Executive functions and academic performance of young tennis players in Greece

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ABSTRACT

The current research project aims to highlight the importance of physical activity (PA) and especially tennis, in the development of cognitive functions related to academic performance (AP). Recent international literature highlights the importance of PA in improving students' executive functions (EF). Additionally, related research finds that the development of EF is closely intertwined with AP. Research with the participation of students specifically involved in the sport of tennis, which is the focus of this paper, leads to similar conclusions. This identifies a research area that should also be the subject of research in Greece as well.

KEYWORDS

Physical activity, cognitive functions, executive functions, academic performance, tennis

RÉSUMÉ

L'objectif de cette étude est de souligner l'importance de l'activité physique, en particulier le tennis, dans le développement des fonctions cognitives liées aux performances académiques. La littérature internationale récente met en évidence l'importance de l'activité physique dans l'amélioration des fonctions exécutives des élèves. De plus, des recherches pertinentes ont établi un lien étroit entre le développement des fonctions exécutives et les performances académiques. Les études impliquant des élèves pratiquant spécifiquement le tennis, qui est le sujet de cette étude, parviennent à des conclusions similaires. Cette observation identifie un domaine de recherche qui devrait être exploré dans le contexte grec.

MOTS CLÉS

Activité physique, fonctions cognitives, fonctions executives, performance académique, tennis

INTRODUCTION

Modern lifestyles have led to a significant reduction in people's motor activities, while a large increase in sedentary behavior (SB) indicators has been observed globally (Zeng et al., 2021). According to the World Health Organization (WHO), physical inactivity is one of the main risk factors for non-contagious diseases and death (World Health Organization, 2020). Also particularly worrying is the rapid increase in childhood obesity and mental illnesses. In recent years, the increased screen time spent by children in everyday life, has negative effects on the shift and flexibility of their attention (Syväoja et al., 2014).

Therefore, adopting a healthy lifestyle and engaging in any form of PA is imperative (Gao et al., 2018; WHO, 2020). PA is defined as any physical movement that originates from the muscular system and increases energy expenditure above normal requirements. A multitude of studies highlight the benefits of PA as an important parameter in improving human health, quality of life, well-being and mental health. Particular emphasis is placed on the importance of PA in children's brain development and learning ability (Milne et al., 2018). Furthermore, in research studies involving elementary and high school students, a correlation was found between PA and higher cognitive functions and, in particular, increased AP (Burton & VanHeest, 2007; Fedewa & Ahn, 2011).

The present study, through the review of the existing relevant literature, aims mainly to highlight the importance of PA, and tennis in particular, in the development of cognitive functions related to AP (Van der Niet et al., 2015).

EXECUTIVE FUNCTIONS, SPORT ACTIVITIES AND ACADEMIC PERFORMANCE

Among cognitive functions, executive functions (EF) have a prominent place, as they are of great importance for human adaptive behavior (Jurado & Rosselli, 2007). EF are defined as higher cognitive skills that facilitate new ways of behaving and are used to control a targeted action or manage an unexpected situation (Gilbert & Burgess, 2008; Van der Niet et al., 2015). The three main EF are inhibitory control (IC), working memory (WM) and cognitive flexibility (CF) (Diamond, 2013; Lehto et al., 2003; Logue & Gould, 2014).

More specifically, IC is an important cognitive function, applicable in everyday life, as it is a prerequisite for inhibiting ongoing or planned actions that are unwanted (Diamond, 2014; Nuri et al., 2013). An important function of IC is the ability to focus on the task the subject is called to perform and the selective inhibition of attention to things unrelated to the intended goal.

WM includes the memory storage of information, but it is not limited to that. It is related to the mental processing of information and its integration into the mental constitution of the subject (Diamond, 2014). WM is involved in a multitude of mental functions. For example, in the choices made in daily activities, in the implementation of thoughts and plans, and in choosing between alternatives. WM enables the subject to relate events and choices between the past and the present. In oral and written language, WM enables appropriate words to be associated in a meaningful sequence. According to researchers, academic activities such as reasoning, problem-solving, and creative thinking would not be possible without WM (Blair & Razza, 2007; Diamond, 2014; Espy et al., 2004; McClelland et al., 2007).

