Cogent Education

ISSN: 2331-186X (Online) Journal homepage: www.tandfonline.com/journals/oaed20

The positive impact of physical activity on academic performance among catalan adolescents

E. Roig-Hierro, X. Ríos-Sisó, F. Buscà, M. Guillem & A. Batalla

To cite this article: E. Roig-Hierro, X. Ríos-Sisó, F. Buscà, M. Guillem & A. Batalla (2025) The positive impact of physical activity on academic performance among catalan adolescents, Cogent Education, 12:1, 2497139, DOI: 10.1080/2331186X.2025.2497139

To link to this article: https://doi.org/10.1080/2331186X.2025.2497139

Published online: 27 Apr 2025.

COGENT EDUCATION
2025, VOL. 12, NO. 1, 2497139
https://doi.org/10.1080/2331186X.2025.2497139

PHYSICAL & HEALTH EDUCATION | RESEARCH ARTICLE

OPEN ACCESS Check for updates

The positive impact of physical activity on academic performance among catalan adolescents

E. Roig-Hierro[a], X. Ríos-Sisó[b], F. Buscà[a], M. Guillem[a] and A. Batalla[a]

[a]Department of Applied Didactics, Universitat de Barcelona, Barcelona, Spain; [b]Department of Didactics of Musical, Visual, and Physical Expression, Universitat Autònoma de Barcelona, Barcelona, Spain

ABSTRACT

Physical activity (PA) positively influences academic performance, yet the specific effects of PA frequency and intensity remain underexplored. This study examines the association between weekly PA frequency and intensity and academic outcomes among 1,524 adolescents in Catalonia, using data from the latest PISA assessment. Academic performance in mathematics, science, and language, along with perceived competence in related tasks, was analyzed using a cross-sectional design. Chi-square tests and Spearman's correlations were conducted. Results indicate that moderate PA (2–5 times per week) is linked to higher academic performance across all subjects, while excessive PA (more than five times weekly) is associated with decreased performance, possibly due to reduced academic focus. Gender moderated the relationship in the language domain but not in mathematics or science. PA also positively influenced perceived competence in teamwork and problem-solving, suggesting broader developmental benefits. These findings emphasize the importance of balancing PA to optimize cognitive and psychosocial outcomes. Integrating structured, moderate PA into school curricula may enhance both academic performance and life skills. Tailored interventions that account for gender and fitness levels could further improve outcomes. Future research should explore longitudinal effects and specific PA characteristics to inform educational strategies..

ARTICLE HISTORY
Received 4 December 2024
Revised 14 April 2025
Accepted 16 April 2025

KEYWORDS
Physical activity; learning; cognition; intensity; academic performance

SUBJECTS
Secondary Education; Sport and Exercise Science; Teaching & Learning - Education

Introduction

The relationship between Physical Activity (PA) and academic performance has received significant attention in educational and health research. The growing body of evidence suggests that regular PA and sports contribute to physical well-being and enhance cognitive and psychological development, which are crucial for academic success (Hillman et al., 2014; Tomporowski & Pesce, 2019). PA improves academic performance through several interrelated mechanisms across physiological (James et al., 2023) and cognitive domains (Latino & Tafuri, 2023).

In the neurophysiological domain, PA, and in particular high-intensity PA (Loprinzi et al., 2023), has been demonstrated to increase cerebral blood flow, neurogenesis and the release of neurotrophic factors such as brain-derived neurotrophic factor (BDNF), which support brain plasticity and cognitive health (Islam et al., 2021; Park & Poo, 2013). These changes are strongly associated with improved cognitive performance (Best, 2010; Cantelon & Giles, 2021). In particular, they enhance executive functions such as attention, working memory, and cognitive flexibility, which are critical for academic success (Vitiello & Greenfield, 2017). Enhanced executive function promotes improved problem solving in mathematics and better reading comprehension (Donnelly et al., 2016).

Moreover, regular PA has been demonstrated to promote better sleep quality, which in turn increases alertness and engagement in learning activities (Pesce, 2012; Wunsch et al., 2017). Exercise also helps reduce symptoms of anxiety and depression, which are known to impair cognitive functioning and

CONTACT Roig-Hierro, E. e.roigh@ub.edu Department of Applied Didactics, Universitat de Barcelona, Barcelona, Spain.

academic performance, while simultaneously promoting emotional well-being and resilience in academic settings (Babic et al., 2014).

Nevertheless, despite the well-established correlation between PA and academic achievement (Singh et al., 2019), there has been comparatively less attention paid to the role of perceived competence – that is to say, adolescents' belief in their abilities – as a mediating factor in this relationship. Extant research indicates that adolescents who regularly engage in PA are more likely to develop self-efficacy, not only in the context of sports but also in academic contexts (Babic et al., 2014). The enhanced perceived competence resulting from regular PA practice may enable adolescents to better manage academic challenges, thereby leading to improved performance through the cultivation of a growth mindset (Brankovic & Hadzikadunic, 2017). In this regard, beyond PA itself, the qualitative characteristics of the practice will also determine the extent to which cognitive benefits are harnessed (Tomporowski & Pesce, 2019).

Furthermore, the gender-specific dynamics linking PA, perceived competence, and academic performance remain insufficiently explored. Research suggests that males report higher perceived competence, greater enjoyment, and more frequent PA participation than females (Ghorbani et al., 2020), with perceived competence in boys being significantly linked to PA both inside and outside school. Social contextual factors, such as unequal interactions in mixed-gender groups, particularly in decision-making, may further explain these gender differences (Muñoz-Arroyave et al., 2021). These findings underscore the need for further investigation into how gender influences the PA-academic performance relationship.

