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The Effects of Physical Activity on Cognitive and Learning Abilities in Childhood

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Abstract: Physical activity breaks in the classroom are an efficient way of promoting healthy behaviors in students, enhancing the development of their cognitive and academic abilities. The effects of active breaks, which are exclusive to the academic environment, are almost entirely positive, only a few papers did not show significant improvements, but they did not show any negative impact on academic performance either. This research was carried out to identify the properties and consequences of active breaks and physical activity during classes in school age. We have examined multiple databases, and we have selected 41 papers accounting for a time span of 15 years. Psychology, medicine, and education databases were the most browsed Most papers revealed positive outcomes for improving skills related to mathematics, language, reading, comprehension, as well as cognitive and executive functions. Overall, the results of this review corroborate the theory that physical education in schools is positively associated with academic performance in children. Education researchers keep investigating in order to fully assess the positive impact on academic performance, behavior during classes, and cognitive functions.

Keywords: academic skills, child, cognitive skills, effect, learning physical activity, physical education

Introduction

Multiple papers prove that academic performance in the first years of primary school is closely associated to healthy behaviors achieved through physical activity (Donnelly et al., 2016), and that its integration in school curricula reduces sedentary behavior. Studies emphasize that children's cognitive function is associated with physical activity, suggesting that physical activity in the classroom could be beneficial (De Bruijn et al., 2019). Exercising leads to the enhancement of memory-related cognitive functions, problem-solving skills, and executive functions (Myer, Faigenbaum, Edwards & Clark, 2015), which help improve academic results in subjects such as mathematics and language (Garcia Hermoso et al, 2020). It's clear that the activities currently offered during physical education classes cannot supply an adequate opportunity to reach the recommended physical activity levels and, in turn, the related benefits (WHO, 2010).

Summary

Research objectives: establishing the degree to which academic performance during the first years of school is linked to health-related behaviors through physical activity; establishing how much can physical activity improve memory-related and problem-solving cognitive functions, as well as executive functions.

Methodology: employment of specific databases such as ERIC, PUBMED, PSYCLINE, EBSCO, SPORTDISCUS for scientifically valid papers with reliable published results; review of the scientific literature.

Results: most papers showed significant improvements, those that didn't show any improvement proved that academic performance is not negatively affected by physical activity; only one study, in one aspect of its results, showed a negative impact.

Conclusions: physical activity in the classroom can provide a practical, low-cost, efficient strategy for improving academic performance with positive effects on behavior both during tasks and during breaks, and on selective attention.

Theoretical Background

Physical activity and academic performance

Sedentarism has consequences on physical health, and on the cognitive and social profile in developmental age. Multiple studies have proven that there is correlation between physical inactivity, reduced cognitive ability, and poor academic performance (Chaddock, Pontifex, Hillman & Kramer, 2011). Intense aerobic exercise, on the other hand, allows the brain to prepare itself for better learning, promoting the most appropriate conditions for learning (Olivieri, 2016). The correlation between academic performance and motor skills is mediated by the executive functions (Marques, Santos, Hillman & Sardinha, 2017). Physical activity incorporated in educational programs as an active break plays a vital part in enhancing attention and concentration levels, thus allowing students to reach the best possible state for learning and for good academic performance (Chagas, Leporace & Batista, 2016). It is remarkably important to regard executive functions as a starting point for the attainment of skills related to action planning, reasoning, or problem solving (Diamond & Kathleen 2011; Pesce, 2012). Such functions are fundamental for physical and mental well-being. They positively impact knowledge acquisition processes, mathematical processing, as well as reading, so they are essential for high-quality learning. The World Health Organization has found a link between health and *Life Skills*, a set of personal and relational skills tied to self-control in relation to reality (WHO, 1986). The development of *Life Skills* and their subsequent consolidation rely on an approach related to the experience that can be attained through exercising and learning (WHO, 1993). Physicality and motor skills are key aspects for attaining *Life Skills* (Bandura, 1977). Physical abilities make it possible to attain competencies linked not only to motor skills, but also to emotional, social, cognitive, moral, and behavioral skills (Rogers, 1969). Research shows that active breaks in school have positive outcomes on learning and cognitive functions (Monacis, Colella & Scarinci, 2020). Studies listed in the systematic review provide proof regarding the positive outcomes with respect to academic performance, cognition, and healthy behaviors.

Methods

In order to optimize the use of space, the reference number indicated in the research summary table will be mentioned between brackets '[]'. The employed methodology took into consideration: PRISMA, PICO, Global

study distribution, inclusion and exclusion criteria, bias risk, and the synthesis table of the examined studies in chronological order.

Eligibility Criteria

This research follows the PRISMA (*Preference Reporting Items for Systematic Reviews and Meta-Analyses*) guidelines. We considered including the following: research that underwent systematic review, published in English, Portuguese, Spanish, or Italian (linguistic criterion); original studies; post facto quantitative evaluation; physical activity presented to an experimental group comprising individuals enrolled in kindergarten, primary school and beyond, in the age group of 1-13 (participants criterion), there were no restrictions regarding gender or timespan of intervention; the studies were carried out between 2007 and 2021 (temporal criterion). The selection of studies aimed to establish a link between physical education or physical activity and academic performance (relationship criteria). Physical activity disrupts the tasks carried out in the classroom. In respect to the exclusion criteria, we discarded the following: studies written in other languages; studies that were incomplete or that lacked data regarding the main results; studies carried out before 2007; active break strategies without physical activity; studies that included disabled children, subjects with special educational needs, and obese children or children with other handicaps; studies carried out on subjects over 13 years old.

Research Strategies

The bibliographic research includes studies published until June 29, 2023, and it was carried out utilizing the following databases: ERIC, PubMed, Google, Google Scholar, PsycLine, EBSCO, SportDISCUS. The keywords were established based on the already existing papers and on the scope of this research. The keywords were utilized in conjunction with the logical operators “and”, “or”, and “not” as part of the research strategy. Keywords: “physical activity”, “physical education”, “learning”, “academic skills”, “cognitive skills”, “child*”, “effect”. In addition, we examined the reference lists of the relevant articles in order to find other potentially eligible studies. We filtered the results based on the type of document: it is for this reason that the selection mainly includes academic research from industry-specific scientific journals. In addition, we set up a chronological filter for the last papers in order to find more recent articles. The systematic research returned a number of potentially relevant papers (827). After excluding the duplicates (174), we turned our focus to the title and the *abstract.* We discarded an additional 315 articles, as their title did not *focus* on the research. We subsequently examined the *abstract* of the remaining 338 papers, 187 of which were discarded because the abstract did not focus on the main topic of our research. Later, we examined the remaining 151 papers in their entirety: only 41 of them were eligible and, therefore, included in the systematic review.

