Systematic Review

A Systematic Review of the Effects of Physical Activity on Specific Academic Skills of School Students

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Abstract: This systematic review examined the effects of distinct physical activity interventions on the academic achievement of school students based on an analysis of four distinct outcomes: mathematics, language, reading, and composite scores. This study was performed in accordance with the PRISMA guidelines and the QUORUM statement. A literature search was conducted using the PubMed-MEDLINE, Scopus, and Web of Science databases. Peer-reviewed studies published in English, Portuguese, and Spanish were considered. A random-effect meta-analysis was employed to determine the effect of interventions on academic performance. The effects between interventions and control groups were expressed as standardized mean differences. Thirty-one studies were included in the meta-analysis based on the inclusion and exclusion criteria. The exercise programs were not capable of significantly improving language, reading skills, and composite scores. Conversely, performance in math tests increased significantly after the interventions compared with the control groups. Regarding the overall effect, a significant improvement in academic achievement was detected after physical activity programs compared with controls. In conclusion, the positive effects of school-based physical education on academic performance are not uniform and may be higher for math skills. The implementation of evidence-based exercise programs in school settings emerges as a promising strategy to increase overall academic achievement in school-aged students.

Keywords: academic skills; active breaks; active classes; school grades; schoolchildren

1. Introduction

Over the last few decades, the rate of sedentarism has increased dramatically around the world, currently being considered a "public health issue" [1–4]. Overall, according to the World Health Organization (WHO), approximately one-third of individuals aged 15 years or older are physically inactive, which potentially results in more than 3 million premature or preventable deaths annually [1,5,6]. In fact, about 5.5% of all deaths worldwide have been attributed to sedentarism, a number that places this growing health concern among the five major risk factors for mortality in adult life [5,7]. Among other things, physical inactivity significantly increases the risk of several chronic diseases, such as different forms of cancer, diabetes, hypertension, dementia, coronary and cerebrovascular events, bone disorders, and obesity [8,9]. Together, these findings highlight the severity of this "global epidemic" and reinforce the need for urgent and effective strategies to increase the levels of physical activity and to reduce sedentary behavior among the general population [3,10,11].

The adverse effects of sedentarism have been consistently recognized to affect distinct age groups, but more recently, a growing body of research has been conducted to evaluate its specific effects on youths [11–13]. Indeed, a progressive decline in physical activity participation is commonly observed during the transition from childhood to adolescence, suggesting that many adolescents are at risk of becoming sedentary adults [14–16]. It has been shown, for example, that a gradual decrease in physical fitness from childhood to adult life is associated with obesity and insulin resistance in adulthood [17]. From an applied

standpoint, this means that the vast majority of children with obesity tend to become obese and "potentially unhealthy" adults [17,18]. In contrast, long-term programs and strategies aimed at maintaining high levels of physical activity during different life stages, from childhood to adulthood, may likely reduce the probability of developing obesity and other chronic diseases (e.g., type 2 diabetes, cardiovascular diseases, hypertension, osteoporosis, etc.) throughout adulthood [18–20]. As such, there is no doubt that regular exercise, especially when performed uninterruptedly from earlier life stages, has numerous physical and physiological benefits [21–24].

Lower levels of physical activity in childhood and adolescence are also associated with body image dissatisfaction, obesity, and adult depression [25–27]. On the other hand, the involvement in sport activities seems to influence the development of important coping and stress management skills in youths, which emphasizes the role played by physical activity in promoting mental health and in preventing mental illness [24,28–30]. Furthermore, there is evidence suggesting that physical activity can also improve cognitive function and learning abilities in both children and adolescents, thus impacting their academic achievement in different areas of knowledge (e.g., mathematics and languages). A recent review addressed this issue in a very comprehensive manner, finding meaningful relationships among physical activity, fitness levels, and academic performance in elementary-aged children (i.e., aged 5–13 years) [31]. Two other reviews have specifically examined the effectiveness of school-based physical activity in academic life, providing encouraging and relevant results [32,33]. Briefly put, the regular practice of physical education in school settings was shown to be capable of improving learning skills through different cognitive processes (e.g., increasing attention and concentration) and was equally efficient in inducing positive changes on a variety of important outcomes, such as quality of life, and social and affective behaviors [32,33].

Although the benefits of physical education are well-established, to date, no review has systematically assessed its effects on different subjects and fields of study in a separate manner (i.e., analyzing its effects on mathematics, language, and reading skills) or in combination (i.e., using "composite scores"). This is essential to provide a deeper and more detailed understanding of the actual effects of physical education on the academic performance of school students. Therefore, the objective of this systematic review and meta-analysis was to evaluate the effects of distinct physical activity interventions on the academic achievement of school students, based on the individual analysis of four distinct outcomes: mathematics, language, reading, and composite scores. We hypothesized that the regular practice of physical education in schools would positively and equally affect academic performance, regardless of the subject being examined.

2. Methods

2.1. Literature Search and Data Resources

This research was completed in accordance with the Preferred Reported Items for Systematic Reviews (PRISMA) guidelines [34] and the QUORUM statement [35]. The literature search included studies published until 13 December 2021 and was conducted using the following databases: PubMed MEDLINE, Scopus, and Web of Science. Keywords were defined based on previous works [36,37] and according to the study purpose by two authors (I.L. and L.A.P.). The following keywords were used in conjunction with the Boolean operators "AND" and "OR" as part of the search strategy: "students", "schoolchildren", "physical activity", "physical education", "sport", "exercise", "academic performance", "academic achievement", and "school grades". The reference lists from relevant articles were also examined to find any other potentially eligible studies.

2.2. Eligibility Criteria

Peer-reviewed studies published in English, Spanish, or Portuguese were considered for inclusion, and no sex or time of intervention restrictions were imposed. Studies were included based on the following criteria: (1) original studies; (2) quantitative assessment of

"academic performance" pre- and post-intervention; (3) at least one group allocated to a physical activity intervention; and (4) samples composed of kindergarten, elementary, middle, or high-school students. Additionally, in relation to the exclusion criteria, studies were not considered for analysis if (1) they were written in other languages; (2) no comparison group was tested; (3) only acute effects were assessed; (4) they were qualitative studies; or (5) no full text or data regarding the main outcomes were available.

2.3. Study Selection

The initial search was carried out by two researchers (I.L. and L.A.P.). After the removal of duplicates, titles and abstracts were screened and studies not meeting the eligibility criteria were excluded. Subsequently, full texts of the remaining articles were analyzed. Next, in a blind, independent fashion, two reviewers selected the studies for inclusion (I.L. and L.A.P.), following the eligibility criteria. If no agreement was obtained, a third independent and experienced researcher, not involved in the study, was consulted.

2.4. Data Extraction

Mean, standard deviation (SD), and sample size data were extracted from the included manuscripts by two authors (I.L. and L.A.P.). If the descriptive data required were not presented in the articles, authors were contacted via email, and in case of no answer or if the requested data were not available, the study was not considered in the analysis. Any disagreements during the process of data extraction and analysis were resolved by consensus among two authors (I.L. and L.A.P.).

2.5. Data Analysis

The meta-analysis was performed using Review Manager software (RevMan 5.4.1; Cochrane Collaboration, Oxford, UK). A random-effect meta-analysis was conducted to determine the summary effect of the interventions on academic performance. Effects between intervention and control groups are expressed as standardized mean differences (SMD) and their 95% confidence intervals (CI). Standardized mean differences were used because academic performance was obtained through distinct methods. Academic performance data were divided into subgroups, according to distinct assessed subjects (e.g., language, mathematics, reading, and composite scores).

Heterogeneity among studies was assessed using I^2 statistics. I values ranged between 0% and 100% and were considered low, modest, or high for <25%, >25–<50%, and >50%, respectively. Heterogeneity may be assumed when the p value of the I test was <0.05 [38]. Statistical significance was considered for $p < 0.05$.

2.6. Risk of Bias and Quality of the Studies

Methodological quality and risk of bias were assessed through the Cochrane risk of bias tool (RoB 2.0) [39] by two authors independently (I.L. and L.A.P.), with disagreements being resolved by a third independent evaluator (not involved in the study), in accordance with the Cochrane Collaboration Guidelines [40].

