EFFECTS OF PHYSICAL EXERCISE ON THE COGNITIVE PROCESSES OF SCHOOLCHILDREN WITH ADHD ATTENTION DEFICIT HYPERACTIVITY DISORDER

[1]PHD. (E) MARIANO JAIRO SALLEG CABARCAS, [2]PHD. JOSÉ ARMANDO VIDARTE CLAROS, [3]PHD. (E) JORGE LUIS PETRO SOTO

[1]Universidad Autónoma de Manizales - Universidad de Córdoba- Colombia
marianoj.sallegc@correo.autonoma.edu.co
msalleg@correo.unicordoba.edu.co
ORCID. https://orcid.org/0000-0003-3137-2547

[2]Docente Universidad Autónoma de Manizales- Caldas -Colombia
jovida@autonoma.edu.co
ORCID https://orcid.org/0000-0002-7982-3848

[3]Universidad de Córdoba- Colombia
Cod ORCID https://orcid.org/0000-0001-5678-1000
jorgelpetro@correo.unicordoba.edu.co
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Abstract
Attention deficit hyperactivity disorder (ADHD) is characterized by an affectation at the brain and cognitive level, which means greater difficulty in behavioral responses. Cognitive stimulation has become a form of rehabilitation of the executive functions, such as inhibition, self-control and attention. Within rehabilitation, physical activity as part of brain training has become popular and an increased number of studies suggests that it can bring benefits in school-age children diagnosed with ADHD. Therefore, the objective of this study is to review specialized texts from the last five years (2018-2022) to understand the state of the research regarding physical activity in cognitive processes in children with ADHD. For this, the guidelines of the Prisma Declaration are followed, through which it is possible to conduct a search format suitable for the selected criteria, which in this case allowed the analysis of thirteen investigations with characteristics that are relevant for the research question. The results showed that the English production has developed satisfactory studies that demonstrate the possibility that children take part in physical programs with positive results. In the case of Latin America, there is a preference for conducting systematic reviews and proposing applicable programs in schools and there are few studies that provide information on the benefits of sport in children diagnosed with ADHD.

Keywords*: ADHD, cognitive processes, executive functions, sport, physical activity.*

INTRODUCTION

Attention deficit hyperactivity disorder or ADHD is a neurobiological impairment of behavior that results in increased difficulty concentrating on day-to-day situations and routines. People who have this disorder may have more difficulty organizing, concentrating, and making plans, especially due to the presence of higher levels of impulsivity, hyperactivity, and inattention (APA, 2014). The symptoms of this disorder can appear during childhood and although 3-7% can be diagnosed in childhood and adolescence (Benzing and Schmidt, cited in Cancio and Ionela, 2020) the American Psychological Association or APA, for its acronym in English, has extended the age range to 12 years to more appropriately identify possible symptoms.

According to Bustamante et al. (2019) ADHD is the most common disorder in the United States, as it occurs in at least 9% of children and adolescents, a similar figure in Latin America although the prevalence may depend on each country. However, studies such as that of Llanos et al. (2019) have shown that in the case of Colombia there is a prevalence above the measure, since it is between 15 and 17%, compared to the world level that is estimated between 4 and 13.3%. Similarly, although it is a disorder that begins in childhood or adolescence, it can also persist into adulthood (Muñoz-Suazo et al., 2019).

The main symptoms and behaviors of ADHD are related to difficulties in executive functions, that is, more work to attend and react to certain stimuli, to plan and organize, to reflect on the consequences before making a decision and to inhibit the automatic response that may not be the best in certain situations (Rusca-Jordán and Cortez-Vergara, 2020). Likewise, physical exercise, understood as any movement that is made with the muscles and that exceeds the energy expenditure that occurs in a resting state (Caspersen et al., cited by Bustamante, et al., 2019), may be affected or there may be deficiencies in control, balance, muscle strength and reaction time due to an increase in cognitive abilities (Cancio and Ionela, 2020).

According to the CADAH Foundation (n.d.) today children and adolescents spend more and more time doing sedentary leisure activities, especially because today's society is identified as an era of technology and communications, however, sport has not been able to be replaced as an activity for the adequate emotional and cognitive development of the little ones. In children and adolescents with ADHD do Physical activities and some sports can help improve behavior, develop better levels of self-control, discipline and motivation, as well as be useful to channel emotions and have tools to work with them (Lomas and Clemente, 2017).

