

Executive Function Development Through Physical Education: A Pedagogical and Cognitive Perspective in School Contexts.

Desarrollo de las Funciones Ejecutivas a través de la Educación Física: Una Perspectiva Pedagógica y Cognitiva en Contextos Escolares.

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Abstract: Adolescence is a critical period for the development of executive functions. Physical education and sports can contribute to cognitive control, but studies in North Africa are scarce. A descriptive–correlational study was conducted with 144 secondary school students (72 boys and 72 girls, mean age 15.8 ± 1.2 years; height 166.2 ± 6.8 cm; weight 55.7 ± 8.9 kg) from the 1st year ($n = 18$), the 2nd year ($n = 63$), and the 3rd year ($n = 63$). The assessment of executive functions: working memory, attention/inhibitory control, cognitive flexibility, planning/organization, and emotional regulation was through a structured questionnaire administered to the subjects. Data analyses were performed using t-tests, ANOVA, Pearson correlation, and simple regression analyses. Sport practice has a positive correlation with total executive function ($r = 0.381$; $p < 0.05$) and explains about 15% of its variance ($R^2 = 0.149$), mainly for planning/organization ($R^2 = 0.157$; $p < 0.001$). Male participants scored higher in attention/inhibitory control and planning/organization compared to females, while physically active students achieved higher scores in planning/organization ($p = 0.015$) and emotional regulation ($p = 0.043$). The findings suggest that structured physical activities within school settings can improve executive functioning among adolescents, particularly in domains related to self-regulation.

Key Words: Physical education; Executive functions; cognitive development; self-regulation; school context

Resumen: La adolescencia es un periodo crítico para el desarrollo de las funciones ejecutivas. La Educación Física y el deporte controlan el rendimiento cognitivo, pero existen pocos estudios en este sentido en África del Norte. Se realizó un estudio descriptivo-correlacional con 144 alumnos de secundaria (72 chicos y 72 chicas; edad media $15,8 \pm 1,2$ años; talla $166,2 \pm 6,8$ cm; peso $55,7 \pm 8,9$ kg) de 1.º ($n = 18$), 2.º ($n = 63$) y 3.º ($n = 63$) ciclo. Las funciones ejecutivas (memoria de trabajo, atención/ control inhibitorio, flexibilidad cognitiva, planificación/ organización y regulación emocional) fueron estudiadas a través de un cuestionario estructurado autoadministrado a los sujetos participantes. Se realizó análisis estadístico mediante pruebas t, ANOVA, correlación de Pearson y regresión lineal simple. La práctica deportiva correlacionó positivamente con la función ejecutiva total ($r = 0,381$; $p < 0,05$) explicando un 15 % de su varianza aproximada ($R^2 = 0,149$), sobre todo en la variable planificación/ organización ($R^2 = 0,157$; $p < 0,001$). Los sujetos masculinos obtuvieron puntuaciones significativamente superiores al control inhibitorio/ atención y a la planificación/ organización que las mujeres y los estudiantes físicamente activos alcanzaron mejores puntuaciones que los no activos físicos en planificación/ organización ($p = 0,015$) y regulación emocional ($p = 0,043$). Los resultados apuntan que la práctica de actividades físicas estructuradas en el entorno escolar incide favorablemente en el desarrollo de las funciones ejecutivas en adolescentes sobre todo en lo relacionado con la autorregulación.

Palabras clave: Educación física; Funciones ejecutivas; Desarrollo cognitivo; Autorregulación; Contexto escolar

Introduction

Executive functions (EFs) represent a core set of higher-order cognitive processes that enable individuals to orchestrate behavior and action towards goals, manage emotional states, and adapt flexibly to dynamic and complex environmental conditions. Commonly, these functions are operationalized as working memory, inhibitory control, cognitive flexibility, planning, and emotional regulation (Best & Miller, 2010; Diamond, 2013). Throughout development, executive functions demonstrate robust associations with academic engagement, mental health, and adaptive behavior (Blair & Razza, 2007; Lubans et al., 2022). From an applied perspective in sport and exercise psychology, the relevance of executive functioning is particularly pronounced during adolescence due to the heightened emotional sensitivity that characterizes this developmental stage alongside the protracted maturation of neural systems responsible for self-regulation (Mizuno & Noda, 2023; Shi et al., 2022). Neurodevelopmental studies reveal substantial structural and functional reorganizations in the prefrontal cortex during adolescence. The prefrontal cortex is primarily involved in processes related to executive control functioning, decision-making capabilities, and behavioral inhibition control (Diamond, 2013).