Table 1

Flowchart of the Study Selection Process. Source: own elaboration

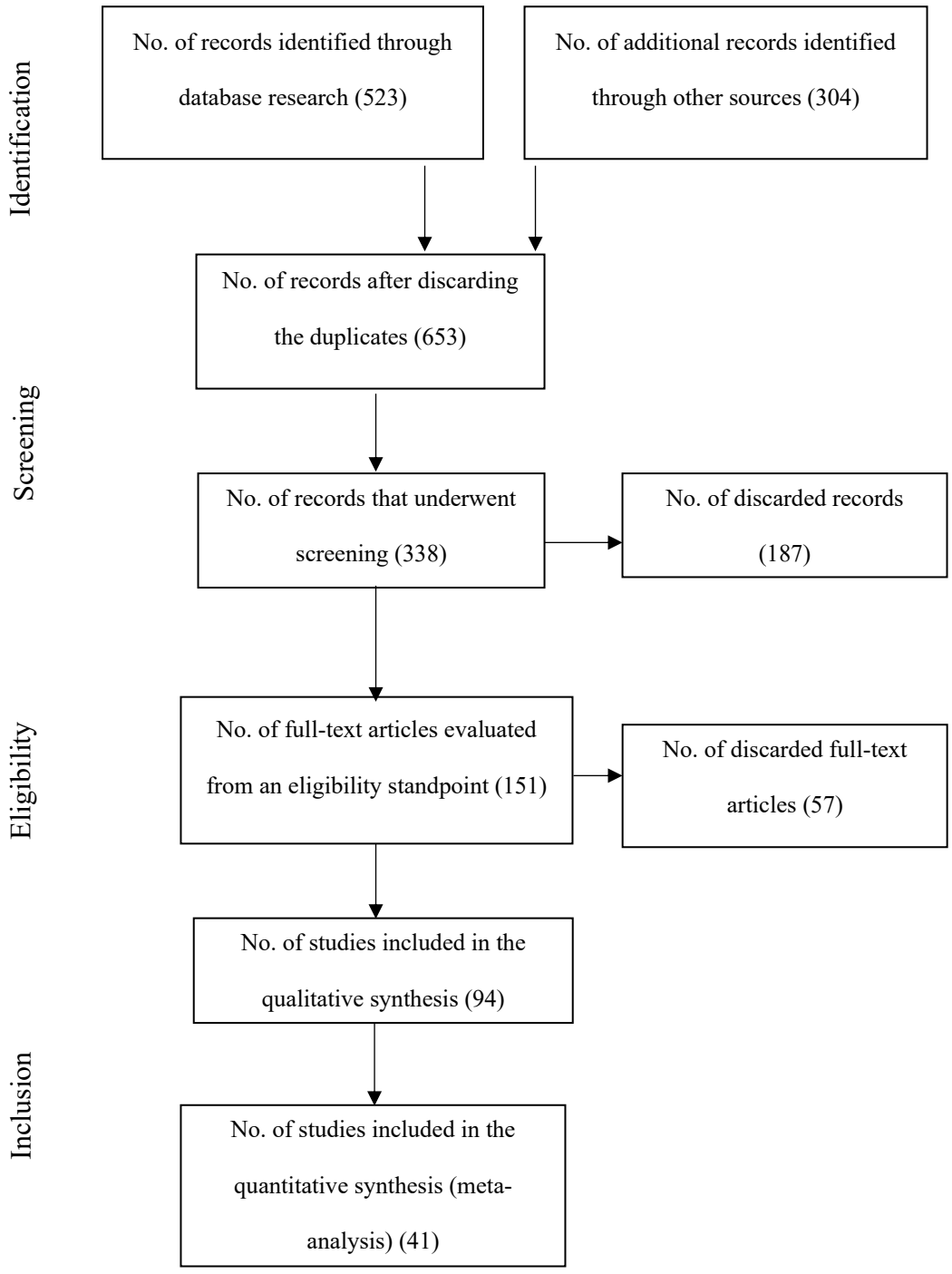


Table 2

PICO Structure of the Research Question. Source: own elaboration

P	I	C	O
Population	Intervention	Comparison	Results
The group of subjects aged 1-13 years old was examined in an academic environment	The interventions consisted in active breaks or physical activity integrated into classes	The comparisons were studied through a control group, and before and after intervention tests	The results show whether or not there are improvements in academic performance that can be attributed to physical activity

Risk of Bias of the Study

We evaluated the methodological quality for each study accounting for (1) selection *bias*; (2) study planning; (3) with founder; (4) blinding; (5) data collection method; (6) withdrawals and renunciations.

