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Effect of Hit-Sport-Game Exercise Training on Self-Control and Regulation in Children With Attention Deficit Hyperactivity Disorder (ADHD)

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Abstract

Objective. To determine the effect of a physical exercise training program, "HitSportGame" (HSG), on self-regulation of children with ADHD. *Subjects and methods*. The participants (N = 44) were children with ADHD aged 8 to 12 years (Mean 10.5 SD 1.4) without comorbidity with other neurodevelopmental disorders. Children were randomized to an experimental group and a wait-list control group. The experimental group participated in the Hit-Sport-Game (HSG) training program thrice a week for 12 weeks. The self-control skills of the participants in both groups were evaluated with the CACIA (Child and Adolescent Self-Control Questionnaire) 1 week before and 1 week after completing the entire intervention. *Results*. The results showed significant improvements with effect sizes from moderate to large in the scales of personal feedback ($P = .003$; $\eta^2_p = 0.183$), criteria self-control ($P = .029$; $\eta^2_p = 0.112$), and procedural self-control ($P = .015$; $\eta^2_p = 0.131$) after the intervention in the experimental group compared to the control group, which showed no difference on any of these scales. The reward delay scale did not show significant changes associated with the intervention ($P = .104$; $\eta^2_p = 0.059$). *Conclusions*. HitSportGame physical exercise training demonstrated favorable effects on some self-control skills such as personal feedback, criterial self-control and procedural self-control of children with ADHD. However, it did not show any effect on the ability to delay rewards in this population.

Keywords

ADHD, self-control, self-regulation, sport, physical exercise

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Introduction

Attention deficit hyperactivity disorder (ADHD) is a neurobiological behavioral disorder characterized by a persistent pattern of inattention and hyperactivity-impulsivity. This disorder significantly affects the subject's ability to organize, focus, and make plans, particularly due to the presence of higher levels of impulsivity, hyperactivity, and inattention. As expected, daily performance at school and work is affected.[1,2]

In general, the manifestations of ADHD arise in childhood, although in some cases (3%-7%) they begin in adolescence or early adulthood.[3,4] These manifestations are relatively chronic and cannot be explained by any major neurological deficit alone, neither can they relate to other sensory, motor, or speech deficits unless intellectual disability or severe emotional disorders are detected.[5-7] Currently, ADHD is considered the most common neurodevelopmental disorder, with a higher global prevalence ranging from 5.9% to 7.2%, with variations between countries.[8,9]

The main symptoms of ADHD are related to difficulties in executive functions. As such, this condition is characterized by difficulties concerning attending, reacting to certain stimuli, planning, organizing, reflecting on

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consequences before making decisions, and inhibiting automatic responses that may seem inappropriate in certain situations.[4,7] The abovementioned signs entail a behavior that is certainly different from what is considered prototypical.

When it comes to cognitive processing, people with ADHD exhibit an impulsive style.[10] This includes the inability to control response inhibition (inhibitory control), difficulty in regulating emotions (emotional self-regulation), restrictions in the perceptual field due to attention deficit, poor analytical thinking abilities, deficiencies in establishing causal relationships, and cognitive rigidity in information processing. Combining these factors results in a lack of cognitive flexibility, that is, the ability to switch from one thought or action to another quickly and accurately, following the demands of the environment.

Self-Regulation and Self-Control Mechanisms

Self-regulation involves the control of cognitive, emotional, and behavioral resources needed to direct behavior toward a goal. This is what allows subjects to adapt to changes, accommodate plans, and modify their behavior under the demands of specific situations. For example, the subject may be confronted with situations that require the ability to initiate or terminate actions according to situational demands, modulate the intensity, frequency, and duration of behaviors, postpone action on an object, and generate socially accepted behaviors in the absence of external control.[11,12]

In the words of Baumeister and Monroe,[13] self-regulation is essentially a matter of altering responses, including thoughts, emotions, and actions, based on the demands of context. According to the authors, acts of self-control generally serve to inhibit a predominant response so as to enable other response alternatives. Self-regulation is a multidimensional construct[14] from which 2 components can be distinguished: a behavioral one and an emotional one.[15] On the one hand, behavioral regulation allows the subject to follow directions, inhibit inappropriate behaviors, adapt responses to context, and match environmental expectations through the regulation of speech and actions.[16] On the other hand, emotional regulation is associated with the ability to regulate, express, and modulate affective states in order to redirect the emotional flow, allowing it to increase, decrease, or sustain its intensity.[17]

In other words, self-regulation corresponds to the ability to control behavior, emotions, and thoughts to pursue long-term goals.[18,19] Consequently, self-regulation is essential for social adaptation,[20] school success[21] and the adequate development of the subject throughout their life cycle, from childhood to adulthood.

Deficit Regulation Model in ADHD

Multiple explanatory theoretical models have been formulated in order to understand the etiology of ADHD, most of which have focused on cognitive deficits.[7,22] However, a review of the advanced studies to date on explanatory models of ADHD suggests that cognitive deficit is not a conclusive constituent of most ADHD cases, as only half of children with ADHD show significant cognitive impairment.[23] In contrast, some authors have proposed that ADHD is essentially a disorder of the subjects' executive processing that affects their ability to control and agency their own behavior, diminishing their ability to guide it in preparation for future events, as well as in the domains of self-regulation of affect/motivation.[24]

As a response to this debate, a model based on the alteration of self-regulation mechanisms in individuals with ADHD.[24,25] emerged. According to Shiels and Hawk Lw and Haelk,[26] regulatory deficit models offer an alternative conceptual framework, integrating cognitive and motivational processes at all levels of information processing to understand behavioral regulation. Because of such a regulatory deficit, people with ADHD show a reduced response to punishment and reward and struggle to await and delay gratification as well as to extinguish maladaptive behaviors.[26]

Adaptive control requires awareness of contextual demands, evaluating behavior to recognize whether it is appropriate for the current situation, and being able to adjust the response flexibly. These adaptive control processes and self-control mechanisms work together to produce goal-directed behavior. Therefore, the deficit of these regulatory processes can result in maladaptive behavior.[26] In the words of Douglas,[25] poor self-regulation is responsible for the deterioration of children's performance in cognitive tasks. At the same time, emotional dysregulation significantly limits the social skills of children with ADHD.[27]

Moreover, the school environment poses numerous challenges to the child's self-control abilities. Some examples of this are schedule management, routines, rules of coexistence, and teamwork, since these skills require putting into practice the ability to modulate emotions, inhibit impulses, postpone gratifications, maintain attention, monitor their own behavior, and manage motivation in response to the demands of school activities.[28] In fact, children need all their self-regulation resources to adjust their behavior to the demands of the school environment. Consequently, children with ADHD, which causes a deficit in their self-regulation resources, will face numerous difficulties in having a good performance at school, which could ultimately be reflected in the performance of various cognitive tasks.

In light of this, various interventions aimed at promoting self-regulation skills in children with ADHD have been investigated, yielding diverse outcomes. These interventions include behavioral therapies,[19] co-regulation strategies,[27] cognitive psychoeducation programs,[29] neurofeedback training,[30] and, less frequently, physical exercise-based programs. While the latter have been shown to benefit other aspects associated with ADHD, there is insufficient evidence regarding their effectiveness in training self-regulation skills in children with ADHD.

ADHD, Self-Regulation, and Physical Exercise

Physical exercise and sport programs, as a complementary intervention for children with ADHD, have been shown to have benefits for physical health, behavior, academic performance, social skills, motor skills, and cognition in individuals with ADHD.[31-35] According to Jacobson,[36] sport presents itself as an alternative or complement to medication; therefore, support and a combination of methods can contribute to children feeling better, performing more effectively, and developing their cognitive functioning.

Regarding the cognitive benefits of physical activity programs in individuals with ADHD, research has been conducted on interventions based on aerobic exercise[31,37-39]; Taekwondo[40]; yoga[41]; and HIIT (*High Intensity Interval Training*) exercise.[42] Most studies have found moderate to large effects of these interventions on different cognitive processes, such as attention,[37,39,40,42,43] cognitive flexibility,[44,45] interference control,[46] memory,[38,43] and inhibitory control.[44,46,47] In sum, available evidence suggests that physical exercise is an effective treatment for improving several cognitive domains in children with ADHD.