Regulatory systems within the prefrontal cortex mature later than those within limbic regions related to emotional reactivity—such as the amygdala—and this contributes toward increased impulsivity and variability of emotions during adolescence (Blair & Raver, 2015; Shi et al., 2022). This developmental mismatch underscores adolescent years as a sensitive period where environmental and behavioral experiences may have significant impacts on trajectories of executive function development (Siregar, Nofita-Sari & Mitsalina, 2023). Physical activity and organized sports are widely acknowledged as contextual determinants in cognitive-psychological development. Neuroscientific literature alongside exercise science indicates that regular physical activity modifies blood flow within the brain as well as expression levels of neurotrophic factors and connectivity between neurons — all mechanisms related to executive functioning (Álvarez-Bueno et al., 2017; Liu et al., 2025; Sun et al., 2022). In school settings specifically focusing on physical education classes, structured environments necessitate goal orientation with rule adherence requiring emotional control while cooperating with others for adaptive decision-making — all directly engaging various aspects of executive functions themselves (Best, 2010; Koutsandreu et al., 2016). Recent pedagogical research supports the idea that cognitive engagement may be enhanced by student-centered instructional models in physical education. Flipped Learning applied to physical education has been linked with increased autonomy and motivation as well as higher-order thinking skills (Sánchez-Gil-Machín et al., 2025).

Innovative approaches that combine physical activity with structured cognitive challenges—like macro board games—have fostered executive functions in children by integrating movement, problem-solving, and strategic thinking in playful contexts (Zapatero-Ayuso, Cerezo-García, González-Notario & Vergara-Morague, 2025). These strategies form enriched learning environments congruent with theoretical perspectives placing self-regulation, flexibility, problem-solving, and planning at the heart of executive development. Empirical evidence generally supports positive associations between physical activity and components of executive functioning in youth (Hillman et al., 2008; McPherson et al., 2018). Recent studies provide further support showing that physical activity is related to enhanced executive processes across several domains (González-Del-Castillo & Barbero-Alcocer, 2025; Liu et al., 2025). Aerobic activity has been associated with improvements in attention and inhibitory control while high-cognitive-demand activities seem to help working memory and cognitive flexibility (Koutsandreu et al., 2016; Sun et al., 2022). The findings are heterogeneous—with variations in age, type of activity, intensity, and contextual factors—but overall evidence highlights the essential role of regular physical activity for executive development.

Another limitation of the existing literature is that it is mostly focused on Western populations. This may not allow the findings to be generalized to other cultural and educational settings (Shi et al., 2022). Cultural, socioeconomic, and institutional factors determine access to opportunities for physical activity and cognitive development; thus, research in various sociocultural contexts is needed. In Algeria, there are few studies merging applied sport and exercise psychology with the assessment of executive functions. The relationship between participation in physical and sports education and executive functioning among adolescents living in Algeria could bring practical insights into pedagogy as well as school-based psychological support strategies. Descriptive and correlational evidence can bring out significant patterns of association without jumping into premature conclusions about causation.

Thus, this study uses a descriptive–correlational design to investigate the relationship between participation in physical education and sports activities with executive functions among students from secondary schools. It also attempts to find out if profiles of executive function differ by gender, academic level, or status of sports participation. The investigation falls under the purview of applied sport and exercise psychology aiming at providing contextually grounded evidence on how structured physical activity is related to cognitive as well as self-regulatory functioning among adolescents. Based on this premise, the present study seeks to address the following central research question: *What is the nature of the relationship between participation in physical and sports education and the development of executive functions among secondary school students?*

Research hypotheses

It is hypothesized that:

1. There is a statistically significant positive relationship between engagement in physical and sports education and executive functions among secondary school students.
2. Statistically significant differences in executive functions exist according to gender, academic level, and participation in sports activities.