These findings may be particularly pertinent in educational contexts, where boosting academic performance is a priority. The study aims to explore the relationship between the frequency of weekly PA and academic performance as measured by the PISA assessments. Considering the multifaceted benefits observed in practicing sports and PA (Vasilopoulos et al., 2023), it is hypothesized that higher levels of PA will correlate with improved academic performance, both in terms of objective measures such as standardized test scores and subjective measures including perceived competence in academic-related tasks. Additionally, the study seeks to ascertain whether the intensity of the PA or gender exerts a moderating influence on these effects.

Method

Design and participants

According to the objectives of this study, a cross-sectional descriptive research design was used based on the data collected and published by PISA in December 2023. A total of 1524 fourth-grade secondary education adolescents (mean age 15.82 ± .028 years; 786 females; 1120 native-born in Catalonia and 404 natives from other countries) from the 65 randomly selected schools of Catalonia participating in the PISA assessment were included in this study. The final number of cases included could be lower in some variables, as indicated in the tables in the results section.

Procedure

An analysis of the PISA dataset student's questionnaire (OECD 2022), collected and published in December 2023, was conducted with a focus on a sample from Catalonia. The PISA dataset includes test scores for 15-year-old adolescents from OECD and partner countries, along with comprehensive background questionnaires completed by adolescents and school principals, providing detailed insights into various aspects of adolescents' lives, family backgrounds, and school environments.

This study examined variables related to PA frequency and academic performance, specifically scores in mathematics, reading, and science. The test scores are standardized, with an average score of 500 and a standard deviation of 100 among the OECD student population. To account for measurement uncertainty, PISA uses plausible values, which represent different possible estimates of a student's ability based on their responses. This method enhances the reliability of the inferences made from the data (see Data Analysis). The dataset was cleaned to ensure accuracy, and descriptive and inferential statistics

were applied to identify patterns, trends, and correlations Perceived competence was measured through subjective self-report items included in the PISA background questionnaire. Adolescents rated their confidence in various academic and social tasks using a Likert-type scale ranging from 1 to 4 (strongly disagree; disagree; agree and strongly agree). Items assessed domains such as leadership, teamwork, emotional control, and mathematics self-efficacy. For example, adolescents were asked to indicate how confident they felt in taking the lead in a group project or solving complex problems. This measure is part of the broader PISA framework, which includes detailed background questionnaires to understand various aspects of adolescents' lives, such as attitudes toward learning, personal goals, and social competencies (OECD, 2022).

This study focused on PA frequency and intensity, which were categorized by PISA based on student responses. The activities considered as part of PA included common exercises such as running, cycling, aerobics, soccer, and skating. PA frequency was categorized into six groups: 0 times, 1 time, 2 times, 3 times, 4 times, and 5 or more times per week. Regarding PA intensity, PISA defined two broad categories: moderate-intensity activities (60 minutes or more per session of moderate energetic demanding PA) and high-intensity activities (20 minutes or less per session of highly energetic demanding PA).

Data analysis

To conduct the data analysis, the main recommendations provided by the OECD for SPSS were followed (OECD, 2009). The dataset underwent cleaning to ensure accuracy and reliability, a process conducted by PISA. This included the exclusion of cases with incomplete or inconsistent responses, such as missing plausible values or contradictory data on PA frequency and intensity. Outliers were identified and addressed, and categorical variables were properly coded. While these procedures were performed by PISA, our team independently verified the dataset to confirm its accuracy and suitability for analysis.

The scores obtained in mathematics, reading and sciences and the influence on the competence perceived by the adolescents were the dependent variable, and the characteristics of PA experimented by the participants in the study in terms of weekly frequency and intensity, were the independent variables. Gender was included as a potential moderator to examine its effect on the relationship between the dependent and independent variables.

To estimate the differences in test performance according to PA, the means of the 10 plausible values for each domain were grouped, resulting in a single value that allowed for subgroup comparisons based on PA frequency. To determine the relationship between the variables of PA frequency, intensity, and gender with performance in the PISA tests, an analysis for complex samples was conducted using the chi-square test, following the technical guidelines provided by PISA and utilizing the 10 plausible values for each domain. To assess the influence of gender on the relationship between PA frequency and plausible values in mathematics, an interaction variable between gender and PA frequency was created and included in the chi-square test. Additionally, to examine the relationship between PA practice and perceived competence in different domains, Spearman's rho test was performed. All the statistical analyses were performed using the SPSS v29 software, with the level of significance being set at $p < 0.05$.

Results

A total of 1326 adolescents engage (87%) in some form of PA, at least once a week, with 45.9% participating in PA at least 5 times or more per week (see Figure 1).

Physical activity influence on academic performance

The plausible values for mathematics, science, and reading were averaged to create a composite score, allowing comparison between groups based on weekly PA frequency. The results indicate higher scores in all domains for adolescents engaging in PA 1–5 days per week, with optimal performance observed at 3 days per week. In contrast, adolescents who do not engage in PA tend to achieve lower scores in all domains, except for those exercising 6 or more days per week, who consistently exhibit the lowest scores in all domains (see Figure 2).