Results

Characteristics of Studies

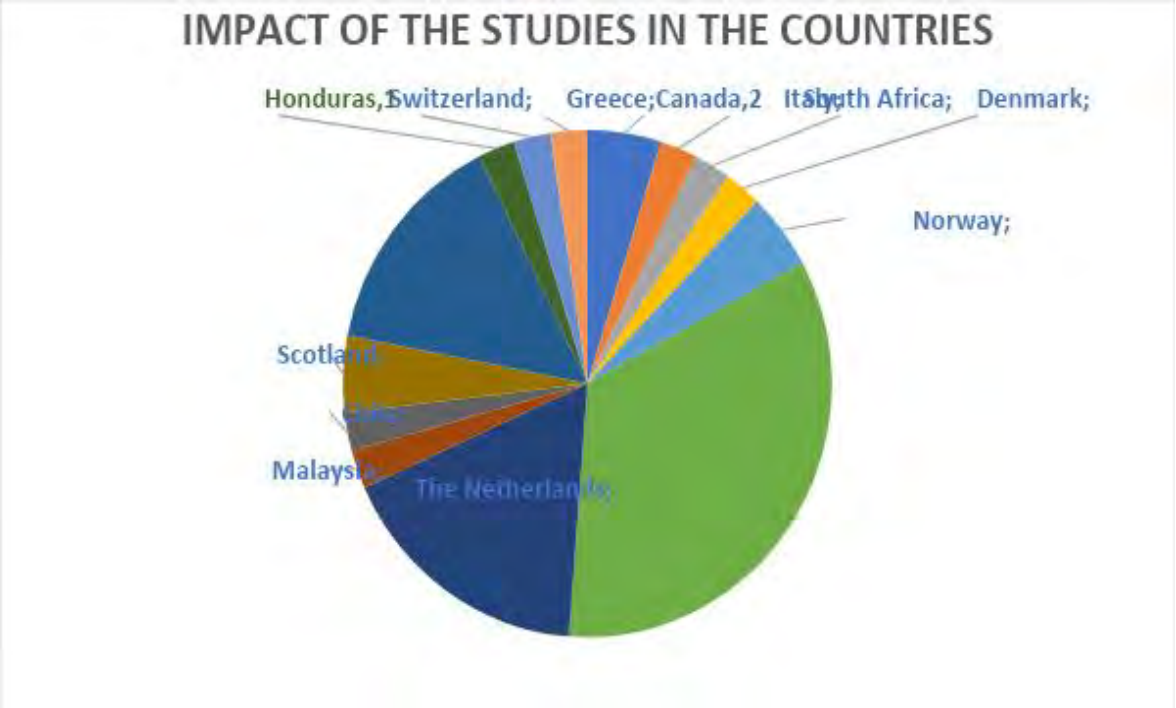
The studies included in the systematic review were published between 2007 and 2021 and were carried out in Canada [1,17]; Italy [36]; South Africa [8]; Denmark [21]; Norway [26,31]; the USA [2,4,6,9,10,14,15,16,23,24,30,33,40,41]; the Netherlands [11,18,19,22,25,29,34]; Malaysia [37]; Chile [38]; Scotland [3,5]; Australia [12,13,20,27,35,39]; Honduras [32]; Switzerland [28]; Greece [7].

Figure 1

Global Study Distribution. Source: own elaboration

Figure 2

Impact of Studies in the Countries. Source: own elaboration



The number of subjects fluctuates between 21 [9] and 4599 [6], with an average of 472.09 subjects. In all the included studies, the subjects were 1 [14] to 13 [29] years old. Only one study has exclusively male subjects [20]. The students' ethnicity was not taken into account. The active breaks or physical activity sessions during classes had different duration: 20 seconds [17]; no more than 5 minutes [15,35,39]; no more than 10 minutes [6,14,20,23,26,28,30,31,33,34,40]; 10 to 15 minutes [2,3,5,24,29]; no more than 15 minutes [1,11]; 5 to 20 minutes [10,16]; no more than 30 minutes [4,8,12,18,19,22,25]; 60 minutes or less [13,21,27,32,36,37]. Some studies did not specify the duration of the active breaks [9,38,41].

The experiments' duration varies between 1 day [2,9] and a maximum of 3 years [30,33]. Specifically, the duration of the experiments were: one day [2,9]; 3 days [29]; up to 4 weeks [3,5,7,10,16,11,17,20,28,39,40]; up to 10 weeks [6,8,13,23,27,31,32,34,35]; up to 6 months [4,12,18,19,22,25,36]; up to 1 year [14,15,26]; between 1 and 3 years [1,30,33]; only one study applied active breaks to language classes exclusively [24]. Some studies did not specify the duration of the experiment [21,37,38,41]. Since an overarching method of measuring academic performance does not exist, the studies refer to experiments that had the objective of researching academic ability and monitoring behavior. Furthermore, no theories were formulated if a study did not include relevant data or results. As a consequence, each study that failed to provide relevant data or results that could be compatible with our study, was discarded.

The Results of Each Study

Table 3

Synthesis of Selected Studies. Source: own elaboration

Author, place	Year	Number of subjects	Age of the subjects	Setting	Intervention	Duration	Coordinator	Assessment instrument	Results
Ahamed et al., Canada [1]	2007	288	9 - 11 years old 4 - 5 years old	Classroom	Active school. 15-minute active break with medium to high intensity physical activity. Assigned once a day	16 months	Teacher	Change of the habitual physical activity; PAQ-C questionnaire; mathematics, reading, and language tests	Mathematics, reading, and language (total score) although the control group had significantly higher base scores, no significant difference was reported between the test subjects (9.6 avg.) and the control group (16.6 avg.). Afterwards, physical activity: a 47-minute increase per week in the schools that took part in the project
Grieco et al., USA [2]	2009	97	8 - 10 years old	Classroom	10 to 15 minutes of medium to high intensity active breaks including mathematics, language, science, social studies, and health. To be executed every now and then	1 day	Teacher	Direct observation of the behavior during tasks	Behavior during tasks: slight increase after the intervention, compared to the control group

Hill et al., Scotland [3]	2010	1224	8 - 12 years old 4 - 7 years old	Classroom	Medium intensity 10-to-15-minute active break. Executed once a day for a week, then stopped for the second week	2 weeks	Not determined	Attention and executive functions	Attention and executive functions: slight improvement only for the subjects that were assigned the active break during the second week as well
Reed et al., USA [4]	2010	155	9 - 11 years old 3 years	Classroom	30 minutes of physical activity integrated into mathematics, language, and civic education classes. Executed 3 times a week	3 months	Teacher	Intelligence	Intelligence: better results for the study subjects, in comparison to the control group. Civic education: better results for the study subjects, in comparison to the control group. Mathematics, language, and science: no difference between the study subjects and the control group
Hill et al., Scotland [5]	2011	552	8 - 12 years old 4 - 7 years old	Classroom	Medium intensity 10-to-15-minute active breaks. Executed once a day for a week, then stopped for the second week	2 weeks	Not determined	Attention and executive functions: better pace, dimensional and aural ordering, visual encoding	Attention and executive functions saw an improvement only in the subjects that underwent the intervention for the second week as well