Finally, CF has to do with the ability of creative thinking to find new ways of dealing with problems and the ability to perceive things from different perspectives. CF includes cognitive abilities such as the ability to adapt when choices are not the most appropriate. It is related to the subject’s ability to take into account the data and the limitations they create, as well as to evaluate their actions, while in the case of detection of an error, to enrich their information and integrating it into their cognitive structures. As succinctly described by Diamond (2014, p. 11): “CF is the opposite of rigidity”.

The enhancement of EF can be achieved in many ways. For example, through storytelling, the child’s WM is enhanced, because in addition to the ability to memorize people and events involved in the story, the ability to relate them is also required for the story to make sense. During storytelling, the child mentally reproduces the stories and often “participates” in them by presenting their opinions and suggesting options, characteristics that are part of CF. Also, Vygotsky (2016), referring to play in general, claims that the child involved in play practices subordinates themselves to rules, and controls spontaneous actions by obedience to the rules of the game.

EF play an important role in human adaptive behaviour. They contribute to the creation of a plan and to the perseverance in its elaboration and execution, until it is completed (Jurado & Rosselli, 2007). In addition, EF contribute to the concentration of the thought process towards the goal which has been set at a particular time. They are considered important for success in school, the work environment, and various manifestations of daily life (Jurado & Rosselli, 2007).

Available research data demonstrate that children who participate in any sport and at any level have more developed EF compared to children who had SB (Alesi et al., 2014; Chou & Houang, 2017; Jacobson & Matthaeus, 2014; Liao et al., 2017). High athletic performance requires not only physical and motor abilities, but also sensory and cognitive skills (Nuri et al., 2013). The majority of sports are performed under stressful conditions due to psychological and environmental factors, expectations and pressure for high performance (Nuri et al., 2013). Under these conditions, the athlete must quickly and accurately collect the necessary information to reduce the time required for decision-making so that more time can be given to preparing their motor behaviour (Nuri et al., 2013).

Relatively recently, a number of studies have focused on participation in sports activities and especially in specific sports, and how this affects the indictors of EF. In the remaining part of this study, representative surveys that link participation in sports activities and the development of EF are presented.

In the research performed by Alesi et al. (2014), the differences in the development of EF (IC, WM, CF) between two groups of 9 year old children were studied. One group engaged in karate, while the children in the other group exhibited SB. The results of the study showed that karate athletes performed better on the EF test than non-athletes. The findings led the researchers to conclude that this sport is a form of exercise with multiple positive effects on the athletes: physical, cognitive and psychological.

Research by Bijleveld and Veling (2014) examined whether WM can affect athletes' ability to perform under pressure. A total of 36 tennis players (25 men, 11 women) aged 25 years old, with many years of athletic experience, participated in the research. The results of this study led the researchers to conclude that the tennis players who participated in the sample had improved WM, resulting in less difficulty in concentrating their attention and thinking under pressure.

In a study similar to the previously mentioned research, differences in cognitive functions between tennis players and non-athletes were examined (Pačesová et al., 2018). The study involved 98 men, aged 16-20 years old. Among them, 44 were tennis players who practiced about 9 hours per week, while 54 participants were not involved in any sport. The results showed an observable difference between tennis players and non-athletes in cognitive functions such as IC, attentional focus, and conscious and selective attention.

