

Effect of physical activity on cognitive performance

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Resumen

En los últimos años, las investigaciones sobre los efectos de la práctica de ejercicio físico en el rendimiento cognitivo han aumentado exponencialmente. Este interés científico ha sido paralelo al incremento del sedentarismo e inactividad física, lo cual ha propiciado el desarrollo no solo de problemas de salud física sino también de problemas de salud mental y rendimiento cognitivo. En relación a esto, en esta tesis doctoral se han incluido cuatro estudios. El primero de ellos, consistirá en una revisión bibliográfica acerca de los efectos de la actividad físico-deportiva practicada durante la infancia y adolescencia sobre la cognición a corto, medio y largo plazo. Por otro lado, la segunda investigación tiene por objetivo conocer los efectos de la práctica de diferentes modalidades deportivas sobre el rendimiento académico de deportistas de élite, favoreciendo que se conozca mejor si determinados tipos de ejercicio físico tienen influencia en unas u otras áreas del ámbito académico. La tercera parte de la tesis evaluará los resultados a nivel cognitivo del programa "Mente y Movimiento", que durante un curso escolar realizarán niños de 7 y 8 años, pertenecientes a 20 colegios de cinco países europeos. Finalmente, para conocer el efecto de la práctica de actividad física en una población especial, se realizará un último estudio con niños y adolescentes del Reino Unido diagnosticados con Trastorno del Espectro Autista. En él se investigará la relación existente entre la práctica de actividad físico-deportiva y determinadas variables cognitivas como el grado de autismo y las relaciones sociales.

Abstract

In recent years, research studying the effects of physical exercise on cognitive performance has experienced an exponential growth. This scientific interest has grown alongside with an increase of sedentary behaviour and physical inactivity, which has favoured not only the development of physical health problems but also mental health and cognitive performance issues. Regarding this frame of reference, four studies have been included in this PhD thesis. The first one will consist of a bibliographical review about the effects of the physical-sports activity practiced during childhood and adolescence on cognition in short, mid and long term. On the other hand, the second research aims to analyse the effects of different sports modality practices on academic performance from elite athletes, favouring the knowledge about if certain types of physical exercise have influence in ones academic areas or anothers. Thirdly, this thesis will evaluate the cognitive effects of the "Mind and movement" program, which will be conducted throughout an academic course by children aged 7 and 8, belonging to 20 schools from five European countries. Finally, in order to learn about the benefits of physical activity in special population, a final study will be conducted with children and adolescents from United Kingdom diagnosed with Autism Spectrum Disorder. It will investigate the relationship between the practice of physical-sports activity and certain cognitive variables such as the autism degree and social relations.

Palabras clave: ejercicio físico, rendimiento académico, cognición, infancia y adolescencia

Keywords: physical exercise, academic performance, cognition, childhood and adolescence

Introduction

In the last few decades, research on brain and nervous system functioning has increased exponentially. Neurosciences development is providing a deeper explanation regarding the mechanisms of different psychological processes such as learning (Clark, 2018). In this way, the effect of physical activity on mental health and cognitive performance has been verified in the short- (Hillman, Buck, Themanson, Pontifex & Castelli, 2009; Esteban-Cornejo et al., 2014), mid- (Hillman et al., 2014; Käll, Nilsson, & Lindén, 2014) and long-term (Åberg et al., 2009; Hamer et al., 2016)

Many authors (Sibley & Etnier, 2003; Hillman, Erickson & Kramer, 2008; Singh, Uijtdewilligen, Twisk, Van Mechelen & Chinapaw, 2012) have shown the effects of physical activity on cerebral function and cognition during adolescence and childhood. Regarding the impact of physical exercise on the brain of athletes, Hillman et al (2009) proved that preadolescents with higher physical fitness exhibit better cognitive function and greater development of neuronal organization. In addition, Hillman et al (2009) demonstrated that brain activity increases after walking just 20 minutes. Thus, children show higher brain activity walking than when physical exercise is not practiced. This cognitive improvement is kept along the following minutes, increasing the attentional mechanisms that entail an upgrade in the results of reading tests.

It has to be pointed out that these cognitive benefits are also found in special populations. Numerous scientists (Scarmeas et al., 2011; Wu, Lee & Huang, 2017; Healy, Nacario, Braithwaite & Hopper, 2018) assert that physical activity is able to decrease typical symptoms of diseases related to the functioning of the brain and nervous system. For instance, Zhao and Chen (2018) show that physical activity improves interaction and communication skills of children with Autism Spectrum Disorder, especially in social skills, communication, prompt response, and frequency of expression.