3. Results

3.1. Study Selection

Figure 1 depicts a flow diagram of the process of study selection. A total of 2718 records were identified through database searching, and 16 additional studies were identified through other sources. After title and abstract screening, from the 1981 studies that remained after removal of duplicates, 1782 studies were excluded. As a result, 199 studies were assessed for eligibility and 31 studies were included in the meta-analysis based on the inclusion and exclusion criteria. From the articles included, 4 assessed academic performance through language tests [41–44], 24 used mathematics tests [41,42,44–65], 10 reading assessments [44,46,47,49,50,57,59,60,63,64], and 9 evaluated academic achievement using composite scores (e.g., student's grades or standard tests) [41,44,59,66–71].
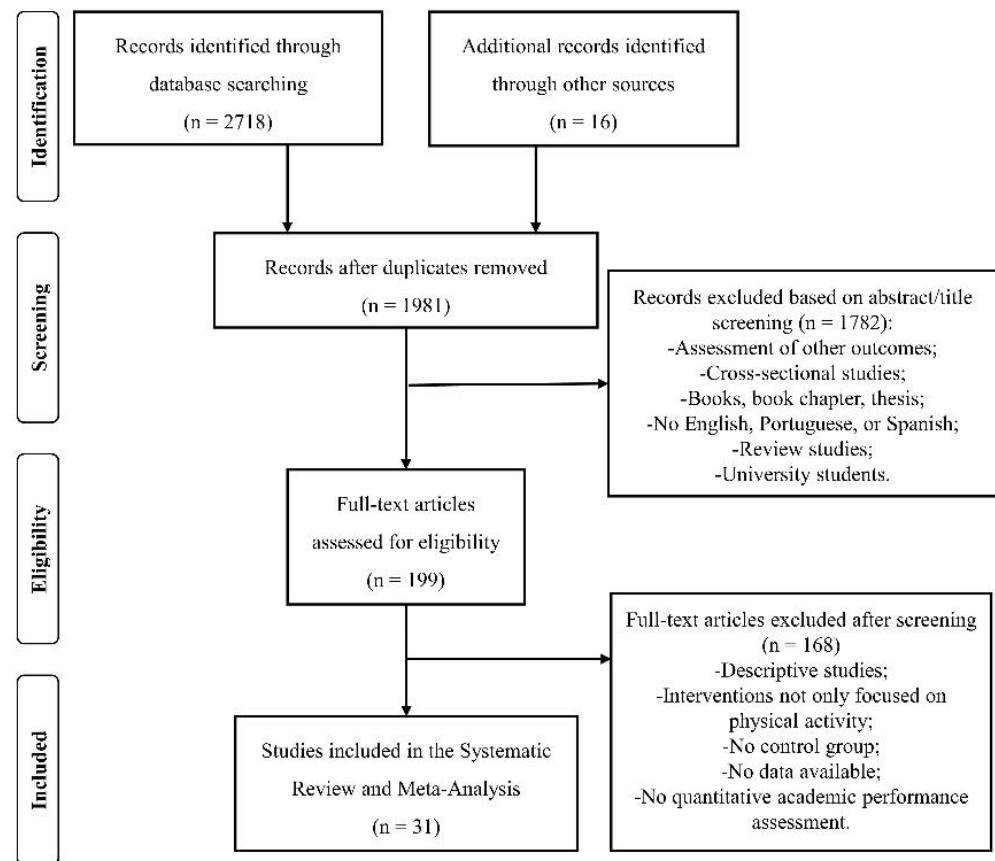
Figure 1. Flow diagram of the process of study selection.

3.2. Characteristics of the Interventions

The characteristics of the training programs and the overall risk of bias of the included studies are displayed in Table 1. The interventions implemented in the distinct studies comprised increasing the volume of physical education classes [41,68], applying classroom-based activities in the regular school practices [66], promoting "active" breaks between regular classes [54,69], and employing specific programs of "active" lessons [49,51].

3.3. Main Effects and Sub-Group Analyses

Figure 2 depicts the forest plot for the effects of the physical activity interventions on the academic performance of students from several grades. The sub-group analyses revealed that the interventions were not capable of significantly improving academic achievement in language, reading, and composite scores. In contrast, performance in the mathematics tests significantly improved after the interventions when compared with control groups. In relation to the overall effect, a significant improvement in academic performance was noticed after physical activity interventions when compared with their respective controls. Overall, irrespective of the sub-group analyzed, the studies presented high levels of heterogeneity ($I^2 > 50\%$).

Table 1. Characteristics of studies included in the meta-analysis.

Study	Country	Participants	Intervention	Comparator	Outcome	*Overall Risk of Bias*
Ahmed et al. (2007)	Canada	Elementary school, 9–11 years, CG = 74, EG = 214	EG schools implemented classroom-based activities for 15-min, 5 days/week. Activities offered by teachers included skipping, dancing, and resistance exercises performed with hand grippers and exercise bands.	Regular PE 40 min/week	Canadian Achievement Test (CAT-3; a standardized test that evaluates student skills related to specific subject areas including mathematics, reading, and language)	*Some concerns*
Ardoy et al. (2014)	Spain	12–14 years, CG = 18, EG1 = 26, EG2 = 23	Adolescents in the EG1 had four PE sessions/week, with the same contents and pedagogical strategies as the sessions performed by the CG. Adolescents in the EG2 complete four PE sessions/week of high intensity, i.e., activities with a heart rate >120 bpm.	Usual PE sessions according to the National Education Program in Spain, i.e., 55 min sessions twice a week	Academic achievement was assessed using students' grades in core subjects (mathematics and language) and other subjects (natural sciences, etc.).	*Low risk*
Beck et al. (2016)	Denmark	165 children, 7.5 years, CG = 57, EG = 55	Children in the EG performed inter-limb gross motor-activities such as skipping, crawling, throwing, and one-legged balancing. The movements were performed while solving mathematical questions (sessions of ~60 min).	CG employed conventional math teaching	Mathematical achievement was tested through a diagnostic test developed by experts of the neuropsychological field in Denmark.	*Some concerns*
Davis et al. (2011)	USA	7–11 years, CG = 60, EG1 = 55, EG2 = 56	Children in EG1 completed a 20 min bout and then a 20 min period of "sedentary activities" (e.g., card games and drawing) per day. Children assigned to EG2 completed two 20 min bouts per day.	CG	Academic achievement was measured using two forms of the Woodcock–Johnson Tests of Achievement III. Broad reading and broad mathematics were the outcomes of interest.	*Low risk*
Donnelly et al. (2017)	USA	Grades 2–3; 7–8 years, CG = 316, EG = 316	Teachers were asked to deliver two 10 min lessons/day (~4–5 METs) in the subject of their choice: one in the morning and one in the afternoon, 5 days/week.	CG	Academic achievement was assessed via the Wechsler Individual Achievement Test-Third Edition (WIAT-III).	*Low risk*
Fakri and Hashim (2020)	Malaysia	Grade 5: 10 years, CG = 35, EG = 35	Participants in the EG engaged in physical activity during math lessons. The activity comprises 60 min/week of moderate physically active lesson.	The CG were taught via traditional classroom method.	Academic achievement for mathematic was measured using a specific math test.	*High risk*