Whitt-Glover et al., USA [6]	2011	4599	3 - 5 years old	Classroom	Medium intensity 10-minute active break. Executable once a day	8 weeks	Teacher	Behavior in the classroom, direct observation	Behavior in the classroom: 11% increase of the time spent on task in comparison to the control group. Physical activity: 16% increase in medium intensity physical activity, and 51% increase in low intensity physical activity
Vazou et al., Greece [7]	2012	147	4 - 6 years old	Classroom	10-minute medium intensity active break that includes artistic languages, mathematics, and social studies. No specified schedule	2 weeks	Teacher	Academic motivation	Academic motivation: increased academic achievement among the study subjects when compared to the control group
Barnard et al., South Africa [8]	2014	149	7.33 - 7.47 years old	Gym	2 intervention programs. Integrated: 30 minutes of academic and motor skills integration. Intensive: 30 minutes of physical activity. Executed 3 times a week	8 weeks	Not determined	ESSI reading and spelling test; VASSI Math skills test	Reading: both the integrated program (26%) and the intensive one (30%) saw an improvement, but not a significant one. Spelling: integrated (32%), intensive (47%), negligeable improvement reported. Mathematics: integrated (30%), intensive (21%), negligeable improvement reported

Graham et al., USA [9]	2014	21	7 - 8 years old 2 years	Classroom	Physical activity integrated into mathematics classes. To be executed every now and then during classes	1 day	Teacher and research team	Mathematics: a questionnaire assigned after classes	Mathematics: no difference between the test subjects and the control group
Howie et al., USA [10]	2014	96	9 - 12 years old 4 - 5 years old	Classroom	Medium and high intensity 5, 10, 20-minute active break. Assigned twice a week	4 weeks	Research team	Direct observation	Remarkable improvement of the behavior during tasks after 10 minutes of active break (d=0.50)
Janssen et al., the Netherlands [11]	2014	123	10 - 11 years old 5 years	Classroom	Variable intensity 15-minute active break (medium and high intensity, with and without active breaks). Undefined schedule	4 weeks	Research team	Attention test (TEA-ch test)	Selective attention: significant improvement after medium intensity physical activity (95%), compared to high intensity physical activity (95%), active breaks (95%), and no condition
Lisahunter et al., Australia [12]	2014	107 students 6 teachers	5 - 10 years old	Classroom	Medium intensity 30-minute active break Executable once a day	20 weeks	Physical education expert	Cognitive functions; academic results; behavior in the classroom; pedometer	No difference among the test subject in any of the examined areas. Physical activity: decrease in daily steps: before (control = 13772; test subjects = 12447), after (control = 12046; test subjects = 9702)

Riley et al., Australia [13]	2014	54	10 - 12 years old 5 - 6 years old	Classroom	Physical activity integrated into a pre-existing mathematics class: 60 minutes every class. To be executed 3 times a week	6 weeks	Research team	Direct observation of the behavior during tasks	Behavior during tasks: increased duration of classes for the test subjects compared to the control group (19.9% difference). Physical activity: 9.7% increase in medium and high intensity physical activity during mathematics classes, and an 8.7% improvement taking into account the entire school day
Carlson et al., USA [14]	2015	1322 students 397 teachers	8.8 years 1 - 6 years old	Classroom	Medium and high intensity 10-minute active break Executed at least once a day	8 months	Teacher	Direct observation during tasks	Behavior in the classroom: the teachers who implemented active breaks reported an increased engagement and perseverance in students (95%), the teachers were more inclined to agree that the students' work improves after engaging in active breaks (95%) and they seemed to also agree that students remain concentrated for longer periods of time on tasks

									after active breaks (95%), in comparison to a regular class. Physical activity: the students assigned active breaks by their teachers had an additional 3.14 minutes of medium and high intensity physical activity a day, they were 75% more likely to meet the recommended 30 minutes of daily physical activity at school (95%)
Fedewa et al., USA [15]	2015	460	3 - 5 years old	Classroom	5-minute active break, 20 minutes of physical activity per day in total. To be executed daily	1 year	Teacher	Learning, reading and mathematics, academic improvement tests	Mathematics and reading: improved engagement, compared to the control group. Learning: no difference between groups
Howie et al., USA [16]	2015	96	9 - 12 years old 4 - 5 years old	Classroom	Medium and high intensity 5, 10, 20-minute active break. Assigned twice a week	4 weeks	Research team	Direct observation; executive functions; digit tracking and recalling test in mathematics (fluidity, 1 minute duration)	Executive function: no difference among mathematics groups. Significant improvement after 10 minutes (0.24) and 20 minutes (0.27) of active break. The results were compared to a sedentary condition

Ma et al., Canada [17]	2015	88	9 - 11 years old	Classroom	Active breaks formed by 20 seconds of high intensity physical activity followed by 10 seconds of rest. Repeated 8 times. Executed once a week	3 weeks	Research team	d2 attention test	Selective attention: significant improvement after active breaks compared to a sedentary condition
Mullender-Wijnsma et al., the Netherlands [18]	2015a	86	8.2 years 2 - 3 years old	Classroom	30 minutes of medium and high intensity physical activity during mathematics and language classes. To be executed 3 times a week	22 weeks	Teacher	Direct observation of the behavior during tasks	Behavior during tasks: greater improvement after the intervention, compared with the situation after the intervention in control classes
Mullender-Wijnsma et al., the Netherlands [19]	2015b	228	8.1 years 2 - 3 years old	Classroom	30 minutes of medium and high intensity physical activity during mathematics and language classes. To be executed 3 times a week	21 weeks	Teacher	Mathematics speed test; 1 minute reading test	Mathematics: 3 years: test subjects score higher than the control group; 2 years: test subjects score lower than the control group. Comprehension: 3 years: test subjects score higher than the control group; 2 years: no difference between the test subjects and the control group
Wilson et al., Australia [20]	2015	58 males	11 years 5 - 6 years old	Courtyard	10 minutes of medium and high intensity active break outside the classroom.	4 weeks	Teacher	Direct observation, attention	Attention: no difference between before the active break (average = 477) and after the active break