Some researchers used children with learning disabilities as a sample and investigated the effect of sports participation on EF (Chen et al., 2015). Specifically, they examined the effect of table tennis training compared to occupational therapy on the visual perception and EF of school-age children with Mild Intellectual Disability and Borderline Intellectual Functioning. A number of 135 children from three special schools and eleven general schools participated in the study. Among them, 46 (26 boys, 20 girls, 10±3 years old) participated in an occupational therapy program and 45 (24 boys, girls, 10±3 years old) participated in table tennis training. The control group consisted of the remaining 41 (23 boys, 18 girls, 10±4 years old). Both programs, occupational therapy and table tennis, lasted 16 weeks and took place three times per week for 60 minutes. Results showed that participants in both the occupational therapy and table tennis programs benefited in visual-perceptual skills compared to the control group. Also, between the two groups, the table tennis group displayed the highest scores on post-intervention measurements in terms of executive and cognitive abilities. Regarding visual-perceptual ability, the table tennis group presented better indicators than the occupational therapy group in spatial perception, stability and sequential memory. Based on the above, Chen et al. (2015), concluded that occupational therapy and table tennis training effectively improve cognitive and visual-perceptual functioning in children with intellectual disabilities.

A study by Chou and Huang (2017) involved 49 children, 8-12 years old, who had been diagnosed with Attention Deficit and Hyperactivity Disorder (ADHD). Participants were divided into an experimental group and a control group. Specifically, 24 children attended the yoga sessions and formed the experimental group, while the remaining 25 formed the control group. Before and after the intervention, selective and sustained attention and discrimination ability, deficit attention and reactive stress tolerance in the presence of continuous but rapidly changing visual and auditory stimuli were assessed. The yoga sessions were held twice a week for a total of eight weeks and lasted 40 minutes.

The results of the measurements, taken after the eight weeks of yoga sessions, showed increased performance for the experimental group compared to the control group. According to Chou and Huang (2017), their results prove that yoga, which consists of exercises in breathing manipulation, body balance, posture maintenance and concentration, can help improve concentration of attention, interference management and attention shifting in children with ADHD.

OPEN AND CLOSED SKILL SPORTS AND EXECUTIVE FUNCTIONS

Research has shown that athletes, depending on the sport they are involved in, have better sensory and cognitive skills in specific areas (Nuri et al., 2013; Pačesová et al., 2018). For example, engaging in open-skill sports (e.g., tennis), as opposed to closed-skill sports (e.g., swimming), is more beneficial to the ability to inhibit reactions, probably because they require different cognitive and motor abilities, due to dynamic changes and the unpredictable external environment in which they are usually conducted (Wang et al., 2013). Many times, however, there can be differences between two sports even if they are both open-skilled. For example, volleyball players may outperform badminton players in some indices of EF, as in addition to the changing environment in which they are both played, players are required to cooperate with other players (Meng et al., 2019).

Research by Wang et al. (2013) investigated the differences in IC between athletes belonging to different sports categories and, specifically, between tennis athletes, belonging to open-skill sports, and swimming athletes, belonging to closed-skill sports. A total of 60 students from a Taiwan university participated in the research. Twenty of them were members of the university tennis team, aged 20 years old, with 3-11 years of experience, 20 were members of the university swimming team, aged 19 years old, with 2.5-9 years of experience, and the remaining 20 had no particular sports background and formed the control group.

The results showed that the tennis players showed significantly shorter reaction times than the swimmers and the sedentary group. At the same time, no difference was noted between swimmers and the control group. Based on the research findings, Wang et al. (2013) concluded that engaging in open-skill sports (e.g., tennis), as opposed to closed-skill sports (e.g., swimming), benefits more the ability to inhibit reactions, probably because they have different cognitive, and motor demands due to the dynamic changes and the unpredictable external environment in which they are usually conducted.

In a study by Jacobson and Matthaeus (2014), it was found that athletes of open-skill sports performed better in problem-solving tests than those of closed-skill sports and non-athletes. Attempting to interpret the findings, Jacobson and Matthaeus (2014) claim that the differences may be because players in open-skill sports such as soccer and tennis must make quick decisions under time pressure in constantly changing conditions. On the other hand, athletes from closed-skill sports performed better in IC tests than those from open-skill sports and non-athletes. This finding may be because, in closed-skill sports such as racing and swimming, athletes have time to plan each critical movement and high levels of concentration and discipline are required.