One of the cognitive effects of practicing physical activity is the improvement of academic performance. An example of this is the longitudinal study conducted by Booth et al. (2013). In this research, academic performance and total amount of physical activity were measured in 4755 participants, demonstrating that moderate-vigorous physical activity increases academic achievement. Ardoy, Fernández-Rodríguez, Jiménez-Pavón, Castillo, Ruiz and Ortega (2013) also proved that a greater number of vigorous Physical Education sessions during five months improves the students' academic performance. Furthermore, Käll, Nilsson and Lindén (2014) demonstrated that Swedish schools with two more sessions of Physical Education than the other schools obtained better results in national tests.

This improvement in academic performance and learning due to the increase of physical activity can be originated by several factors. Taking Chaddock, Pontifex, Hillman and Kramer (2011) for reference, it is verified that physical activity increases the development of new neurons and stimulates neurotrophic factors, increasing blood flow and oxygen levels on the brain. Likewise, Diamond, Barnett, Thomas and Munro (2007) confirmed that physical activity improves executive functions, mainly comprising inhibition, working memory and cognitive flexibility, leading to success in school and life. This upgrade in executive functions is due to the fact that physical activity is related to components located in the prefrontal cortex, i.e., the anterior cingulate cortex and the insular cortex with bidirectional mechanisms. This reduces the stress and improves the concentration, facilitating the contextual transference from physical activity to learning (Subramanian, Sharma, Arunachalar, Radhakrishnan and Ramamurthy, 2015).

Animal studies (Van Praag, Christie, Sejnowski & Gage, 1999; Wu et al., 2008; Ding, Zhou, Rafols, Clark & Ding, 2006; Nokia et al., 2016) have also revealed that physical exercise improves memory, connections density between nerve cells, neuronal complexity, myelination and irisin hormone in the muscle, which triggers the development of new neurons in the brain, especially in the hippocampus. Therefore, physically active people would get benefits in their brain development and learning improvement.

Taking into account this literature, four studies are presented in order to better know the effects of physical activity in childhood and adolescence on cognitive performance and mental health.

Study 1. Bibliographic review about the effect of physical activity practiced during childhood and adolescence on cognitive performance and mental health

In this study, a scientific literature search will be conducted concerning the effects of physical activity practiced in childhood and adolescence on mental health and cognitive performance. Accordingly, the aims of this research will be the following:

- To review scientific literature related to acute and chronic effects of physical activity practiced by youth people on cognition
- To synthesize the main research, drawing applicable conclusions for innovative and educational improvement programs.
- To analyze the research methods and assessment instruments used in the different studies.
- To lay the foundations for future empirical research in this field.

For these purposes, a bibliographic search will be carried out in different databases, including human articles in English, French, Portuguese and Spanish into Endnote bibliographic manager. Then, PRISMA guide will be conducted eliminating duplicated articles and those that do not meet the inclusion criteria. The inclusion criteria will be: peer review, relationship between physical activity and cognitive performance, physical activity practiced between three and eighteen years of age, non-special populations, description and measurement of physical activity and cognitive performance and a minimum number of participants in longitudinal, cross-sectional and experimental studies.

After reading the articles, risk of bias and quality of the studies will be analyzed. Subsequently, the information will be synthesized summarizing the main research methods and assessment instruments until the results are extracted. Once the information obtained is analyzed, the conclusions applicable to the educational practice will be established.

Study 2. *Erasmus + Sport at School* program effects on cognitive performance

In this investigation, the cognitive and behavioral variables from the Erasmus + Sport at School program will be evaluated. Erasmus + Sport at school is a European project that involves 20 schools from Germany, France, Poland, Portugal and Spain. The educational centers have been selected according to a homogeneous distribution within each country regarding the location, including public, private and state schools, from the North, South, East and West, with male and female teachers.

In these schools we will analyze whether a motor intelligence intervention oriented to karate during a school year influences on the academic performance, learning skills and mental health of the students. Accordingly, along the 2017-2018 academic year, karate will be integrated into the school curriculum of the second year Primary Education pupils (7-8 years). These students will practice two hours per week of “karate mind and movement” activities, contributing to the development of their motor literacy. Classes will be taught by karate trainers who previously received specific training about the project’s activities.

Before the beginning of the school year, authorizations of the government from each country, the karate federations, the schools, the teachers and the parents have been obtained. At the beginning of the academic course two groups will be created. The experimental group will conduct the motor intelligence program activities oriented to karate while the control group will continue with their usual Physical Education classes. In this way, a pre-test, mid-test and post-test design with a control group will be made.

Beforehand, in the middle and after the intervention, different physical, cognitive and behavioral aspects will be measured with validated and reliable instruments. Regarding the physical aspects, online Physical Activity Questionnaire for Children (PAQ-C) will be used in order to measure the practice of moderate-vigorous physical activity along one usual week. By the same token, aerobic fitness will be measured by the Shuttle Run Test. Furthermore, Body Mass Index will be collected as anthropometric measure.