Table 1. *Cont.*

Study	Country	Participants	Intervention	Comparator	Outcome	*Overall Risk of Bias*
Fedewa et al. (2015)	USA	Grades 3–5, CG = 276, EG = 153	The EG classrooms integrated physical activity into their academic program for 20 min/day, 5 days/week using a set of movement cards. These cards consisted of standardized aerobic-based activities for ~5 min.	The CG classrooms went about business as usual, with no additional physical activity.	Students' achievement in mathematics and reading were assessed with the "Measures of Academic Progress" (MAP).	*Some concerns*
Gao et al. (2013)	USA—Latino School	Grades 3–5, CG = 58 (year 1) and 44 (year 2), EG = 85 (year 1) and 53 (year 2)	Dance Revolution (DDR)—15-min; center activity station (e.g., aerobic dance and jump rope)—15-min; 3/week.	CG	To measure academic achievement, reading and math scores for the Utah Criterion—Referenced Test were retrieved from the school district.	*High risk*
Garcia-Hermoso et al. (2020)	Chile	Grade 4: 8–10 years	The intervention was delivered 5 times/week before starting the first school-class. Active-Start is mainly a program of cooperative physical games, structured to make group cooperation essential to game success and to encourage prosocial skills.	Standard physical education lessons	Academic performance was assessed using children's grades for core subjects (mathematics and language).	*Low risk*
Hagins and Rundle (2016)	USA	Grade 9–11: ~15 years, CG = 48, EG = 64	The PE class included weightlifting, stationary biking, fitness exercises, and sports such as soccer and volleyball.	Yoga classes, same volume	Composite score was calculated as the numeric average of scores of all courses using a standard process from New York City public schools.	*Low risk*
Hraste et al. (2018)	Croatia	Grade 4: 10.4 ± 0.55 years, CG = 17, EG = 19	The EG classes consisted of four integrated lessons of mathematics/geometry and PA. Each lesson lasted for 45 min.	CG: traditional teaching methods for mathematics	The mathematics test was approved by the National School Program as a standard test for assessing mathematical knowledge.	*High risk*
Layne et al. (2020)	USA	8–9 years, CG = 21, EG = 19	EG played a FitNexx 1.0 active video game 10-min/day before every mathematics class.	CG waited in the homeroom to enter the mathematics class	Mathematics tests were regular assessments prepared by teachers.	*Low risk*
Lima et al. (2020)	Brazil	~15 years, CG = 188, EG = 242	Schools that doubled the PE classes augmented from 2 to 4 classes/week.	Schools in the CG maintained their habitual routine	Academic performance was assessed by two different mathematics tests.	*Low risk*

Table 1. *Cont.*

Study	Country	Participants	Intervention	Comparator	Outcome	*Overall Risk of Bias*
Lubans et al. (2018)	Australia	Grade 8: ~13 years, CG = 580, EG = 584	Activity and Motivation in Physical Education (AMPED)	CG	Mathematics performance was assessed as part of the National Assessment Program Literacy & Numeracy (NAPLAN).	*Low risk*
Mavilidi et al. (2018a)	Australia	Grade 4: 10–11 years, CG = 26, EG = 29	"Thinking While Moving in English", a primary school program that integrates physical activity into English lessons.	CG	Children's spelling and grammar skills were assessed using the South Australian Spelling and Grammar and Punctuation tests.	*High risk*
Mavilidi et al. (2018b)	Australia	4.7 ± 0.5 years, CG = 27, EG = 30	In the EG, children performed physical activity related to learning tasks.	CG	Math test consisted of counting, number line estimation, block counting, and numerical magnitude comparison and identification.	*Some concerns*
Mavilidi et al. (2020)	Australia	Grades 3–4: ~9 years, CG = 29, EG = 29	This EG involved two types of activity breaks delivered in separate classes, totaling 5 min.	CG	Students' mastery of basic facts was assessed using the Stage 2 version of the Individual Basic Facts Assessment Tool (IBFA).	*Low risk*
Mavilidi and Vazou (2021)	USA	Grades 4–5: 9–11 years, CG = 205, EG1 = 221, EG2 = 134	The EG1 classes utilized a kit named 'Move for Thought', which offers options for integrating physical activity with academic subjects. The EG2 classes offered a package of an equal amount of simple and safe activities including the most commonly used classroom-based activity breaks.	CG	Timed comprehensive grade-level appropriate and standardized math tests in algebra and equations (16 items) were used (easyCMB Light Edition).	*High risk*
Mead et al. (2016)	USA	Grade 6: 11–12 years, CG = 22, EG = 28	Five-minute physical activity breaks were implemented and occurred immediately after the math message but prior to the beginning of work time.	CG	Minnesota Comprehensive Assessments (MCAs): state achievement tests in mathematics, reading, and science. Measures of Academic Progress (MAP): standardized test assessing reading, mathematics, and language	*Low risk*
Mullender-Wijnsma et al. (2016)	The Netherlands	Grades 2–3: ~8 years, CG = 170, EG = 181	The EG participated in Fit & Vaardig op School lessons.	CG	Academic achievement was measured by two mathematics and two language tests.	*Low risk*

Table 1. *Cont.*

Study	Country	Participants	Intervention	Comparator	Outcome	*Overall Risk of Bias*
Pinto-Escalona and Martínez-de-Quel (2019)	Spain	13.6 ± 0.7 years, CG = 60, EG = 56	The experimental group participated in 10 min of moderate to vigorous physical exercise related to the contents of the teaching unit.	The CG carried out 10 min of study and review seated in their chairs.	An objective assessment test was drawn up for the contents of Spanish language and literature.	*Low risk*
Polo-Recuero et al. (2020)	Spain	~13 years, CG = 13, EG = 14	EG used bike desks during their four weekly math sessions.	CG	Mathematics test	*Low risk*
Quinto-Romani and Klausen (2016)	Denmark	Grade 6: 11–13 years, Grade 8: 13–15 years, CG = 371, EG = 554	The core of the intervention was physical activity	CG	Grade point average	*Some concerns*
Resaland et al. (2016)	Norway	Grade 5: 10.2 ± 0.3 years, CG = 533, EG = 596	(1) 90 min/week of physically active educational lessons mainly carried out in the school playground; (2) 5 min/day of physical activity breaks during classroom lessons; (3) 10 min/day physical activity homework	CG	Academic performance in numeracy, reading, and English was measured via standardized Norwegian national tests.	*Low risk*
Riley et al. (2016)	Australia	11.1 ± 0.73 years, CG = 98, EG = 142	The program involved classroom teachers adapting mathematics lessons over a 6 week (3 × 60 min sessions/week) period to ensure students were involved in movement-based learning.	CG	Mathematics performance was measured using a standardized mathematics progressive achievement test.	*Low risk*
Sallis et al. (1999)	USA	Grades 4–6: ~9 years, CG1 = 124, CG2 = 141, EG1 = 177, EG2 = 312	SPARK is a comprehensive curriculum and professional development program designed to promote physical activity in/out of school.	CG	Academic achievement was measured using Metropolitan Achievement Tests.	*Low risk*
Shore et al. (2014)	USA	Grade 6: ~11 years, CG = 46, EG = 46	All students had PE class twice every 6 days. Students in the EG also received two verbal prompts in PE class to attain a 3200 step-count goal during classes.	The CG participated in the standard PE curriculum.	Academic performance was determined by grade point averages.	*Low risk*
Shoval et al. (2018)	Israel	4–6 years, CG = 45, EG1 = 61, EG2 = 54	Two movement-based interventions	Children learned in a conventional kinder-garten environment.	Mathematics Achievement Test (MAT) Comprehension Reading Test (CRT)	*High risk*

Table 1. *Cont.*

Study	Country	Participants	Intervention	Comparator	Outcome	*Overall Risk of Bias*
Tarp et al. (2016)	Denmark	Grades 6–7: 12–14 years, CG = 419, EG = 191	Targeting classroom, recess, and leisure-time activity and through active transportation	CG	Custom-made grade-specific mathematics tests were used to assess academic performance.	*Low risk*
Vazou and Skrade (2017)	USA	Grades 4–5, CG = 118, EG = 107	The EG utilized a kit named "Move for Thought", which offers flexible options for integrating PA with academic subjects.	CG: math content without any changes in their regular instructional format	Timed, comprehensive, grade-level appropriate, and standardized math tests in algebra and operations were used to measure math performance.	*High risk*
Watson et al. (2019)	Australia	Grades 3–4: 8–10 years, CG = 218, EG = 123	EG involved teachers incorporating 3×5 min active breaks into their classroom routine daily.	CG	Academic achievement was assessed using 1 min tests in reading and mathematics.	*Low risk*

CG: control group; EG: experimental group; PE: physical education.