Aerobic exercise has been shown to enhance cognitive task performance in neurotypical individuals by increasing serotonin and dopamine levels.[31] In individuals with ADHD, physical exercise, along with diet, has been demonstrated to have an impact on the maintenance of catecholamines (adrenaline, noradrenaline, and dopamine). Consequently, physical activity has been found to lead to cognitive improvements associated with a greater release of neurotrophic factors (BDNF) during exercise.[39]

These findings are consistent with previous systematic reviews[31-33,35] that compiled studies on the effects of physical exercise in individuals with ADHD. Indeed, the reviewed studies found that physical activity-based interventions contributed to improvements in cognitive processes in executive functions such as inhibitory control, cognitive flexibility, interference control, and attentional control,[31-33,35,46] with benefits that were shown to be cumulative over time.[31] However, the effects on other dimensions such as working memory were inconclusive.[32]

Additionally, these reviews have found that physical activity programs have contributed to a reduction in ADHD symptoms,[31] an improvement in motor skills,[31] an improvement in affective symptoms such as depression and anxiety,[48] a strengthening of social skills such as cooperation,[33,39] and a modulation of cortical excitability.[35] While other studies have not been able to clearly demonstrate the effects of these programs on other behavioral dimensions such as social skills, behavior, hyperactivity, and emotional functioning, as their results were inconclusive; thus, the authors emphasized the need to strengthen studies and evidence in this field of study.[31,32]

While some studies address variables associated with self-regulation, such as cognitive self-control mechanisms,[40,44,47] few studies have specifically targeted the impact of physical activity programs on self-regulation skills in children with ADHD. One such study is that of Bowling et al.,[48] who found through correlational analysis that more intense and frequent exercise is associated with better self-regulation and emotional capacity, which also contributed to a decrease in impulsivity and hyperactivity in children with complex behavioral disorders, including a subsample of ADHD.

Sports and physical activity have been shown to have multiple benefits in typically developing children, including improvements in cognitive and executive functions, which have a positive impact on their academic performance,[49] psychological, cognitive, and social benefits such as sleep quality,[50] increased levels of neurotransmitters,[31] cognitive processing speed, increased inhibitory control, and self-regulation skills.[2,51,52]

A growing body of research is exploring the applicability and usability of physical activity interventions for children with ADHD, with substantial evidence supporting their positive effects on various symptom and cognitive dimensions. However, studies investigating the impact of these interventions on self-regulation skills, the ability to delay rewards, and adaptive control in individuals with ADHD remain limited. Though studies evaluating the effect of physical activity interventions on self-regulation skills, the ability to defer rewards, and adaptive control are still scarce, a large part of these studies has focused on a component of self-control mechanisms such as inhibitory control, assessed with instruments such as the Flanker task[44,47] or the Stroop Test.[40] These studies are framed in processes associated mostly with cognitive control and less with behavioral self-control mechanisms. Furthermore, the limited existing studies lack detailed information regarding intervention characteristics and adequate study

details that would enable replication and confirmation of their findings.

Addressing the research gap, the present study aims to contribute to this field of inquiry by designing a physical training program, "HitSportGame," specifically tailored to enhance emotional regulation and behavioral self-control in children with ADHD. Additionally, a randomized controlled trial has been formulated to evaluate the program's effectiveness on the self-control and self-regulation abilities of children with ADHD. In line with this objective, the following hypothesis is proposed: "HitSportGame" (HSG) physical exercise training can lead to improvements in the behavioral self-regulation skills of children with ADHD.

Method

The current study had an Single-blind RCT (Randomized Controlled Trial), this study had the endorsement of the research center and the bioethics committee of the Autonomous University of Manizales registered in record 135 to 2022. Participants were randomly assigned to 2 study arms, an experimental group and a waitlist group. Pre- and post-intervention measures were administered by an evaluator blinded to the allocation. Randomization was conducted by an external researcher using the OxMaR clinical trial randomization tool; the Spanish version designed by Guillaumes and O'Callaghan.[53]

Participants

Based on the database provided by the Secretariat of Education of Montería (Colombia), 94 families of children with ADHD from public educational institutions in the municipality were invited to participate in the study. Of the families asked, 49 agreed to participate in the study. Once it was verified that the children met inclusion criteria, a total sample of 44 children (girls N = 4, 11%; boys N = 32, 89%) was randomized to one of the study branches (control group and waiting list group). The children had a mean age of 10.5 (SD 1.4) years, aged between 8 and 12 years. Their socioeconomic status was categorized as follows: very low (69.4%), low (27.7%), and medium low (2.8%). As it is typical in this type of study, families and children who agreed to participate in the study signed the informed consent and the informed assent.

Inclusion and Exclusion Criteria

All participants met the following inclusion criteria: 1) fifth-grade boys and girls; 2) 8 to 12 years at the start of the study; 3) with a previous diagnosis of ADHD; (4) attending to public educational institutions; (5) to date, not having started a pharmacological drug; 6) with or without common comorbidities such as oppositional defiant disorder; 7) sign the informed consent and assent. The exclusion criteria were as follows: 1) children presenting with a dual diagnosis with another neurodevelopmental disorder such as intellectual disability or autism spectrum disorder; 2) children with a clinical condition that limits their mobility or participation in physical activity training.

Outcome Measures

To measure the self-control and regulation skills of the participating children, Child and Adolescent Self-Control Questionnaire (CACIA) was applied[54,55] (see Supplemental file). This measurement scale assesses the basic processes and self-control skills necessary for the effective achievement of self-control in children and adolescents and has been successfully implemented in different experimental studies[56,57] including studies in populations with ADHD.[58,59]

CACIA test is a self-report test, which is composed of an 89-item questionnaire that analyzes self-control through 4 scales that were extracted with exploratory factor analysis[54]; 3 positive scales: Personal Feedback (PF), Reward Delay (RD), and Criterial Self-Control (CSC); and a negative one: Processual Self-Control (PSC). CACIA test was applied in groups of 5 children by 2 trained evaluators and was completed by the children individually.

The CACIA test has been shown to have adequate consistency with a Cronbach's alpha greater than 0.7 in 3 of its scales (PF = 0.79; PSC = 0.76; RD = 0.71) and 0.50 on the Criterial self-control scale.[54] The stability of the CACIA test has been evaluated through Test-Retest in a sample of 111 subjects showing satisfactory stability coefficients with values above 0.64 for 3 of the scales (PF = 0.68; PSC = 0.76; RD = 0.69) and 0.51 on the Criterial self-control scale.[54]

This instrument was validated in a sample of 949 children from grades fifth to eighth.[55] Construct validity was extracted through factor analysis and Varimax rotation, from which the 4 factors that make up the test were extracted. The discriminant validity between the subscales was analyzed through correlational analysis; the scales showed sufficient independence from each other to evaluate the constructs they intend to measure.

The CACIA subscales demonstrated adequate criterion validity when comparing the results with other tests that measure associated constructs, such as the RAVEN matrix test, the EPQ-J test, Birleson depression scale, anxiety inventory, internal questionnaire. external and

the inventory of irrational beliefs. The findings showed that the subscales had sufficient predictive validity.[55]

Personal feedback (PF). Personal feedback refers to the person's ability to observe and self-monitor their own behavior, to be aware of their own actions and their consequences, which allows them to evaluate their performance, judge their own actions, have an interest in knowing their own motivations, and explain the reason for their behavior. This scale, composed of 21 items, is positive, that is, the higher the score, the greater the personal feedback.

Reward delay (RD). This scale, composed of 19 items, measures the ability to control impulsive reactions, adhere to rules and goals, prioritizing the sense of duty over pleasure, which allows the subject to prioritize important tasks over gratifications and attractive stimuli. Therefore, people with a high score on this scale tend to show more organized behavior.

Criterial self-control (CSC). The Criterial Self-Control Scale (CSC) measures the subject's ability to endure unpleasant situations. It is associated with greater resistance to stress, tolerance to frustration, and situations that demand a high emotional or cognitive effort, as well as greater personal responsibility. This scale is composed of 10 items.

