apunts EDUCACIÓN FÍSICA Y DEPORTES

ISSUE 149

Published July 1, 2022
https://doi.org/10.5672/apunts.2014-0983.es.(2022/3).149.03

PHYSICAL EDUCATION

OPEN ACCESS

Review of Interventions in Physical Activity for the Improvement of Executive Functions and Academic Performance in Kindergarten

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Cite this article
Padial-Ruz, R., Rejón-Utrabo, M.C., Chacón-Borrego, F. & González-Valero, G. (2022). Review of Interventions in Physical Activity for the Improvement of Executive Functions and Academic Performance in Kindergarten. *Apunts Educación Física y Deportes, 149*, 23-36. https://doi.org/10.5672/apunts.2014-0983.es.(2022/3).149.03

Publisher:
© Generalitat de Catalunya
Departament de la Presidència
Institut Nacional d'Educació Física de Catalunya (INEFC)

ISSN: 2014-0983

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Section:
Physical Education

Original language:
Spanish

Received:
December 3, 2021

Accepted:
April 20, 2022

Published:
July 1, 2022

Cover:
Sports practice in childhood favours the growth and emotional health of children.
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Abstract

Recent research has shown that continued physical activity (PA) has benefits on academic performance in students at different stages, the kindergarten stage being the least studied one. The aim of this research was to study and synthesise the existing relation between PA practice and the improvement of executive functions and academic performance in kindergarten, giving an overview of the current state of the question. To do so, a systematic review was carried out, focusing on identifying the general characteristics and effectiveness of intervention programmes conducted in this educational context. For the development of the study, a search of scientific literature was carried out in the Web of Science (WOS), Scopus and Proquest databases. "Physical activity", "academic achievement" and "preschool" were used simultaneously as key terms, "and" and "or" as Boolean operators, and a valid sample of a total of 18 scientific articles was set for the qualitative synthesis of this study. The results of the study indicate that there is a positive association between the integration of PA in the classroom and the improvement of executive functions and academic results, regardless of the curriculum content studied and the type of PA used. Thus, integrating PA into the classroom (as physically active lessons or active breaks) can be an important strategy to improve early literacy and curriculum content learning, while achieving PA levels close to the daily recommended levels.

Keywords: academic performance, executive functions, kindergarten education, physical activity, systematic review.

Introduction

Increasing the time spent practising physical activity (PA) and minimising sedentary time are important goals for children's health from a very young age (Hnatiuk et al., 2014). Consistent PA practice leads to many benefits for people's overall health (Jaksic et al., 2020; Popović et al., 2020). Despite this evidence, PA levels in kindergarten children remain relatively low (Hnatiuk et al., 2014) and one of the current main factors for sedentary lifestyles in students is the rise and increase in the use of latest information and communication technologies (Ortiz-Sánchez et al., 2021), which leads to excess weight, hypokinetic diseases and cardiovascular pathologies (Fang et al., 2019; Roscoe et al., 2019). It also increases the probability of suffering from other mental or affective and emotional illnesses (Loewen et al., 2019; Wu et al., 2017). Furthermore, from a motor point of view, decreased PA is associated with a low capacity to master motor skills in kindergarten (Lubans et al., 2010; Roscoe et al., 2019). Basic motor skills are typically developed in early childhood and provide the necessary building blocks for future motor skills. If the repertoire of physical-sports activities that the teacher offers for the development of these motor skills is poor, insufficient, and does not result in the exercise of skills, they will not be mastered sufficiently and consequently will lead to a decrease in the repertoire of motor skills (Castañer & Camerino, 1991). In this sense, the conceptual model offered by Stodden et al. (2008) suggests that, as children grow older, those with medium/high-level motor skills, and higher levels of PA, will perform better in their locomotor and object control skills. The literature supports the conceptual model, which, during the kindergarten stage, has a weak association between motor competence and PA, but the development of fundamental motor skill competence is important in order to reduce sedentary behaviour and increase PA. Thus, kindergarten children with better developed motor skills spend much more time on moderate to vigorous PA and much less time on sedentary behaviour than children with less developed motor skills (Williams et al., 2008). These negative aspects result in a decrease in children's quality of life in the long term (Emeljanovas et al., 2018; Hoare et al., 2019).