Study or Subgroup	Intervention Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
1.1.1 Language								
Ardoy et al. (2014) EG1	0.2	2.5	26	-0.5	1.56	18	0.5%	0.32 [-0.29, 0.92]
Ardoy et al. (2014) EG2	0.1	2.35	23	-0.5	1.56	18	0.5%	0.29 [-0.33, 0.91]
García-Hermoso et al. (2020)	0.02	0.81	94	-0.61	0.95	64	1.3%	0.72 [0.39, 1.05]
Mavilidi et al. (2018a)	-0.11	2.5	29	0.12	2.45	26	0.7%	-0.09 [-0.62, 0.44]
Sallis et al. (1999) EG1 Cohort 1	-5.9	28.63	59	-7.4	24.94	124	1.4%	0.06 [-0.25, 0.37]
Sallis et al. (1999) EG1 Cohort 2	-18	29.1	118	-11.1	28.74	141	1.7%	-0.24 [-0.48, 0.01]
Sallis et al. (1999) EG2 Cohort 1	-1.5	24.71	147	-7.4	24.94	124	1.8%	0.24 [-0.00, 0.48]
Sallis et al. (1999) EG2 Cohort 2	-8.7	27.36	165	-11.1	28.74	141	1.9%	0.09 [-0.14, 0.31]
Subtotal (95% CI)			**661**			**656**	**9.7%**	**0.16 [-0.06, 0.38]**
Heterogeneity: Tau² = 0.06; Chi² = 23.56, df = 7 (P = 0.001); I² = 70%								
Test for overall effect: Z = 1.42 (P = 0.16)								
1.1.2 Mathematics								
Ardoy et al. (2014) EG1	-0.7	2.5	26	-0.3	1.56	18	0.5%	-0.18 [-0.78, 0.42]
Ardoy et al. (2014) EG2	0	2.94	23	-0.3	1.56	18	0.5%	0.12 [-0.50, 0.74]
Beck et al. (2016)	4.3	10.21	51	3.1	10.87	49	1.0%	0.11 [-0.28, 0.51]
Davis et al. (2011) EG1	1	15.77	55	0	15.24	60	1.1%	0.06 [-0.30, 0.43]
Davis et al. (2011) EG2	1	14.08	56	0	15.24	60	1.1%	0.07 [-0.30, 0.43]
Donnelly et al. (2017)	3.1	15.32	316	4.1	15.33	316	2.3%	-0.07 [-0.22, 0.09]
Fakri and Hashim (2020)	2.29	8.2	35	4.24	8.48	35	0.8%	-0.23 [-0.70, 0.24]
Fedewa et al. (2015)	6.05	36.08	153	-0.06	25.36	276	2.0%	0.21 [0.01, 0.40]
Gao et al. (2013) Year 1	0.68	0.74	85	0.09	0.87	58	1.2%	0.74 [0.39, 1.08]
Gao et al. (2013) Year 2	0.72	0.62	53	0.27	0.82	44	1.0%	0.62 [0.21, 1.03]
García-Hermoso et al. (2020)	0.02	0.82	94	-0.48	1.1	64	1.3%	0.53 [0.20, 0.85]
Hraste et al. (2018)	3.6	4.19	19	1.87	4.18	17	0.5%	0.40 [-0.26, 1.07]
Layne et al. (2021)	10.28	31.71	19	14.17	26.54	21	0.5%	-0.13 [-0.75, 0.49]
Lubans et al. (2018)	59.31	79.1	584	51.27	99.92	580	2.6%	0.09 [-0.03, 0.20]
Mavilidi and Vazou (2021) EG1	2.01	7.83	221	0.57	7.95	205	2.1%	0.18 [-0.01, 0.37]
Mavilidi and Vazou (2021) EG2	0.2	6.43	134	0.57	7.95	205	1.9%	-0.05 [-0.27, 0.17]
Mavilidi et al. (2018b)	11.62	13.6	30	2.35	11.97	27	0.7%	0.71 [0.17, 1.25]
Mavilidi et al. (2020)	0.19	12.03	29	2.14	12.14	29	0.7%	-0.16 [-0.67, 0.36]
Mullender-Wijnsma et al. (2016)	34.33	22.2	179	28.89	21.64	162	1.9%	0.25 [0.03, 0.46]
Polo-Recuero et al. (2020)	2.8	2.13	14	3.04	2.37	13	0.4%	-0.10 [-0.86, 0.65]
Quinto Romani and Klausen (2017)	0.11	1.3	554	0.24	1.26	371	2.5%	-0.10 [-0.23, 0.03]
Resaland et al. (2016)	6.14	11.87	551	5.51	11.33	488	2.6%	0.05 [-0.07, 0.18]
Riley et al. (2016)	1.4	45.05	142	2.32	41.75	98	1.7%	-0.02 [-0.28, 0.24]
Sallis et al. (1999) EG1 Cohort 1	-6.1	30.36	59	-5.8	24.45	124	1.4%	-0.01 [-0.32, 0.30]
Sallis et al. (1999) EG1 Cohort 2	-21.8	29.76	118	-22.3	27.3	141	1.7%	0.02 [-0.23, 0.26]
Sallis et al. (1999) EG2 Cohort 1	-5.8	25.43	147	-5.8	24.45	124	1.8%	0.00 [-0.24, 0.24]
Sallis et al. (1999) EG2 Cohort 2	-16.3	27.72	165	-22.3	27.3	141	1.9%	0.22 [-0.01, 0.44]
Shoval et al. (2018) EG1	13.5	17.34	61	8.54	20.1	45	1.0%	0.27 [-0.12, 0.65]
Shoval et al. (2018) EG2	7.91	12.19	54	8.54	20.1	45	1.0%	-0.04 [-0.43, 0.36]
Tarp et al. (2016)	2.6	12.78	191	2.5	12.63	419	2.2%	0.01 [-0.16, 0.18]
Vazou and Skrade (2017)	14.07	23.01	107	4.18	20.29	118	1.6%	0.46 [0.19, 0.72]
Watson et al. (2019)	2.36	8.83	123	2.27	8	218	1.9%	0.01 [-0.21, 0.23]
Subtotal (95% CI)			**4448**			**4589**	**45.4%**	**0.11 [0.04, 0.18]**
Heterogeneity: Tau² = 0.02; Chi² = 68.50, df = 31 (P = 0.0001); I² = 55%								
Test for overall effect: Z = 3.16 (P = 0.002)								
1.1.3 Reading								
Davis et al. (2011) EG1	0	14.53	55	0	12.05	60	1.1%	0.00 [-0.37, 0.37]
Davis et al. (2011) EG2	-1	18.05	56	0	12.05	60	1.1%	-0.07 [-0.43, 0.30]
Donnelly et al. (2017)	3.4	16.41	316	6	16.86	316	2.3%	-0.16 [-0.31, 0.00]
Fedewa et al. (2015)	6.56	39.25	153	-0.79	23.81	276	2.0%	0.24 [0.04, 0.44]
Gao et al. (2013) Year 1	0.15	0.65	85	-0.1	0.74	58	1.2%	0.36 [0.03, 0.70]
Gao et al. (2013) Year 2	0.06	0.66	53	0.14	0.73	44	1.0%	-0.11 [-0.51, 0.29]
Mullender-Wijnsma et al. (2016)	44.61	35.15	181	44.01	38.18	170	2.0%	0.02 [-0.19, 0.23]
Quinto Romani and Klausen (2017)	0.65	1	554	0.83	1.14	371	2.5%	-0.17 [-0.30, -0.04]
Resaland et al. (2016)	5.3	12.05	555	5.56	11.49	488	2.6%	-0.02 [-0.14, 0.10]
Sallis et al. (1999) EG1 Cohort 1	4.9	30.11	59	-3.6	26.9	124	1.4%	0.30 [-0.01, 0.61]
Sallis et al. (1999) EG1 Cohort 2	-21.8	29.76	118	-22.3	27.3	141	1.7%	0.02 [-0.23, 0.26]
Sallis et al. (1999) EG2 Cohort 1	-0.2	25.48	147	-3.6	26.9	124	1.8%	0.13 [-0.11, 0.37]
Sallis et al. (1999) EG2 Cohort 2	-16.3	27.72	165	-22.3	27.3	141	1.9%	0.22 [-0.01, 0.44]
Shoval et al. (2018) EG1	11.29	20.69	61	6.29	21.94	45	1.0%	0.23 [-0.15, 0.62]
Shoval et al. (2018) EG2	6.39	17.16	54	6.29	21.94	45	1.0%	0.01 [-0.39, 0.40]
Watson et al. (2019)	1.86	49.24	123	1.89	47.6	218	1.9%	-0.00 [-0.22, 0.22]
Subtotal (95% CI)			**2735**			**2681**	**26.5%**	**0.04 [-0.04, 0.13]**
Heterogeneity: Tau² = 0.01; Chi² = 30.71, df = 15 (P = 0.010); I² = 51%								
Test for overall effect: Z = 0.99 (P = 0.32)								
1.1.4 Composite Score								
Ahamed et al. (2007)	76.8	182	214	11.9	180.2	74	1.6%	0.36 [0.09, 0.62]
Ardoy et al. (2014) EG1	0.2	2.1	26	0.1	0.9	18	0.5%	0.06 [-0.54, 0.66]
Ardoy et al. (2014) EG2	0.7	2.35	23	0.1	0.9	18	0.5%	0.32 [-0.31, 0.94]
Hagins and Rundle (2016)	0.07	9.88	64	0.09	9.95	48	1.1%	-0.00 [-0.38, 0.37]
Lima et al. (2020)	0.17	2.41	242	0.14	2.41	188	2.1%	0.01 [-0.18, 0.20]
Mead et al. (2016) MAP	7.1	17.61	28	4.8	19.24	22	0.6%	0.12 [-0.44, 0.68]
Mead et al. (2016) MCA	93.6	38.38	25	99.2	15.76	22	0.6%	-0.18 [-0.76, 0.39]
Pinto-Escalona and Martinez-de-Quel (2019)	2.32	3.3	56	1.04	3.63	60	1.1%	0.37 [-0.00, 0.73]
Quinto Romani and Klausen (2017)	0.45	0.97	554	0.66	1.1	371	2.5%	-0.20 [-0.34, -0.07]
Sallis et al. (1999) EG1 Cohort 1	-2	29.64	59	-6	24.28	124	1.4%	0.15 [-0.16, 0.46]
Sallis et al. (1999) EG1 Cohort 2	-17.3	28.84	118	-15.9	27.41	141	1.7%	-0.05 [-0.29, 0.19]
Sallis et al. (1999) EG2 Cohort 1	-3.2	24.39	147	-6	24.28	124	1.8%	0.11 [-0.12, 0.35]
Sallis et al. (1999) EG2 Cohort 2	-9.1	27.42	165	-15.9	27.41	141	1.8%	0.25 [0.02, 0.47]
Shore et al. (2014)	0.2	0.07	46	0.22	0.09	46	1.0%	-0.25 [-0.66, 0.16]
Subtotal (95% CI)			**1767**			**1397**	**18.3%**	**0.07 [-0.05, 0.19]**
Heterogeneity: Tau² = 0.03; Chi² = 29.38, df = 13 (P = 0.006); I² = 56%								
Test for overall effect: Z = 1.09 (P = 0.28)								
Total (95% CI)			**9611**			**9323**	**100.0%**	**0.09 [0.04, 0.14]**
Heterogeneity: Tau² = 0.02; Chi² = 159.56, df = 69 (P < 0.00001); I² = 57%								
Test for overall effect: Z = 3.65 (P = 0.0003)								
Test for subgroup differences: Chi² = 2.12, df = 3 (P = 0.55), I² = 0%								