Processual self-control (PSC). The Processual Self-Control subscale measures 3 aspects of self-control behavior: self-evaluation, self-gratification, and self-punishment. Processual self-control allows subjects not only to evaluate and judge their own behavior based on environmental demands, but also to act accordingly and assume the consequences of their actions with self-determination. This scale has 25 items and is the only negative scale of the Child and Adolescent Self-Control Questionnaire, which means that the higher the score, the lower the procedural self-control skills.

Procedure

The Hit-Sport-Game (HSG) training program[60] lasted 12 weeks and had a frequency of 3 times a week. The program included a variety of components related to physical fitness and physical exercise, in addition to sports that address elements such as strength, speed, flexibility, and endurance, and activities that stimulate academic performance such as emotional regulation and self-control.

Likewise, the implemented program included a macrocycle comprised of 3 mesocycles and 12 microcycles of 3 sessions each, with a duration of 45 minutes, where the following components were tackled: volume (number of repetitions, sets, and exercise), density (ratio, work time, and pause time), frequency, number of weekly sessions, and duration (total time of the session).[61] In addition, physical-sports activities focused on improving strength, speed, endurance, coordination, balance, and flexibility were incorporated.

On the other hand, it was necessary to indicate that the program is organized into a macrocycle of 3 mesocycles. The first is adaptation with 4 microcycles: 3 adaptations and 1 shock with 3 sessions per week each. The second developing mesocycle consists of 4 microcycles: 3 shocks and 1 recovery, with 3 sessions per week each. The third is a stabilizing mesocycle with 4 microcycles: 2 shocks and 2 recoveries with 3 sessions per week each (see Figure 1).

Similarly, the structure of the session introduced a general warm-up for 10 minutes, followed by the core component of the session of 25 minutes for the first 2 weeks, 30 minutes for weeks 3 and 6, and 35 minutes for weeks 7 and 12. Finally, there is a return to calm with stretching and relaxation activities. Then 3 weekly sessions were worked on Wednesdays, Fridays, and Saturdays. Finally, all sessions were implemented and supervised by a professional group in physical education, recreation, and sport.

Lastly, intensity was estimated with the EPInfant scale for measuring children's perceived exertion,[60] which has been validated. The EPInfant scale comprises 11 numerical descriptors (0-10) and includes 5 verbal descriptors for each of the 2 intensity levels. It is complemented by a series of figures depicting a child running at increasing intensity along an incremental bar height scale.[60] The work was conducted at intensities between 60% and 90% with endurance exercises, strength, speed, flexibility, coordination, balance, body scheme, and movement patterns, as well as cardiorespiratory exercise in HIIT mode and pre-sports games such as swimming, cycling, and karate. In addition, strength training at moderate-low intensity and the modality of strength stations or circuits with self-loading were implemented. Finally, it should be noted that the children on the waiting list were able to participate in the intervention once the post-test of the experimental group was completed.

Data Analysis

In order to know the effect of the HSG intervention on the self-regulation and control skills of the participating children, a hypothesis test with analysis of variance of repeated samples (ANOVA-MR) was carried out, through which intra-subject and inter-subject analyses

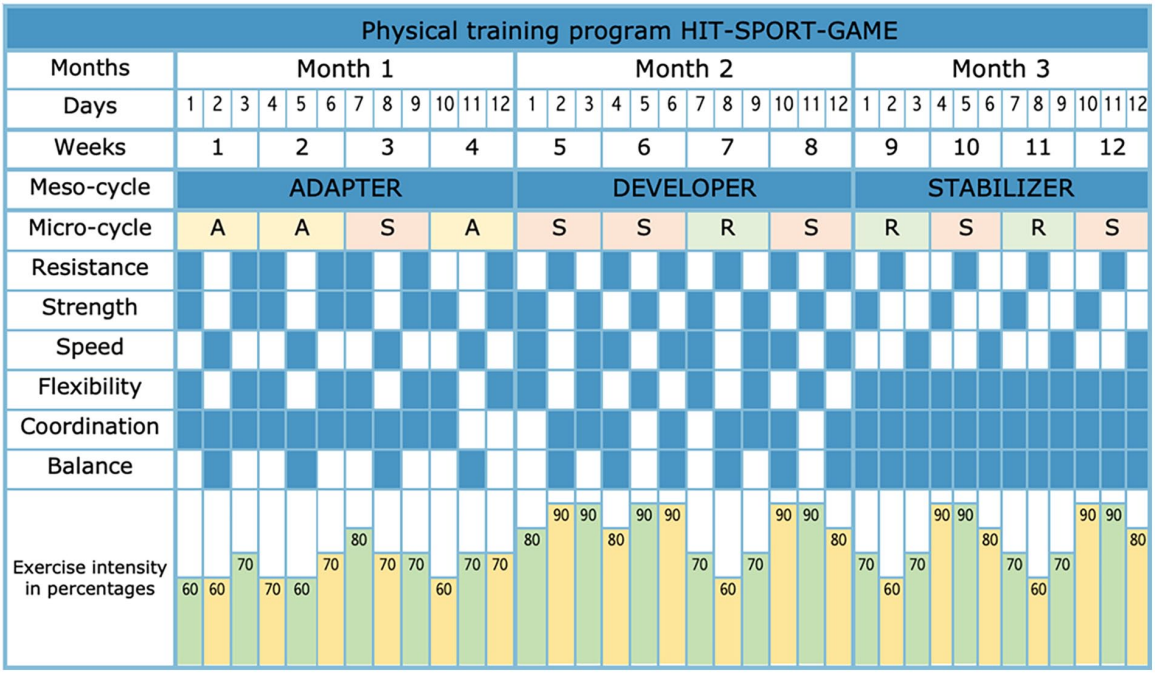

Figure 1. Physical training program Hit-Sport-Game.
A: Adaptation; S: Shock; R: Recovery.

were performed. To measure the effect size, a partial Eta squared was used. To interpret the results of this test, a partial Eta squared value close to 0.01 is considered low, 0.06 is considered medium, and a value greater than 0.14 is considered large. As this was a parametric test, it was first verified that the samples met the criteria of normality and homoscedasticity.

Results

Of the initial sample of 44 children, 8 did not complete the post-test evaluation; 2 belonged to the experimental group and discontinued treatment because they moved to other cities. Of the control group, 6 children did not complete the post-test due to various conditions such as moving to another city, logistical difficulties, or desistance to continue to participate. The final sample consisted of 36 children: 16 from the control group and 20 from the experimental group (Figure 2).

The scores of the indicators to assess self-control met the assumptions of normality and homoscedasticity for the pretest and post-test in all measures ($P > .05$). A comparison of mean performance scores is shown in Figure 3, indicating that no statistically significant differences were observed between the groups in pre-training measures of self-control.

The statistical analyses revealed no significant overall differences between the experimental and control groups ($F(1, 43) = 0.61$, $p = .388$, $\eta^2_p = 0.78$; Table 1). However, a significant within-group difference was observed, with a large effect size, between the pretest and posttest assessments ($F(1, 43) = 21.314$, $p < .001$, $\eta^2_p = 0.326$). Additionally, a significant interaction emerged between the test time and the group ($F(1, 43) = 9.870$, $p = .003$, $\eta^2_p = 0.183$), indicating that the change over time differed significantly between the experimental and control groups. These findings were further corroborated by the post hoc tests (Table 2), which specifically demonstrated a significant difference between the pretest and posttest scores of the experimental group ($t = -5.214$, $p < .001$). These findings suggest that the intervention led to improvement in the personal feedback capacity of children with ADHD.