In addition to the overall health benefits of PA in children (physical condition, cardiometabolic health, bone health, reduction of adipose tissue, mental health, psychosocial and motor skills development; Padial et al., 2021), the WHO (2020) includes improved cognitive outcomes (academic performance and executive function [EF]). Thus, a positive relation is established between PA and academic performance, the latter being understood not only as academic achievement (grades and exam results), but also executive functions (memory, attention/concentration, problem solving, reasoning, decision making and verbal ability; Jarraya et al., 2019), as well as academic skills (behaviour, attendance and time spent on tasks; Vazou et al., 2021), which are highly dependent on the proper development of executive functions. From this perspective, recent reviews such as the one by Romero et al. (2017, p. 257) indicate that "physical activity not only improves overall cognitive functioning, but also improves performance on tasks that require executive functions".

The concept of EF is a multidimensional and evolving concept, due to advances in neuroscience, and is a basic component in explaining human cognition and behaviour (Ardila & Solís, 2008; Portellano & García, 2014). It consists of different components that work together in order to guide cognitive activity (Enríquez, 2014) and whose purpose is related to the ability to organise and plan (Rosselli et al., 2008). Generally, "EFs are defined as a group of mental processes that allow the control and regulation of other skills and behaviours, including those necessary to direct actions towards the achievement of previously established goals" (Gil, 2020, p. 116). Among its different components are: inhibition of reflexes and impulsive responses, speed of information processing, selection of task-relevant goals (planning, resource organisation, working memory), flexibility of goal-directed behaviour, interruption of ongoing activities according to needs, interference control, change of strategies in response to new demands of the environment or to new information received, behaviour monitoring, decision-making, regulation of emotional and behavioural/social responses, application of social cognition, motivation, drive, self-awareness and awareness of others (Gil, 2020; Gioia et al., 2017). Among these, those investigated in the articles found for this review are inhibitory control, behavioural flexibility, self-regulation, attention and working memory.

Another positive relation is that of motor and cognitive development, with motor skills being necessary for learning and later academic performance. The development of both of them occurs simultaneously, and it is between the ages of 5 and 10 years that the most important time for their growth is established (Escolano-Pérez et al., 2020). Motor skills acquired from an early age are related to the cognitive functions that the child will have in later stages (Michel et al., 2016). Furthermore, there is a well-documented relation at the primary school stage that associates the type of activity to cognitive control (Ureña et al., 2020). Thus, the cognitive efforts made when learning complex skills, or new motor skills, generate improvements in cognitive control. The effort made for learning these skills results in

greater cognitive control, which in turn influences greater autonomy and increasingly adaptive behaviour in children. Cognitively involved PA improves self-regulation and cognitive control in kindergarten children (Escolano-Pérez et al., 2020), although there is insufficient evidence of this relation in the early stages.

In order to contribute to research at this stage, the aim of this research was to study and synthesise the existing relation between the practice of PA and the improvement of executive functions and academic performance in kindergarten, giving an overview of the current state of the question. To do so, a systematic review was carried out, focusing on identifying the general characteristics and effectiveness of intervention programmes conducted in this educational context.

Methodology

Once the PA, health, and academic performance terms were seen, a systematic literature review was carried out, as the selection process has been developed according to the Spanish version of the items for publishing systematic reviews and meta-analyses of the PRISMA statement (*Preferred Reporting Items for Systematic reviews and Meta-Analyses*) (Yepes-Núñez et al., 2020), in order to establish an adequate review of the state of the question and evolution of the production.

Eligibility criteria, information sources and search strategy

For the development of the project, a scientific literature search was carried out in the Web of Science (WOS), Scopus and Proquest databases during the months of April and May 2021. Specifically, all databases were considered, with no delimitation of time range. The key terms "physical activity", "academic achievement" and "preschool" were used simultaneously, with "and" and "or" as Boolean operators, and a simple search by title and abstract was added. All areas of research were taken into account. This is how a total number of 9,219 scientific publications were set between the three databases.

The following inclusion and exclusion criteria were used to determine the sample of articles comprising the core body of this study (Figure 1).

In order to apply the inclusion and exclusion criteria, a first reading of the abstract and title was carried out. Which was followed by an in-depth reading of the full text. Then, a third and final screening was carried out in which, based on the abstract, only studies in which intervention programmes had been conducted in kindergarten were selected, limiting the sample to 293 articles. After the inclusion and exclusion considerations, the following figure shows the process, setting a valid sample for this study with a total of 18 scientific articles for the qualitative synthesis.