Of according to the Clinical Practice Guidelines on Attention Deficit Hyperactivity Disorder (ADHD) in Children and Adolescents (2010) ADHD influences school performance, so that the child and adolescent population presents more and greater difficulties in learning processes than the rest of the population, so it is common to find cases of low academic performance and associated disorders such as dyslexia. Similarly, it is mentioned in the guide that there are non-neurobiological risk factors involved in ADHD, such as family and certain environmental factors that influence the development and ability to emotional and cognitive control of children and adolescents diagnosed.

Well mentioned Valda et al. (2018) that talking about strategies is related to a vision of horizons and long-term perspectives that entails the recognition and change of situations, attitudes or states towards the achievement of a certain end, which in this case responds to progressive cognitive improvement and what is linked to this in people in a fundamental phase of growth. In the case of cognitive processing, children with ADHD find that there is an impulsive style that occurs:

due to the failure of control to inhibit the response (inhibitory control) to the deficit in emotion regulation (emotional self-regulation), field limitations perceptual due to attention deficit, unanalytical thinking along with deficiencies in the establishment of causal relationships and also the presence of cognitive rigidity in information processing, this set of factors is translates into lack of cognitive flexibility, i.e. the ability to change quickly and correctly from one thought or action to another, according to the environmental demands. (Valda et al., 2018)

The interest of studies around the effect of sport and physical activity arises from observations on neurocognitive deficits related to ADHD and the benefits that this can provide in populations without ADHD, such as increased levels of neurotransmitters, speed in cognitive processing and an increase in inhibitory control (Bustamante et al., 2019). According to Jacobson (2021) sport is presented as An alternative to medication, which do not represent a definitive solution, so support and combination of methods can help the child feel, perform better and develop cognitive functioning.

On this there is evidence that exercise and diet can have an impact on the maintenance of catecholamines (adrenaline, noradrenaline and dopamine), so in people with ADHD it is considered that these practices can lead to cognitive improvements associated with a greater release of

neurotrophic factors (BDNF) during the sport performed recurrently and, therefore, to develop synaptic plasticity (Muñoz-Suazo et al., 2019).

Rivera and Clemente (2017) point out that because most cases occur during childhood and therefore are school-age people, it is necessary to identify how and if tools have been introduced for the appropriate cognitive and psychomotor development of children and adolescents and in what state the research is around this. Therefore, this research proposes that from a literary review it is identified how physical exercise mediates the development of cognitive processes in school-age subjects diagnosed with ADHD. In other words, from the specialized literature, what are the benefits of the practice of physical activity and sports in children? and school-age girls with attention deficit hyperactivity disorder?

In this case, an exploratory systematic review can allow evaluating the quality and methodology used in research that has been carried out on physical exercise and its incidence in school-age children diagnosed with ADHD, synthesizing information and scientific evidence in this regard, as well as being useful in decision-making (Manchado et al., 2009). In addition, this type of review allows not only to describe the knowledge that exists about The theme indicated, but also makes it possible to generate lines of research and propose areas that are and are not developed in a widespread way.

The studies carried out in Spanish around the improvement in symptoms and behaviors in children with ADHD after different types of sports or physical intervention seem to be increasing, however, each one has particularities in its approaches, so there are some who opt for age, type of improvement or type of physical activity. That is why carrying out systematic studies from a delimitation that allows interested people to identify studies from certain characteristics can be essential so that knowledge is available to readers and so that it is not lost in the midst of an increasing production around mental disorders.

METHOD

The research is based on the postulates of the PRISMA statement and its update of the year 2020, so it is necessary to define the eligibility criteria of the review (inclusion and exclusion) and how the studies are being grouped for their synthesis. The inclusion criteria are:

- Research conducted during the last five years (2018-2022) on the effects of physical exercise on cognitive processes in school-age children (between 6 and 17 years approximately) diagnosed with ADHD.
- Investigations that can be accessed in full.
- Research conducted in Spanish and/or English.
- Research and theses published either in indexed journals or in institutional repositories.