					Executable once a day, 3 times a week				(average = 479). Behavior during breaks: no difference: test subjects before active break (average = 13.6) vs after active break (average = 14.8)
Beck et al., Denmark [21]	2016	165	7.5 years	Gym	The children were assigned random physical activity such as jumping, crawling, throwing and balancing on one foot. The intervention was assigned during the solving of mathematics problems with less than 60 minutes sessions	Not determined	Teacher	Mathematics results attained through a test developed by experts	Learning activities influenced by physical activity can improve performance in mathematics
De Greeff et al., the Netherlands [22]	2016	499	2 - 3 years old 8 years	Classroom	30 minutes of medium and high intensity active break, during mathematics and language classes. Executed 3 times a week	22 weeks per year	Teacher	Executive functions, inhibition: Golden Stroop test, working memory	Inhibition: no difference between the test subjects (M = 19.6) and the control group (M = 19.9)
Goh et al., USA [23]	2016	2010	8 - 12 years old 3 - 5 years old	Classroom	Take 10!: 10-minute active break that comprises the art of language, mathematics, science, social studies, and general health. To be executed at the teacher's discretion	8 weeks	Teacher	Direct observation of behavior during tasks	Behavior during tasks: significant percentual improvement when comparing the before and after the task

Grieco et al., USA [24]	2016	320	7 - 12 years old	Classroom	10/15-minute active break integrated into orthography classes, assigned in different ways: from a regular class to a game with medium and high intensity	Every orthography class	Research team	Direct observation of behavior during tasks	Behavior during tasks: significant improvement of time spent on tasks, when comparing the before and after physical activity
Mullender-Wijnsma et al., the Netherlands [25]	2016	499	2 - 3 years old 8,1 +/- 0,7 years old	Classroom	30 minutes of medium and high intensity physical activity during mathematics and language classes. Executed 3 times a week	22 weeks per year	Teacher	Reading: 1 minute test. Mathematics: arithmetic speed test and general mathematics results. Spelling: results extracted from a monitoring system	Mathematics: the test subjects showed great improvements in speed tests and in mathematics achievements in general, in comparison to the control group. Spelling: the test subjects showed great improvements in speed tests and in mathematics achievements in general, in comparison to the control group. Reading: no difference between groups
Resaland et al., Norway [26]	2016	1129	10.2 years	Classroom	3 step intervention: 1. 90 minutes a week of physical education. 2. 5 minutes of active break a day during classes. 3. 10 minutes of physical activity a day at home	7 months	Not determined	Norwegian standardized tests	No significant improvement was reported in regards to mathematics, reading, and English. However, physical activity significantly influenced mathematical calculation

Riley et al., Australia [27]	2016	240	10 - 12 years old 5 - 6 years old	Classroom	Physical activity integrated into a pre-existing mathematics class: 60 minutes every class. To be executed 3 times a week	6 weeks	Teacher	Direct observation of behavior during tasks, Mathematics: Progressive Achievement Test	Behavior during tasks: 13.8% improvement in comparison to the control group. Mathematics: no difference between groups. Physical activity: 2.6% increase in medium and high intensity physical activity during mathematics classes, and a 1.7% improvement taking into account the entire school day
Schmidt et al., Switzerland [28]	2016	98	5 years	Gym	10-minute active break comprising running at various speeds. Executed 5 days over 3 weeks	3 weeks	Not determined	d2 attention test	No significant improvement
Van den Berg et al., the Netherlands [29]	2016	195	10 - 13 years old 5 - 6 years old	Classroom	12-minute medium intensity active break with 3 options (aerobics, coordination, and strength). Executable every now and then	3 days	Research team	Heart rate; d2 attention test; Letter Digit Substitution Test	Information processing speed: no difference. Selective attention: no difference
Donnelly et al., USA [30]	2017	632	7 - 8 years old	Classroom	10-minute active breaks twice a day, once in the morning, and once in the afternoon, 5 times a week	3 years	Teacher	Academic learning evaluated via WIAT III test	No significant improvement

Berg et al., Norway [31]	2019	448	10,9 +/- 0,7 years old	Classroom	10-minute active break once a day	9 weeks	Teacher	Attention, inhibition, memory	No significant improvement
Padial et al., Honduras [32]	2019	88	5 years	English classroom	Physical activity integrated into language learning. To be executed for 60 minutes a week	5 weeks	Teacher	Vocabulary (test)	Significant improvement in word learning
Szabo-Reed et al., USA [33]	2019	584	8 years	Classroom	Medium and high intensity integrated active breaks, executed for 10 minutes, twice a day, 5 days a week	3 years	Teacher	Reading, comprehension, and spelling (WIAT III)	Great improvements in spelling. No difference in reading
Van den Berg et al., the Netherlands [34]	2019	512	11 years	Classroom	Medium and high intensity active breaks To be executed for 10 minutes a day	9 weeks	Teacher	Observation, verbal fluidity to be confirmed through a test	No significant difference
Watson et al., Australia [35]	2019	312	9 years	Classroom	5-minute active breaks, 3 times a day	6 weeks	Teacher	Reading with WARP test, and one minute test	No significant reading improvements reported
Alesi et al., Italy [36]	2020	454	4 - 6 years old	Gym	Enhanced physical education classes, focused on tasks aimed at improving motor skills and executive functioning. To be executed for 60 minutes, 3 times a week	3 months	Teacher	Reading, comprehension, and verbal fluidity: IPDA Erikson test	Significant improvement in reading, comprehension, and verbal fluidity

Fakri & Hashim, Malaysia [37]	2020	70	10 years	Gym	Medium intensity physical activity during mathematics classes. To be executed for 60 minutes a week	Not determined	Teacher	Mathematics learning measured through test	No significant results
Garcia Hermoso et al., Chile [38]	2020	Not determined	8 - 10 years old	Gym	Active breaks consisting in physically active cooperative games structured in a way that renders cooperation crucial for succeeding, and for encouraging social skills. To be executed 5 times a week, compared to regular physical education classes	Not determined	Teacher	Academic performance with mathematics and language grades	Physical activity improves cognitive parameters
Mavilidi et al., Australia [39]	2020	58	9 years	Classroom	5-minute active breaks executed in two sessions	4 weeks	Teacher	National School Program approved mathematics test	The results highlight an improvement in motor and cognitive skills integrated into the learning of geometry
Layne et al., USA [40]	2021	40	8 - 9 years old	Classroom	Medium and high intensity 10-minute active breaks every day. To be executed before mathematics classes	4 weeks	Teacher	Mathematics learning and cognitive functions	Improvement in mathematics learning and executive functions
Mavilidi & Vazou, USA [41]	2021	560	9 - 11 years old	Classroom	Test subjects divided into two groups: 1. physical activity integrated into classes; 2. active breaks	Not determined	Teacher	Mathematics test	Improvement in mathematics skills