Theoretical background

The current study is based on educational psychology and pedagogical theories which emphasize active learning environments as a means to achieve cognitive development (Best & Miller, 2010; Diamond, 2013). Executive functions are seen as basic cognitive capacities that develop through interaction with structured tasks, social regulation, and contextual demands of school learning (Blair & Razza, 2007). From the perspective of embodied cognition, learning is understood as an integrated cognitive activity and bodily action (Guzmán-Muñoz et al., 2025). Physical education provides embodied learning experiences in which students must coordinate movement with perception, decision-making, and self-control. These experiences are believed to stimulate executive processes by engaging students in goal-directed and rule-governed activities (Diamond & Lee, 2011). In addition to this, self-regulation theory within educational contexts has described environments that promote behavioral control of attention management and adaptive flexibility as important factors (Matrisciano, Pugliese, Forte, & D’Anna, 2020). PE lessons when pedagogically structured offer repeated opportunities for students to practice these skills in authentic motivating situations hence supporting the development of executive functions (Best, 2010; Tomayko et al., 2021).

Executive functions

Executive functions are defined as a set of higher-order cognitive processes that enable individuals to regulate goal-directed behavior (Hadar & Lakahal, 2024). These functions play a central role in adaptive behavior and academic performance and include the following core components:

- Working memory: the ability to temporarily store and manipulate information simultaneously.
- Inhibitory control: the capacity to resist distractions and suppress automatic or impulsive responses.
- Cognitive flexibility: the ability to shift strategies, adapt to changing demands, and adopt alternative perspectives.
- Planning and organization: the ability to set goals, develop action plans, and monitor their execution.

Collectively, these processes constitute a fundamental cognitive system that supports self-regulation, problem-solving, and decision-making across diverse contexts.

Physical and sports education as a neurocognitive stimulator

Research in the neuroscience of sport has demonstrated that physical activity activates multiple neural mechanisms that contribute to cognitive enhancement. One of the most prominent mechanisms is the increase in cerebral blood flow, which improves oxygen delivery and nutrient supply to the brain, thereby supporting neural efficiency and metabolic functioning. In addition, the theory of neuroplasticity posits that the brain possesses a remarkable capacity for structural and functional reorganization through the formation of new synaptic connections (synaptogenesis) and the strengthening or elimination of existing ones via synaptic pruning. Empirical evidence suggests that regular physical activity facilitates these neuroplastic processes by promoting vascular growth and enhancing neural network efficiency Seidel-Marzi & Cañal-Bruland (2025). Neuroscientific studies further indicate that physical activity elevates levels of neurotrophic factors, particularly brain-derived neurotrophic factor (BDNF), which plays a crucial role in neuronal survival, synaptic plasticity, and learning. Increased BDNF levels have been associated with improvements in working memory, greater cognitive flexibility, and enhanced inhibitory control—core components of executive functioning (Saha, 2025). These findings underscore the role of physical and sports education as a powerful educational and neurocognitive intervention capable of supporting executive function development, especially during sensitive developmental periods such as adolescence (see figure 1).

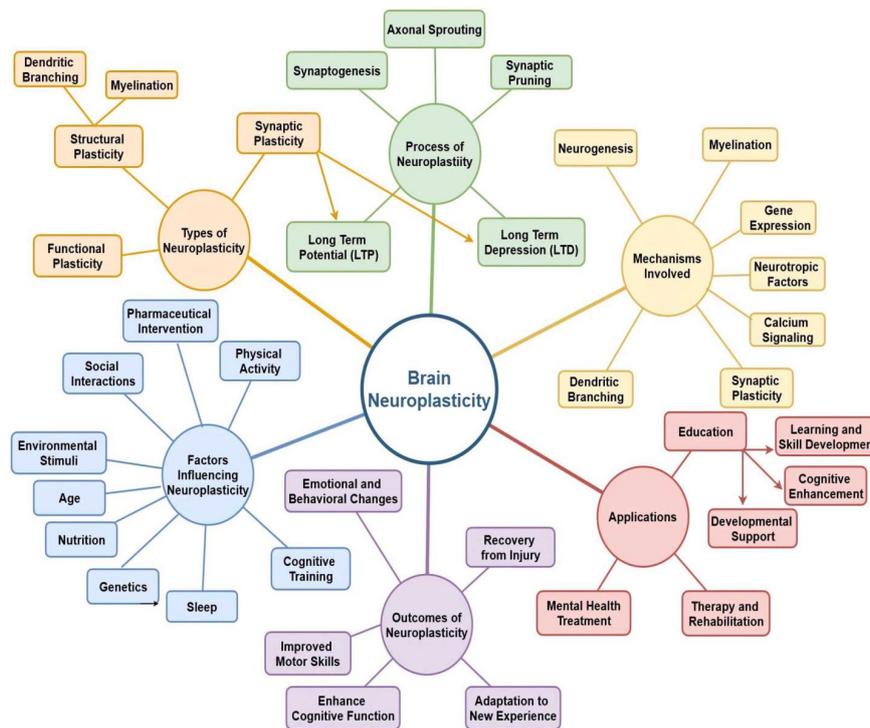


Figure 1. Conceptual map of brain neuroplasticity and its relationship with physical and sports education (adapted from Saha, 2025).