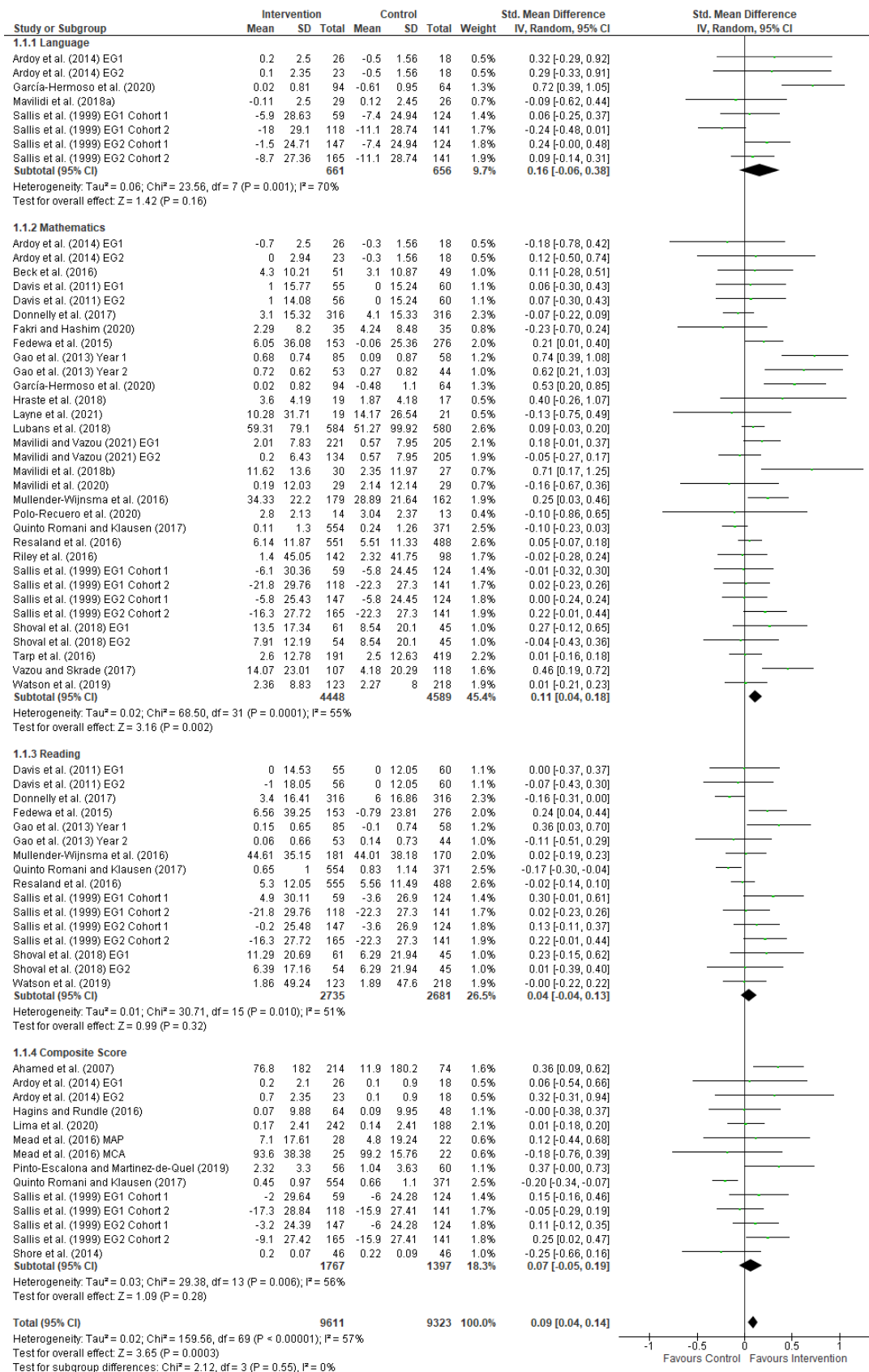Favours Control   Favours Intervention

Figure 2. Standardized mean difference (95% confidence intervals, CI) between intervention and control groups. Squares represent the SMD for each trial. Diamonds represent the pooled SMD across trials.

4. Discussion

In this systematic review, we examined the effects of different types of physical activity programs on the academic performance of school students. After analyzing these effects on an individual basis (i.e., via sub-group analyses), it was possible to verify that these interventions did not increase academic achievement in language skills, reading skills, and composite scores. In contrast, performance in mathematics significantly improved, which reveals the important role played by physical education in some specific learning processes and cognitive functions. Moreover, an analysis of the "overall effect" (i.e., through the use of a pooled computation, considering all scores simultaneously) confirmed that physical activity interventions are useful resources for enhancing the academic performance of children and adolescents.