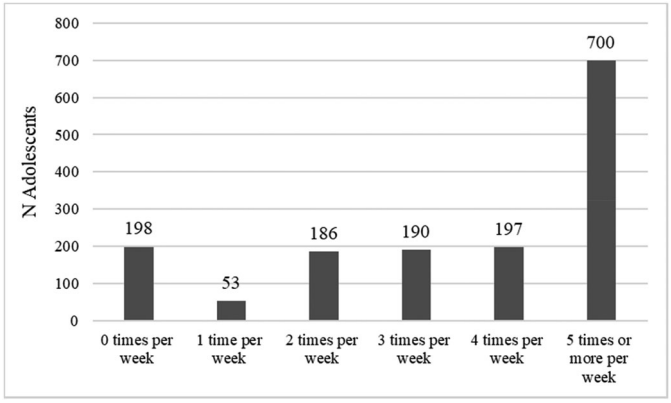

Figure 1. Weekly frequency of PA.

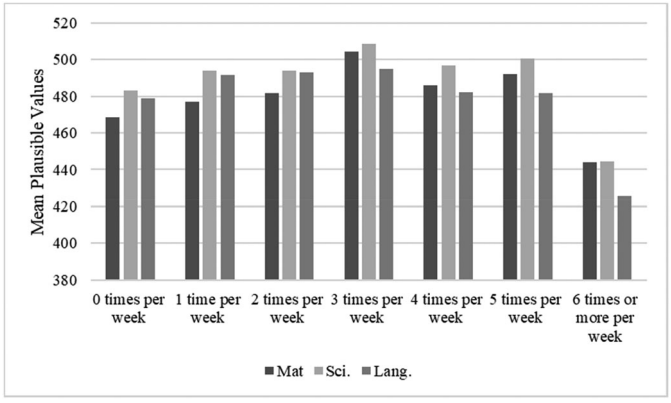

Figure 2. Mean values in different academic domains according to the frequency of PA.

To determine whether the observed relationships between the weekly frequency of PA and the values in different academic domains are significant, the chi-square test was performed using all the plausible values for each domain. Additionally, the influence of PA frequency at different intensities (moderate or high) on the results were analyzed.

Mathematics

In mathematics, the results indicate that the weekly frequency of PA and the intensity at which it is performed, especially moderate intensity, are significantly correlated with performance in the tests. Adolescents engaging in moderate-intensity PA consistently demonstrated higher mathematics scores across plausible values, while high-intensity PA did not show a consistent association with mathematics performance. Detailed results are presented in Table 1.

Science

In science, the weekly frequency of PA was significantly correlated with test performance. Similar to the findings in mathematics, significant correlations were observed for adolescents engaging in moderate-intensity PA, while few correlations were evident for the high-intensity group (see Table 2).

Language

In language, similar results are observed compared to the other domains. Weekly PA frequency is significantly correlated with performance in the tests. While moderate-intensity PA frequency is significantly correlated with all plausible language values, in the case of high intensity, such correlation is observed in more than half of the plausible values (see Table 3).

Table 1. Relationship between PA frequency and intensity on plausible values in mathematics.

	Exeprac			Moderate Intensity			High Intensity		
	χ^2	gl	*p*	χ^2	gl	*p*	χ^2	gl	*p*
PV1 MAT	197,895	10	**.000**	31,422	7	**.000**	20,301	7	**.005**
PV2 MAT	118,657	10	**.000**	29,269	7	**.000**	12,447	7	.087
PV3 MAT	158,072	10	**.000**	48,674	7	**.000**	9,561	7	.215
PV4 MAT	105,209	10	**.000**	39,901	7	**.000**	11,069	7	.136
PV5 MAT	165,910	10	**.000**	35,710	7	**.000**	10,803	7	.147
PV6 MAT	133,383	10	**.000**	33,201	7	**.000**	16,067	7	**.025**
PV7 MAT	213,102	10	**.000**	48,126	7	**.000**	13,028	7	.071
PV8 MAT	151,970	10	**.000**	39,113	7	**.000**	16,125	7	**.024**
PV9 MAT	132,124	10	**.000**	35,918	7	**.000**	7,342	7	.349
PV10 MAT	142,530	10	**.000**	40,882	7	**.000**	9,818	7	.199

Notes. X^2 : Chi-square value; gl: degrees of freedom; *p*= *p*-value for significance; PV: plausible values.

Table 2. Relationship between PA frequency and intensity on plausible values in science.

	Exeprac			Moderate intensity			High intensity		
	χ^2	gl	*p*	χ^2	gl	*p*	χ^2	gl	*p*
PV1 CIEN	181,911	10	**.000**	38,650	7	**.000**	13,305	7	.065
PV2 CIEN	145,200	10	**.000**	24,927	7	**.001**	13,117	7	.069
PV3 CIEN	212,574	10	**.000**	50,571	7	**.000**	7,038	7	.425
PV4 CIEN	137,905	10	**.000**	29,718	7	**.000**	13,418	7	.069
PV5 CIEN	189,724	10	**.000**	23,624	7	**.000**	13,977	7	.052
PV6 CIEN	233,343	10	**.000**	47,267	7	**.000**	9,145	7	.242
PV7 CIEN	170,054	10	**.000**	34,948	7	**.000**	12,101	7	.097
PV8 CIEN	180,604	10	**.000**	33,173	7	**.000**	11,746	7	.109
PV9 CIEN	175,853	10	**.000**	33,555	7	**.000**	10,856	7	.145
PV10 CIEN	148,545	10	**.000**	43,508	7	**.000**	22,374	7	**.002**

Notes. X^2 : Chi-square value; gl: degrees of freedom; p: *p*-value for significance; PV: plausible values.

Table 3. Relationship between PA frequency and intensity on plausible values in language.