The reward delay measure showed no significant difference between groups ($F(1, 43) = 0.668$, $p = .418$ $\eta^2_p = 0.015$), neither between the pretest and the post-test ($F(1, 43) = 1.601$, $P = .212$ $\eta^2_p = 0.035$); last, no significant differences were observed when reviewing the interaction between the group and the test ($F(1, 43) = 2.760$, $P = 104$ $\eta^2_p = 0.059$; Table 1). These findings were further corroborated by the post hoc tests that reported the pre-test and post-test differences ($t = -2.736$

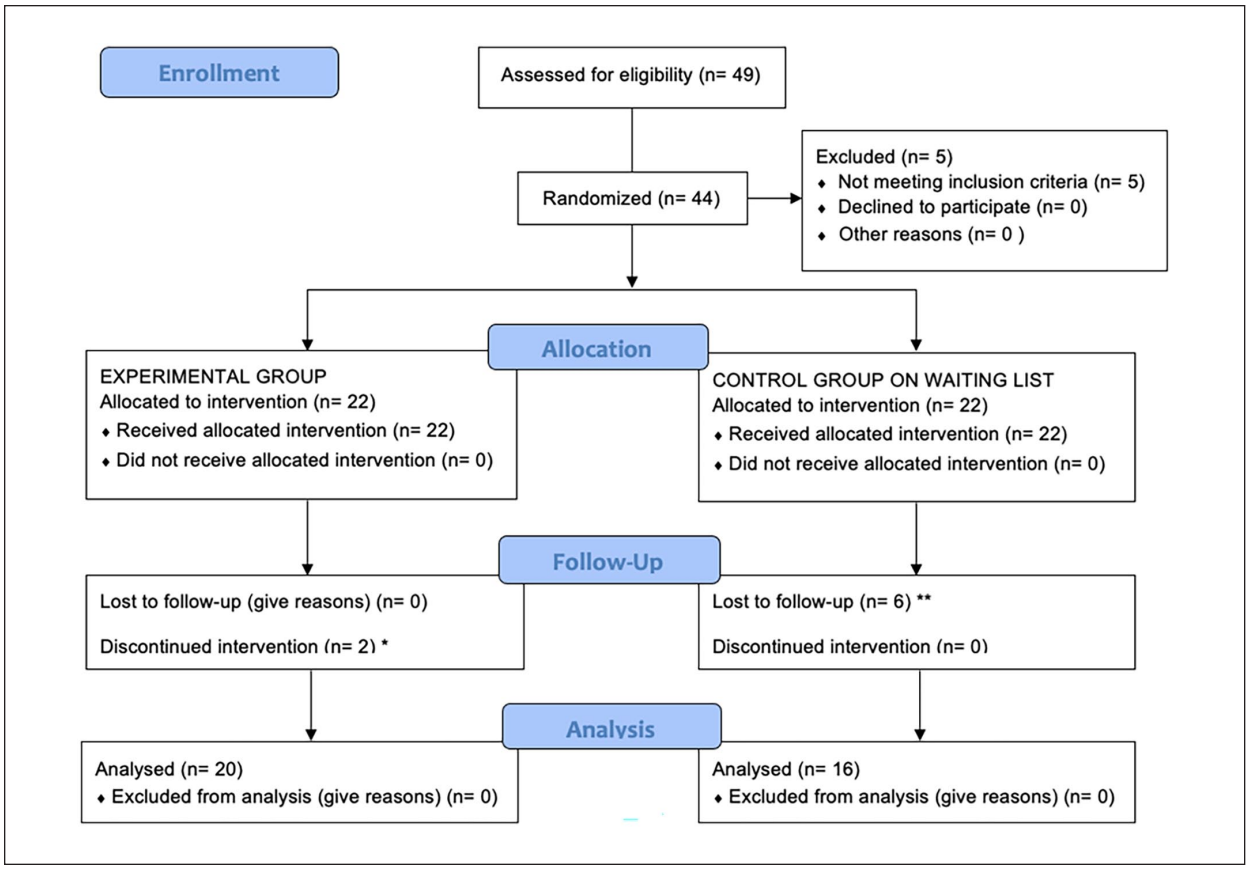

Figure 2. CONSORT diagram.

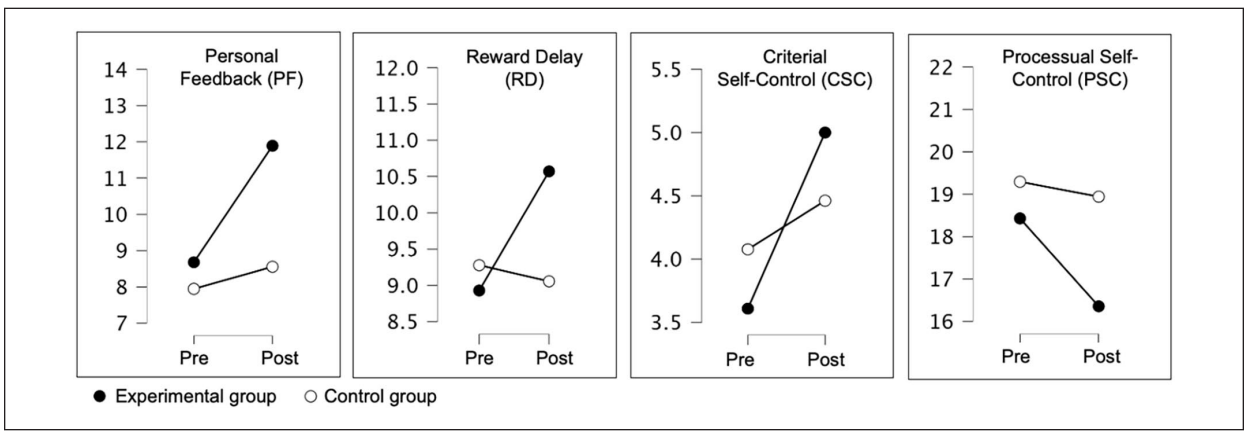

Figure 3. Pre-test and post-test results for each subscale of the Child and Adolescent Self-Control Questionnaire.

P=.059; Table 2). Therefore, the intervention did not show to influence the ability to delay rewards in participating children.

The criterial self-control showed no significant difference between groups ($F(1, 43)$=0.737 p=.614 η^2_p=0.008), while showed a significant overall difference between the pretest and the post-test with a large effect size ($F(1, 43)$=13.382 p=.001 η^2_p=0.282), an associated difference in the interaction between the group and the test; it also showed a significant difference with moderate to large effect size ($F(1, 43)$=7.593 p=.029 η^2_p=0.112; Table 1). The findings are further complemented by the pre-test and post-test differences observed in the experimental group of the post hoc tests

Table 1. Effect Size for Each Subscale of the CACIA Scale.

	Overall difference between pretest and posttest			Difference associated to group-test interaction			Between subjects effects		
Task/measure	F(1, 43)	*P*	η^2_p	F(1, 43)	*P*	η^2_p	F(1, 43)	*P*	η^2_p
PF	21.314	***<.001***	0.326	9.870	***.003***	0.183	3.71	.061	0.078
RD	1.601	.212	0.035	2.760	.104	0.059	0.668	.418	0.015
CSC	13.382	***.001***	0.282	7.593	***.029***	0.112	0.737	.614	0.008
PSC	11.000	***.002***	0.204	6.474	***.015***	0.131	2.807	.101	0.061

Abbreviation: PF, personal feedback; RD, reward delay; CSC, criterial self-control; PSC, processual Self-control.
Note. Values in bold are the p-values of the measures that show a statistically significant difference.

Table 2. Diferencias Pretest y Postest Intragrupales (Pruebas Post Hoc).

Task/measure	Group	Mean difference	SD	*t*	Tukey	Bonf
PF	Experimental	−3.304	0.634	−5.214	**<0.001**	**<0.001**
	Control	−0.462	0.843	−0.548	0.947	1.000
RD	Experimental	2.087	0.763	−2.736	**0.046**	0.059
	Control	0.462	1.015	0.455	0.968	1.000
CSC	Experimental	−1.130	0.342	−3.304	**0.012**	**0.014**
	Control	−0.077	0.455	−0.169	0.998	1.000
PSC	Control	−2.522	0.856	−2.946	**0.028**	**0.035**
	Experimental	0.538	1.139	0.473	0.965	1.000

Abbreviations: DS, standard deviation; t, Student's t-test; Tukey, Tukey's test; Bonf, Bonferroni correction.
Note. Figures in bold are the Tukey and Bonferroni tests values of the measures that show a statistically significant difference.

(t=−3.304; p=.014; Table 2). These findings suggest that physical training improved the criterial self-control of children with ADHD.

Similar results were observed on the Processual Self-Control Scale (Table 1). This scale did not show any significant differences between the groups ($F(1, 43)$=2.807, p=.101, η^2_p=0.061), while it did show significant changes between the pretest and the post-test with large effect size ($F(1, 43)$=11.00, P=.002, η^2_p=0.204*);* when examining the association between the group and the test, a significant change was demonstrated with moderate to large effect size ($F(1, 43)$=6.474, p=.015, η^2_p=0.131). The statistically significant pre-test and post-test differences observed in the experimental group of the post hoc tests provide corroboration for these findings (t=−2.946; p=.035), suggesting that physical training led to improvements in the study participants' processual self-control.