The contrasting results among the different subjects and learning abilities (i.e., mathematics, language, and reading skills, and composite scores) are difficult to interpret and may also be influenced by a variety of external factors (i.e., type and mode of exercise, duration and frequency of training intervention, etc.) [59]. However, some similar results can be found in several studies, thus requiring more detailed discussion. In this regard, Quinto Romani et al. [59] examined the effects of five distinct training programs on the academic performance of 1479 Danish students and reported some interesting findings: (1) on average, all interventions seem to have a "very limited beneficial impact" on academic achievement; (2) this beneficial impact tends to be higher for "high-intensity training programs". The superior effects of more intensive training sessions on cognition and learning skills were also highlighted in other investigations on this topic [41,44,50,62]. For example, Ardoy et al. [41] analyzed the role played by exercise frequency and intensity on academic success by comparing the effects of three different experimental conditions: (1) standard physical education ("control group") (i.e., sessions prescribed according to the "National Law of Education"; 2×55 min/week); (2) increased exercise volume ("experimental group 1"; "EG1") (i.e., 4×55 min/week); and (3) increased exercise volume and intensity ("EG2") (i.e., more intensive 55 min sessions; 4 times/week). In general, the EG2 group improved more than the control group and the EG1 group in several cognitive functions and domains (i.e., non-verbal and verbal skills, abstract reasoning, and spatial and numerical skills), which also indicates that the simple increase in frequency of physical education sessions (e.g., from 2 to 4 times/week) is not sufficient to promote positive effects on academic achievement (at least when these increases are not accompanied by concomitant changes in exercise intensity). With that said, teachers and policy makers should be aware that more intensive physical activities are required to achieve greater gains in academic performance.

The positive effects of school-based physical activity programs were larger for mathematics skills, with sub-group analyses revealing no significant effects for language- and reading-related abilities and composite scores (Figure 2). Accordingly, Mavilidi et al. [43] reported no improvements in cognitive function and some specific learning outcomes (i.e., grammar skills) after examining the effects of a 4-week school-based program that integrated physical activity into English lessons in children aged 11–12 years. Likewise, Shore et al. [70] did not find any differences in academic achievement (assessed by composite scores) after comparing the effects of a "school-based pedometer intervention" (i.e., a sample of sixth-grade students who received instructions to achieve 3200 steps during physical education classes and a total of 10,000 daily steps for 6 weeks) with the effects of "standard physical education" (i.e., students who participated in regular physical education classes). Despite the short duration of the abovementioned studies (i.e., ≤6 weeks), their findings contrast with previous investigations with similar time periods and aims, which assessed the effects of physical activity on mathematics skills. For instance, a 6-week study comparing the effects of three different strategies (i.e., "conventional math teaching" versus math teaching combined with "fine" or "gross" motor tasks) showed that participation in the math classes that integrated more vigorous physical activities (i.e., inter-limb movements such as skipping, throwing, and one-legged balancing) could positively influence

mathematical achievements in pre-adolescent children [45]. Vazou et al. [62] observed a similar trend in an 8-week intervention that tested the effects of physical activity (combined with math) in fourth- and fifth-grade students. In that study, the increase in math performance was significantly larger in the "integrated physical activity group" (compared with that of the control group, who participated in traditional math classes). From these results, it is possible to infer that (1) improvements in math skills are more expected and consistent than in other skills (e.g., improvements in language or reading abilities) after short- or mid-term ($\leq$8 weeks) physical education programs and (2) the integration of physical activity into regular classes (especially mathematics) could be an effective strategy to enhance learning in school-aged students.

In fact, the benefits of physical education for math learning appear to be more pronounced even in long-term studies. In this sense, Lubans et al. [53] demonstrated the positive (small-to-medium) effects of a 15-month "multicomponent physical activity program" (including physical education classes with moderate-to-vigorous exercises) on mathematics performance in an investigation conducted with hundreds of eighth-grade students. Mullender-Wijnsma et al. [57] confirmed this tendency after analyzing the results of a 2-year intervention that integrated physical activities into math and spelling lessons in almost 500 s- and third-grade students from 12 elementary schools. Curiously, in that study, both spelling and general math skills increased (compared with the control group); nevertheless, the positive effect on mathematics performance (revealed by the "child academic monitoring system test") was already detected after one year of intervention, whereas spelling ability was only enhanced after two years. Together, these findings suggest that the improvements in mathematics learning obtained through the implementation of systematic physical education programs might be superior, at least when compared with language- and reading-related abilities. This also holds true for analyses integrating a variety of learning scores (i.e., composite scores) and agrees with the main outcome of this systematic review, which highlights the positive influence of physical education programs on mathematics achievement.

5. Conclusions

In general, the positive effects of school-based physical education programs on academic performance are not uniform and seem to be higher for mathematics skills. These effects may be optimized with the integration of multi-component exercise schemes into regular classes of different education levels as an efficient and alternative learning strategy. The concomitant prescription of "gross motor tasks" and more intensive (and appropriate) physical activities is also recommended in an attempt to maximize students' learning outcomes. In addition to the recognized benefits of systematic exercise on both health and psychological well-being, the implementation of evidence-based physical education programs in distinct school settings emerges as a promising strategy to increase overall academic achievement in school-aged students.