Selection process and data collection

To organise results found in eligible works, a data extraction form was developed and tested on the sample of included studies (n = 18). Data collection was carried out by the first author and revised by the second author. For any discrepancies, the authors held a discussion in order to reach a consensus. Two tables (Table 1 and 2) were created and the following data were recorded and coded for each eligible article: for general data table 1: (1) Author/s; (2) Year of publication; (3) Country;

	INCLUSION	EXCLUSION
Date of publication	Articles published between 2012 and 2021	Articles published in 2011 and previous years
Evaluation	Peer-reviewed articles published in English or in Spanish	Articles published in these languages not subject to expert assessment
Keywords	Studies containing them in the abstract, title or keywords	Studies that do not contain them in the abstract, title or keywords
Population and sample	Kindergarten pupils (0-6 years)	Pupils in primary education and above
Study cut	Longitudinal	Transversal
Type of research	Studies following an intervention programme	Studies that do not follow an intervention programme (literature review, trial...)

Figure 1
Inclusion and exclusion criteria of the studies selected for review.

(4) Sample; (5) Gender; (6) Age. For table 2 of data specific to the interventions carried out at the kindergarten stage: (1) Author/s; (2) Objective; (3) Time of intervention; (4) Type of study; (5) Type of Physical Activity; (6) Variables; (7) Data collection instruments; (8) Conclusions of the study.

Eligibility assessment was carried out in a standardised and independent manner by two researchers, an expert in Physical Education with a degree in Early Childhood Education and the other with a degree in Early Childhood Education, and experience in conducting scientific research and systematic reviews. Discrepancies were resolved through consensus, with the help of a third researcher in case of disagreement. Studies were included and excluded according to the PRISMA criteria. After searching the databases, duplicate studies were removed. Lastly, based on the eligibility criteria, three steps were followed to select the studies: reading the title, reading the abstracts and reading the full texts.

Assessment of the methodological quality of studies

The risk of bias for each eligible article was assessed by adopting a dichotomous nominal scale of two single values (yes/no), which was developed to assess agreement in the 18 studies of the sample. As scale variables, the inclusion and exclusion criteria indicated in section 4.1 (eligibility criteria). The degree of agreement obtained in the classification of works was 93%, which was obtained by dividing the number of matches by the total number of categories defined for each study, then multiplying by 100.

The extracted studies were organised and archived using Endnote software (X7), while categorisation and analysis were performed using QSR NVivo PRO software (version 12). In accordance with the information presented in the studies, the characteristics (year; location of the study; gender; stage of sport development, based on age and type of sport; social agents investigated; type of research; instruments and software used) and the quality of the studies were analysed quantitatively through the use of descriptive statistics (absolute frequency).

Results

Figure 2 describes the results of the process and sample selection, from the number of records identified in the search to the number of final studies included in the review ($n = 18$), represented in the flow chart below.

Tables 1 and 2 set out the main characteristics of each of the articles that comprise the core body of the systematic review.