Discussion

One of the core features of ADHD is an alteration in executive functioning.[7,62,63] Executive functioning is at the heart of all human activities, especially those directed toward goals, since it is crucial for directing, controlling, and regulating both cognitive operations and emotional and behavioral aspects.[64] Executive functions are precursors to successful Self-Regulation[28,65]; therefore, they are crucial for school learning, following instructions, adhering to rules, and general functioning in daily life.

These regulatory skills are acquired progressively throughout life. Nonetheless, in people with ADHD, their development is clearly affected, which is expressed in difficulty managing and organizing their own behavior, a diminished ability to respond to daily demands, problems in guiding and monitoring their actions, projecting their consequences in the future, regulating their emotional, attentional, and motivational states, as well as inhibiting impulses and postponing gratification.[5,25]

In this vein, supporting the development of self-agency and behavioral self-control is a key goal for educational and clinical interventions in children with ADHD. Current research suggests that specific modalities of physical activity can positively impact certain aspects of self-control, particularly cognitive control, in children diagnosed with ADHD. In the study by de Liang et al,[38] an aerobic exercise intervention led to improvements in the performance of inhibitory control measured with the Flanker task in reaction time (P=.001, η^2=0.23) and inhibition (P=.001, η^2=0.15). Similar to these findings, a daily 14-minute intervention of moderate to vigorous exercise had significant beneficial effects on reaction times in inhibition (P=.022, η^2_p=0.117) and

change ($P=.024$, $\eta^2_p=0113$), also measured with Flanker task,[46] while the study by Kadri et al.[40] found improvements in attentional inhibitory control measured with the Stroop test ($d=2.16$ [95% CI 1.10-3.26], $P<.001$).

However, as mentioned above, these studies focused on cognitive control processes and not on behavioral self-control. The current study sought to provide evidence on the effects of physical activity not only on the symptoms or cognitive variables of children with ADHD but also on behavioral self-control mechanisms. In response to this problem, this randomized controlled study aimed to evaluate the effect of a physical activity intervention called Hit-Sport-Game on the self-control skills of children with ADHD.

For the present study, a multicomponent physical activity program titled HitSportGame was developed. The design of this intervention was grounded in the findings of previous studies involving ADHD populations. These studies have demonstrated the effectiveness of physical activity programs in reducing inattentive and hyperactive behaviors in children, with programs of moderate-to-high intensity yielding superior outcomes compared to low-intensity programs.[39,66,67] Additionally, moderate-to-high intensity programs have been shown to contribute to the reduction of oppositional behaviors in preschoolers with ADHD.[68] Furthermore, studies have reported more favorable outcomes for programs that incorporate both physical and cognitive demands, such as the Exergame program.[46]

Based on these prior findings, the multicomponent physical activity program HitSportGame was structured in 3 guidelines articulated with each other: training with high-intensity hit physical exercise, sport as a formative and norm-regulating element, and play as a motivational substrate for the development of the potential of physical-cognitive and motor stimuli. The distinctive methodology of the HitSportGame program lies in the carefully crafted training phases. Recognizing the emotional dysregulation, low frustration tolerance, and potential dropout rates among children with ADHD, the program commences with an intensity of 60% in the initial phases, gradually increasing to 90% in the final phases. This approach effectively addresses the unique challenges faced by children with ADHD, promoting adherence and maximizing training outcomes. The program was developed 3 times a week for 12 weeks, where 3 phases of training called adaptation, development and maintenance were developed.

From the results, it could be observed that the children who participated in the intervention showed better performance in some of the self-control skills measured with the Child and Adolescent Self-Control Questionnaire (positive feedback, criterial self-control, procedural self-control) compared to the children in the control group on the waiting list.

The scale that showed the greatest change associated with the intervention was personal feedback ($P=.00$; $\eta^2_p=0.183$). Children in the experimental group had significantly higher scores than children in the control group. This increase in personal feedback scores indicates an improvement in children's ability to know themselves, to realize the consequences of their own actions, and an increase in interest in understanding the reasons that determine behavior. Other behaviors associated with personal feedback include the ability to remember rules, commit to their own goals, recognize what is right or wrong, and be aware of what reassures or disturbs them.[54]

In an earlier study[65] found statistically significant differences in the Personal Feedback Scale score of Child and Adolescent Self-Control Questionnaire -CACIA- between children with ADHD who engaged in physical activity every week ($P=.005$) and those who engaged in physical activity every day ($P=.029$) compared to children who did not engage in physical activity. Their findings also showed that children whose parents played sports in their free time scored higher on this scale ($P=.037$).

The current results align with previous research conducted on neurotypical populations. A similar study[52] found significant changes with a moderate effect size ($P<.00$; $d=0.49$) in the CACIA personal feedback scale for the experimental group following an educational intervention in physical activity. Furthermore, a prior correlational study employing linear regression[69] provided additional support. This study revealed a significant positive correlation between CACIA personal feedback scale scores and physical activity engagement in children with antisocial behaviors. Children who engaged in physical activity weekly ($P=.005$) or daily ($P=.029$) exhibited higher scores compared to those who did not participate in physical activity. Interestingly, the study also found that children whose parents engaged in leisure-time physical activity had higher scores on this scale ($P=.037$). These collective findings underscore the consistent and positive association between physical activity and personal feedback perception in neurotypical children, in children with disruptive behaviors and based on the current study, also in children with ADHD.

HSG intervention activities continuously reinforce the child's capacity for personal feedback. On the one hand, it increases awareness of one's own physical effort, as it requires the child to identify the rules of the game and monitor their ability to respond to them. In

this regard, 3 key points are presented. The first is inhibition, since to perform adequately in the activities of the Hit-Sport-Game program, the child needs to learn to inhibit or censor some of the predominant impulsive responses of ADHD. In the same way, it helps to control attention. The second is the change between tasks or mental sets, associated with flexibility, while the development of physical activities based on circuits sets in motion the child's ability to change the set of rules for an adequate execution of the circuit. The third has to do with working memory, which accounts for the retention and processing of information; in this case, keeping instructions for as long as necessary until a task is completed.

Another scale that showed a significant increase in the experimental group compared to the control group was the Criterial Self-Control; the effect size associated with this change was moderate ($P = .090$; $\eta^2_p = 0.064$). The study by Smith-Palacio et al[52] also found that neurotypical children who participated in a physical activity education program exhibited improvements in their criterion-based self-control ($P < .00$; $d = 0.20$); however, this effect was of small magnitude. A high score on the CSC scale reflects those subjects improved their resistance to stress and tolerance in threatening situations, exhibiting safety behaviors in situations where other children would be frightened or avoided, and indicating the ability to endure unpleasant situations.

Within the framework of this intervention, the activities carried out by the children included a plan where aspects such as the ability to await their turn, resist sustained effort, learn to tolerate frustrating situations as a team, and strategically face stressful situations through the development of physical abilities (strength, speed, endurance, flexibility, and coordination) were trained. Added to this is the integration of recreational activities that involve components of physical fitness such as intensity, volume, duration, and weekly frequency that involved diversified games articulated to the technical gestures of sports such as boxing, cycling, swimming, table tennis, and athletics, which have shown improvements in the regulatory components of behavior.[70-72]

In this sense, considering the relationship between the physical and the mental, the particularity of the population with ADHD plays an important role for medical and educational science. The challenge embarks on the differentiation of the voluntary versus the involuntary kinesthetic gesture, that is, the inquiry into the purpose of movement as a vehicle for knowledge and not merely the biological response of a special condition. This leads to a discussion about whether it is just about moving the body or the link between the movement, how we are moving, and what is generated by the movement. To the extent that the subject modifies his or her levels of arousal, the trainer adapts the thresholds of demand. In this context, according to the results obtained, the practice of these activities in the field of sports training has a moderate impact on this dimension of self-control in the child's behavior.

