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Cognitive and Executive Functions of Young Men regarding Sport Activity and Personality Traits

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Abstract: Sport activity can be a moderator of change in the level of cognitive and executive functions. This research sample consisted of 71 men aged 22.66 ± 1.91 years. This group was split into two subgroups: nonathletes (n = 26) and athletes (n = 45). The athletes included open skill sport athletes (n = 21) and closed skill sport athletes (n = 24). We used a standardized S-test to detect the level of cognitive functions, a standardized EPQ-R questionnaire to find out the degree of neuroticism and a standardized IVE questionnaire to measure the level of impulsivity. For data processing, we used the Kruskal–Wallis test following the Mann–Whitney test. To calculate the effect of size differences we used the coefficients η^2 and r. Our research showed a higher level of cognitive function of athletes compared to nonathletes. More detailed data analysis showed that open skill sport disciplines are influential. There is also a negative relationship between the level of cognitive function and the degree of impulsivity and neuroticism. It seems that sport activity, specifically open skill sport disciplines, has the potential to increase the cognitive functions of young adult men. Personality traits—neuroticism and impulsivity—have a negative relationship with the level of cognitive functions of young men.

Keywords: open and closed skill sport; impulsivity; neuroticism; cognition

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1. Introduction

Exercise and physical activity, which are performed outdoors in the fresh air, are very often mentioned as part of a healthy lifestyle.

Most cognitive functions reach their highest level at the end of adolescence or at the beginning of younger adulthood. Compared to adolescents, the thinking and problem solving of young adults is more flexible. They can also combine information better and use memory more efficiently [1,2]. The basic cognitive functions include thinking, attention, memory and perception. The subcategory of cognitive functions consists of executive functions, which include the ability to anticipate, plan, make decisions, etc.

Executive functions are a system of management processes that prioritize certain processes while suppressing the activity of others. In addition to the functions mentioned above, this also includes the ability to create analogies or store, process and retrieve information from working memory. Some authors describe executive functions in terms of the type of information processing that is associated with a specific task. These processes can be summarized as the ability to set tasks and solve problems, the ability to inhibit reactions, the ability to move attention between two tasks and the ability to engage in two or more tasks simultaneously (so-called multitasking) [3,4].

In the context of sport, we can also name executive function as a psychomotor process, meaning psychological function connected with motor activities—perception on a conceptual-motor level, speed and accuracy of motor responses, sense of timing, fast decision making, etc. [5].

Cognitive and executive functions can be influenced by several aspects—such as sport activity, in the context of this paper—but also by personality traits. Each type of physical

activity has its own unique psychological characteristics. These characteristics are related to the natural aspects and content of the activity, as well as the activity's requirements for motor skills, tactics and mental processes such as cognition, perception, memory, attention, thinking or executive functions. In connection with the involvement of cognitive and executive functions in sport, we can talk about the so-called open and closed sport disciplines [6,7].

Aerobic sports activities such as running, swimming, cycling or walking are typical closed skill sports activities. Very often these are outdoor activities. Closed skill sport disciplines are typically met with a simple sensory–motor response in which athletes may anticipate a stimulus that is about to occur and prepare an adequate action in a specific way in advance. The athlete knows the goal of his movements and the way of executing them [8]. Aerobic physical activity that is repeated regularly could increase cognitive and executive function. The design of past research demonstrates that engaging in regular aerobic sport activity may lead to positive changes in cognitive performance [9–11]. Other studies focused on the general population showed that aerobic activities are an effective tool for streamlining cognitive performance [12,13]. Aerobic exercise is not the only type of sport with the potential to impact cognitive functions. Other types of sports can have a major impact on cognitive and executive functions as well. This may be because cognitive functions are essential in sport disciplines known as open skill sports, such as volleyball, basketball, tennis or football. These sport disciplines typically involve goal-oriented behavior, which must constantly adapt to the changing situation in the game [14]. Thus, open skill sports are characterized by a higher involvement of cognitive functions in performance. Those disciplines have higher requirements for the coordination of whole-body movements and for the ability to adapt to the constantly changing requirements of the game [6]. In terms of the type of sensory-motor response, it is a so-called choice sensory-motor response. This type of response involves the possibility of multiple varied stimuli and several varied replies, i.e., the athlete does not yet know which of the stimuli will appear nor with which reply (which action) he should react to a given stimulus. This is because each stimulus may require a varied number of sensory-motor responses [8].

