Relationship between physical fitness components, executive functions, and socioemotional skills in school-aged children

Relación entre los componentes de la aptitud física, las funciones ejecutivas y las habilidades socioemocionales en niños en edad escolar

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Abstract

Introduction: A growing body of evidence indicates that physical activity and physical fitness are positively associated with brain function and cognitive performance, particularly during childhood. However, it remains unclear which specific physical fitness components are more strongly related to executive function subdomains and socioemotional skills.
Objective: This study aimed to evaluate the relationships between physical fitness components, executive functions, and socioemotional skills in school-aged children.
Methodology: This cross-sectional study included 93 children aged 8-12 years (44.1% girls). Inhibitory control, working memory, physical fitness components, and socioemotional skills were assessed. Pearson and Spearman correlations were conducted according to data distribution, followed by multiple linear regression analyses controlling for age.
Results: Several physical fitness components were significantly correlated with executive function outcomes. Hand-eye coordination showed the strongest and most consistent associations, particularly with inhibitory control ($r_s = 0.570$; $p < 0.001$). In regression analyses, hand-eye coordination emerged as the most consistent predictor of global executive function and inhibitory control, explaining up to 33.5% of the variance. Although working memory was correlated with physical fitness, it was primarily explained by age ($p = 0.004$). No significant associations were observed between physical fitness and socioemotional skills.
Discussion: These findings suggest that different components of physical fitness may contribute differently to executive function domains, with perceptual-motor coordination playing a central role in inhibitory control.
Conclusions: Specific components of physical fitness, particularly hand-eye coordination, are associated with executive function performance in children, especially inhibitory control, highlighting the importance of motor coordination in cognitive development during childhood.

Keywords

Child development; cognitive performance; inhibitory control; motor coordination; working memory.

Resumen

Introducción: La evidencia indica que la actividad y la aptitud física se asocian con la función cerebral y el rendimiento cognitivo en la infancia, aunque aún no está claro qué componentes específicos se relacionan con los subdominios de la función ejecutiva y las habilidades socioemocionales.
Objetivo: Evaluar las relaciones entre los componentes de aptitud física, funciones ejecutivas y habilidades socioemocionales en niños en edad escolar.
Metodología: Estudio transversal con 93 niños de 8 a 12 años. Se evaluaron el control inhibitorio, la memoria de trabajo, la aptitud física y las habilidades socioemocionales. Se realizaron correlaciones, seguidas de regresión lineal múltiple ajustada por edad.
Resultados: Varios componentes de la aptitud física se correlacionaron con la función ejecutiva. La coordinación ojo-mano mostró las asociaciones más fuertes, especialmente con el control inhibitorio ($r_s = 0{,}570$; $p < 0{,}001$). En la regresión, fue el principal predictor de la función ejecutiva global y del control inhibitorio, explicando hasta el 33,5 % de la varianza. La memoria de trabajo se correlacionó con la aptitud física, pero se explicó principalmente por la edad ($p = 0{,}004$). No se observaron asociaciones con habilidades socioemocionales.
Discusión: Diferentes componentes de la aptitud física pueden contribuir de manera distinta a los dominios de la función ejecutiva, con la coordinación perceptivo-motora desempeñando un papel central.
Conclusiones: Componentes específicos de la aptitud física, en particular la coordinación ojo-mano, se asocian con la función ejecutiva, especialmente el control inhibitorio, destacando la importancia de la coordinación motora en el desarrollo cognitivo infantil.

Palabras clave

Control inhibitorio; coordinación motora; desarrollo infantil; memoria de trabajo; rendimiento cognitivo.

Introduction

Physical fitness is a multidimensional construct composed of several components that influence physical performance and health (Gallahue et al., 2012; Marques et al., 2021). These components include endurance, speed, agility, coordination, flexibility, body composition, power, strength, and balance (Donnelly et al., 2016; Marques et al., 2021). Because these components can be independently developed and trained, investigating their individual relationships with cognitive outcomes may contribute to a more precise understanding of the mechanisms linking physical fitness and cognition (Mora-Gonzalez et al., 2019).

Executive functions comprise a set of cognitive processes responsible for goal-directed behavior, including inhibitory control, working memory, and cognitive flexibility (Best & Miller, 2010; Diamond, 2013; Fernández García et al., 2021; Miyake et al., 2000). These functions are essential for planning, problem-solving, and behavioral regulation in daily life (Donnelly et al., 2016). In addition, executive functions contribute to children's social adaptation and behavioral regulation, influencing the development of socioemotional skills throughout childhood (Liew, 2012; Moffitt et al., 2011; Pesce et al., 2021).