Processual self-control was also a scale that showed a moderate to large effect after the intervention in the experimental group compared to the control ($P = .015$ $\eta^2_p = 0.131$). In general, the children in the experimental group had significantly lower scores in the pretest than in the post-test, and this change was differential when compared to the post-test of the control group. In contrast to the observed improvements in criterion-based self-control, similar studies conducted on neurotypical populations found no significant differences in procedural self-control ($p = .55$; $d = 0.104$) following a physical exercise program.[52] This lack of effect was also observed in correlational studies employing the CACIA scale.[65] This is a negative scale, so the lower the score, the greater the child's capacity for self-evaluation and self-criticism, the better they accept external feedback, the greater their interest in complying with the rules, and the greater their awareness of achievements and failures. The latter would be associated with the ability to self-reinforce or self-reproof.

In the practice of HSG training, it is possible to recognize aspects that contribute to the development of processual self-control. For example, when designing a physical, motor, and ludic task, intrinsic and external objectives are pursued and conscious and regulated active participation is expected, which makes the individual susceptible to acknowledge accomplishments and failures at any time. In this sense, ludic allows for non-punitive feedback for the subjects to sustain themselves in the activity within the framework of its development.

The results are consistent with previous studies that sought to strengthen self-control through an educational intervention in physical activity in typically developing children.[52,73-75] Some of the interventions studied have been based on the Delphi program, which involves "personal and social responsibility" in physical education classes. Among them, 2 studies in children aged 11 to 13 years evaluated the effect of an Intervention incorporated into physical education classes of 20 sessions based on the Delphi Program on the self-control skills measured with the Child and Adolescent Self-Control Questionnaire; the findings showed significant effects on all scales of the test, especially on personal feedback and criterial self-control.[2,52] The authors conclude that educational interventions in physical activity can generate positive transfer in the process of obtaining self-control.

Another randomized controlled study that implemented the same questionnaire as an outcome measure to evaluate the effect of a Delphi-based physical activity intervention on 13- and 14-year-old children found significant improvements in self-control with large effect sizes across all the questionnaire scales ($\eta^2 > 0.33$; $P < .001$, a value above 0.14 is considered a large effect).[70] In another study, the same authors integrated a sports activity program (soccer) with the Delphi program and evaluated its effect on children at risk of exclusion due to aggressiveness and disruptive behavior; children showed improvements in all self-control skills.[74,75]

These studies provide evidence of how structured physical activity interventions with content aimed at children's self-regulation are favorable for the self-control of typically developing children. Our results contribute to this corpus of study by presenting evidence of the effects of structured physical activity training Hit-Sport-Game, leading to improvements in some children's self-control skills in children with ADHD.

However, HSG training failed to have a statistically significant effect on reward delay skills in this population ($p = .104$ $\eta^2_p = 0.059$), unlike previous studies that did find improvements in this component in neurotypical children. Previous studies have also consistently failed to find significant effects of physical exercise programs on reward delay in neurotypical children ($p = .84$; $d = -0.01$).[52] This lack of effect was also observed in correlational studies employing the CACIA scale.[65] The delay to reward is expressed in an adequate ability to stick to objectives, without easily giving in to one's own impulses or attractive stimuli, an improvement in this component of self-control indicates a high capacity to resist impulses, postpone gratifications, and structure their actions toward medium-term goals.

On this aspect, although it is true that the physical and sports activities of the HSG program include elements of planning and organization, they did not reflect improvements in the ability to postpone the satisfaction of rewards in this study. On the contrary, other studies have found that certain interventions in exercise and physical activity led to significant improvements in this self-control skill in children with ADHD, such as the work carried out by Smith-Palacio et al.[52] in which they used the Delphi method together with moral dilemmas to raise reflections on fair play. These findings could also propose a window of discussion on the possibility of integrating other social and cognitive components into physical activity interventions, which invite to cognitively mediate behavioral responses in a way that is better projected to the consequences and, therefore, to sports' (or play) goals as a strategy to facilitate the postponement of immediate satisfaction in the child with a view to achieving medium-term achievements.

The present study possesses several strengths that enhance the robustness of its findings. These include the randomized allocation of participants to groups, the blinding of the evaluator to both the allocation of subjects and the type of intervention to be implemented. However, the study also presents some limitations. One such limitation is the high dropout rate (17%), particularly in the control group (N = 6). This phenomenon is associated with the characteristics of the target population, which consisted of children with ADHD from low-income backgrounds who were not affiliated with any treatment center. Due to their socioeconomic conditions, many of the families tend to change their place of residence frequently.

Our investigation offers significant novel findings to this field of study. Firstly, it stands as one of the few studies that sought to evaluate the impact of physical activity on children with ADHD on behavioral variables directly associated with self-regulation skills, such as reward delay, self-feedback, criterial self-control, and procedural self-control. In contrast, previous studies have opted to examine variables of a more cognitive nature that, while involving self-control mechanisms, do not account for whether the child has improved their ability to regulate behavior. However, as a behavioral variable, it is only possible to express oneself through observed or self-reported behavior, as has been done in other similar studies that have sought to evaluate the effect of physical training on behavioral aspects of children with ADHD.[66,67] Consequently, in the present investigation, it was necessary to use a self-report measure such as the CACIA scale to report the self-regulation skills of the participating children. Nevertheless, as a subjective measure reported by the children themselves, it presents a greater risk of bias than objective measures.

Given the aforementioned considerations, a cautious interpretation of the study's findings is warranted, and replication in future studies with larger sample sizes is encouraged. Additionally, the study highlights the need for validated measures to assess behavioral variables associated with self-control and self-regulation. Currently, the CACIA scale is the only validated instrument available in Spanish. Consequently, one direction for future research is the design and validation of more objective measures, potentially task-based measures, that allow for the observation of children's behaviors and thus their ability to self-regulate their actions.

Conclusions

The multicomponent physical activity program "HitSportGame" was shown to lead to improvements in some dimensions of self-control measured with the

Child and Adolescent Self-Control Questionnaire, namely, personal feedback, criterion self-control, and procedural self-control compared to a wait-list control group, although it did not show significant effects on the reward delay variable. Based on the results, the hypothesis is confirmed that "HitSportGame" (HSG) physical exercise training can have a favorable effect on the self-regulation of behavior of children with ADHD. These findings show the potential and relevance of integrating physical activity into the framework of intervention and care for children with ADHD as an adjunctive treatment to strengthen children's behavioral self-control skills.

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CRediT author statement

Mariano Jairo Salleg-Cabarcas: Conceptualization, Investigation, data collection, Resources, methodological design, intervention design, Writing—original, Project administration. Carolina Robledo-Castro: conceptualization, measurement selection, Data curation, Writing—original draft, Writing—review & editing. Claudia Patricia Monsalve-Vertel: Conceptualization, Investigation, Writing—review.

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Human Subjects Approval Statement

The study has been formulated following the ethical measures for human studies indicated in the Helsinki Declaration and in Resolution 8430 of 1993 of the Ministry of Health of Colombia. All participants signed the informed consent and assent and were notified of the objectives of the study and the procedures in which they would participate. The study was previously approved and endorsed by the bioethics committee of the Autonomous University of Manizales through Act 135 issued on July 13, 2022.