On the other hand, the exclusion criteria are:

- Research that does not consider the effects of physical exercise in school-age children diagnosed with ADHD (approximately 6 to 17 years old).
- Research that only allows access to its abstract or part of its content.
- Systematic reviews.
- Research in languages other than English and Spanish.
- Other types of works, articles, news and other research that do not comply with a formal, professional and academic character on the delimited topic.

Review question

What are the benefits of practicing physical activity and sports in children? and school-age girls with attention deficit hyperactivity disorder?

Instruments

Thematic terms

Keywords: ADHD, ADH, physical exercise, Physical Activity y desarrollo cognitivo, Cognitive Development.

Sources of information

As can be seen within the inclusion and exclusion criteria, it is necessary to resort to databases that allow searches that yield information contained in virtual databases with free access such as:

- ✓ Scopus
- ✓ Pubmed
- ✓ Springer Link

Search strings

To perform the search thematic thermals and boléanos operators (AND, OR, NOT) are used to account for as many results as possible and then work on the selection of those with more relevant information. The main search strings, with their respective results, were:

Board 1.

Database search strategy

Databases	**Search strings**	**Limits**	**Results**
Scopus	• (("physical activity" [TITLE] OR "physical exercise") AND ("ADHD" [title] OR "attention deficit hyperactivity disorder" [title]) AND ("children" [title] OR "school-age child" [title])AND (“cognitive” [title])) • (("Physical activity" [title] OR "exercise") AND ("ADHD" [title] OR "attention deficit hyperactivity disorder" [title]) AND ("children" [title] OR "school-age children" [title]) AND ("cognitive development" [title]))	Five-year period (2018-2022) English or Spanish School-age children (6 and 17 years old)	9
PubMed			4
Springer Link			80
Manual online search			15

Procedure

For the selection of the texts, 108 total records from three databases and a general review in the Google search engine were taken into account. After eliminating the duplicates, there were a total of 72 results from which it was necessary to read both the titles and the abstracts, or abstracts, to eliminate those that did not have full access to their texts. From this reading it was possible to eliminate another 30 texts because they are not open access, leaving 42 documents that could be accessed for free. From this reading it was also possible to discard another 22 texts that did not meet the other inclusion and exclusion criteria, either the age of the participants and the years of publication. Finally, a final general revision of the texts allowed to eliminate 7 remaining investigations because they are systematic review works, leaving 13 studies selected for the respective review.