Cognitive and motor development are closely interconnected, as many motor tasks require the simultaneous activation of cognitive and motor processes involving brain regions such as the prefrontal cortex, striatum, and cerebellum (Leisman et al., 2014; Tószegi et al., 2023). In addition, both acute and chronic effects of physical activity may promote neurobiological adaptations that support cognitive functioning, including increased cerebral blood flow, improved oxygen delivery to neural tissue, and stimulation of neuroplasticity (Deslandes et al., 2009; Guzmán-Muñoz et al., 2025; Stillman et al., 2020).

Growing evidence indicates that physical activity and physical fitness are positively associated with brain structure, brain function, and cognitive performance across the lifespan (Donnelly et al., 2016; Guzmán-Muñoz et al., 2025; Shi et al., 2022). In childhood, higher levels of physical fitness have been linked to better performance in several cognitive domains, particularly executive functions, which play a central role in goal-directed behavior and academic achievement (García-Alonso et al., 2025; Lakicevic et al., 2026).

Specific motor skills, particularly hand-eye coordination, appear to be associated with cognitive outcomes and academic achievement (Bao et al., 2024; V. Fernandes et al., 2024; V. R. Fernandes et al., 2016), and more recent findings indicate that physical fitness and executive functions may partially mediate this relationship (Fernández-Sánchez et al., 2025). Hand-eye coordination requires the integration of sensory information and motor responses to perform goal-directed hand movements, which are fundamental to interacting with and manipulating objects in everyday activities (Edwards et al., 2019; Visser et al., 2026). This functional relevance may help explain the close relationship between sensorimotor and executive processes during childhood, when these systems develop in parallel. Developmental associations between hand-eye coordination, working memory, and inhibitory control have been reported in children aged 8–12 years (Gordon-Murer et al., 2021), while more recent evidence identified hand-eye coordination as an important predictor of executive function performance in school-aged children, suggesting that coordination-related fitness may be particularly relevant to cognitive outcomes (V. Fernandes et al., 2024).

Importantly, recent evidence also suggests that executive functions may contribute to the association between motor performance and socioemotional outcomes, with these cognitive functions mediating relationships between motor skills, social skills, and behavioral problems in children (S. Li et al., 2025). Together, these findings collectively suggest that motor coordination may be particularly relevant to cognitive functioning and, potentially, to broader developmental outcomes during childhood.

Despite growing evidence linking physical fitness and executive functions in children, fewer studies have examined the relationships between specific physical fitness components, distinct executive function domains, and socioemotional skills within the same framework. Examining these domains together may provide a more comprehensive understanding of child development and help inform more holistic educational practices that consider physical, cognitive, and socioemotional development simultaneously.

The aim of this study was to examine the relationships between specific components of physical fitness, executive function domains, and socioemotional skills in school-aged children, as well as to identify which physical fitness components are independently associated with executive function performance.

Based on previous evidence linking motor and sensorimotor performance with executive functioning during childhood (Bao et al., 2024; Gordon-Murer et al., 2021), and on recent findings highlighting the relevance of hand-eye coordination to cognitive outcomes (V. Fernandes et al., 2024), we hypothesized that specific physical fitness components would be positively associated with executive function performance and socioemotional skills in school-aged children. More specifically, we expected that coordination-related fitness components, particularly hand-eye coordination, would show stronger associations with executive function performance than other fitness components and would independently predict inhibitory control and working memory performance.

Method

Participants

This cross-sectional study was conducted with 93 children aged 8 to 12 years attending a private school in Rio de Janeiro, Brazil. Children of both sexes were eligible to participate if they were literate and had medical clearance to engage in physical activity. Prior to participation, children and their legal guardians were informed about the study procedures and provided written assent and informed consent.

Participants were assessed for socioemotional skills, executive functions, and physical fitness components. Children with diagnosed neurodevelopmental or mental disorders (e.g., intellectual disability, attention-deficit/hyperactivity disorder, or autism spectrum disorder), as well as those with uncorrected visual or hearing impairments, were excluded from the analyses. Information regarding these conditions was obtained from parents or legal guardians and verified through available school records.

The study was approved by the Research Ethics Committee of Estácio de Sá University (CAAE: 96566818.8.0000.5284) and all procedures were conducted and reported in accordance with STROBE guidelines (von Elm et al., 2008).