	Exeprac			Moderate intensity			High intensity		
	χ^2	GI	*p*	χ^2	gl	*p*	χ^2	gl	*p*
PV1 LANG	101,164	10	**.000**	30,728	7	**.000**	12,727	7	.079
PV2 LANG	82,066	10	**.000**	33,308	7	**.000**	14,819	7	**.038**
PV3 LANG	136,101	10	**.000**	47,297	7	**.000**	13,190	7	.068
PV4 LANG	121,503	10	**.000**	60,601	7	**.000**	18,853	7	**.009**
PV5 LANG	110,505	10	**.000**	38,763	7	**.000**	21,023	7	**.004**
PV6 LANG	113,405	10	**.000**	45,346	7	**.000**	10,168	7	.179
PV7 LANG	112,402	10	**.000**	46,118	7	**.000**	15,288	7	**.032**
PV8 LANG	113,249	10	**.000**	70,311	7	**.000**	14,769	7	**.039**
PV9 LANG	103,321	10	**.000**	69,937	7	**.000**	17,096	7	**.017**
PV10 LANG	116,214	10	**.000**	51,804	7	**.000**	10,341	7	.170

Notes. X^2 : Chi-square value; gl: degrees of freedom; p: *p*-value for significance; PV: plausible values.

Gender influence

Significant association between gender and PA frequency was observed, as revealed by the chi-square test ($\chi^2(10) = 126.15$, $p < 0.001$). Males reported higher levels of PA, with 58.35% engaging in PA five or more times per week, compared to 33.37% of females. In contrast, females were more likely to report no PA, with 17.54% indicating no participation, compared to 8.48% of males.

These gender-specific differences in PA frequency were further analyzed in relation to academic performance. No significant interaction effects between gender and PA frequency were found in the mathematics or science domains. However, a significant interaction was observed in the language domain, with all plausible values yielding significant results (see Table 4).

Table 4. Influence of the interaction between gender and weekly PA frequency on performance in different academic domains.

	Gender and PA interaction		
	χ^2	gl	*P*
PV1 MAT	12,079	10	.280
PV2 MAT	11,810	10	.298
PV3 MAT	11,077	10	.352
PV4 MAT	13,44	10	.200
PV5 MAT	18,230	10	.051
PV6 MAT	15,283	10	.122
PV7 MAT	15,66	10	.110
PV8 MAT	11,16	10	.345
PV9 MAT	12,31	10	.264
PV10 MAT	9011	10	.531
PV1 CIEN	10,356	10	.410
PV2 CIEN	3002	10	.981
PV3 CIEN	5993	10	.816
PV4 CIEN	9243	10	.509
PV5 CIEN	10,378	10	.408
PV6 CIEN	12,501	10	.253
PV7 CIEN	7373	10	.690
PV8 CIEN	16,425	10	.088
PV9 CIEN	13,392	10	.203
PV10 CIEN	6106	10	.806
PV1 LANG	35,721	10	**.000**
PV2 LANG	23,622	10	**.009**
PV3 LANG	19,455	10	**.035**
PV4 LANG	32,203	10	**.000**
PV5 LANG	27,290	10	**.002**
PV6 LANG	25,449	10	**.005**
PV7 LANG	19,687	10	**.032**
PV8 LANG	20,940	10	**.022**
PV9 LANG	29,498	10	**.001**

Notes. X^2 = Chi-square value; gl = Degrees of freedom; p = p-value for significance; PV = Plausible Values.

Physical activity influence on perceived competence

When analyzing the differences between adolescents engaged in PA (EXE) and those who do not (NOT), consistently positive results were found in favor of the EXE group in terms of perceived competence. Significant differences favoring the EXE group were observed in the perceived ability to work under pressure (U = 25799; p= .005), completion of complex tasks (U = 24921; p= .004), perceived withstand stress (U = 93424; p= .000), completion tasks in mathematical reasoning (U = 98329; p= .021), and applied mathematics (U = 96315; p= .038).

However, it was found that the characteristics of PA could determine positive effects on different domains of adolescent life. Specifically, both the frequency of PA and the intensity at which it is performed (high or moderate) were analyzed.

Physical activity characteristics influence on perceived competence

The characteristics of PA proved to be determinants of adolescents' perceived competence. The frequency of weekly PA was significantly positively correlated with perceived teamwork ability, stress resistance scale, emotional control scale, and perceived mathematical ability for reasoning and 21st-century skills. In contrast, it was negatively correlated with the empathy scale. Concerning intensity, significant correlations were observed exclusively in favor of EXE_INT in the perceived teamwork ability and emotional control scale. Conversely, significant correlations were observed only in EXE_MOD and not in EXE_INT for the perceived leadership ability, curiosity scale, perceived competence for self-learning, and perceived digital competencies. Comprehensive results are provided in Table 5 for further reference.

Discussion

The results of this study highlight the complex relationship between PA and academic performance among adolescents. The findings indicate that moderate PA is associated with improved academic

Table 5. PA characteristics influence on adolescent's self-competence perception.