Analysis of the Studies in Table 3

By analyzing in detail, the studies included in the systematic review, we can compile a brief description of the experiments and their respective results. All the included studies are listed in Table 3. In the study carried out by Donnelly et al. (2017) [30] the focus of the experiment was to examine the effect active breaks in the classroom had on children by utilizing a set of measures such as (WIAT-III) tests. The experiment involved 10-minute active breaks executed twice a day: once in the morning and once in the afternoon, 5 days a week. The study did not find any relevant benefits regarding the improvement of learning abilities. Beck et al. (2016) [21] carried out a study on 165 children with an average age of 7.5 years. Their experiment involved physical activity during mathematics classes, during which children performed random exercises such as jumping, crawling, and balancing. The results were examined through tests developed by industry experts and have proven that learning abilities, especially the ones linked to mathematics, can be enhanced by physical activity. Riley et al. (2014; 2016) carried out two studies, one in 2014 [13] and the other in 2016 [27]. Both the first and the second study examined subjects of the same age, but the number of subjects changed (54 vs. 240). The experiment was the same for both studies and it involved physical activity during mathematics classes, with a duration of 60 minutes, 3 times a week; the children's behavior was examined, and the outcome was positive. In the 2016 study the researchers also examined the students' performance in mathematics classes via the *Progressive Achievement* test, which did not highlight any difference between the control group and the subjects of the experiment. The research carried out by Fedewa et al. (2015) [15] did not highlight an improvement in fluid intelligence with 20 minutes of physical activity every day for a year, although in regards to mathematics and reading the results are quite different. The results were similar for Van den Berg et al. (2016; 2019) neither of their studies [29,34] were able to attain a shift in executive functions during the implementation of short-term medium to high intensity physical activity programs. Similarly, Lisahunter et al. (2014) [12] did not observe differences in regard to cognitive functions, academic performance, and behavior in the classroom after 20 weeks of 30-minute active breaks. The study carried out by Garcia-Hermoso et al. (2020) [38] examined the effects of active breaks on mathematics and language grades and it highlights a significant tendency towards better grades; the study furthermore reported improvements in regard to cognitive abilities. One of the most recent studies was carried out by Layne et al. (2021) [40] and it resulted in an improvement of the executive functions and the ability to learn mathematics by stimulating children through active breaks of medium and high intensity for 10 minutes a day. Reed et al. (2010) [4] reported a significant improvement after 3 months of physically active classes. Similarly, Grieco et al. (2009; 2016) [24] found a significant improvement regarding the time spent on tasks when comparing the levels before and after physical activity. The same researchers carried out another study [2] that highlighted a slight, negligeable, improvement after a medium to high intensity active break of 15 minutes once a day. Mullender et al. (2015a; 2015b; 2016) carried out three studies [18,19,25]. With the first one, carried out in 2015 [18], they proved that, thanks to a combination of medium and high intensity 30-minute physical activity sessions, the behavior of the subjects improved. In the same year, they carried out another study [19] that highlighted, using the same process, an improvement in performance in regard to mathematics, but also a decrease in comprehension in 2-year-olds. This is the only study that found a decline in learning abilities tied to physical activity. One year later, in 2016 [25], another study highlighted major improvements in calculation speed and spelling thanks to the same process. The study

conducted by Carlson et al. (2015) [14] revealed a better behavior in the classroom, as reported by the teachers, proving that medium and high intensity active breaks once a day can foster an inclination to coordination. Whitt-Glover et al. (2011) conducted a study [6] the results of which reported an 11% increase of the time spent on tasks compared to the control group; furthermore, they observed a 16% increase in medium intensity physical activity and a 51% increase in low intensity physical activity. Mavilidi et al. (2020) [39] noticed that, by introducing 5-minute active breaks scheduled in two sessions, there is an improvement in the cognitive approach related to geometry learning. These results were obtained through a test approved by the *Nation School Program*. Mavilidi, together with Vazou (2021), carried out a study [41] with two groups of subjects: the first one was assigned physical activity during classes, while the second one was assigned active breaks. All subjects saw an improvement in mathematical skills. Vazou et al. (2012), carried out another study [7] on active breaks: 10 minutes of medium intensity physical activity, without a specific schedule. The result showed an improvement in academic performance compared to the control group. Conversely, Berg et al. (2019) [31], came to the conclusion that 10-minute active breaks once a day do not make a difference when it comes to attention, inhibition, and memory. Likewise, Wilson et al. (2015) [20] did not detect any improvement in behavior and attention after their experiment, which consisted in medium to high intensity 10-minute active breaks The study carried out by Howie et al. (2014; 2015) [10], which focused on medium to high intensity 5-, 10-, and 20-minute active breaks, highlighted a significant improvement in behavior during tasks after the 10-minute active break. The same researcher, a year later [16], carried out the same study, examining not only the behavior during tasks, but also mathematical abilities and executive functions. The results pertaining to executive functions did not show any improvement; mathematical skills, on the other hand, showed a significant improvement after the 10-minute active break. Hill et al. (2010; 2011) conducted two studies [3,5] which consisted in medium intensity 10 to 15 minute active breaks once a day for a week and then no active breaks for the following week. The results confirmed an improvement in executive functions and attention only for those that were assigned active breaks during the second week as well. Ahamed et al. (2007) [1] assigned the subjects a medium and high intensity 15-minute active break once a day. The results of the experiment highlighted significant improvements in mathematics, reading, and language, while physical activity levels increased. Padial et al. (2019) [32], after integrating physical activity into language learning, reported significant improvements in the memorization of words. The studies carried out by Schmidt et al. [28] and by Watson et al. (2019) [35] did not highlight any significant improvements in attention and reading after active breaks. Alesi et al. (2020) [36] reported, on the other hand, significant improvements in reading, comprehension, and verbal fluency. Consistent with Alesi, Szabo-Reed et al. (2019) [33] also experimented with active breaks that led to great improvements in grammar, but that had no effects on reading. Goh et al. (2016) [23] and De Greeff et al. (2016) [22], did not report differences after active breaks. Barnard et al. (2014) [8] proposed a program that involved physical activity integrated into classes, reporting some negligeable improvements. Other researchers that studied the matter were Janssen et al. (2014) [11] and Ma et al. (2015) [17], who did not report any improvements associated with active breaks. Graham et al. (2014) [9] experimented with physical activity integrated into mathematics classes: there were no differences between the test subjects and the control group. Researchers Fakri and Hashim (2020) [37], obtained the same result by using the same method. Resaland et al. (2016) [26] carried out an experiment divided into

3 components, each of them regarding physical activity integrated into classes or active breaks. The results did not show significant effects on reading and English. However, the operation positively affected mathematical calculation.

