of the athletes did not decrease in athletes, compared to the control group, it could be concluded that perceptual-cognitive activities improve with exercise. This is due to the secondary path of stress, which is the sympathetic and adrenal path. In conclusion, it was found that perceptual-cognitive activities measured by PASAT, including mental general health, continuous attention, mental fatigue, and response time was relatively improved among athletes. The higher level of cortisol, which is due to exercise, may have contributed to this improvement. Along with previous studies, the results show the effect of exercise and physical activity on the increase in neurogenesis in cognitive areas of the brain, such as hippocampus. Moreover, the effect of physical activity on the verbal memory and other cognitive capabilities can serve as a simple, effective, cheap, and less time consuming method in carrying out studies in the fields of sports and its role in improving cognitive activities [19,20].

## 5. CONCLUSION

In conclusion, it can be suggested that physical activity may improve the cognitive function

including general mental health and, sustained attention. However, since the cortisol was higher in the athletes, it is difficult to provide a clear discussion in this regard. Further experiments may convey the importance of physical activity on cognition function improvement. One more explanation is that recent finding in Multiple Sclerosis patients revealed alterations in the venous hemodynamic of the cerebral vessels [21,22]. Such alterations can be present also in "healthy" subjects with less physical activity and may predispose to alterations in cerebral functions which in fact may influence our results as well.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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