As illustrated in Figure 1, physical and sports education interact with multiple dimensions of brain neuroplasticity (Saha, 2025), Brain plasticity is a multidimensional construct comprising several interrelated components. The central node, labeled brain neuroplasticity, branches into six main categories, each of which further expands into specific domains that either contribute to or are influenced by neuroplastic processes. The conceptual map employs a color-coding system to distinguish among the different categories, while connecting lines illustrate the reciprocal relationships between physical and sports education and the various dimensions of brain plasticity. This integrative representation highlights the dynamic role of physical activity in modulating neuroplastic mechanisms from an educational perspective, sports activities promote self-regulation, emotional control, and social cooperation skills, all of which are directly linked to executive functions. Given that the adolescent brain is undergoing a dynamic phase of development, engagement in physical and sports education acts as an environmental–neural stimulator, accelerating the maturation of executive neural networks.

Numerous studies have demonstrated that physical and sports activities enhance executive functions. In particular, Hillman, Erickson, and Kramer (2008) found that aerobic exercises, such as running and swimming, are associated with improvements in working memory and attention. These benefits are mediated by increased cerebral blood flow and elevated levels of brain-derived neurotrophic factor (BDNF), which supports synaptic plasticity and cognitive development. In a recent systematic review, Liu, Xin, and Zhang (2025) included 21 articles following a comprehensive search across multiple databases, including Web of Science, Embase, PubMed, and the Cochrane Central Register of Controlled Trials, to examine the effects of physical exercise on cognitive function in adolescents. The results indicated that various types of exercise interventions produced significant improvements in multiple executive function domains among adolescents compared to control groups. These models and theories explain the relationship between executive functions and physical activity, highlighting how exercise contributes to the strengthening of neural synapses, thereby providing the brain with greater cognitive flexibility.

Participation in sports also promotes the release of endorphins, which improve energy levels and mood by reducing and managing anxiety and stress. Moreover, adherence to aerobic exercise has been shown to enhance sleep patterns, which in turn supports cognitive performance, attention, and daytime alertness (Dollaway et al., 2024).

Material and Methods

The current study used a descriptive-correlation design to assess the relationship between physical education participation and sports education with executive functions among secondary school students. This design is suitable for describing patterns of association without making inferences about causal relationships.

Participants

The sample consisted of 144 secondary school students from Moussaoui Massoud Secondary School (Berahal, Annaba, Algeria). A total of 72 males and 72 females participated with an average age of 15.8 ± 1.2 years. Descriptive anthropometric characteristics were as follows: Height: 166.2 ± 6.8 cm; Weight: 55.7 ± 8.9 kg. With students from the 1st ($n=18$), 2nd ($n=63$), and 3rd ($n=63$) years of secondary education enrolled in this school that was chosen because it had a sufficiently large number of students to represent all genders and academic levels. The study was conducted on a voluntary basis while upholding the principle of confidentiality in compliance with ethical research requirements.

Instruments

Data were collected using a structured self-report questionnaire developed specifically for this study based on contemporary models of executive functioning, particularly the framework proposed by Adele Diamond (2013). The instrument conceptualized executive functions as comprising working memory, inhibitory control, and cognitive flexibility. Planning/organization and emotional regulation were also included to better reflect school-based executive functioning.

Demographic and Anthropometric Information

This section sought information on gender, age, grade level, height (cm), weight (kg), and whether or not they participated in organized sports outside the school premises. The height and weight data were self-reported to give a descriptive anthropometric profile of the sample.

Physical Activity Scale (10 items)

This scale assessed frequency, duration, intensity, and type of participation in school physical education classes and extracurricular sports activities. Responses were rated on a five-point Likert scale ranging from 1 (Never) to 5 (Always). Higher scores indicated greater engagement in structured physical activity. The Physical Activity Scale showed good internal consistency in the main study sample (Cronbach's $\alpha = 0.84$).