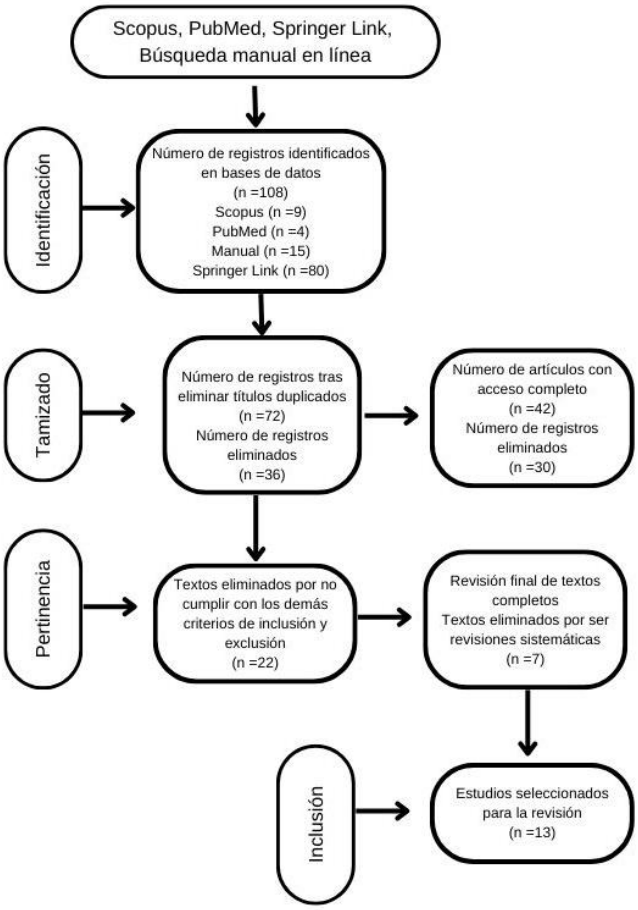

Figure 1. Study selection process flowchart

Board 2.*Review matrix*

Author(s) and year	Study design	Sample	Variables	Results	Conclusions
Miklos et al. (2020)	The physical program consisted of half of the group performing moderately intense physical activity for 20 minutes at 60-80% of their heart rate while watching cartoons. The other half saw the same material while sitting.	150 children with ADHD between the ages of 6 and 12.	Alert Distraction Divided attention Flexibility Reflex to go or not to go	The results support the idea that impaired cognitive flexibility and switching between tasks are characteristic of ADHD, however measures decreased from pre-test to post-test in all groups and all conditions.	20 minutes of moderately intense exercise has a positive and significant result on two of the parameters (median reaction of time on alerting tasks and error rate on divided attention tasks) in the medication group. Positive responses were measured on two of the parameters (number of total errors and distraction errors) for the no-treatment group. The number of omissions in divided attention and performance did not change in the non-medicated group after physical activity, while the control condition increased in skip rates.
Ludyga and Ishihara (2022)	Statistical analysis with R Studio (version 1.1.463). Examination of longitudinal associations within the cross panel with the sem function of the lavaan package. The first model investigated	4576 children with ADHD between the ages of 9 and 11.	Diagnosis ADHD Body mass index Physical activity Brain structure Interferential control	ADHD, low physical activity and high body mass index at the start of the study predicted lower interference control. Gray matter volume, surface area, and gray-to-white matter	Maintaining a low body mass index is related to the control of interference by a tendency to normalize regional alterations in the proportion in a gray and white manner. Increased physical activity may mean greater control of interference, although brain structure may not

	the association between baseline ADHD status, physical activity, BMI, and performance of the follow-up Flanker task, while controlling for autoregressive effects.			ratio contributed to interference control. The association between body mass index and interference control was mediated by the proportion of gray and white matter. The mediating effect was stronger in children with ADHD than for neurotypical children and regions related to cognitive control were restricted.	be the basis of the association.
Liang et al. (2022)	Controlled trial design with two groups. Experimental design of aerobic and neurocognitive exercise of 12 weeks, with control group of children with typical development. A Polar heart rate monitor was used for follow-up.	80 children with ADHD between the ages of 6 and 12.	Inhibitory control Working memory Cognitive flexibility	The intervention was beneficial in improving core endpoints, decreasing sleep latency and sleep disturbances. The effects of the intervention were maintained for at least 12 weeks. Children with ADHD demonstrated non-significant differences in inhibitory control, cognitive flexibility, and sleep quality	The findings suggest that a combined aerobic and neurocognitive exercise intervention for 12 weeks may have a positive effect on the treatment of executive functions and sleep quality in children with ADHD.

				compared to the control group. A significant correlation was found in executive functions and sleep in children with ADHD after the intervention.	
Sun et al. (2022)	Two groups of children randomly participated in a randomized controlled trial of an 8-week HIIT program and a structured, game-based aerobic exercise program. A control group maintained their regular physical activity during the same period.	42 children with ADHD between the ages of 6 and 13.	Executive function Cerebral hemodynamic response Physical activity Fitness Enjoyment and adherence of intervention	HIIT exercise has lately been considered as an effective and feasible strategy to improve and increase health status and cognitive function, including executive function, in healthy young people. It is necessary to identify whether executive function can improve in children with ADHD through HIIT.	It is hoped to gather enough information to understand whether in 8 weeks a HIIT-style exercise has a positive impact on children with ADHD. The results plan to contribute to the literature in novel ways, as well as inform the development of exercise programs aimed at children with ADHD.
Chan, Jang and Ho (2022)		Case analysis	Exercise and neurophysiology Exercise and cognitive function Model exercise and intensity Aerobics with interval training Motor perception and meditation	Evidence shows that both acute and chronic physical exercise can be beneficial for ADHD symptoms, executive function, and motor skills. These can accumulate	Aerobics can increase neurotransmitters (serotonin, dopamine, brain-derived neutrophic factors, and cerebral blood flow). Motor perception and meditation can lead to a neuroplasticity of nerve cells and synaptic connections