Procedure

Data collection was conducted at the school facilities over three consecutive assessment days. Assessments were scheduled during the students' regular school periods; therefore, participants who attended school in the morning were assessed in the morning, whereas those attending school in the afternoon were assessed in the afternoon. Each participant was assessed at the same time of day throughout the three assessment days to maintain consistency in testing conditions. In the first stage of the study, information about the research was disseminated within the school and all students aged 8–12 years were invited to participate. Children who agreed to participate and returned the signed consent and assent forms were included in the assessment procedures.

On the first day, anthropometric measurements were obtained as part of the PROESP-Br battery, followed by the Plate Tapping Test for the assessment of hand-eye coordination and subsequently by the remaining physical fitness tests included in the PROESP-Br battery. These assessments were conducted in a large, covered, and well-ventilated gymnasium. The physical fitness assessment took approximately 30–45 minutes per participant. On the second day, executive functions were assessed individually in a quiet and air-conditioned classroom. Each child completed the cognitive tasks in a standardized order, with the Stroop task administered first, followed by the Digit Span task, with a total duration of approximately 15 minutes per participant. On the third day, socioemotional skills were assessed through questionnaires completed by children in groups of up to ten students in classroom settings, averaging 25 minutes per session. In addition, teachers completed the socioemotional questionnaires for each participating student during class breaks. This process required approximately 10 minutes per child, with completion times varying according to each teacher's availability. All assessments were conducted by trained researchers following standardized procedures.

Instrument

Executive Functions were assessed individually using paper-based tasks.

Stroop task

The Stroop task was used to assess inhibitory control and selective attention (Pontifex et al., 2019; Strauss et al., 2006; Stroop, 1935). The test consists of three conditions with increasing cognitive demand: two congruent conditions and one incongruent condition. In the first condition, participants named the color of sequences of the letter "X". In the second condition, they named the color of printed words. In the third condition (incongruent condition), participants were required to name the color of color words printed in an incongruent ink color, requiring inhibition of the automatic reading response.

Response time (RT) and accuracy (number of errors) were recorded for each condition. The Stroop interference score was calculated as the difference between the RT in the incongruent condition and the RT in the first congruent condition. Lower scores indicate better inhibitory control. The Stroop task is validated for Brazilian children (Oliveira et al., 2016) and has demonstrated good test-retest reliability in children and adolescents, with values above 0.78 across all conditions (Rodríguez Barreto et al., 2016).

Digit Span task

Working memory was assessed using the Digit Span Task, composed of forward and backward conditions (Wechsler, 2003). In the forward digit span condition, participants were required to repeat verbally presented sequences of numbers in the same order, while in the backward digit span condition, participants repeated the number sequences in reverse order. The score corresponded to the maximum sequence length correctly recalled. A total digit span score was calculated as the sum of the forward and backward span scores, with higher scores indicating better performance. This assessment is validated for Brazilian children and adolescents (Angeli Dos Santos et al., 2018), and has demonstrated good reliability, with an internal consistency coefficient of r=0.87 in the WISC-IV standardization sample (Wechsler, 2003).

Physical Fitness

Physical fitness components were assessed using the PROESP-Br battery, a standardized system for monitoring growth, body composition, and physical fitness in Brazilian children and adolescents aged 6–17 years (Gaya et al., 2021). Weight and height were measured to characterize the sample, and body mass index (BMI) was subsequently calculated.

Health-related physical fitness components were evaluated through specific field tests. Flexibility was assessed using the sit-and-reach test, cardiorespiratory fitness through the 6-minute run/walk test, and muscular endurance using the 1-minute sit-up test.

Performance-related physical fitness was also examined. Upper limb power was assessed using the 2-kg medicine ball throw, while lower limb power was measured using the standing long jump test. Agility was evaluated with the 4×4 meters square test, and speed was assessed using a 20 meters sprint test.

The PROESP-Br is standardized for Brazilian children and adolescents and is supported by extensive national normative data. Evidence of validity has been reported for specific tests included in the battery, including the 6-min run/walk and sit-and-reach tests (Gaya et al., 2021). Good test-retest reliability has also been reported for selected tests, including the 6-min run/walk (r=0.82) (González-Devesa et al., 2025) and standing long jump (ICC=0.94) tests (Fernandez-Santos et al., 2015).