Summary of the Results

Figure 3

Inquiry Elements. Source: own elaboration

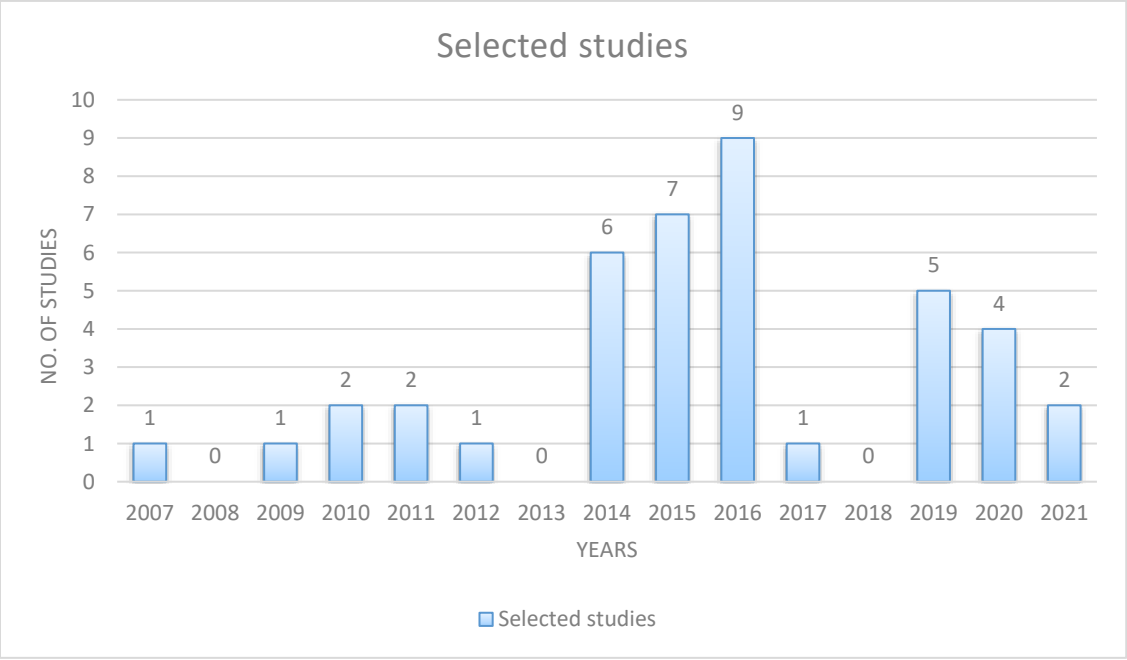
This article showcases a significant heterogeneity in regards to the study parameters. Said parameters include: characteristics of the subjects; measurement of the academic performance; evaluation methods of physical education in schools, and evaluation methods of the different classes such as mathematics, language, and English. The details of each study, such as measurements, characteristics of the subjects, of the authors, of the groups of subjects, and of the results, are indicated in a coherent manner. As for the method of assessment of each study, the most frequently utilized was the ability to learn mathematics, which can be assessed, in most cases, through tests [1,8,9,15,16,19,21,25,26,27,37,38,39,40,41]. Another widely utilized method was the monitoring of behavior [2,6,10,12,13,14,16,18,20,23,24,27,34]. Some studies used levels of attention as their assessment method [3,5,11,12,16,17,20, 28,29,31]. Other studies, on the other hand, drew their conclusions based on inhibition and

memory [3,5,12,16,22,31], the increase of physical activity levels [1], reading [1,8,15,25,33,35,36], language [1,32,38], verbal fluency [34,36], grammar [8,25,29,33], comprehension [19,36,33], academic learning [4,7,15,30,38], and cognitive functions [4,12,40]. Of the 41 studies, 25 reported significant improvements based on the aforementioned assessment methods [2,3,4,5,6,7,10,11,13,14,15,16,17,18,19,21,23,24,27,32,36,38,39,40,41]. One study reported a negligeable improvement [8]. 3 studies highlighted significant improvements in some areas of evaluation, while for other areas no improvement was reported [1,26,33]. 11 other studies did not highlight significant improvements in regards to the areas of evaluation [9,12,20,22,28,29,30,31,34,35,37]; only one study reported a negative outcome in one of the areas of assessment [25].

Of the 41 studies we found and included in the meta-analysis, 29 examined the effects of active breaks [1,2,3,6,5,7,10,11,12,17,16,14,15,20,22,23,24,26,28,29,30,31,33,34,35,38,39,40,41]. The remaining 12 studies examined the effects of physically active classes [4,8,9,13,18,19,21,25,27,32,36,37]. None of the 41 studies was published before 2007. The oldest study was published in 2007 [1]; other studies were published between 2009 and 2011 [2,3,4,5,6]; other studies between 2012 and 2014 [7,8,9,10,11,12,13]; other studies between 2015 and 2018 [14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30]; the rest between 2019 and 2021 [31,32,33, 34,35,36,37,38,39,40,41]. The studies were either carried out by the teacher [1,2,4,6,7,14,15,18,19,20,21, 22,23,25,27,30,31,32,33,34,35,36,37,38,39,40,41] or by researchers [10,11,13,16,17,24,29]; only one study was conducted by the teacher in collaboration with researchers [9]. Only one study was conducted by an expert in physical education [12]. 5 studies did not specify who was in charge of the experiment [3,5,8,26,28].