References

1. Baker, B.; Castelli, D. Physical activity and sedentary behavior influences on executive function in daily living. In *Neuroergonomics*; Chang, S.N., Ed.; Springer: Champaign, IL, USA, 2020; pp. 161–181.
2. Bermúdez, V.J.; Rojas, J.J.; Córdova, E.B.; Añez, R.; Toledo, A.; Aguirre, M.A.; Cano, C.; Arraiz, N.; Velasco, M.; López-Miranda, J. International physical activity questionnaire overestimation is ameliorated by individual analysis of the scores. *Am. J. Ther.* **2013**, *20*, 448–458. [CrossRef] [PubMed]
3. Di Cesare, M.; Sorić, M.; Bovet, P.; Miranda, J.J.; Bhutta, Z.; Stevens, G.A.; Laxmaiah, A.; Kengne, A.P.; Bentham, J. The epidemiological burden of obesity in childhood: A worldwide epidemic requiring urgent action. *BMC Med.* **2019**, *17*, 212. [CrossRef] [PubMed]
4. Middelbeek, L.; Breda, J. Obesity and sedentarism: Reviewing the current situation within the who european region. *Curr. Obes. Rep.* **2013**, *2*, 42–49. [CrossRef]
5. Mathers, C.; Stevens, G.; Mascarenhas, M. *Global Health Risks: Mortality and Burden of Disease Attributable to Selected Major Risks*; World Health Organization: Geneva, Switzerland, 2009.
6. Normansell, R.A.; Holmes, R.; Victor, C.R.; Cook, D.G.; Kerry, S.; Iliffe, S.; Ussher, M.; Ekelund, U.; Fox-Rushby, J.; Whincup, P. Op23 exploring the reasons for non-participation in physical activity interventions: Pace-up trial qualitative findings. *J. Epidemiol. Community Health* **2014**, *68*, A14. [CrossRef]
7. Sánchez Oliver, A.J.; Martín García, C.; Gálvez Ruiz, P.; González-Jurado, J.A. Mortality and economic expenses of cardiovascular diseases caused by physical inactivity in spain. *J. Phys. Educ. Sport* **2018**, *18*, 1420–1426.
8. Knight, J.A. Physical inactivity: Associated diseases and disorders. *Ann. Clin. Lab. Sci.* **2012**, *42*, 320–337.
9. World Health Organization. *Global Status Report on Noncommunicable Diseases 2014*; World Health Organization: Geneva, Switzerland, 2014.
10. Singh, R.; Pattisapu, A.; Emery, M.S. US physical activity guidelines: Current state, impact and future directions. *Trends Cardiovasc. Med.* **2020**, *30*, 407–412. [CrossRef]
11. Tran, B.X.; Dang, K.A.; Le, H.T.; Ha, G.H.; Nguyen, L.H.; Nguyen, T.H.; Tran, T.H.; Latkin, C.A.; Ho, C.S.H.; Ho, R.C.M. Global evolution of obesity research in children and youths: Setting priorities for interventions and policies. *Obes. Facts* **2019**, *12*, 137–149. [CrossRef]
12. Arancibia, B.A.V.; Silva, F.C.; Dos Santos, P.D.; Gutierres Filho, P.J.B.; Silva, R. Prevalence of physical inactivity among adolescents in brazil: Systematic review of observational studies. *Phys. Educ. Sport* **2015**, *34*, 331–358. [CrossRef]
13. Gómez, S.F.; Homs, C.; Wärnberg, J.; Medrano, M.; Gonzalez-Gross, M.; Gusi, N.; Aznar, S.; Cascales, E.M.; González-Valeiro, M.; Serra-Majem, L.; et al. Study protocol of a population-based cohort investigating physical activity, sedentarism, lifestyles and obesity in spanish youth: The pasos study. *BMJ Open* **2020**, *10*, e036210. [CrossRef]
14. Do Nascimento, A.C.S.; Suano-Souza, F.I.; Sarni, R.O.S. Extracurricular physical activities practiced by children: Relationship with parents' nutritional status and level of activity. *Nutrire* **2019**, *44*, 7. [CrossRef]
15. McCaul, K.; Baker, J.; Yardley, J.K. Predicting substance use from physical activity intensity in adolescents. *Pediatr. Exerc. Sci.* **2004**, *16*, 277–289. [CrossRef]
16. Pate, R.R.; Long, B.J.; Heath, G.W. Descriptive epidemiology of physical activity in adolescents. *Pediatr. Exerc. Sci.* **1994**, *6*, 434–447. [CrossRef]
17. Clarke, W.R.; Lauer, R.M. Does childhood obesity track into adulthood? *Crit. Rev. Food Sci. Nutr.* **1993**, *33*, 423–430. [CrossRef]
18. Dwyer, T.; Magnussen, C.G.; Schmidt, M.D.; Ukoumunne, O.C.; Ponsonby, A.L.; Raitakari, O.T.; Zimmet, P.Z.; Blair, S.N.; Thomson, R.; Cleland, V.J.; et al. Decline in physical fitness from childhood to adulthood associated with increased obesity and insulin resistance in adults. *Diabetes Care* **2009**, *32*, 683–687. [CrossRef] [PubMed]
19. Bouchard, C.; Després, J.P. Physical activity and health: Atherosclerotic, metabolic, and hypertensive diseases. *Res. Q. Exerc. Sport* **1995**, *66*, 268–275. [CrossRef]
20. Kravitz, L. The 25 most significant health benefits of physical activity and exercise. *IDEA Fit. J.* **2007**, *4*, 54–63.
21. Biddle, S.; Fox, K.R.; Boutcher, S.H. *Physical Activity and Psychological Well-Being*; Routledge: London, UK, 2000; Volume 552.
22. Calfas, K.J.; Taylor, W.C. Effects of physical activity on psychological variables in adolescents. *Pediatr. Exerc. Sci.* **1994**, *6*, 406–423. [CrossRef]
23. Kokkinos, P. Physical activity, health benefits, and mortality risk. *ISRN Cardiol.* **2012**, *2012*, 718789. [CrossRef]
24. Malina, R.M. Physical activity and fitness: Pathways from childhood to adulthood. *Am. J. Hum. Biol.* **2001**, *13*, 162–172. [CrossRef]
25. Delgado-Floody, P.; Guzmán-Guzmán, I.P.; Caamaño-Navarrete, F.; Jerez-Mayorga, D.; Zulic-Agramunt, C.; Cofré-Lizama, A. Depression is associated with lower levels of physical activity, body image dissatisfaction, and obesity in chilean preadolescents. *Psychol. Health Med.* **2021**, *26*, 518–531. [CrossRef] [PubMed]
26. Jacka, F.N.; Pasco, J.A.; Williams, L.J.; Leslie, E.R.; Dodd, S.; Nicholson, G.C.; Kotowicz, M.A.; Berk, M. Lower levels of physical activity in childhood associated with adult depression. *J. Sci. Med. Sport* **2011**, *14*, 222–226. [CrossRef] [PubMed]
27. Tomson, L.M.; Pangrazi, R.P.; Friedman, G.; Hutchison, N. Childhood depressive symptoms, physical activity and health related fitness. *J. Sport Exerc. Psychol.* **2003**, *25*, 419–439. [CrossRef]
28. Brand, S.; Kalak, N.; Gerber, M.; Clough, P.J.; Lemola, S.; Sadeghi Bahmani, D.; Pühse, U.; Holsboer-Trachsler, E. During early to mid adolescence, moderate to vigorous physical activity is associated with restoring sleep, psychological functioning, mental toughness and male gender. *J. Sports Sci.* **2017**, *35*, 426–434. [CrossRef] [PubMed]

29. Doré, I.; Sylvester, B.; Sabiston, C.; Sylvestre, M.P.; O'Loughlin, J.; Brunet, J.; Bélanger, M. Mechanisms underpinning the association between physical activity and mental health in adolescence: A 6-year study. *Int. J. Behav. Nutr. Phys. Act.* **2020**, *17*, 9. [CrossRef]

30. Slater, A.; Tiggemann, M. The contribution of physical activity and media use during childhood and adolescence to adult women's body image. *J. Health Psychol.* **2006**, *11*, 553–565. [CrossRef]

31. Donnelly, J.E.; Hillman, C.H.; Castelli, D.; Etnier, J.L.; Lee, S.; Tomporowski, P.; Lambourne, K.; Szabo-Reed, A.N. Physical activity, fitness, cognitive function, and academic achievement in children: A systematic review. *Med. Sci. Sports Exerc.* **2016**, *48*, 1223–1224. [CrossRef]

32. Marques, A.; Corrales, F.R.G.; Martins, J.; Catunda, R.; Sarmento, H. Association between physical education, school-based physical activity, and academic performance: A systematic review. *New Trends Phys. Educ. Sport Recreat.* **2017**, *31*, 316–320.

33. Zach, S.; Shoval, E.; Lidor, R. Physical education and academic achievement—Literature review 1997–2015. *J. Curric. Stud.* **2017**, *49*, 703–721. [CrossRef]

34. Moher, D.; Shamseer, L.; Clarke, M.; Ghersi, D.; Liberati, A.; Petticrew, M.; Shekelle, P.; Stewart, L.A. Preferred reporting items for systematic review and meta-analysis protocols (prisma-p) 2015 statement. *Syst. Rev.* **2015**, *4*, 1. [CrossRef]

35. Moher, D.; Cook, D.J.; Eastwood, S.; Olkin, I.; Rennie, D.; Stroup, D.F. Improving the quality of reports of meta-analyses of randomised controlled trials: The quorom statement. *Br. J. Surg.* **2000**, *87*, 1448–1454. [CrossRef]

36. Álvarez-Bueno, C.; Pesce, C.; Cavero-Redondo, I.; Sánchez-López, M.; Garrido-Miguel, M.; Martínez-Vizcaíno, V. Academic achievement and physical activity: A meta-analysis. *Pediatrics* **2017**, *140*, e20171498. [CrossRef] [PubMed]

37. Bedard, C.; St John, L.; Bremer, E.; Graham, J.D.; Cairney, J. A systematic review and meta-analysis on the effects of physically active classrooms on educational and enjoyment outcomes in school age children. *PLoS ONE* **2019**, *14*, e0218633. [CrossRef]

38. Higgins, J.P.; Thompson, S.G.; Deeks, J.J.; Altman, D.G. Measuring inconsistency in meta-analyses. *BMJ* **2003**, *327*, 557–560. [CrossRef] [PubMed]

39. Higgins, J.P.; Altman, D.G.; Gøtzsche, P.C.; Jüni, P.; Moher, D.; Oxman, A.D.; Savovic, J.; Schulz, K.F.; Weeks, L.; Sterne, J.A. The Cochrane collaboration's tool for assessing risk of bias in randomised trials. *BMJ* **2011**, *343*, d5928. [CrossRef]

40. Higgins, J.P.T.; Thomas, J.; Chandler, J.; Cumpston, M.; Li, T.; Page, M.J.; Welch, V.A. *Cochrane Handbook for Systematic Reviews of Interventions*; John Wiley & Sons: Chichester, UK, 2019.