Executive Functions Scale (25 items)

Executive functions were measured using five subscales:

- Working Memory (5 items) – $\alpha = 0.81$
- Attention and Inhibitory Control (6 items) – $\alpha = 0.83$
- Cognitive Flexibility (5 items) – $\alpha = 0.79$

- Planning and Organization (5 items) – $\alpha = 0.82$
- Emotional Regulation (4 items) – $\alpha = 0.76$

Each item was rated according to participants' behavior during the previous three weeks using a four-point Likert scale (1 = Does not apply to; 4 = Applies strongly). Negatively worded items were reverse-coded prior to analysis. The overall Executive Functions Scale demonstrated high internal consistency with satisfactory reliability as indicated by Cronbach's alpha of .88. Content Validity and Pilot Study Content validity was established by a panel of five university experts in physical education and educational psychology. The items were rated for clarity, relevance, and theoretical congruence. Minor language adjustments were made according to the experts' recommendations. A pilot study involving 20 secondary school students tested the clarity of items and provided preliminary reliability data. Cronbach's alpha coefficients obtained from pilot analysis were 0.85 for the Executive Functions Scale and 0.80 for the Physical Activity Scale. The pilot participants were not included in the final sample. Methodological Consideration Because executive functions and anthropometric variables were measured through self-report; results should be interpreted in light of possible subjective bias. Nonetheless, self-report instruments have been very commonly used in school-based research to capture perceived executive functioning within ecological educational contexts.

Procedure

Questionnaires were conducted at school under standard conditions by trained personnel. Each session took about 30 - 40 minutes. Data collection happened between October 10 and December 20, 2025. The same administration protocol was used across all classes for data reliability and consistency. Students were asked to answer all items honestly and told that their responses would be kept confidential.

Statistical analysis

Statistical Analysis All statistical analyses were performed using IBM SPSS Statistics, Version 26. The significance level was set at $\alpha = 0.05$. Quantitative data were expressed as means \pm standard deviations (SD). To compare differences in executive function variables: Independent-samples t-tests were used for gender comparisons and sports participation comparisons. One-way ANOVA (or t-tests where appropriate) was used for academic level comparisons (1st, 2nd, 3rd-year secondary). Pearson correlation coefficients were calculated to assess the strength and direction of linear relationships. The coefficients are interpreted as follows: $r < 0.20$: negligible; $0.20 \leq r \leq 0.39$: low; $0.40 \leq r \leq 0.59$: moderate; $0.60 \leq r \leq 0.79$: moderately high; $r \geq 0.80$: high. Simple linear regression was performed to determine the predictive effect of sports participation on executive function performance.

Results

Descriptive statics

Table 1 presents the mean scores and standard deviations (SD) of executive function components across academic levels. Students from 1st ($n = 18$), 2nd ($n = 63$), and 3rd ($n = 63$) year secondary were included. Significant differences were observed for cognitive flexibility ($F = 3.540$, $p = 0.032$) and planning and organization ($F = 4.349$, $p = 0.015$).

Variable	1st Year (n=18) Mean ± SD	2nd Year (n=63) Mean ± SD	3rd Year (n=63) Mean ± SD
Working Memory	14.28 ± 2.35	13.32 ± 2.01	13.89 ± 1.98
Attention & Inhibitory Control	19.50 ± 3.01	18.02 ± 3.48	17.54 ± 3.46
Cognitive Flexibility	15.56 ± 2.53	15.59 ± 2.72	14.40 ± 2.61
Planning & Organization	15.39 ± 2.20	14.33 ± 3.02	13.22 ± 3.23
Emotional Regulation	11.56 ± 2.20	11.43 ± 2.74	10.44 ± 3.14

Note: SD = Standard Deviation. t-values and p-values indicate statistical significance of differences between groups. *p < 0.05

Table 2 presents the executive function scores based on gender. Significant differences were found in attention and inhibitory control ($t = 5.462$, $p = 0.021$) and planning and organization ($t = 7.407$, $p = 0.007$), with males scoring higher. No significant gender differences were found in the other components.

Variable	Male (n=72) Mean ± SD	Female (n=72) Mean ± SD
Working Memory	13.72 ± 2.05	13.65 ± 2.08
Attention & Inhibitory Control	18.65 ± 3.47	17.33 ± 3.33
Cognitive Flexibility	15.24 ± 2.61	14.89 ± 2.79
Planning & Organization	14.67 ± 2.73	13.29 ± 3.30
Emotional Regulation	11.38 ± 2.50	10.65 ± 3.21

Table 3 presents executive function scores based on sports participation. Significant differences were found in the planning and organization ($t = 1.764$, $p = 0.015$) and emotional regulation ($t = 1.573$, $p = 0.043$) scores of students classified as active (>3 sessions/week).