Hand-eye coordination was assessed using the Plate Tapping Test from the EUROFIT battery (Adam et al., 1993). Participants performed fast alternating hand movements between two discs placed on a table while keeping the non-dominant hand fixed at the center. The task consisted of completing 25 cycles as quickly as possible. The best performance time from three trials was recorded. Shorter times indicate better performance. The Plate Tapping Test has demonstrated moderate to excellent test-retest reliability, with 75% of the reported ICCs exceeding 0.75 (Grgic, 2023).

Socioemotional Skills

Socioemotional skills were assessed using the Social Skills Rating System (SSRS) (Gresham & Elliott, 1990), in its Brazilian validated version (Del Prette et al., 2016). Two informant forms were used: the student self-report and the teacher report. The student form assessed social skills across dimensions such as responsibility, self-control, assertiveness, empathy, affectivity, and civility. The questionnaire consisted of 20 items rated on a three-point Likert scale ranging from 0 ("never") to 2 ("very often"). The teacher form assessed social skills, behavioral problems and academic competence. Social skills were measured using 22 items rated on a similar three-point Likert scale. The SSRS demonstrates adequate psychometric properties and has been validated for Brazilian children (Bandeira et al., 2009).

Data analysis

Data distribution was assessed using the Kolmogorov–Smirnov test, and homogeneity of variances was verified using Levene's test. Descriptive analyses were reported as mean, standard deviation, minimum, and maximum values. Correlations between physical fitness, executive functions, and socioemotional skills were examined and a correlation heatmap was constructed to provide a comprehensive overview of the relationships among all study outcomes. Spearman correlation coefficients were used for this analysis due to the non-normal distribution of most variables. To control multiple comparisons, Bonferroni correction was applied, and adjusted significance levels were considered in the interpretation of the results.

Composite scores were created to reduce dimensionality and improve interpretability of the data. The Global Executive Function Score was calculated by averaging standardized (z-score) values of inhibitory control and working memory outcomes, with higher scores indicating poorer executive function. The Global Physical Fitness Score was computed as the mean of standardized scores from all physical fitness components, including flexibility, hand-eye coordination, muscular fitness (abdominal endurance and upper and lower limb power), cardiorespiratory fitness, speed, and agility. For physical fitness variables in which lower values indicated better performance (e.g., time-based tests), scores were inverted prior to standardization so that higher scores consistently represented better physical fitness performance. The Global Socioemotional Score was calculated as the average of standardized scores derived from the SSRS questionnaire, including child-reported social skills and teacher-reported social skills, academic competence, and behavior problems (inverted prior to standardization).

Subsequently, correlations between these global composite scores were examined using Pearson correlation coefficients for normally distributed variables, whereas Spearman correlation coefficients were applied for variables that deviated from normality. The magnitude of correlations was interpreted according to Cohen's criteria (1988): weak (<0.30), moderate (0.30-0.49), and strong (≥0.50).

Multiple linear regression analyses were performed to examine whether selected physical fitness components predicted executive function outcomes. Regression models were conducted using the strongest correlations identified between physical fitness and executive functions outcomes, with models adjusted for age. All statistical analyses were conducted using JASP (version 0.19.1), and the significance level was set at $p \leq 0.05$.

Results

A total of 183 children were initially invited to participate in the study. Of these, 89 were excluded for not meeting the inclusion criteria, and one child dropped out. Therefore, the final sample consists of 93 children, of whom 44.1% are girls. Descriptive characteristics of the sample, as well as the results of physical fitness, cognitive assessments and socioemotional skills are presented in Table 1.

Table 1. Descriptive analyses

Variable	Mean	SD	Minimum	Maximum
Age (years)	9.74	1.34	8.00	12.00
Weight (kg)	41.81	15.12	22.70	98.70
Height (cm)	142.61	10.46	124.60	172.50
Body Mass Index (BMI, kg/m^2)	20.15	5.24	13.54	41.56
Flexibility (cm)	37.32	8.53	10.60	69.00
Hand–eye coordination (s)	21.02	3.93	13.39	40.00
Muscular endurance (sit-up test, repetitions/min)	28.25	8.66	4.00	55.00
Cardiorespiratory Fitness (m)	729.92	109.87	453.26	1061.30
Lower Limb Power (cm)	117.77	24.36	37.50	180.50
Speed (s)	4.29	0.60	3.00	6.18
Upper Limb Power (cm)	245.72	53.96	139.60	363.00