41. Ardoy, D.N.; Fernández-Rodríguez, J.; Jiménez-Pavón, D.; Castillo, R.; Ruiz, J.; Ortega, F. A physical education trial improves adolescents' cognitive performance and academic achievement: The edufit study. *Scand. J. Med. Sci. Sports* **2014**, *24*, e52–e61. [CrossRef]

42. García-Hermoso, A.; Hormazábal-Aguayo, I.; Fernández-Vergara, O.; González-Calderón, N.; Russell-Guzmán, J.; Vicencio-Rojas, F.; Chacana-Cañas, C.; Ramírez-Vélez, R. A before-school physical activity intervention to improve cognitive parameters in children: The active-start study. *Scand. J. Med. Sci. Sports* **2020**, *30*, 108–116. [CrossRef]

43. Mavilidi, M.F.; Lubans, D.R.; Eather, N.; Morgan, P.J.; Riley, N. Preliminary efficacy and feasibility of the "thinking while moving in English": A program with integrated physical activity into the primary school english lessons. *Children* **2018**, *5*, 109. [CrossRef]

44. Sallis, J.F.; Lewis, M.; McKenzie, T.L.; Kolody, B.; Marshall, S.; Rosengard, P. Effects of health-related physical education on academic achievement: Project spark. *Res. Q. Exerc. Sport* **1999**, *70*, 127–134. [CrossRef]

45. Beck, M.M.; Lind, R.R.; Geertsen, S.S.; Ritz, C.; Lundbye-Jensen, J.; Wienecke, J. Motor-enriched learning activities can improve mathematical performance in preadolescent children. *Front. Hum. Neurosci.* **2016**, *10*, 645. [CrossRef]

46. Davis, C.L.; Tomporowski, P.D.; McDowell, J.E.; Austin, B.P.; Miller, P.H.; Yanasak, N.E.; Allison, J.D.; Naglieri, J.A. Exercise improves executive function and achievement and alters brain activation in overweight children: A randomized, controlled trial. *Health Psychol.* **2011**, *30*, 91–98. [CrossRef] [PubMed]

47. Donnelly, J.E.; Hillman, C.H.; Greene, J.L.; Hansen, D.M.; Gibson, C.A.; Sullivan, D.K.; Poggio, J.; Mayo, M.S.; Lambourne, K.; Szabo-Reed, A.N.; et al. Physical activity and academic achievement across the curriculum: Results from a 3-year cluster-randomized trial. *Prev. Med.* **2017**, *99*, 140–145. [CrossRef] [PubMed]

48. Fakri, N.F.N.; Hashim, H.A. The effects of integrating physical activity into mathematic lessons on mathematic test performance, body mass index and short term memory among 10 year old children. *J. Phys. Educ. Sport* **2020**, *20*, 425–429.

49. Fedewa, A.L.; Ahn, S.; Erwin, H.; Davis, M.C. A randomized controlled design investigating the effects of classroom-based physical activity on children's fluid intelligence and achievement. *Sch. Psychol. Int.* **2015**, *36*, 135–153. [CrossRef]

50. Gao, Z.; Hannan, P.; Xiang, P.; Stodden, D.F.; Valdez, V.E. Video game-based exercise, latino children's physical health, and academic achievement. *Am. J. Prev. Med.* **2013**, *44*, S240–S246. [CrossRef]

51. Hraste, M.; De Giorgio, A.; Jelaska, P.M.; Padulo, J.; Granić, I. When mathematics meets physical activity in the school-aged child: The effect of an integrated motor and cognitive approach to learning geometry. *PLoS ONE* **2018**, *13*, e0196024. [CrossRef]

52. Layne, T.; Yli-Piipari, S.; Knox, T. Physical activity break program to improve elementary students' executive function and mathematics performance. *Education* **2021**, *49*, 583–591. [CrossRef]

53. Lubans, D.R.; Beauchamp, M.R.; Diallo, T.M.O.; Peralta, L.R.; Bennie, A.; White, R.L.; Owen, K.; Lonsdale, C. School physical activity intervention effect on adolescents' performance in mathematics. *Med. Sci. Sports Exerc.* **2018**, *50*, 2442–2450. [CrossRef]

54. Mavilidi, M.F.; Drew, R.; Morgan, P.J.; Lubans, D.R.; Schmidt, M.; Riley, N. Effects of different types of classroom physical activity breaks on children's on-task behaviour, academic achievement and cognition. *Acta Paediatr.* **2020**, *109*, 158–165. [CrossRef]

55. Mavilidi, M.F.; Okely, A.; Chandler, P.; Louise Domazet, S.; Paas, F. Immediate and delayed effects of integrating physical activity into preschool children's learning of numeracy skills. *J. Exp. Child. Psychol.* **2018**, *166*, 502–519. [CrossRef]

56. Mavilidi, M.F.; Vazou, S. Classroom-based physical activity and math performance: Integrated physical activity or not? *Acta Paediatr.* **2021**, *110*, 2149–2156. [CrossRef] [PubMed]

57. Mullender-Wijnsma, M.J.; Hartman, E.; De Greeff, J.W.; Doolaard, S.; Bosker, R.J.; Visscher, C. Physically active math and language lessons improve academic achievement: A cluster randomized controlled trial. *Pediatrics* **2016**, *137*, e20152743. [CrossRef] [PubMed]

58. Polo-Recuero, B.; Moreno-Barrio, A.; Ordonez-Dios, A. Physically active lessons: Strategy to increase scholars' physical activity during school time. *Rev. Int. Cien. Dep.* **2020**, *16*, 342–357. [CrossRef]

59. Quinto Romani, A.; Klausen, T.B. Physical activity and school performance: Evidence from a danish randomised school-intervention study. *Scand. J. Educ. Res.* **2017**, *61*, 479–502. [CrossRef]

60. Shoval, E.; Sharir, T.; Arnon, M.; Tenenbaum, G. The effect of integrating movement into the learning environment of kindergarten children on their academic achievements. *Early Child. Educ. J.* **2018**, *46*, 355–364. [CrossRef]

61. Tarp, J.; Domazet, S.L.; Froberg, K.; Hillman, C.H.; Andersen, L.B.; Bugge, A. Effectiveness of a school-based physical activity intervention on cognitive performance in danish adolescents: Locomotion-learning, cognition and motion—A cluster randomized controlled trial. *PLoS ONE* **2016**, *11*, e0158087. [CrossRef]

62. Vazou, S.; Skrade, M.A.B. Intervention integrating physical activity with math: Math performance, perceived competence, and need satisfaction. *Int. J. Sport Exerc. Psychol.* **2017**, *15*, 508–522. [CrossRef]

63. Watson, A.J.L.; Timperio, A.; Brown, H.; Hesketh, K.D. A pilot primary school active break program (acti-break): Effects on academic and physical activity outcomes for students in years 3 and 4. *J. Sci. Med. Sport* **2019**, *22*, 438–443. [CrossRef]

64. Resaland, G.K.; Aadland, E.; Moe, V.F.; Aadland, K.N.; Skrede, T.; Stavnsbo, M.; Suominen, L.; Steene-Johannessen, J.; Glosvik, Ø.; Andersen, J.R.; et al. Effects of physical activity on schoolchildren's academic performance: The active smarter kids (ask) cluster-randomized controlled trial. *Prev. Med.* **2016**, *91*, 322–328. [CrossRef]

65. Riley, N.; Lubans, D.R.; Holmes, K.; Morgan, P.J. Findings from the easy minds cluster randomized controlled trial: Evaluation of a physical activity integration program for mathematics in primary schools. *J. Phys. Act. Health* **2016**, *13*, 198–206. [CrossRef]

66. Ahamed, Y.; Macdonald, H.; Reed, K.; Naylor, P.J.; Liu-Ambrose, T.; McKay, H. School-based physical activity does not compromise children's academic performance. *Med. Sci. Sports Exerc.* **2007**, *39*, 371–376. [CrossRef] [PubMed]

67. Hagins, M.; Rundle, A. Yoga improves academic performance in urban high school students compared to physical education: A randomized controlled trial. *Mind Brain Educ.* **2016**, *10*, 105–116. [CrossRef]

68. Lima, R.A.; Soares, F.C.; Bezerra, J.; de Barros, M.V.G. Effects of a physical education intervention on academic performance: A cluster randomised controlled trial. *Int. J. Environ. Res. Public Health* **2020**, *17*, 4287. [CrossRef] [PubMed]

69. Mead, T.; Scibora, L.; Gardner, J.; Dunn, S. The impact of stability balls, activity breaks, and a sedentary classroom on standardized math scores. *Phys. Educ.* **2016**, *73*, 433. [CrossRef]

70. Shore, S.M.; Sachs, M.L.; DuCette, J.P.; Libonati, J.R. Step-count promotion through a school-based intervention. *Clin. Nurs. Res.* **2014**, *23*, 402–420. [CrossRef]

71. Pinto-Escalona, T.; Martinez-de-Quel, O. Ten minutes of interdisciplinary physical activity improve academic performance. *Apunts Educ. Fís. Esports* **2019**, *138*, 82–94.