Figure 4

Selected Studies. Source: own elaboration



Discussion

The systematic review aims to examine the effects of physical activity on academic performance in schoolchildren. 25 out of 41 studies showed significant improvements based on our evaluation instrument [2,3,4,5,6,7, 10,11,13,14,15,16,17,18,19,21,23,24,27,32,36,38,39,40,41]. One study showed an improvement that was not significant [8]. 3 studies showed significant improvements for some of the evaluated elements, and reported no improvements for other ones [1,26,33]. 11 studies did not show any improvement based on our evaluation instrument [9,12,20,22,28,29,30,31,34,35,37]; only one study showed a negative impact, in one aspect of the results [25]. After examining the results, we were able to confirm that these measures did not significantly affect academic performance linked to language abilities, reading skills, spelling, and grammar. In contrast, mathematical performance saw significant improvements. This highlights how significant physical activity can prove to be in a number of specific learning processes and cognitive functions.

By calculating the aggregate value, and simultaneously taking into account the benefits, it is confirmed that physical activity is a useful resource that helps improve academic performance in children. The results may be contrasting among the various classes and learning capabilities: for example, the comparison between mathematical, language-related, and reading skills. It is sometimes difficult to interpret the results, and they can be influenced by multiple external factors, such as the type and method of the exercises, the duration and the frequency of the interventions. Some experiments regarding physical activity during classes highlighted that high intensity physical activity programs produce negligeable improvements in learning abilities [20,22,34]. Other experiments, on the other hand, by employing the same type of program, reported a significant increase in academic performance [1,2,10,11, 13,14,16,17,18,19,24,25,34,40]. One of the effects of physical activity was the development of cognitive functions as well [4,12,40]. Given the results, when evaluated in a general context, it is possible to observe that mathematical skills were improved more frequently and by a higher margin than other skills, such as language-related or reading skills, after the integration of physical activity into classes.

The study conducted by Mullender-Wijnsma et al. (2016) [25] is of remarkable importance, as it confirms the general trend. This research examined the results of a 22 weeks long experiment, in which they assigned 30 minutes of medium to high intensity physical activity during mathematics and language classes. General skills saw a significant improvement, both in regards to mathematics, and language and grammar. These crucial results suggest that the improvements observed in the learning of mathematics, and obtained through physical education programs, could potentially be higher, if compared to subjects such as language and reading. A study conducted by Beck et al. (2016) [21] compared the effects of mathematics lessons combined with random physical activity (jumping, crawling, throwing, balancing on one foot), and it showed an improvement in the mathematic skills of children, when high intensity physical activity was introduced.

The study carried out by Carlson et al. (2015) [14] is of great interest, as their experiment was 8 months long, and the children were assigned a medium and high intensity 10-minute active break every day. The teachers studied the

children's behavior, reporting a direct link between the increase in active breaks and the perseverance of the students when carrying out tasks, even cooperatively. Furthermore, they noticed increased attention and concentration in students after active breaks. Both the study conducted by Mavilidi et al. (2020) [39], and Mavilidi and Vazou (2021) [41] researched the learning of mathematics with an increase in active breaks and/or physical activity integrated into classes. Both studies reported significant improvements in the learning abilities linked to mathematics and geometry. As proved by some studies, the experiments that involved active breaks during classes showed, in the majority of cases, an improvement in the linguistic competencies as well, including reading, comprehension, and vocabulary learning. This improvement is associated with the functional and structural cortical development of the brain. Furthermore, most linguistic abilities developed in early childhood are positively associated with later linguistic abilities.

The results also confirm that physical activity sessions during classes can contribute to the improvement of cognitive functions. In order to obtain an improvement in academic learning, it is necessary to keep in mind that not all types of physical activity measures give the same results. A recent study suggests that language and action are linked together through the neuronal overlapping of the mirror neuron system for actions and Broca's area for speech articulation (Rizzolatti & Sinigaglia, 2006). In this regard, there is scientific proof supporting the hypothesis that language and cognition are rooted in the sensorimotor system (Rizzolatti & Sinigaglia, 2006). This approach confirmed that the sensorimotor system plays a vital role in language processing, and it is necessary for an adequate comprehension. It is important to note the positive correlation between the number of physical activity sessions and academic performance. Some researchers believe that the decrease of physical education and the increase of the time spent on other subjects will lead to an overall improvement in the academic performance of children (Van den Berg, Saliasi, De Groot, Jolles, Chinapaw, & Singh, 2016).

The studies examined in the review do not prove this connection to be significant, even though they reported that physical education in schools is not correlated in any significant way to academic performance [1,26] and that, by dedicating 10 extra minutes to daily physical activity at school, there is no shift in the academic performance of students. This proves that physical activity in schools can either have a positive effect or no effect whatsoever on academic performance. In view of the studies examined during the systematic review, the researchers recommend that children engage in at least 90 minutes of physical activity per week. This does not negatively affect academic performance and is associated with multiple health benefits. Future research should focus on establishing an optimal amount of physical activity in order to attain an improvement of the academic performance. The studies could also take into account different types of physical activity measures and assess the effect they could potentially have on the individualized academic needs of children.

Conclusion

Physical activity during classes can provide a cost-effective and efficient practical strategy to improve academic performance, having positive effects also on behavior both during tasks and during breaks, and on selective attention.

Physical activity interventions in schools seem an effective way of improving skills in all subjects, such as language, comprehension, reading, and mathematics, as well as executive functions and cognitive development. Generally speaking, the effects of scholastic physical activity programs on academic performance are not consistent and seem to be greater in the case of mathematical competencies. The effects can be optimized through the integration of physical activity plans into regular classes with different levels of education as an alternative and efficient learning strategy. Future studies could examine the effect of physical activity interventions during classes on specific cognitive aspects, as well as the effect of different types of physical activity (aerobic training, anaerobic training, endurance, with cognitive engagement) on academic results. Hopefully, more experiments will be conducted over longer periods of time, in order for us to work with always up-to-date results to create efficient and targeted procedures. Furthermore, we hope to see efforts being made to assess the optimal amount of physical activity for improving academic performance. Also, we hope for diversified physical activity procedures in order to examine their verified effects on the individual academic needs of the students.

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