Rho's Spearman correlation		PA weekly frequency	PA high intensity (EXE_INT)	PA moderate intensity (EXE_MOD)
Finish complex tasks	Corr.	.056	**.092***	**.087***
	Sig.	.131	.019	.025
	N	732	659	665
Work in a team	Corr.	**.138****	**.107***	−.009
	Sig.	.000	.006	.821
	N	746	669	671
To be a leader	Corr.	.026	.039	**.098***
	Sig.	.497	.324	.013
	N	710	643	645
Working under pressure	Corr.	.063	**.128***	.110*
	Sig.	.087	.001	.004
	N	733	664	669
Perseverance scale	Corr.	.048	**.096****	**.082***
	Sig.	.064	.000	.003
	N	1477	1326	1330
Curiosity scale	Corr.	−.013	−.003	**.060***
	Sig.	.617	.911	.030
	N	1471	1325	1329
Cooperation scale	Corr.	.042	.043	.029
	Sig.	.109	.121	.296
	N	1467	1324	1328
Empathy scale	Corr.	**−.073***	**−.071***	**−.057***
	Sig.	.005	.010	.037
	N	1467	1325	1329
Resistance to stress scale	Corr.	**.170****	**.211****	**.150****
	Sig.	.000	.000	.000
	N	1441	1310	1315
Emotional control scale	Corr.	**.088***	**.159****	.124*
	Sig.	.001	.000	.000
	N	1453	1321	1326
Mathematics self-efficacy scale (Formal and applied maths)	Corr.	−.029	**.085***	**.104****
	Sig.	.285	.002	.000
	N	1409	1306	1307
Mathematics self-efficacy scale (Reasoning and 21st century skills)	Corr.	**.062***	**.128****	**.138****
	Sig.	.021	.000	.000
	N	1394	1298	1300
Self-directed learning self-efficacy scale	Corr.	.003	.039	**.101***
	Sig.	.909	.211	.001
	N	1107	1043	1047
Self-efficacy in digital competencies	Corr.	−.044	.013	**.077***
	Sig.	.114	.639	.006
	N	1317	1262	1263

Notes.
*$p < 0.05$.
**$p < 0.001$. N = Total adolescents included; Corr.: Correlation coefficient; Sig.: statistical significance.

outcomes in mathematics, science, and reading, aligning with existing literature on the cognitive and psychological benefits of regular exercise (Vasilopoulos et al., 2023). Specifically, in this study adolescents who engage in PA 2-5 times per week tend to score higher in these academic domains compared to their peers who either do not exercise or exercise excessively (6 or more times per week).

The positive effects of moderate PA can be linked to improvements in cognitive functions due to physiological changes such as increased cerebral blood flow, neurogenesis, and the release of neurotrophic factors, which enhance memory, attention, and overall brain health (Ferrer-Uris et al., 2022; Hillman et al., 2014). In addition to these factors, the qualitative characteristics and specific demands of each type of PA may be relevant for the development of higher-order cognitive functions, such as improvements in adolescents' ability to focus and engage in tasks requiring higher-order thinking, which is critical for academic success (Cantelon & Giles, 2021; Donnelly et al., 2016). Incorporating cognitively challenging PA games that target these cognitive skills may be particularly relevant in Physical Education to enhance adolescents' holistic development (Kolovelonis & Goudas, 2022). Additionally, the psychological benefits of regular PA, such as reduced levels of stress, anxiety, and depression (Biddle & Asare, 2011), contribute to a more supportive learning environment. This allows adolescents to approach academic challenges with greater resilience and adaptability (Singh et al., 2019), fostering both emotional well-being and academic achievement (Belcher et al., 2021).

Consistent with Babic et al. (2014), adolescents who engaged in regular PA reported higher perceived competence in academic and non-academic tasks, such as teamwork, problem-solving, and stress management. The enhanced perceived competence resulting from regular PA may play a significant role in academic achievement (Macakova & Wood, 2022). These perceptions of competence are crucial, as they may foster a growth mindset, wherein adolescents believe in their ability to overcome challenges and succeed academically (Brankovic & Hadzikadunic, 2017). In this way, sports practice not only improves physiological and psychological well-being but also could contribute to the development of essential skills that facilitate academic success.

This study also highlights an important caveat regarding the intensity and frequency of PA. Adolescents who engaged in PA more than five times per week displayed lower academic scores across all domains. This finding may suggest that excessive PA interferes with academic study time, rest, or recovery, leading to fatigue and suboptimal cognitive performance (Abd-Elfattah et al., 2015). It may also indicate a subset of adolescents who prioritize PA at the expense of academic endeavors. The findings underscore the necessity of a balanced approach to PA, advocating for moderate and regular PA while ensuring that academic commitments and rest periods are not compromised. In this context, schools play a crucial role in facilitating this balance (McLellan et al., 2020), promoting classroom-based PA (Xu et al., 2024).

Moreover, the study explored the influence of gender on these relationships. While gender did not significantly impact the correlation between exercise and performance in mathematics and science, it did have a notable effect in the domain of language. The observed gender differences in physical activity (PA) participation may be influenced by broader socio-cultural factors (Muñoz-Arroyave et al., 2021). Previous research indicates that males are often encouraged to engage in PA more frequently than females (Ghorbani et al., 2020), which may help explain the higher levels of PA observed in this study. These gender-specific disparities in PA have been shown to impact academic achievement (Escolano-Pérez & Bestué, 2021), potentially mediated by factors such as self-efficacy and motivation—key determinants of academic performance, particularly in the language domain (Guo et al., 2023).

Gender disparities in physical activity and academic performance underscore the importance of investigating the factors driving these differences. Understanding the role of gender in this context is crucial, as it may help to identify specific mechanisms—such as social norms, emotional factors, and motivational differences—that influence how physical activity impacts academic outcomes. Exploring these factors in greater depth can provide valuable insights that may inform targeted interventions aimed at improving both physical and academic performance in different gender groups, ultimately leading to more effective and inclusive educational strategies.