Moreover, it seems that even within a group of open skill sport disciplines there may be some differences in cognitive and executive function requirements. According to the transfer hypothesis, the more cognitive and executive requirements are involved in a specific sport discipline, the more athletes' cognitive and executive functions are used and trained. These functions may be also transferred to non-sport cognitive or executive tasks. This points to the potential of these types of sports activities [15,16].

The brain hierarchy of cognitive and executive functions is in three levels. The first level is in the posterior parts of the hemispheres, formed by the primary sensory projection areas. In the frontal lobe, the first level of the hierarchy is represented by the motor cortex. The second level is made up of bark areas that process more complex information. Each of these areas is connected to one of the sensory areas and is adjacent to the primary sensory projection cortex areas. The third level of the hierarchy is made up of bark areas. This is where the most complex information processing takes place [17].

Research points to physical activity-linked benefits related to cognitive functions such as switching between tasks, selective attention, prepotent responses inhibition and the capacity of working memory. Generally, physical exercise may be considered as a factor for improving the neuroplasticity of brain cells and for reducing damage in the gray matter [18,19].

Improved neuroplasticity of brain cells is one of the neuroprotective and cognitive benefits of physical activity. It is based on the generation of new neurons and their incorporation into hippocampal circuits. This process is called physical activity-mediated hippocampal neurogenesis. Neurogenesis is largely mediated by neurotransmitter and neuroendocrine systems with acetylcholine as a key regulator [20,21].

However, physical activity-mediated neurogenesis in humans is not easy to study. Nowadays, we have evidence that neurogenesis occurs in the adult human brain, especially

in the dentate gyrus. Moreover, evidence suggests that physical activity may increase the size of the hippocampus (related to some cognitive and executive functions such as learning process, memory and spatial orientation) in human adults [22].

In young adults, working memory improvement is the main benefit from regular exercise in the field of cognitive and executive functions [8]. Moreover, prolonged open skill sport activities induced by ß-oxidation of free fatty acids may stimulate so-called BDNF activation [23], which is how we can explain their potential in the field of cognitive functions.

Cognitive and executive functions appear to be associated with some personality traits. Nevertheless, the association between personality and cognitive and executive functions remains understudied [24].

Impulsivity as a personality trait may modulate several cognitive functions, e.g., planning specific steps of an activity, decision making, or inhibition of response [25]. The level of impulsivity may be a strong factor in this behavior, thus, a connection with cognitive functions is possible [26].

We can also talk about impulsivity in connection with sport disciplines in which cognitive functions are applied. Impulsivity may be considered as a strong factor in the interference of motor performance in open skill sport disciplines. Open skill sports are characterized by various fast changes in time (position of players in the field), which force the player to reconsider pre-planned actions, inhibit impulsivity in their behavior, anticipate situations in the game and coordinate their movement based on the constant reception of sensorial inputs. Thus, some of the elements of cognition are in high demand in some sports (e.g., any sport game) to ensure the player performs well [27,28].

Neuroticism as a personality trait may affect cognitive functions as well. Its higher level is correlated with a negative bias in attention, interpretation and recall of information and increased reactivity [29]. As well, some authors [30] assume that higher neuroticism may be associated with the variability of motor performance in the part that relates to cognitive functions.

We also have to take into account that the personalities of athletes can be affected by several factors related to sport activity—long-term sport success, interpersonal relationships and the mental states of athletes before, during and after competition. Even pressure exerted on the opponent may influence personality traits of athletes [31,32].

Based on the above findings, our study is aimed at determining the level of cognitive functions of young men in terms of their involvement in sports activities, followed by an analysis of the cognitive functions of athletes in more detail to determine the level of cognitive functions in terms of engaging in open and closed skill sport disciplines. The second aim of the study is to determine the relationship between the level of cognitive functions of men and the degree of their neuroticism and impulsivity.