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Supplemental Material

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References

1. Black DW, Grant JE. *DSM-5 Guidebook*. American Psychiatric Pub; 2014.
2. Smith-Palacio E, Bermejo-García S. Effectiveness of the development of self-control through physical education. *Revista Iberoamericana de Ciencias de la Actividad Física y el Deporte*. 2019. doi:10.24310/riccafd.2021.v10i2.11160
3. Cancio S, Ionela M. *Beneficios del ejercicio físico en niños con TDAH: Una revisión sistemática*. Degree Thesis. University of Oviedo; 2021. https://digibuo.uniovi.es/dspace/bitstream/handle/10651/62856/TFG_MariaIonelaPopescu.pdf?sequence=6#:~:text=En%20los%20ni%C3%B1os%20con%20TDAH,y%20bajo%20tiempo%20de%20reacci%C3%B3n
4. Robledo-Castro C. *Trastorno por déficit de atención e hiperactividad: Algunas preguntas y respuestas*. Universidad del Tolima; 2018.
5. Barkley RA. *Attention-Deficit Hyperactivity Disorder*. Guilford Publications; 1990.
6. Barkley R. *Niños Hiperactivos*. Grupo Planeta (GBS); 2002.
7. Brown TE. ADD/ADHD and impaired executive function in clinical practice. *Curr Psychiatry Rep*. 2008;10(5):407-411. doi:10.1007/s11920-008-0065-7
8. Thomas R, Sanders S, Doust J, Beller E, Glasziou P. Prevalence of attention-deficit/hyperactivity disorder: A systematic review and meta-analysis. *Pediatrics*. 2015;135(4):e994-1001. doi:10.1542/peds.2014-3482
9. Willcutt EG. The prevalence of DSM-IV attention-deficit/hyperactivity disorder: a meta-analytic review. *Neurother*. 2012;9(3):490-499. doi:10.1007/s13311-012-0135-8
10. Valda V, Suñagua R, Coaquira R. Estrategias de intervencion para niños y niñas con TDAH en edad escolar. *Rev de Investig Psicol*. 2018;20(3):119-134. https://www.semanticscholar.org/paper/d35bea18f9526698349e0577a7066fe794bb66d5
11. Kopp CB. Antecedents of self-regulation: A developmental perspective. *Dev Psychol*. 1982;18(2):199-214. doi:10.1037/0012-1649.18.2.199
12. Vohs KD, Baumeister RF. *Handbook of Self-Regulation: Research, Theory, and Applications*. Guilford Press; 2017.
13. Baumeister R, Monroe A. Recent research on free will: conceptualizations, beliefs, and processes. *Adv Exp Soc Psychol*. 2008;50(4):1-52. doi:10.1016/B978-0-12-800284-1.00001-1
14. Baumeister RF, Vohs KD. *Handbook of Self-Regulation. Research, Theories, and Applications*. Guildford Press; 2004.
15. Bronson MB, Bronson M. *Self-Regulation in Early Childhood*. Guilford Press; 2001.
16. Carvers CS, Scheier MF. Self-regulation of action and affect. In: Vohs KD, Baumeister RF, eds. *Handbook of*

Self-Regulation: Research, Theory, and Applications. Guilford Press; 2021:3-21.
17. Gómez-Pérez O, Calleja-Bello N; Universidad Nacional Autónoma de México, Universidad Nacional Autónoma de México. Regulación emocional: definición, red nomológica y medición. *Rev Mex de Investig Meded Psicol*. 2016;8(1):96-117. https://www.medigraphic.com/pdfs/revmexinvpsi/mip-2016/mip161g.pdf
18. Murray D, Rosanbalm K. *Promoting Self-Regulation in Adolescents and Young Adults: A Practice Brief* (OPRE Report 2015-82). Office of Planning, Research and Evaluation, Department of Health and Human Services.
19. Reid R, Trout A, Schartz M. Self-regulation interventions for children with attention deficit/hyperactivity disorder. *Except Child*. 2005;71(4):361-377. https://www.semanticscholar.org/paper/9e0a5b0caa2676961938d914ac4df818da65db9e
20. McClelland MM, Cameron CE. Self-regulation in early childhood: improving conceptual clarity and developing ecologically valid measures. *Child Dev Perspect*. 2012;6(2):136-142. doi:10.1111/J.1750-8606.2011.00191.X
21. Zelazo PD, Müller U. Executive function in typical and atypical development. In: Goswami U, ed. *Handbook of Childhood Cognitive Development*. Blackwell; 2002:445-469.
22. Bauermeister JJ. *Hiperactivo, Impulsivo, Distraído ¿Me Conoces?* Guilford Publications; 2014. https://play.google.com/store/books/details?id=nGWaAgAAQBAJ&source=gbs_api
23. Nigg JT. Neuropsychologic theory and findings in attention-deficit/hyperactivity disorder: the State of the field and salient challenges for the coming decade. *Biol Psychiatry*. 2005;57(11):1424-1435. doi:10.1016/j.biopsych.2004.11.011
24. Barkley RA. Behavioral inhibition, sustained attention, and executive functions: constructing a unifying theory of ADHD. *Psychol Bull*. 1997;121(1):65-94.
25. Douglas VI. *"Core Deficits" and Contingency Management in Attention Deficit Hyperactivity Disorder*. University at Buffalo Center for Children and Families Speaker Series; 2008.
26. Shiels K, Hawk Lw Jr. Self-regulation in ADHD: the role of error processing. *Clin Psychol Rev*. 2010;30(8):951-961. doi:10.1016/j.cpr.2010.06.010
27. Cibrian FL, Lakes KD, Schuck SEB, Hayes GR. The potential for emerging technologies to support self-regulation in children with ADHD: a literature review. *Int J Child Comput Interact*. 2021;31:100421. doi:10.1016/j.ijcci.2021.100421
28. Robledo-Castro C, Ramírez GR. *Desarrollo de Las Funciones Ejecutivas En La Niñez En Contexto Escolares*. Universidad del Tolima; 2023.
29. Sökmen Z, Karaca S. The effect of self-regulation based cognitive psychoeducation program on emotion regulation and self-efficacy in children diagnosed with attention deficit hyperactivity disorder. *Arch Psychiatr Nurs*. 2023;44:122-128. doi:10.1016/j.apnu.2023.04.005
30. Saif MGM, Sushkova L. Clinical efficacy of neurofeedback protocols in treatment of attention deficit/hyperactivity disorder (ADHD): a systematic review. *Psychiatry Res Neuroimaging*. 2023;335:111723. doi:10.1016/j.pscychresns.2023.111723
31. Chan YS, Jang JT, Ho CS. Effects of physical exercise on children with attention deficit hyperactivity disorder. *Biomed J*. 2022;45(2):265-270. doi:10.1016/j.bj.2021.11.011
32. Dastamooz S, Sadeghi-Bahmani D, Farahani MHD, et al. The efficacy of physical exercise interventions on mental health, cognitive function, and ADHD symptoms in children and adolescents with ADHD: an umbrella review. *eClinicalMedicine*. 2023;62(102137):1-15. doi:10.1016/j.eclinm.2023.102137
33. Kamp CF, Sperlich B, Holmberg H. Exercise reduces the symptoms of attention-deficit/hyperactivity disorder and improves social behaviour, motor skills, strength and neuropsychological parameters. *Acta Pediatrica*. 2014;103(7):709-714. doi:10.1111/apa.12628
34. González G, Ramirez I, Melguizo E, Ubago JL. Importancia de la Actividad Física en jóvenes con tdah. Una Revisión Sistemática. In: González G, Ramirez I, Melguizo E, Ubago JL, eds. *Hacia Nuevos Estándares Educativos Para Una Educación de Calidad*. Dykinson; 2023:11-22.
35. Wang YH, Gau SF, Yang LK, Chang JC, Cheong PL, Kuo HI. Acute aerobic exercise at different intensities modulates inhibitory control and cortical excitability in adults with attention-deficit hyperactivity disorder (ADHD). *Asian J Psychiatr*. 2024;95:103993. doi:10.1016/j.ajp.2024.103993
36. Jacobson R. *TDAH y Ejercicio*. Child Mind Institute; 2021. https://childmind.org/es/articulo/el-tdah-y-el-ejercicio/
37. Kang KD, Choi JW, Kang SG, Han DH. Sports therapy for attention, cognitions and Sociality. *Int J Sports Med*. 2011;32(12):953-959. doi:10.1055/s-0031-1283175
38. Liang X, Qiu H, Wang P, Sit CHP. The impacts of a combined exercise on executive function in children with ADHD: a randomized controlled trial. *Scand J Med Sci Sports*. 2022;32(8):1297-1312. doi:10.1111/sms.14192
39. Suazo DM, Muñoz JN, Lazarraga PC, et al. Mejora de la atención en niños y niñas con TDAH tras una intervención física deportiva dirigida. *Cuad de Psicol Inst Deport*. 2019;19(3):37-46. doi:10.6018/CPD.360451
40. Kadri A, Slimani M, Bragazzi NL, Tod D, Azaiez F. Effect of taekwondo practice on cognitive function in adolescents with attention deficit hyperactivity disorder. *Int J Environ Res Public Health*. 2019;16(2):204. doi:10.3390/ijerph16020204
41. Haffner J, Roos J, Goldstein N, Parzer P, Resch F. The effectiveness of body-oriented methods of therapy in the treatment of attention-deficit hyperactivity disorder (ADHD): results of a controlled pilot study. *Z Kinder Jugendpsychiatr Psychother*. 2006;34(1):37-47. doi:10.1024/1422-4917.34.1.37
42. Sun F, Chow GC, Yu CC, et al. Effect of game-based high-intensity interval training program on the executive function of children with ADHD: protocol of a randomized controlled trial. *PLoS One*. 2022;17(7):e0272121. doi:10.1371/journal.pone.0272121