These findings hold important implications for educators and policymakers seeking strategies to enhance adolescents' academic learning. Experiential domains of knowledge, such as art and music, have been shown to facilitate the acquisition of specific academic skills, including mathematics (Holmes & Hallam, 2017; Schoevers et al., 2020). Similarly, the present study demonstrates that encouraging moderate PA among adolescents could be an effective approach to improving academic performance and overall well-being. Adopting a holistic educational framework that integrates Physical Education can be particularly beneficial for schools (Smith, 2022). Such an approach ensures that adolescents reap the cognitive, emotional, and physical benefits of PA while maintaining a strong emphasis on academic achievement. However, it is also essential to design interventions that prevent excessive engagement in PA, which may detract from academic focus and performance. Monitoring adolescents' activity levels is crucial to striking a balance, ensuring that PA supports rather than hinders their educational progress.

This study is not without its limitations. First, the use of secondary data constrains the depth of the analysis, as the original data collection methodologies and the variables analyzed were predetermined, thereby limiting the scope of the findings obtained. Moreover, the cross-sectional design limits our ability to establish causal relationships between PA and outcomes related to academic or personal development. The absence of detailed data on physical activity intensity in the PISA program limits the ability to precisely differentiate between activity levels and their potential effects. From a methodological perspective, it is also important to highlight the potential biases associated with self-reported data, as participants' subjective perceptions could affect the reliability of the results.

Future research should focus on conducting longitudinal studies to investigate the long-term effects of physical activity on both academic and personal development. Specifically, it is essential to examine the types and intensities of physical activity that are most beneficial for different academic subjects. Such research would provide valuable insights for optimizing physical education programs, with the goal of enhancing student outcomes.

Considering children's regular participation in sports, it will also be important to analyze the qualitative characteristics of each sports practice, as well as to differentiate between sports and PA itself. The cognitive demands specific to each sport may have a distinct impact on both academic and cognitive development (Tomporowski et al., 2015). Exploring these dimensions, as well as moderating factors such as diet, sleep, familiar support and socio-economic status, can provide a more comprehensive understanding of the optimal conditions for leveraging PA to support academic and personal development in adolescents.

Similarly, future research could incorporate a qualitative approach to complement existing perspectives. Additionally, expanding the sample to include adolescents of different ages, beyond 15 years, would allow for a broader and more representative understanding of this subject.

Conclusion

The findings of this study underscore the fundamental role of moderate PA in promoting both academic success and overall well-being among adolescents. Specifically, engaging in PA two to five times per week was associated with improved performance in mathematics, science, and language, which can be attributed to physiological, cognitive, and psychological benefits. However, excessive PA was found to negatively impact academic outcomes, highlighting the necessity of adopting a balanced approach that maximizes the benefits of exercise without compromising educational priorities. Furthermore, the observed gender differences, particularly in language domain, reveal the influence of socio-cultural factors and the importance of designing inclusive interventions that address the specific needs of diverse adolescents.

In light of these findings, it is crucial for schools and policymakers to develop educational frameworks that incorporate moderate PA into daily routines, while ensuring adequate monitoring of participation to prevent excessive engagement. Active learning strategies, such as Active Breaks or Physical Active Learning, are already being implemented in some school settings and have proven effective in enhancing student learning. This approach exemplifies how the findings of the present study can be integrated. These results, combined with future research, can serve as a valuable resource for educators, policymakers, and sports professionals in designing evidence-based interventions that promote the holistic well-being, academic success, and personal development of children and young people.

Data is extracted from the PISA study; therefore, the ethical criteria are applied by the OECD in the collection of data. In Spain, participation in PISA is governed by the Ley Orgánica 2/2006 (LOE) and its subsequent amendments, including LOMCE and LOMLOE, which regulate the involvement of schools and adolescents in educational assessments. Additionally, data protection standards are upheld by the Spanish government. All data used in this study were anonymized, and informed consent was obtained from participants during the PISA 2023 assessment.

External grant funding was not used to fund this work. The authors declare that they have no conflicts of interest to disclose.

Ethical approval

This study was performed in line with the European Code of Conduct for Research Integrity (ALLEA, 2023) for ethical research practices and adhered to the ethical guidelines of PISA, which ensured participant privacy and institutional confidentiality. In Spain, participation in PISA is governed by the Ley Orgánica 2/2006 (LOE) and its subsequent amendments, including LOMCE and LOMLOE, which regulate the involvement of schools and adolescents in educational assessments. Additionally, data protection standards are upheld by the Spanish government. All data used in this study were anonymized, and informed consent was obtained from participants during the PISA 2023 assessment.

Disclosure statement

No potential conflict of interest was reported by the author(s).

About the authors

E. Roig Hierro is Full-Time Professor of Education at the University of Barcelona, Spain. He holds a PhD in Education. His research interests include physical education, cognition, and motor learning. He is a member of the research groups GISEAFE, EDUFISES, and MCIE.

X. Ríos Sisó is Full-Time Professor of Education at Universitat Autònoma of Barcelona, Spain. She is PhD in Education and is focused on physical education and bullying. She is affiliated with the research groups GISEAFE and IRE.

F. Buscàis Senior Lecturer of Education at the University of Barcelona, Spain. He holds a PhD in Education. His research interests include physical education, didactics, and rural education. His current research focuses on enhancing the teaching-learning process in schools through the integration of motricity as a pedagogical method. He is a member of the research groups GISEAFE, EDUFISES, and MCIE.

M. Guillem is an associate Professor of Education at the University of Barcelona, Spain. He is PhD in Education and his research interests lie in physical education and executive functions. He is affiliated with the research groups GISEAFE, EDUFISES, and MCIE.

A. Batalla is Senior Lecturer of Education at the University of Barcelona, Spain. He holds a PhD in Education and his research focuses on motor learning, physical education, and society. He is a member of the research groups GISEAFE, EDUFISES, and MCIE.