				and improve over time, which is reflected in positive correlation between cognition and physical activity.	and strengthening the sensorimotor base contributes to improved attention.
Liang et al. (2022)	Participants wore an accelerometer for seven days to measure physical activity and sleep quality. Four sleep parameters and three executive functions were recorded and assessed with Flanker's task and with the Tower of London test and with Trail Making.	56 children with ADHD between the ages of 6 and 12.	Cognitive tasks Sleep quality Flanker's task Tower of London Trail Making	We examined the relationships between moderate to vigorous physical activity and executive and cognitive functions to understand the relationship between sleep quality with children with ADHD. With more activity during the day, sleep latency decreased, contradicting that physical activity can lead to better sleep patterns.	The role of sleep latency in children with ADHD suggests that physical activity intensity plays a key role in linking sleep quality and executive function.
Benzing, Chang and Schmidt (2018)	Participants were randomly assigned to 15 minutes of moderate-intensity physical activity or to remain sedentary. Executive function performance of inhibition,	46 children with ADHD between 8 and 12 years old.	Executive functions Flanker's task Color Span Backwards Task	At least 14 minutes of moderate to vigorous exercise had significant beneficial effects on reaction times on inhibition and change, but not on the accuracy or performance of visual	The results suggest that participants in the exercise group performed faster than those in the control group in terms of inhibition and change, but there was no significant difference between task accuracy or working memory performance. Acute physical activity

	change, and visual working memory was measured before and after each exercise using a version of the Flanker task and Color Span Backwards Task.			working memory. Central executive functions and the way they are measured have a mediating role between physical activity and cognitive function. The use of active video games can be used as a modality of physical activity, as they require the development of cognitive skills: coordination and speed of action.	may improve specific aspects of executive functions in children with ADHD.
Hattabi et al. (2019)	Participants were randomly assigned to either a recreational swimming program or a control group.	40 children with ADHD between 8 and 12 years old.	Cognitive function Executive control Physical activity Recreational Swimming Program	There were significant improvements in memory accuracy, selective attention and inhibition of processes in the experimental group, compared to the control group. In subsequent programs, children experienced general shortening of task execution times with	The findings suggest that a recreational swimming program may give preliminary support to alternative therapeutic interventions that can be used by parents, educators, researchers, and clinicians to support and normalize cognitive impairments in children with ADHD.

				fewer errors and omissions, as well as in situations of interference, which evidences better cognitive functioning.	
Kadri et al. (2019)	Effects of a one-and-a-half-year taekwondo intervention on cognitive function in adolescents with ADHD. Two instruments were applied: the Stroop and Ruff tests 2 and 7 to evaluate attentional inhibitory control and sustained and selective visual attention.	36 men and 4 women with ADHD between the ages of 12 and 18.	Cognitive function Stroop Color-Word test Ruff 2 and 7 Intervention with Taekwondo	It is the first study to analyze the effects of a long-term Taekwondo practice on adolescents with ADHD. The results show that the participants had an improvement in their cognitive abilities in terms of selective attention, unlike the control group. Taekwondo can be effective due to its characteristics that allow the relationship between body, mind and spirit and leads to balance and harmony.	Taekwondo practice increased selective attention in participants with ADHD. Practitioners should implement martial arts programs in their general activities to positively influence attention and to promote health related to the characteristics of ADHD.
Benzing and Schmidt (2019)	Participants trained for 8 weeks, three times a week for at least 30 minutes, with Shape up.	51 children with ADHD between 8 and 12 years old.	Central executive function Commutation Update ADHD Symptoms	The analyses of covariance (using pre-test values as covariates) showed that children in the	The analysis revealed that children in the intervention group improved in their specific executive functions, general