Agility (s)	8.09	1.15	5.72	12.65
SSRS Total Score Child Report	47.68	27.44	3.00	97.00
SSRS Teacher Report (Social Skills)	58.15	28.64	3.00	100.00
SSRS Teacher Report (Behavior Problems)	48.26	31.01	1.00	99.00
SSRS Teacher Report (Academic Competence)	56.97	32.11	1.00	100.00
Stroop task 3 (s)	32.20	9.51	15.70	54.11
Stroop task 3 (Errors)	1.86	2.02	0.00	9.00
Stroop Effect (s)	12.01	6.91	-2.48	31.17
Digit Span Total Score	13.36	2.33	10.00	19.00
Inhibitory Control Composite Score	0.00	0.83	-1.33	2.52
Global Executive Functions Score	0.00	0.74	-1.43	1.62
Global Socioemotional Score	0.01	0.72	-1.36	1.38
Global Physical Fitness Score	0.03	0.65	-1.47	1.72

The total sample comprised 93 children (41 girls and 52 boys). BMI = Body Mass Index. SSRS = Social Skills Rating System.

Significant correlations are observed primarily between physical fitness and executive function, showing that better physical fitness is related to better executive function. However, an unexpected result is the absence of significant correlations between physical fitness components and socioemotional skills.

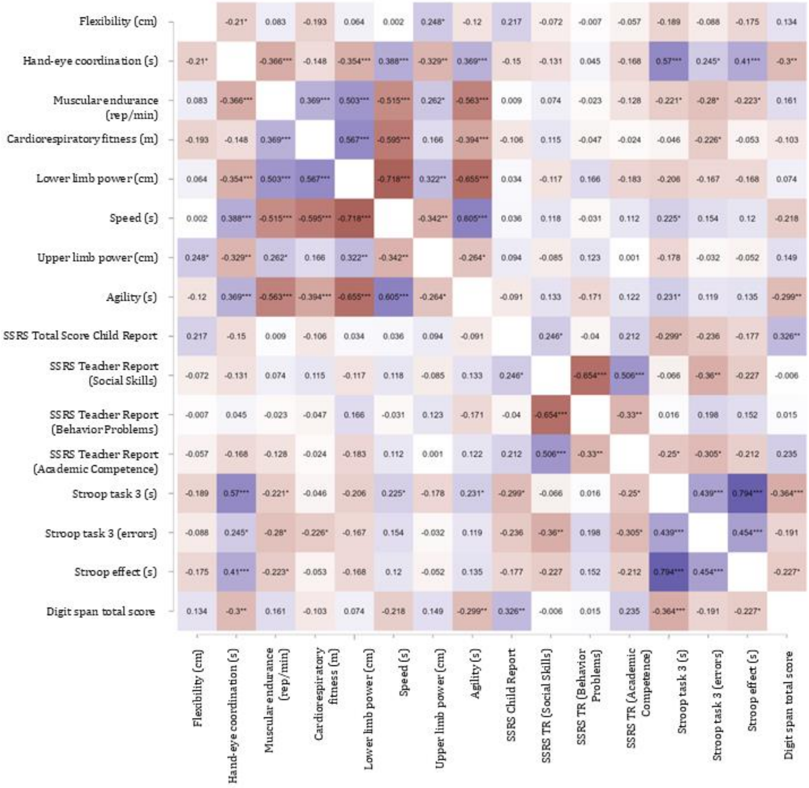
Among the physical fitness variables, hand-eye coordination emerges as the component most consistently associated with executive function performance. As performance is assessed based on completion time, longer times reflect poorer hand–eye coordination, which is correlated with poorer inhibitory control, as evidenced by significant moderate-to-strong correlations with Stroop task 3 RT ($rs = 0.570$, $p < 0.001$) and Stroop effect ($rs = 0.410$, $p < 0.001$). In addition, better hand-eye coordination is correlated with better working memory performance ($rs = -0.300$, $p = 0.006$). This negative correlation indicates that children who completed the hand-eye coordination task faster tended to obtain higher working memory scores. Muscular endurance is also related to inhibitory control outcomes, with higher muscular endurance being associated with better inhibitory control, as reflected by fewer Stroop task 3 errors ($rs = -0.280$, $p = 0.011$). Furthermore, better agility performance is associated with better working memory performance ($rs = -0.299$, $p = 0.007$). Thus, children who completed the agility test more quickly, that is, in less time, tended to achieve higher working memory scores, accounting for the negative correlation. No significant associations were observed between the remaining physical variables and executive functions.