TENNIS AND EXECUTIVE FUNCTIONS

Tennis is part of the open-skill sports, and presents particular cognitive and motor demands, due to the dynamic changes and extremely variable external environment in which it is conducted. For this reason, the interest of many researchers has turned to the relationship that tennis can have with EF, giving special emphasis to the sports experience and the teaching methodology.

In their research, Ishihara et al. (2017a; 2018) examined the relationship between the frequency of practicing in tennis and EF (IC, WM, CF) in children and adolescents. The study involved 117 tennis players (57 boys, 60 girls), 6-15 years old, who participated 3-6 times per week in tennis training sessions and had about 2 years of athletic experience.

The findings showed frequent tennis play was associated with better IC and WM, while greater experience in the sport was associated more with increased levels of CF. From the findings, the researchers were led to the conclusion that experience and the frequency of engaging in this specific sport are linked to improved indicators of executive functioning of the athletes in the sample.

Previous research by the same team (Ishihara et al., 2017b) studied the possible correlation between tennis training methodology and EF. Specifically, they examined the relationship between game-based exercises and coordination exercises with EF (IC, WM) in a sample of children involved in tennis. The study involved 40 children (23 boys, 17 girls), 6-12 years old, who regularly attended tennis lessons for approximately 2.5 years. The duration of the training activities of each training session, including coordination training, game-based drills, rally, ball collection and time when no PA took place, was recorded by an observer. Assessment of EF was performed for all participants at rest.

The findings showed that tennis training sessions containing game-based exercises appear to have positive effects on IC and are associated with improved levels of physical fitness. In contrast, applying matching training over a long period may positively benefit WM. In conclusion, according to Ishihara et al. (2017b), exercise programs that include game-based activities and coordination exercises positively contribute to developing EF.

In another study, Ishihara et al. (2017c) examined the effects of two different tennis training methods. Specifically, they studied the correlation of the “technique-based approach” and the “game-based approach’ with EF. 81 children, 6-12 years old (38 boys, 43 girls) from three tennis clubs participated in the research. The participants had been playing tennis for 0.1-7.3 years and were divided into two groups according to the content of the training sessions they attended. The 32 children practiced according to the “technique-based approach” and the 39 with the “game-based approach”.

The results showed that the overall score for EF improved significantly for both groups compared to the control group composed of children who did not participate in this specific sport. In addition, the group that attended classes with the “game-based approach” showed a greater improvement in their overall performance on tests of EF compared to the group that attended classes based on the technique of the sport. In conclusion, according to the researchers (Ishihara et al., 2017c), playing tennis and, in particular, tennis training with game-based exercises is more effective in improving EF. In addition, research by Ishihara & Mizuno (2018) showed that recreational tennis training programs significantly enhance the development of children's EF.

RESEARCH IN GREECE ON TENNIS AND EXECUTIVE FUNCTIONS

In Greece, research that studies the contribution of tennis to the development of EF is particularly limited. In this paragraph we will present data from research recently conducted in tennis clubs in Athens, Greece (Zacharou-Otapasidou et al., 2021, 2023).

Survey sample. This study involved 33 children (18 boys and 15 girls), 8-12 years old (M=10.35, SD=0.99) from two tennis clubs with 1-8 years (M=3.86, SD=2.01) of athletic experience. Furthermore, they had no diagnosed mental disorders, or learning or motor disabilities.

Data collection process. During the data collection process, three consecutive meetings were held: The first meeting was informative and involved the coaches, the children, and their parents/carers. In the second, information on the participants' demographics was obtained, followed by measurement of their somatometric characteristics (height, weight). Finally, each child was given an Omron HJ-720IT pedometer and instructions on how to use it properly for the one week that they had to wear it. The pedometer had to be worn with a clip on the right hip throughout the day, except during sleeping, bathing or water activities. The third and last meeting took place a week after the second. After the children returned the pedometers, the EF were evaluated for 15-20 minutes through special software on a computer.