ORCID

E. Roig-Hierro http://orcid.org/0000-0003-1040-8379

References

Abd-Elfattah, H. M., Abdelazeim, F. H., & Elshennawy, S. (2015). Physical and cognitive consequences of fatigue: A review. *Journal of Advanced Research*, *6*(3), 351–358. https://doi.org/10.1016/j.jare.2015.01.011

ALLEA. (2023). *The European code of conduct 2023*. https://allea.org/portfolio-item/european-code-of-conduct-2023/

Babic, M. J., Morgan, P. J., Plotnikoff, R. C., Lonsdale, C., White, R. L., & Lubans, D. R. (2014). PA and physical self-concept in youth: Systematic review and meta-analysis. *Sports Medicine* , *44*(11), 1589–1601. https://doi.org/10.1007/s40279-014-0229-z

Belcher, B. R., Zink, J., Azad, A., Campbell, C. E., Chakravartti, S. P., & Herting, M. M. (2021). The roles of PA, exercise, and fitness in promoting resilience during adolescence: Effects on mental well-being and brain development. *Biological Psychiatry. Cognitive Neuroscience and Neuroimaging*, *6*(2), 225–237. https://doi.org/10.1016/j.bpsc.2020.08.005

Best, J. R. (2010). Effects of PA on children's executive function: Contributions of experimental research on aerobic exercise. *Developmental Review*, *30*(4), 331–551. https://doi.org/10.1016/j.dr.2010.08.001

Biddle, S. J., & Asare, M. (2011). PA and mental health in children and adolescents: A review of reviews. *British Journal of Sports Medicine*, *45*(11), 886–895. https://doi.org/10.1136/bjsports-2011-090185

Brankovic, E., & Hadzikadunic, M. (2017). Physical education experimental program to test the effect on perceived competence. *Sport Mont*, *15*(2), 25–32. http://www.sportmont.ucg.ac.me/?sekcija=articleandartid=1371

Cantelon, J. A., & Giles, G. E. (2021). A review of cognitive changes during acute aerobic exercise. *Frontiers in Psychology*, *12*, 653158. https://doi.org/10.3389/fpsyg.2021.653158

Donnelly, J. E., Hillman, C. H., Castelli, D., Etnier, J. L., Lee, S., Tomporowski, P., Lambourne, K., & Szabo-Reed, A. N. (2016). PA, Fitness, cognitive function, and academic achievement in Children: A systematic review. *Medicine and Science in Sports and Exercise*, *48*(6), 1197–1222. https://doi.org/10.1249/MSS.0000000000000901

Escolano-Pérez, E., & Bestué, M. (2021). Academic achievement in Spanish secondary school students: The interrelated role of executive functions, physical activity and gender. *International Journal of Environmental Research and Public Health*, *18*(4), 1816. https://doi.org/10.3390/ijerph18041816

Ferrer-Uris, B., Ramos, M. A., Busquets, A., & Angulo-Barroso, R. (2022). Can exercise shape your brain? A review of aerobic exercise effects on cognitive function and neuro-physiological underpinning mechanisms. *AIMS Neuroscience*, *9*(2), 150–174. https://doi.org/10.3934/Neuroscience.2022009

Ghorbani, S., Nouhpisheh, S., & Shakki, M. (2020). Gender differences in the relationship between perceived competence and PA in middle school students: Mediating role of enjoyment. *International Journal of School Health*, *7*(2), 14–20. https://doi.org/10.30476/intjsh.2020.85668.1056

Guo, W., Lau, K. L., Wei, J., & Bai, B. (2023). Academic subject and gender differences in high school students' self-regulated learning of language and mathematics. *Current Psychology*, *42*(10), 7965–7980. https://doi.org/10.1007/s12144-021-02120-9

Hillman, C. H., Pontifex, M. B., Castelli, D. M., Khan, N. A., Raine, L. B., Scudder, M. R., Drollette, E. S., Moore, R. D., Wu, C.-T., & Kamijo, K. (2014). Effects of the FITKids randomized controlled trial on executive control and brain function. *Pediatrics*, *134*(4), e1063–e1071. https://doi.org/10.1542/peds.2013-3219

Holmes, S., & Hallam, S. (2017). The impact of participation in music on learning mathematics. *London Review of Education*, *15*(3), 425–438. https://doi.org/10.18546/LRE.15.3.07

Islam, M. R., Valaris, S., Young, M. F., Haley, E. B., Luo, R., Bond, S. F., Mazuera, S., Kitchen, R. R., Caldarone, B. J., Bettio, L. E. B., Christie, B. R., Schmider, A. B., Soberman, R. J., Besnard, A., Jedrychowski, M. P., Kim, H., Tu, H., Kim, E., Choi, S. H., … Wrann, C. D. (2021). Exercise hormone irisin is a critical regulator of cognitive function. *Nature Metabolism*, *3*(8), 1058–1070. https://doi.org/10.1038/s42255-021-00438-z

James, J., Pringle, A., Mourton, S., & Roscoe, C. M. P. (2023). The effects of PA on academic performance in school-aged children: A systematic review. *Children*, *10*(6), 1019. https://doi.org/10.3390/children10061019

Kolovelonis, A., & Goudas, M. (2022). Exploring the effects of three different types of cognitively challenging physical activity games on students' executive functions and situational interest in physical education. *Cogent Education*, *9,* 1–17. https://doi.org/10.1080/2331186X.2022.2148448