Regarding the relationship between physical fitness components and socioemotional skills, no significant correlations were observed, indicating that these components were not significantly related in the present sample. Regarding the relationship between executive functions and socioemotional skills, better working memory performance is correlated with higher child-reported social skills ($rs = 0.326$, $p = 0.006$). In addition, better inhibitory control is correlated with more favorable teacher ratings.

Overall, the findings suggest that executive functions are related to selected physical fitness components and socioemotional outcomes, whereas no significant correlation is observed between physical fitness components and socioemotional skills in the present sample.

The correlations between physical fitness components, executive functions, and socioemotional skills are presented in Figure 1.

Figure 1. Heatmap of Spearman correlations among physical fitness components, executive functions, and socioemotional skills. Colors indicate the strength and direction of the correlations (Spearman's rho, rs). Positive correlations are shown in blue and negative correlations in red. *p<0.05, **p<0.01, *p<0.001.



The Global Executive Function Score was significantly related to both the Global Physical Fitness Score and the Global Socioemotional Score. Notably, lower scores on the Global Executive Function Score indicate better executive function performance, whereas higher scores on the Global Physical Fitness Score and Global Socioemotional Score indicate better performance. Thus, negative correlations indicate that better physical fitness and more favorable socioemotional outcomes are associated with better executive function performance. Specifically, better physical fitness is moderately correlated with better executive function performance (rs = -0.336, p = 0.003). Similarly, better executive function performance is correlated with more favorable socioemotional outcomes (rs = -0.293, p = 0.015). In contrast, the absence of a significant correlation between the Global Physical Fitness Score and the Global Socioemotional Score (r = -0.038, p = 0.766), reinforces the finding that physical fitness and socioemotional skills were not directly related in this sample. All significant correlations remain significant after Bonferroni correction.

These findings indicate that executive functions may represent a central domain linking physical fitness and socioemotional functioning, whereas physical fitness and socioemotional skills do not appear to be directly associated in the present sample. Correlations between the global composite scores are presented in Table 2.

Table 2. Correlations between global composite scores

Variables	Global Executive Function Score	Global Socioemotional Score	Global Physical Fitness Score
Global Executive Function Score	—	-0.293 (p = 0.015)*	-0.336 (p = 0.003)**
Global Socioemotional Score	-0.293 (p = 0.015)*	—	-0.038 (p = 0.766)
Global Physical Fitness Score	-0.336 (p = 0.003)**	-0.038 (p = 0.766)	—

Values represent Spearman's rho for correlations involving executive function variables. Values represent Pearson's r for correlations between physical fitness and socioemotional scores. * p ≤ 0.05, ** p ≤ 0.01. Bonferroni correction was applied, with the adjusted significance level set at p ≤ 0.017.

To further examine the relationship between physical fitness and executive functions, linear regression analyses are conducted using the main physical fitness components associated in the correlation analyses (hand-eye coordination, muscular endurance and agility), controlling for age.

For the Global Executive Function Score, the overall model is significant, explaining 22.3% of the variance (adjusted $R^2 = 0.223$, $p < 0.001$). Among the predictors, hand-eye coordination is the only variable significantly associated with executive function performance, indicating that better coordination is associated with better executive function outcomes. Muscular endurance ($p = 0.386$), agility ($p = 0.875$) and age ($p = 0.053$) are not significant predictors.

For inhibitory control composite score, the regression model is also significant, explaining 33.5% of the variance (adjusted $R^2 = 0.335$, $p < 0.001$). Additionally, muscular endurance is significantly associated with inhibitory control ($p = 0.039$), suggesting that higher muscular endurance is related to better inhibitory control performance. Agility ($p = 0.538$) and age ($p = 0.756$) are not significant predictors.

For working memory (digit span total score), the regression model is significant, explaining 13.3% of the variance (adjusted $R^2 = 0.133$, $p = 0.005$). In this model, age is the only significant predictor ($p = 0.004$), indicating that older children perform better on the working memory task. Hand-eye coordination ($p = 0.742$), muscular endurance ($p = 0.790$), and agility ($p = 0.517$) are not significantly associated with working memory performance.

Overall, these findings indicate that hand-eye coordination is the most consistent predictor of executive function outcomes, particularly inhibitory control, while other physical fitness components show limited associations.

The overall results of the regression analyses are presented in Table 3.