2. Materials and Methods

2.1. Participants

We used a snowball sampling to obtain participants in three research groups—nonathletes, open skill sport athletes and closed skill sport athletes. The research sample consisted of 71 males age 22.66 ± 1.91 years (age range 18–25 years). This group was divided into two subgroups in terms of sport activity. The first group consisted of males not engaged in any sport activity (n = 26) and the second group consisted of athletes (n = 45). Inclusion criterion for the participants in the group of athletes was engaging sport activities at least three times weekly, lasting minimally 60 min (per one training session), continuously for at least the last year. Further, all athletes were divided into two groups—open skill sport athletes (n = 21) and closed skill sport athletes (n = 24). Closed skill sport disciplines were represented specifically by swimming (n = 11), running (n = 1), cycling (n = 5), fitness (n = 5) and golf (n = 2); open skill sport disciplines were represented by tennis (n = 3), football (n = 15) and volleyball (n = 3) in this study.

2.2. Measures

We used a standardized S-test—a recognition of segments to measure the level of cognitive functions, in the "pen-paper" form [33]. This is a test of cognitive and executive functions, selective attention and spatial orientation, carried out for a specific time, so it is necessary to adapt the pace of activity and decision making to more demanding conditions. It also diagnoses immediate memory and concentration of attention. Decision making also affects executive functions. This test is based on recognizing parts of the whole. The basis is four complete figures in the model. In each task, the participant has to mark one of these figures that he thinks part of it comes from. The time to complete the task is limited to 7 min (Figure 1).

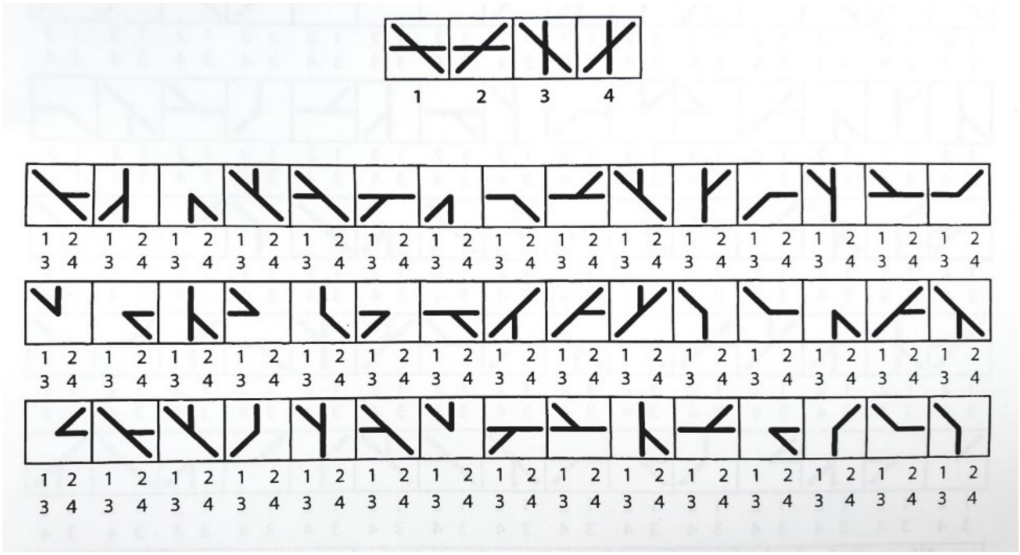

Figure 1. S-test; recognition of segments; sample of tasks.

We also used a standardized test to measure personality traits—EPQ-R (Eysenck Personality Questionnaire-Revised). It contains 48 items. The basic personality traits on which the scales of the EPQ-R questionnaire are focused are neuroticism, extraversion and psychoticism. Only the scale of neuroticism was relevant to our research. There are 12 items to measure neuroticism and all items are dichotomous, so the participant answers yes/no. It is important to emphasize that the EPQ-R questionnaire deals with normal behavior and not with symptoms of disorders. The characteristics of a typical extrovert and introvert can be considered as idealized extremes on the continuum, which individuals approach to a greater or lesser extent. Similarly, in the case of neuroticism, there are personality variables and latent behavior, which become pathological only in extreme cases. For this reason, the scale is intended for a normal, non-pathological population [34]. To calculate the reliability of the neuroticism scale we used the formula of Kuder and Richardson no. 21, with the result $KR_{21} = 0.61$.