	Performance was recorded on a computer, allowing children to compete with their highest scores.		Motor capacity	exergame intervention group improved in specific functions: reaction times of inhibition and change, compared to the control group.	psychopathology and motor skills, unlike the control group. Exergaming can benefit children with ADHD regarding their executive functions and motor skills, which can mean that the intervention becomes individualized from the children's home, however, it is necessary to keep in mind that the games must be personalized for each case.
Hair (2021)	Development of an intervention proposal for the improvement of symptoms derived from ADHD from an inclusive perspective. The instrument was evaluated by expert judgment.	Aimed at primary school students.	Evaluation of learning Self-evaluation Evaluation of training	For the development of the proposal, the evaluations of expert professionals were available, which led to the improvement of the intervention. The 20 sessions are distributed over eight weeks in order to meet different objectives such as favoring self-control of cognitive and behavioral impulsivity, among others.	Interventions with children with ADHD in schools are scarce, especially if teacher training on the subject is taken into account. Therefore, the school must learn to respond to the needs and diversity of its students, addressing the difficulties and possibilities for improvement that children diagnosed with ADHD have. In the absence of this, a program is developed to help reduce the learning difficulties of the students diagnosed.
Muñoz-Suazo et al. (2020)	The effect of aerobic physical sports	24 children and adolescents	Quality of care Sustained attention span	Aerobic physical exercise	Physical activity can improve attention in children with ADHD

	activity for six weeks consisting of two one-hour sessions per week, at an intensity of between 60 and 70% of VO2max, is studied. The Borg scale of perceived subjective effort was used, as well as pre-test and post-test.	with ADHD between 5 and 15 years old.	Impulsiveness	reduces not only the risk of heart disease, coronary heart disease, among others, but also has a positive impact on the brain. Physical activity has cognitive benefits that can affect learning abilities and sociability. The results suggest that exercise has effects on cognition, which justifies sports-type interventions in schools as therapeutic support.	and directed sport can be useful as a complementary treatment to pharmacological therapy. It is necessary to have sports professionals who support and direct the activities in order to see a clinical evolution in children and adolescents diagnosed.
Muñoz (2018)	Proposal of didactic physical-sports intervention, with its respective evaluation. Methodology directed with structured sessions and four core activities.	24 students with ADHD in the second school cycle.	Self-knowledge and personal autonomy Knowledge of the environment Language, communication and representation	The development of an intervention proposal that focuses on sport as a tool for the development of skills in children with ADHD, must be mediated by different degrees of difficulty and the adequate and timely support of professionals.	It is necessary to carry out activities that help promote the development of areas where children have more difficulties, as well as work on group cohesion, attention, relaxation, among others related to cognitive dysfunctions in students with ADHD.

MATRIX RESULTS

The review yielded 13 investigations conducted in Spanish and English and published between 2018 and 2022. From reading the works it is possible to find that all report positive results to some extent compared to the application of sports programs and activities in children and adolescents of school age. It was possible to identify the use of different strategies and tools, as well as there is a variation in study times and in the number of participants per research.

There is an importance in addressing the difficulty of executive functions and motor and cognitive skills, so it is proposed that physical exercise seems to help build habits and help control, motivate and improve the general quality of the people intervened. Physical activity is suggested as support in all cases, either with people medicated or not or in other therapeutic processes, as well as insisting on the importance of developing programs within schools where the needs of those with a diagnosis of ADHD are taken into account.

DISCUSSION

The aim of the systematic review was to identify the benefits of physical activity and sports in school-age children diagnosed with ADHD. After the realization of this, the respective reading and selection, it was possible to find different approaches from which it is sought to identify, through proposals and field work, different ways in which physical exercise can contribute to the improvement or development of processes and skills that are beneficial for children and adolescents between 6 and 17 years, approximately.

Most research, especially in English, They develop longitudinal processes where it is possible to identify the previous and subsequent state of the participants who were part of the realization or application of programs where physical exercise was involved. It is evident that the interventions have mostly a positive relationship between cognitive and physical development, in addition to having impacts on the different executive functions, especially if the exercise is developed for a considerable period of time in which it is possible to identify progressive improvements in children and adolescents with ADHD.

Sports such as swimming and Taekwondo show to have generally positive effects that affect sleep, attention, impulsivity, among other behaviors that affect learning processes and growth. Likewise, interval sport, moderate to intense physical activity and the use of virtual platforms and video game programs that allow physical activity are used to identify the advantages of sport and movement in people in full stages of growth where it is important to generate and motivate customs that help the cognitive development of those diagnosed with ADHD.

The research that proposes programs to be applied in the respective institutions needs an application to understand their impact on school-age children and adolescents. This, especially for those recent investigations carried out in Spanish and that have not yet been carried out. It seems important to continue expanding research on the effects of sport on people with ADHD, especially to have more information and comparable results on the young population in regions such as Latin America.

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