Related to cognitive and behavioral aspects, academic performance will be evaluated by numerical scholar scores from 0 to 10. The long version of the Wisconsin Card Sorting Test will be completed online to assess executive functions, abstract reasoning and problem solving. Moreover, Strengths and Difficulties Questionnaire (SDQ) will calculate students’ emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems, and pro-social behavior.

Furthermore, participants' socio-demographic features will be measured by the Short Questionnaire Rotation A, belonging to the World Health Survey 2002 from the World Health Organization. Also, attendance to Physical Education classes, as well as learning problems and health problems will be registered.

Once the data has been collected, the descriptive and inferential statistics will be conducted using Excel and SPSS programs. Finally the results of the investigation will be obtained and the conclusions will be extracted.

Study 3. Effect of several sports modalities practice on different curricular areas

The main objective of this research is to analyze the relationship between different sports disciplines practiced by elite athletes and the academic performance in the several curricular areas. Thus, another aim is to identify the relationship between each sport modality demands (perceptive-cognitive aspects, cardiovascular endurance, coordination, flexibility, strength, balance, speed, etc.) and the academic performance in each curricular area studied by elite athletes.

For these purposes, students' academic performance from Ortega y Gasset Secondary School in Madrid will be used due to the fact that most of the pupils are high sports performance athletes, belonging to the Sports Technification Programs of the Spanish Government and Community of Madrid. The Ortega y Gasset has three headquarters for elite students, located at José María Cagigal Municipal Sports Center, the High Performance Sports Center and the 86 World Swimming Center. In this school, elite athletes have studied, such as the swimmer Mireia Belmonte, the gymnasts Gervasio Deferr and Manuel Carballo, the Formula 1 driver Carlos Sainz and the badminton player Carolina Marín.

To do this research, the first step was to contact with the management team of the Secondary School in order to explain them the study and request their participation. Subsequently, the centre provides the University Entrance Examinations grades of all its students, including non-athletes, from the 2009-2010 to 2016-2017 academic years, including June and September. It should be mentioned that University Entrance Examinations was chosen to measure academic performance because it is a battery of examinations completed at the regional level of Madrid that unifies the evaluation criteria and reduces the subjectivity since all students of one period perform the same exam and it is evaluated by an external panel.

Likewise, the sport and its specialty were provided for all the students, taking into account whether they are in categories of elite athletes, high sports performance athletes or amateur athletes. All the procedures will be done taking into account the Organic Law 15 / 1999 of Personal Data Protection. Finally, the coded data will be recorded in an Excel document that will be exported later to SPSS in order to make the descriptive and inferential statistical analyses and obtain the results and conclusions.

Study 4. Effect of physical activity on the cognition and behaviour of autistic children and adolescents

This research will involve children and adolescents from 6 to 18 years of age diagnosed with Autism Spectrum Disorder (ASD). Participants come from three different centres in the United Kingdom: a Welsh school, a Welsh high school and a British trampoline centre. For this purpose, the management team of the school and institute located in Flint has been previously contacted. Both centres are specialized in students with special educational needs, being around 80% of them ASD students. Likewise, the participation of a trampoline centre in Liverpool was requested. There, children and adolescences diagnosed with ASD attend every weekend in order to keep them physically active through several activities standing out trampolining.

The aim of this investigation is to know the influence of physical activity practice on cognition and behaviour in autistic participants from 6 to 18 years old. So, once the permissions are obtained from all the management teams and the ethics committee has approved it, the researchers begin to attend

progressively to the school classes and trampolining sessions. Thus, the participants become familiar with the researchers and associate them as a part of their daily routine, which is very important with this population.

Thereafter, the participants' and parents' informed consents have been obtained and the evaluation could start. In relation to physical activity, accelerometers, PAQ-C and Physical Activity Questionnaire for Adolescents (PAQ-A) United Kingdom online versions will be used depending on the age of the participants. Moreover, motor control will be evaluated with two motor control tasks made with a digital system to detect time and space movements.

Likewise, to assess difficulties in several dimensions, the online Pediatric Quality of Life Inventory (PedsQL), children, adolescents and parents version, Sensory Profile 2 (SP-2), and SDQ parents version will be used to know the difficulties in physical, emotional, social and school scales. In addition, in order to assess the autism spectrum disorders across age, development level and language skills, the Social Responsiveness Scale (SRS), Peabody Picture Vocabulary Test (PPVT) and Autism Diagnostic Observation Schedule (ADOS-2) will be used through highly qualified expert people.

Once the data has been collected, the descriptive and inferential statistics will be conducted using Excel and SPSS programs. Finally, the results of the investigation will be obtained and the conclusions will be extracted

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