Variable	Active (n=74) Mean ± SD	Inactive (n=70) Mean ± SD
Working Memory	14.04 ± 2.06	13.31 ± 2.00
Attention & Inhibitory Control	18.20 ± 3.32	17.77 ± 3.60
Cognitive Flexibility	14.96 ± 2.58	15.17 ± 2.82
Planning & Organization	14.99 ± 2.78	12.91 ± 3.08
Emotional Regulation	11.12 ± 2.88	10.90 ± 2.92

Correlation Analysis Pearson correlations are shown in Table 4. There was a strong correlation between total executive function scores and attention/inhibitory control ($r = 0.790$, $p < 0.01$), cognitive flexibility ($r = 0.666$, $p < 0.01$), and emotional regulation ($r = 0.730$, $p < 0.01$). Sports participation had a moderate correlation with total executive functions ($r = 0.381$, $p < 0.01$).

Variable	1	2	3	4	5	6	7	8	9	P
1. Academic Level	1									—
2. Gender	0.397**	1								0.000
3. Sports Participation	-	-	1							0.000
4. Working Memory	0.010	-0.17	0.166*	1						0.047
5. Attention and Inhibitory Control	-0.165*	-0.192*	0.232**	0.222**	1					0.005
6. Cognitive Flexibility	-0.193	-0.065	0.183*	0.121	0.481**	1				0.028
7. Planning and Organization	-	-	0.418**	0.669**	0.201*	0.259**	1			0.000
8. Emotional Regulation	-0.161	-0.125	0.252**	0.116	0.495**	0.341**	0.400**	1		0.002
9. Executive Functions (Total Score)	-0.238	-0.201	0.381**	0.428**	0.790**	0.666**	0.669**	0.730**	1	0.000

Note. $p < 0.01$ (*) and $p < 0.05$ (**); ** Correlations are 2-tailed.

Regression analysis indicated a significant prediction of total executive function scores by sports participation in simple linear regression ($R^2 = 0.149$, $F = 24.17$, $p = 0.041$). The strongest predictive effect was for planning and organization ($R^2 = 0.157$, $p < 0.001$). Other subcomponents had smaller, sometimes non-significant predictive relationships.

Dependent Variable	β	t	p	R^2
Executive Functions	0.062	2.062	0.041*	0.149
Working Memory	0.028	0.887	0.376	0.028
Attention & Inhibitory Control	0.054	0.658	0.512	0.054
Cognitive Flexibility	0.033	0.361	0.719	0.033
Planning & Organization	0.157	4.121	0.000*	0.157
Emotional Regulation	0.063	0.650	0.517	0.063

Summary of Findings

Sports participation positively impacts executive functions, particularly in the areas of planning, organization, and emotional regulation. Gender differences were found in favor of males for attention/inhibitory control and for planning/organization. The academic level had minor effects, being significant only for cognitive flexibility and planning/organization. The correlation and regression analyses confirm that structured physical activity contributes differently to the various domains of executive function.

Discussion

This paper adds to the increasing number of studies on executive function growth through physical education from both cognitive and pedagogical angles inside school environments. The results show that organized involvement in physical and sports education has a strong relationship with important parts of executive functioning, especially planning–organization and emotional control. These findings back up the idea that physical education is not just an area for motor skill development but also a planned learning space that can help higher-level thinking abilities during the teenage years when the brain is maturing significantly. Instead of implying direct causation, these outcomes emphasize the interaction between structured physical activity and self-regulatory growth within educational contexts. The results of this study are consistent with a vast body of literature that supports the positive relationship between cognitive performance and physical activity. In the studies conducted by Dollaway et al. (2024) and McPherson et al. (2018), it was observed that the brain area responsible for learning and memory processes was more active in children and adolescents who performed moderate-to-high physical exercise regularly every week compared to those who did not or performed less frequently. Such neural activity allows for quicker processing during physical exertion, which could potentially facilitate academic learning while stress reduction and physical fatigue resulting from such activities would support memory, attention, and general cognitive functioning.