Table 3. Multiple linear regression analyses predicting executive function outcomes

Dependent variable	Predictor	B	p
Global Executive Function Score	Hand-eye coordination	0.058	0.006
	Muscular endurance	-0.009	0.386
	Agility	0.013	0.875
	Age	-0.129	0.053
Model summary	$R^2 = 0.262$	Adjusted $R^2 = 0.223$	< 0.001
Inhibitory Control	Hand-eye coordination	0.106	< 0.001
	Muscular endurance	-0.022	0.039
	Agility	-0.053	0.538
	Age	0.021	0.756
Model summary	$R^2 = 0.369$	Adjusted $R^2 = 0.335$	< 0.001
Digit Span Total Score	Hand-eye coordination	-0.023	0.742
	Muscular endurance	-0.009	0.790
	Agility	-0.185	0.517
	Age	0.648	0.004
Model summary	$R^2 = 0.177$	Adjusted $R^2 = 0.133$	0.005

B = unstandardized coefficient. Models adjusted for age

Discussion

The present cross-sectional study investigates the associations between physical fitness components, executive functions, and socioemotional skills in school-aged children. The findings indicate that specific components of physical fitness, rather than overall fitness, are differentially associated with executive function domains. Hand-eye coordination emerges as the most consistent correlate and the strongest predictor of executive function performance, particularly inhibitory control. These results suggest that motor coordination tasks may serve as sensitive indicators of integrated motor-cognitive functioning during childhood. This interpretation is consistent with previous evidence indicating that motor competence and executive functions are closely associated during childhood, although the magnitude and specificity of these associations may vary across executive function domains (Bao et al., 2024; Gordon-

Murer et al., 2021; Van Der Fels et al., 2019). Taken together, the results reinforce the notion that physical fitness, especially motor coordination, is related to cognitive functioning during early developmental stages.

Among the physical fitness variables analyzed, hand-eye coordination, muscular endurance, and agility show the strongest correlations with inhibitory control performance. However, hand-eye coordination remains as the strongest and most consistent predictor in regression models, highlighting its central role in executive functioning. This pattern suggests that although multiple physical fitness components are related to inhibitory control at a correlational level, motor coordination may capture more specific cognitive-motor integration demands. These findings are consistent with previous studies reporting associations between motor coordination, muscular endurance, and cognition in children (V. R. Fernandes et al., 2016; Kao et al., 2017; Sánchez Martín et al., 2025; Torrijos-Niño et al., 2014; Van Der Fels et al., 2019). In addition, Sartori et al. (2020) observed that children with poorer motor performance also present lower performance in inhibitory control, working memory, and cognitive flexibility tasks, supporting the relationships identified in the present study.

In addition to the analysis of individual components, the composite score approach provides further support for the relationship between physical fitness and executive functions. A moderate association was observed between the Global Physical Fitness Score and the Global Executive Function Score, indicating that overall physical fitness is related to general executive functioning. These findings are consistent with previous research, such as Fernandes et al. (2024), which also reported significant associations between global indicators of physical fitness and executive function performance in children. Together, these findings suggest that both specific physical fitness components and overall physical fitness may be relevant to executive functioning during childhood.

The stronger associations observed for inhibitory control compared to working memory suggest that this executive function domain may be more sensitive to variations in physical fitness during childhood. Inhibitory control tasks, such as the Stroop task, require rapid processing, attentional control, and the suppression of automatic responses, which may be more directly linked to motor coordination and physical activities that demand quick reactions and precise movements. This interpretation is supported by evidence indicating that sensorimotor and cognitive functions share common neural substrates and networks, as well as similar developmental trajectories, reflecting a close integration between motor and executive processes throughout development (Tószegi et al., 2023). Moreover, similar findings have been reported by Fernandes et al. (2024), who also identified hand-eye coordination assessed through a similar test as one of the main physical predictors of executive function performance in children.

In contrast, although working memory is also related to physical fitness at a correlational level, its performance appears to be more strongly influenced by developmental factors, as evidenced by the significant effect of age in the regression models. This distinction is consistent with findings showing that the relationship between executive functions and sensorimotor performance varies across developmental stages, with stronger integration observed during childhood (Gordon-Murer et al., 2021). Moreover, meta-analytic evidence indicates that associations between motor competence and executive functions are generally small to moderate, supporting the pattern observed in the present study (Bao et al., 2024).