Latino, F., & Tafuri, F. (2023). PA and academic performance in school-age children: A systematic review. *Sustainability*, *15*(8), 6616. https://doi.org/10.3390/su15086616

Ley Orgánica 2/2006, de 3 de mayo, de Educación (LOE), modificada por la Ley Orgánica 8/2013, de 9 de diciembre (LOMCE) y por la Ley Orgánica 3/2020, de 29 de diciembre (LOMLOE). (2006). *Boletín Oficial del Estado (BOE)*. https://www.boe.es/buscar/doc.php?id=BOE-A-2006-7899

Loprinzi, P. D., Roig, M., Tomporowski, P. D., Javadi, A. H., & Kelemen, W. L. (2023). Effects of acute exercise on memory: Considerations of exercise intensity, post-exercise recovery period and aerobic endurance. *Memory & Cognition*, *51*(4), 1011–1026. https://doi.org/10.3758/s13421-022-01373-4

Macakova, V., & Wood, C. (2022). The relationship between academic achievement, self-efficacy, implicit theories and basic psychological needs satisfaction among university students. *Studies in Higher Education*, *47*(2), 259–269. https://doi.org/10.1080/03075079.2020.1739017

McLellan, G., Arthur, R., Donnelly, S., & Buchan, D. S. (2020). Segmented sedentary time and PA patterns throughout the week from wrist-worn ActiGraph GT3X + accelerometers among children 7–12 years old. *Journal of Sport and Health Science*, *9*(2), 179–188. https://doi.org/10.1016/j.jshs.2019.02.005

Muñoz-Arroyave, V., Pic, M., Luchoro-Parrilla, R., Serna, J., Salas-Santandreu, C., Damian-Silva, S., Machado, L., Rodríguez-Arregi, R., Prat, Q., Duran-Delgado, C., & Lavega-Burgués, P., (2021). Promoting interpersonal relationships through elbow tag, a traditional sporting game: A multidimensional approach. *Sustainability*, *13*(14), 7887. https://doi.org/10.3390/su13147887

OECD. (2009). *PISA data analysis manual: SPSS.* (2nd ed.) OECD Publishing. https://doi.org/10.1787/9789264056275-en

OECD. (2022). *PISA 2022 database*. OECD Publishing. https://www.oecd.org/pisa/data/

Park, H., & Poo, M. M. (2013). Neurotrophin regulation of neural circuit development and function. *Nature Reviews. Neuroscience*, *14*(1), 7–23. https://doi.org/10.1038/nrn3379

Pesce, C. (2012). Shifting the focus from quantitative to qualitative exercise characteristics in exercise and cognition research. *Journal of Sport & Exercise Psychology*, *34*(6), 766–786. https://doi.org/10.1123/jsep.34.6.766

Schoevers, E. M., Leseman, P. P. M., & Kroesbergen, E. H. (2020). Enriching mathematics education with visual arts: Effects on elementary school students' ability in geometry and visual arts. *International Journal of Science and Mathematics Education*, *18*(8), 1613–1634. https://doi.org/10.1007/s10763-019-10018-z

Singh, A. S., Saliasi, E., van den Berg, V., Uijtdewilligen, L., de Groot, R. H. M., Jolles, J., Andersen, L. B., Bailey, R., Chang, Y.-K., Diamond, A., Ericsson, I., Etnier, J. L., Fedewa, A. L., Hillman, C. H., McMorris, T., Pesce, C., Pühse, U., Tomporowski, P. D., & Chinapaw, M. J. M. (2019). Effects of PA interventions on cognitive and academic performance in children and adolescents: A novel combination of a systematic review and recommendations from an expert panel. *British Journal of Sports Medicine*, *53*(10), 640–647. https://doi.org/10.1136/bjsports-2017-098136

Smith, W. (2022). Enactive cognition and physical education – a natural coupling. *Sport, Education and Society*, *27*(9), 1061–1070. https://doi.org/10.1080/13573322.2021.1960497

Tomporowski, P. D., McCullick, B., Pendleton, D. M., & Pesce, C. (2015). Exercise and children's cognition: The role of exercise characteristics and a place for metacognition. *Journal of Sport and Health Science*, *4*(1), 47–55. https://doi.org/10.1016/j.jshs.2014.09.003

Tomporowski, P. D., & Pesce, C. (2019). Exercise, sports, and performance arts benefit cognition via a common process. *Psychological Bulletin*, *145*(9), 929–951. https://doi.org/10.1037/bul0000200

Vasilopoulos, F., Jeffrey, H., Wu, Y., & Dumontheil, I. (2023). Multi-level meta-analysis of PA interventions during childhood: Effects of PA on cognition and academic achievement. *Educational Psychology Review*, *35*(2), 59. https://doi.org/10.1007/s10648-023-09760-2

Vitiello, V. E., & Greenfield, D. B. (2017). Executive functions and approaches to learning in predicting school readiness. *Journal of Applied Developmental Psychology*, *53*, 1–9. https://doi.org/10.1016/j.appdev.2017.08.004

Wunsch, K., Kasten, N., & Fuchs, R. (2017). The effect of physical activity on sleep quality, well-being, and affect in academic stress periods. *Nature and Science of Sleep*, *9*, 117–126. https://doi.org/10.2147/NSS.S132078

Xu, Y., Lin, N., Wu, C., Wen, X., Zhong, F., Yu, K., Shu, L., & Huang, C. (2024). The effect of classroom-based PA Elements on academic performance in children and adolescents: A meta-analysis. *Journal of Teaching in Physical Education*, *43*(1), 79–92. https://doi.org/10.1123/jtpe.2022-0175