Apart from physiological mechanisms, recent pedagogical research indicates that quality in the physical education environment may also play a role in cognitive engagement. Sánchez-Gil-Machín et al. (2025), through their study about Flipped Learning in Physical Education, proved that student-centered and cognitively engaging instructional models enhance autonomy, active participation, and higher-order thinking. Enriched learning environments like this one might be providing additional stimulation to executive processes—particularly planning, self-monitoring, adaptive decision-making—which are closely aligned with the components of executive function being examined in this study. This study coincides with a systematic review by Schearz (2025) on the biological basis of executive functions. That review found that the degree of benefit to

executive functions from physical activity is contingent on the dose-response nature of engagement frequency and constancy. Additionally, how participation in sports influences these functions is moderated by a complex interaction of social and physical factors—parental support, peer influence, competitive environments within sports, and socioeconomic conditions in general.

Contextual variables should not be ignored; for instance, Arancón-Gómez (2022) reported that simply changing the physical characteristics of the school environment (dynamic versus conventional schoolyards) did not automatically result in higher levels of physical activity. This suggests that environmental design alone may be inadequate without some form of structured engagement strategy. It emphasizes further that cognitive benefits associated with physical activity might depend not only upon setting but also upon organization, guidance as well as intentional structuring toward participation. Zhao et al., (2024) reported that daily physical activity increases executive function, self-efficacy, and confidence levels among adolescents with a moderate positive effect on negative mood which means better regulation of highly intense negative emotions. This is similar to our findings where physical activity was significantly associated with planning organization as well as emotional regulation meaning exercise contributes to cognitive as well as affective aspects of executive function. In terms of mediating variables during adolescence, it may be noted that increased participation in daily physical activities improves executive functions and self-efficacy among adolescents with a moderate positive effect on negative moods.

The study also looked at the kind, length, and strength of physical activity that matter the most for results in executive function. For example, playing team sports like soccer and basketball have been especially linked to better cognitive flexibility and social-emotional control (Blair & Raver, 2015; Hillman et al., 2008). On the other hand, individual sports such as gymnastics and weightlifting were more closely connected with self-discipline and inhibitory control (Diamond, 2013; Lubans et al., 2022). These results show that future studies should define which kinds of activities at what intensities and durations work best for maximizing cognitive benefits and thus improving academic performance. All in all, the present results tend to support the hypothesis that regular structured physical activity may serve as both an environmental and neural facilitator for the maturation of executive functions during adolescence, which is a critical period for neuroanatomical and neurocognitive development. In addition to its general theoretical implications, this result has particular relevance in the Algerian educational context where physical education sometimes takes on a secondary role relative to other subjects that are academically examined (Hadar & Lakahal, 2024).

The findings suggest that by marginalizing physical education one might be overlooking an important resource for development towards self-regulation and higher order cognitive processes. Hence, integrating well-designed cognitively engaging physical education and sports programs into secondary schools should not be perceived only as a recreational complement but rather as an educational strategy aimed at enhancing cognitive development, emotional regulation, and academic success.

Limitations and future directions

Despite the relevance of the findings, several limitations should be noted. The descriptive–correlational design precludes causal inferences, and future longitudinal or experimental studies are recommended. Self-report measures may be subject to bias, and inclusion of objective assessments would strengthen future research. Contextual variables such as socioeconomic status, parental involvement, or sleep quality were not examined, limiting ecological interpretation. Finally, the sample was drawn from a limited geographic area, restricting generalizability. Future

research should examine dose–response relationships, intervention fidelity, and neurocognitive markers to clarify underlying mechanisms.

Practical implications for applied sport and exercise psychology

The findings suggest that physical education may support adolescents' self-regulatory development. Teachers and coaches could structure activities to emphasize goal-setting, emotional control, and adaptive decision-making. Gender and academic-level differences highlight the need for tailored interventions. At the institutional level, integrating regular physical activity within school curricula may enhance executive functioning, emotional well-being, and academic engagement.

Conclusion

This study shows that executive functioning is positively related to participation in physical education among high school students. The findings emphasize the cognitive relevance of physical education beyond its traditional dimensions of being physical and recreational. Engaging students in rule-based, strategically demanding, and adaptive activities may help develop inhibitory control, working memory, and cognitive flexibility through physical education. Variations across gender and academic levels further underline the importance of developmentally appropriate and inclusive pedagogical approaches. Overall, positioning physical education within a holistic educational framework reinforces its role in supporting both cognitive and self-regulatory development in secondary education contexts.

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