Finally, we used the standardized IVE questionnaire (Eysenck's questionnaire of impulsivity) as a tool to measure the level of impulsivity. In addition to the impulsivity scale, the questionnaire also includes a scale of adventure and a scale of empathy. Given that impulsivity is a very important factor from a psychological point of view, there was a need to compile a special questionnaire to measure this personality trait. The questionnaire in its current form contains 54 items. There are 16 items to measure impulsivity, and they are dichotomous, so the participant answers yes/no [34]. The reliability of the impulsivity scale is $KR_{21} = 0.81$.

2.3. Procedures

Data were collected from May 2019 to September 2019. All diagnostic tools were distributed together at the same time in paper form to the participants. The study was

anonymous, and participants received information about the purpose of the research. Participation in the study was voluntary. Participants' questions were answered before the measurement. None of the participants had participated in the measurement of cognitive function with this standardized test in the past.

All participants provided informed consent. The study was completed according to the Declaration of Helsinki. Methods used in the study were approved by the Ethics Committee of the Faculty of Physical Education and Sports, Comenius University (no. of decision 10/2019).

2.4. Statistics

The statistical evaluation of the data was performed in the IBM SPSS program (version 23 for Windows, IBM). The Shapiro–Wilk test for testing data normality was used. Then, the nonparametric Kruskal–Wallis test was used. For pairwise comparison of the independent groups the Mann–Whitney U-test was used. To determine the effect of size differences we used η^2 and r coefficients. The magnitude of the η^2 coefficient was evaluated in ranges: $\eta^2 \geq 0.26$ (large effect), $\eta^2 = 0.03$–0.25 (medium effect) and $\eta^2 \leq 0.02$ (small effect) [35]; the magnitude of the r coefficient was evaluated in ranges: $r \geq 0.5$ (large effect), r = 0.3–0.5 (medium effect) and r = 0.1–0.3 (small effect) [36]. We set the level of statistical significance at $p < 0.05$.

3. Results

Results showed that there are differences in the level of cognitive function regarding the involvement in the sport activity (U = 356.5, $p = 0.006$ and r = 0.32). Athletes achieved a higher level of cognitive function compared to nonathletes.

The difference in the level of cognitive function may also be due to the type of sport discipline. Therefore, it is necessary to focus on the difference between open skill sports and closed skill sports. Our evaluated data showed differences in this respect (H(2) = 9.119, $p = 0.010$ and $\eta^2 = 0.16$). The pairwise comparison showed differences between nonathletes and open skill sport athletes (U = 143, $p = 0.005$ and r = 0.41), but no difference between nonathletes and closed skill sport athletes (U = 213.5, $p = 0.056$ and r = 0.27) nor between open skill and closed skill sport athletes (U = 186, $p = 0.133$ and r = 0.22) (Table 1).

Table 1. Score in cognitive function test regarding sport activity.

		Mean	SD
Sport activity			
	Nonathletes	109.35	31.67
	Athletes	131.78	22.97
Type of sport			
	Open skill athletes	136.57	15.95
	Closed skill athletes	127.58	27.36

Results also showed significant relations between the level of cognitive functions and chosen personality traits of young men. We found a negative relationship between the S-test score and neuroticism ($p = 0.002$) and impulsivity ($p < 0.001$) (Table 2).

Table 2. Relation between the level of cognitive functions and personality traits.

	Neuroticism	Impulsivity
S-test score (cognitive functions)	−0.369 **	−0.731 **

** 0.01 level of significance.

4. Discussion

Generally, our study showed better results in the cognitive tasks of athletes compared to nonathletes. According to the research conclusions, physical activity of men in adolescence may be beneficial for cognitive operations in which attention plays a role [37]. Some other studies came to similar conclusions [38–40]. However, other cognitive and executive functions were also measured. Higher levels of cognitive and executive functions of elite badminton players (compared to nonathletes) were demonstrated by a greater success rate to inhibit their motor responses during stop signal trials [41].

It may seem that the benefits of sport activity in this area were proven, but sport activity as a moderator of change in cognitive functions cannot be seen in general. Thus, it is also interesting to observe differences between groups of athletes, suggesting differences potentially caused by different sport disciplines.