43. Hattabi S, Forte P, Kukic F, et al. A randomized trial of a swimming-based alternative treatment for children with attention deficit hyperactivity disorder. *Int J Environ Res Public Health*. 2022;19(23):16238. doi:10.3390/ijerph192316238
44. Liang X, Li R, Wong SHS, et al. Physical activity and executive function in children with ADHD: the mediating role of sleep. *Front Pediatr*. 2021;9(775589):1-8. doi:10.3389/fped.2021.775589
45. Miklós M, Komáromy D, Futó J, Balázs J. Acute physical activity, executive function, and attention performance in children with attention-deficit hyperactivity disorder and typically developing children: an experimental study. *Int J Environ Res Public Health*. 2020;17(11):4071. doi:10.3390/ijerph17114071
46. Benzing V, Schmidt M. The effect of exergaming on executive functions in children with ADHD: a randomized clinical trial. *Scand J Med Sci Sports*. 2019;29(8):1243-1253. doi:10.1111/sms.13446
47. Benzing V, Chang YK, Schmidt M. Acute physical activity enhances executive functions in children with ADHD. *Sci Rep*. 2018;8(1):12382. doi:10.1038/s41598-018-30067-8
48. Bowling A, Slavet J, Miller DP, Haneuse S, Beardslee W, Davison K. Cybercycling effects on classroom behavior in children with Behavioral Health Disorders: an RCT. *Pediatrics*. 2017;139(2):e20161985. 10.1542/peds.2016-1985
49. Jarraya S, Wagner M, Jarraya M, Engel FA. 12 weeks of Kindergarten-based Yoga practice increases visual attention, visual-motor precision and decreases behavior of Inattention and hyperactivity in 5-year-old children. *Front Psychol*. 2019;10:796. doi:10.3389/fpsyg.2019.00796. Published 2019 Apr 10.
50. Cabello B. *Diseño de Un Programa de Intervención Para La Mejora de Los Síntomas Derivados de TDAH Desde Una Perspectiva Inclusiva*. Degree thesis. University of Sevilla; 2021. https://idus.us.es/bitstream/handle/11441/131350/Cabello%20Cabello%2C%20Beatriz.pdf?sequence=1&isAllowed=y
51. Bustamante EE, Santiago-Rodriguez ME, Ramer JD, Balbim GM, Mehta TG, Frazier SL. Actividad física y TDAH: evidencia sobre el desarrollo, efectos neurocognitivos a corto y largo plazo y sus aplicaciones. *Pensar Movimiento Rev Cienc Ejercicio Salud*. 2019;17(1):1-28. doi:10.15517/pensarmov.v17i1.37863
52. Smith-Palacio E, Alcalá-Recuero J, Lamoneda-Prieto J. In life as in sport: Implications of a program to educate Spanish youth on values. *Front Educ*. 2022;7(899433):1-10. doi:10.3389/feduc.2022.899433
53. Guillaumes S, O'Callaghan CA. Versión en español del software gratuito OxMaR para minimización y aleatorización de estudios clínicos. *Gac Sanit*. 2019;33(4):395-397. doi:10.1016/j.gaceta.2018.07.013
54. Capafons A, Silva F. *CACIA, Cuestionario De Autocontrol Infantil Y Adolescente*. Cuarta edición. TEA ediciones; 2011.
55. Capafons A, Silva F, Barreto P. Un cuestionario de autocontrol para niños y adolescentes: primeros resultados. *Anal Y Modif de Conduct*. 2013;12:31-32. doi:10.33776/amc.v12i31-32.1750
56. Pina D, Ruiz-Hernández JA, Llor-Esteban B, Matás-Castillo M, Pagán-Escribano M, Puente-López E. "Count on me" program to improve school coexisting in primary education. *Child Youth Serv Rev*. 2021;127:106121. doi:10.1016/j.childyouth.2021.106121
57. Luna-Tascón EG, Gomez-Jojoa JA, Lasso-Belalcazar TJ. Relationship between academic performance and Self-control. *Plumilla Educativa*. 2013;11(1):199-219.
58. Rey-Anacona CA, Paitán-Ávila LC, Monguí-Merchán ZL. Neuropsychological, biographic, psychological, familiar, and communities' differences between female and male adolescents with and without conduct disorder. *Interdicipliaria: journal of psychology and related sciences*. 2014;31(2):275-295. https://dialnet.unirioja.es/servlet/articulo?codigo=5962100
59. Durán R, Bella M. *Intervención en TDAH: un programa de apoyo para padres*. Tesis Universidad Pontificia C omillas; 2022.
60. Salleg M, Ortiz D, Sanchez JA. Mediation of physical exercise on brain electrical activation and heart rate variability in children with attention deficit/hyperactivity disorder. *Educ Psychol*. 2024;44:2.
61. Naclerio Ayllón F, Moody J, Chapman M. Applied periodization: A methodological approach. *J Hum Sport Exerc*. 2013;8(2):350-466.
62. Barkley RA. *Executive Functioning and Self-Regulation: Integration, Extended Phenotype, and Clinical Implications*. The Guilford Press; 2011.
63. Barkley RA, Edwards G. Diagnostic interview, behavior rating scales and the medical examination. In: Barkley RA, ed. *Attention-Deficit Hyperactivity Disorder: A Handbook for Diagnosis and Treatment*. 2nd ed. The Guilford Press; 2011;510-551.
64. Soprano A. Las Funciones Ejecutivas en Niños y Adolescentes: Propuestas de Tratamiento Clínico y Educativo. *Rev Neuropsicol Neuropsiquiatr Y Neurocienc*. 2021;21(1):1.
65. Kalbfleisch L. Neurodevelopment of the executive functions. In: Goldberg E, ed. *Executive Functions in Health and Disease*. Academic Press; 2017:143-168.
66. Ganjeh P, Meyer T, Hagmayer Y, et al. Physical Activity improves mental health in children and adolescents irrespective of the diagnosis of attention deficit hyperactivity disorder (ADHD)-A multi-wave analysis using data from the KiGGS study. *Int J Environ Res Public Health*. 2021;18(5):1-15.
67. Chen K, Phipps S. "Why can't you sit still?" The effect of daily physical activity on childhood inattention/hyperactivity and the educational gender gap. *Soc Sci Med*. 2021;284(114232):1-8.
68. Hoza B, Shoulberg EK, Tompkins CL, et al. Moderate-to-vigorous physical activity and processing speed: predicting adaptive change in ADHD levels and related impairments in preschoolers. *J Child Psychol Psychiatry*. 2020;61(12):1380-1387.
69. López C, Freixinos M, López J. Delayed gratification and self-control in antisocial youths: gender-associated characteristics. *Psicopatol Clin Leg Y Forense*. 2003;4(3):5-21.

70. Barrios-Duarte R. Autorregulación emocional en el deporte y la actividad física: una propuesta metodológica para su enseñanza. *Efdeportes*. 2014;19(296):195.
71. Englert C, Graham JD, Bray SR. Self-control in sport and exercise psychology. *Sport Exerc Perform Psychol*. 2020;9(2):161-166. doi:10.1037/spy0000205
72. Englert C. The strength model of self-control in sport and exercise psychology. *Front Psychol*. 2016;7:314. doi:10.3389/fpsyg.2016.00314
73. Cecchini J, Losa J, González C, Arruza J. Effect of the Delfos Program of Education in Values Thrugh Sport in Studentes. *Rev Educ*. 2008;346:167-186. https://tinyurl.com/y5m67rpc5
74. Cecchini JA, Montero J, Alonso A, Izquierdo M, Contreras O. Effects of personal and social responsibility on fair play in sports and self-control in school-aged youths. *Eur J Sport Sci*. 2007;7(4):203-211. doi:10.1080/17461390701718497
75. Valiente-Barroso C. Health habits, behavioural self-control and academic performance. *Procedia Soc Behav Sci*. 2014;132:216-221. doi:10.1016/j.sbspro.2014.04.301