An interesting finding of the present study was the absence of a direct association between physical fitness and socioemotional skills, despite both domains being significantly related to executive functions. This pattern raises the possibility that executive functions may represent a potential link between physical fitness and socioemotional functioning. However, this interpretation should be considered as a hypothesis rather than evidence of an intermediary mechanism, given the cross-sectional design of the present study. In the present sample, children with better executive function performance also presented more favorable socioemotional profiles, whereas physical fitness was not directly related to socioemotional outcomes. This is consistent with previous studies suggesting that executive functions mediate the relationship between motor competence and socioemotional development. For instance, Li et al. (2022) demonstrated that executive functions significantly mediated the association between gross motor skills and emotion understanding in young children. Similarly, a recent study reported that inhibitory control and cognitive flexibility mediated the relationship between motor skills and both social skills and behavioral problems (S. Li et al., 2025). Although these mediation findings from previous studies provide a theoretical basis for considering executive functions as a potential pathway linking motor-related abilities and socioemotional development, the present findings do not establish such a pathway.

Longitudinal and experimental studies are therefore needed to determine whether changes in physical fitness or motor competence are associated with subsequent changes in executive and socioemotional functioning.

The present findings also have relevant practical implications for educational and intervention contexts. The consistent association between hand-eye coordination and executive function performance suggests that activities targeting motor coordination, particularly those involving rapid, visually guided movements, may provide an effective pathway to support cognitive development in children. Within school settings, these findings highlight that motor coordination and executive functions tend to co-occur, particularly in tasks requiring visuomotor integration and rapid responses. Rather than indicating a direct causal effect, the results suggest that environments that naturally engage both motor and cognitive demands may be relevant for child development. The socioemotional findings provide an additional perspective for educational practice. Although physical fitness was not directly associated with socioemotional skills in the present study, better socioemotional skills were associated with better executive function performance. This finding highlights the potential importance of addressing cognitive and socioemotional development together in educational contexts. In school-based programs, activities that simultaneously engage motor, cognitive, and social demands may therefore represent a promising approach for supporting multiple dimensions of child development, although intervention studies are needed to determine their effectiveness.

Some limitations of the present study should be acknowledged when interpreting the findings. The cross-sectional design precludes causal inferences regarding the associations between physical fitness, executive functions, and socioemotional skills. Although the results suggest a potential integrative role of executive functions in these relationships, longitudinal and experimental designs are necessary to clarify directionality and underlying mechanisms. In addition, the sample was drawn from a single private school, which may limit the generalizability of the findings to more diverse populations. In this context, habitual physical activity, socioeconomic status, biological maturation, and academic performance were not assessed, and therefore their potential confounding effects on the observed associations could not be controlled. Besides that, the assessment of socioemotional skills was also constrained by the absence of parental reports, which may have reduced the sensitivity of this outcome measure.

Future research should address these limitations by incorporating longitudinal designs and randomized controlled trials to examine whether changes in physical fitness lead to improvements in executive functioning and related developmental outcomes. It is also recommended to include a wider range of tasks to capture distinct executive function domains more comprehensively. Furthermore, given the pattern of associations observed, future investigations should explicitly test mediation models to examine whether executive functions act as a mechanism linking physical fitness and socioemotional development. Such approaches may help clarify whether the associations observed in the present study reflect developmental pathways between motor, cognitive, and socioemotional domains during childhood.

Conclusions

The present findings partially supported our hypothesis that physical fitness components would be associated with executive function performance and socioemotional skills in school-aged children. As expected, physical fitness was related to executive functioning, with hand-eye coordination emerging as the component most consistently associated with cognitive outcomes and the strongest independent predictor of inhibitory control. In addition, overall physical fitness was moderately associated with global executive functioning, reinforcing the relevance of both specific motor-related skills and broader fitness indicators for cognitive performance during childhood.

However, contrary to our initial expectations, no direct association was observed between physical fitness and socioemotional skills. Instead, executive functions were associated with both physical fitness and socioemotional outcomes, suggesting that executive functioning may represent an important domain linking these constructs. Although this possibility could not be confirmed within the present cross-sectional design, the findings raised the hypothesis that executive functions may contribute to explaining how physical fitness relates to socioemotional development.

Taken together, these results highlighted the close relationship between motor coordination and executive functioning during childhood and suggested that activities involving visuomotor coordination and cognitively demanding motor tasks may be particularly relevant within educational and physical activity contexts. Future longitudinal and experimental studies are needed to clarify the causal pathways underlying these associations and to determine whether executive functions mediate the relationship between physical fitness and socioemotional development.

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