According to some studies, aerobic activities are associated with the improvement of cognitive functions [9]. This is probably the reason why there is no difference between open and closed skill sport athletes in several other studies. These findings are thus consistent with other research [42] focused on the cognitive and executive functions of track-and-field athletes and handball players. The authors found no difference between athletes in terms of sport disciplines.

Another study [43] did not find differences in visual choice reaction time tests between athletes engaged in open and closed skill sports. However, sprinters achieved better results in auditory reaction, and volleyball players achieved better results in anticipatory tasks. This can be explained by saying that the cognitive functions of athletes are associated with the sport discipline, respective to what is required in the performance of certain sport disciplines, either open or closed. However, an important variable can be the performance and expertise of athletes, not only in closed skill sports, but also in open skill sports. One study proved that compared with slower runners, faster runners seem to have better cognitive and executive functioning, including inhibitory control, showing a superior ability not only to inhibit motor response, but also to suppress the processing of irrelevant information [44].

However, in the field of cognitive and executive functions of athletes from open skill sport disciplines, the results are not entirely clear. Some results showed that athletes differ in their expertise in some functions (elite athletes have greater inhibitory control, cognitive flexibility and metacognition) [45], while other results did not show any difference [46]. Athletes in open skill sport disciplines may be more successful due their greater level of cognitive and executive functions, but the opposite may be true as well—higher cognitive and executive functions are related to greater sport experience, because some executive functions, such as a decision making, can be improved with practice [47]. This is an important question that may be answered by a study with an experimental design.

Our findings are in line with the above findings—we did not find a difference in the level of cognitive functions between athletes (open and closed skill sports). However, an important finding from our research was the difference between open skill sport athletes and nonathletes. Our data showed a difference in favor of higher levels of cognitive functions of athletes. The reason is probably that in open skill sports there are typically constantly changing game conditions, which require anticipation in the game or selective concentration on the ball (puck, etc.), which may stimulate cognitive processes.

These results correspond with the findings of [48], according to which, the practice of open skill sport disciplines was related to better executive functions, as a subcategory of cognitive functions.

From the point of view of the study of cognitive functions in sports games some authors came to interesting conclusions. Namely, the authors found an improvement in some cognitive and executive functions (inhibition of impulsive behavior and planning) after four months of the season in American football players [27]. However, several factors can come into play, such as personality. In this regard, we can talk about impulsivity in the athlete's behavior and decisions. The study demonstrated that participation in competitive

sports may lead to efficient decision making, without sacrificing accuracy, which is often a consequence of impulsive decision making [49].

In the context of researching this issue, it is interesting to conduct a more detailed and thorough observation of the area of personality traits. The study we carried out revealed a negative relationship between the level of cognitive function and personality traits (neuroticism and impulsivity). According to other authors [50], neuroticism was associated with worse performance in the cognitive tasks, so our results are consistent with this finding.

This may also be due to the fact that neuroticism is related to faster error reaction time. A higher frequency of multiple responses in action also appears. A high level of neuroticism seems to be associated with making mistakes [24]. However, there seems to be much more behind the relationship between neuroticism and cognitive performance. A negative association between neuroticism and cognitive performance may also be mediated by intrusive thoughts of individuals [51]. Knowledge about this may also be related to the association of neuroticism and cognitive noise between stimulus and response [30].

Although this study brings new and interesting findings, it has its potential limitation. Firstly, the research groups were relatively small. Secondly, the results of the study may also be reflected in the fact that the representation of open and closed skill sports is unequal—although open and closed skill sports have certain common features within the groups, it must be said that footballers dominated in the open skill sports group and swimmers in the closed skill sports group. This may affect the results of the study.

Thirdly, the conditions for studying and researching cognitive and executive functions in sports are not yet completely appropriate. There is a lack of diagnostic tools usable for various sports. It is necessary to know that sports performance is multifactorial as it is difficult to focus on only one isolated factor [42].

5. Conclusions

The cognitive and executive functions of young men differ based on their involvement in sport activity—in general, athletes achieved a better performance in cognitive tasks than nonathletes. However, after a deeper analysis, we must state that only men engaged in open skill sport disciplines had a higher level of cognitive and executive function than nonathletes. The personality traits of young men also seem to play a role in the level of cognitive functions. Namely, there exists a negative relationship between the level of cognitive performance of men and the degree of their neuroticism and impulsivity.

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