Analysis of findings. Initially descriptive statistics (means, standard deviations and percentages), and afterwards inductive statistics were used to analyze the data. Specifically, in a first stage, a correlation analysis was performed between (a) the age and (b) the years engaged in tennis and the variables of interest. A correlation analysis was then performed between PA (number of weekly steps) and performance in the EF tests. To assess the strength of statistically significant correlations, Cohen's (1988) and Cramer's (1998) thresholds were used. Specifically, if $r < .29$, the correlation was considered weak; if $.30 < r < .39$, it was considered moderate; if $.40 < r < .69$, strong; and finally, if $r > .70$, the correlation was considered very strong.

The analysis of the research findings of Zacharou-Otapasidou et al. (2023) showed that age affected the participants' performance in some EF tests. Specifically, older children recorded shorter reaction times on tests of CF and IC, which means that older children in this sample adapted more quickly and correctly in tests of CF and had faster reaction times in tests of IC, both in the simple and in the complex conditions of the research condition.

The data analysis of the findings of the study by Zacharou-Otapasidou et al. (2023) showed that children who play tennis have more developed WM than children who do not play any sport. In fact, in a similar study by Chrysochoou et al. (2011), the performance of non-athletes of similar age in the WM test was lower than that of the participants in the study of Zacharou-Otapasidou et al. (2023). Also, in the CF test, tennis players had shorter reaction times than non-athletes. In fact, the findings showed that the participants in this research had better performance (shorter reaction times) than those in similar research by Ralli et al. (2021). The findings led the researchers of this study to the conclusion that children who play tennis have more developed EF than children who do not play any sport, with the age factor playing an important role.

One of the purposes of Zacharou-Otapasidou’s et al. (2023) was the literature review of research investigating the correlation between sports and EF of school-age children. In particular, the focused was on the sport of tennis and its contribution to the improvement of EF. Research shows the positive contribution of sports to the improvement of EF. Similarly, positive is the contribution of tennis to the improvement of EF. In particular, playing tennis showed improved performance in EF. Therefore, there remains an urgent need for the systematic involvement of children, from an early age, in sports activities.

DISCUSSION

One of the important indicators for evaluating the educational process is the high AP of students. Academic success is based on a set of factors such as communication skills, problem-solving ability, self-control of behaviour, methodicalness and persistence in solving tasks, conceptual immersion in the subjects taught, and others.

Numerous studies have focused on the relationship between EF and AP, concluding that EF are associated with better performance in simple arithmetic, helping children to maintain the order of numbers in counting as well as to collect and evaluate the information contained in a mathematical problem (Bindman et al., 2015). Also, EF appear to be related to children's writing and reading performance, allowing them to focus on individual letters and store the accompanying phonetic information for word decoding (Bindman et al., 2015). Beyond supporting such cognitive processes, EF can support children in regulating their attention and behaviour in changing learning environments.

Also, other studies (e.g. Ahmed et al., 2018; Cortes Pascual et al., 2019; Gordon et al., 2018) lead to the conclusion that WM, which is an important aspect of EF, plays an important role in AP, especially in the early years of school life. Research with elementary school students has shown that good AP in language courses and mathematics is particularly related to WM (López, 2013). Also, research by Latzman et al. (2010) highlighted the effect of EF in different subjects such as science, mathematics, social studies, and reading, while research by Gerst et al. (2017) highlighted the correlation of IC with the subjects of science and mathematics.

Summarizing the findings of various studies, we can conclude the following:

- Different dimensions of EF affect performance on different fields.
- The development of skills related to EF plays an important role in improving AP.

Nevertheless, future research in Greece involving the effects of tennis on the development of EF in combination with the AP, of early aged students, would be useful.

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