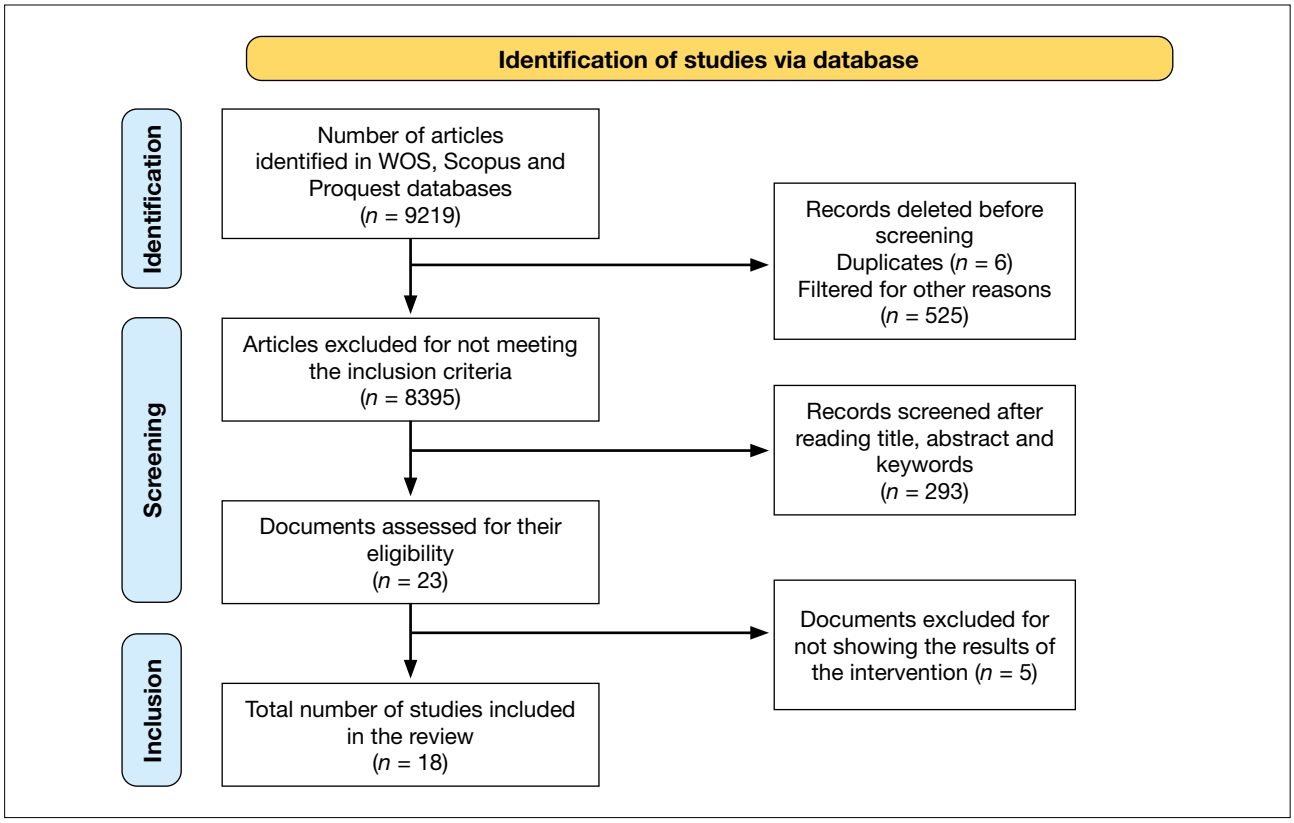

Figure 2
Results of the process and sample selection.

Table 1
General data concerning the studies in the sample.

Art.	Authors	Year	Country	Sample	Gender	Age
1.	Jarraya et al.	2019	Tunisia	45	F: 28 / M: 17	5 years
2.	Kirk & Kirk	2016	U.S.	54	F: 37 / M: 17	4 years
3.	Kirk et al.	2013	U.S.	54	F: 23 / M: 31	3 to 4 years
4.	Kirk et al.	2014	U.S.	72	F: 38 / M: 34	3 to 4 years
5.	Lundy & Trawick-Smith	2021	U.S.	21	F: 12 / M: 9	3 to 4 years
6.	Mavilidi et al.	2016	U	90	F: 45 / M: 45	4 to 5 years
7.	Mavilidi et al.	2017	Australia	90	F: 45 / M: 45	4 to 5 years
8.	Mavilidi et al.	2015	Australia	111	F: 61 / M: 64	4 to 5 years
9.	Omidire et al.	2018	South Africa	20	U	6 years
10.	Padial-Ruz et al.	2019	Honduras	88	F: 48 / M: 44	4 to 7 years
11.	Robinson et al.	2016	U.S.	113	F: 45 / M: 68	4 to 5 years
12.	Shoval et al.	2018	U.S.	160	F: 65 / M: 95	4 to 6 years
13.	Stein et al.	2017	Germany	102	F: 49 / M: 52	5 to 6 years
14.	Toumpaniari et al.	2015	Greece	67	F: 37 / M: 30	4 years
15.	Ureña et al.	2020	Spain	49	F: 33 / M: 16	4 to 5 years
16.	Vazou et al.	2021	U	245	F: 105 / M: 141	3 to 7 years
17.	Wen et al.	2018	China	57	F: 26 / M: 31	3 to 4 years
18.	Xiong et al.	2017	China	39	F: 19 / M: 20	4 to 5 years

Note: Unknown (U); Male (M) and Female (F) Gender.

Table 2
Data concerning intervention programmes.

Art.	Objective	Type of study	Time	Variables	Measuring Instruments	Conclusions
1.	Investigate the effects of yoga on visual attention, visual motor perception, hyperactivity and attention deficit.	Pret-Post (EG1: 15; EG2: 15; CG: 15)	12 weeks 24 ss/30 m	Visual attention, visual motor perception and attention deficit and hyperactivity behaviours	Visual attention test (NEPSY), visuomotor accuracy (NEPSY II), ADHD Rating Scale-IV	Children who participated in the yoga programme improved their executive functions, attention deficit and hyperactivity.
2.	Evaluate the impact of academic lessons, integrating PA, on early literacy, rhyme and alliteration.	Pret-Post-Post (EG: 39; CG: 15)	8 months 300 m/wk	PA, early literacy (picture naming, rhyme and alliteration), teacher satisfaction	IGDI, SOFIT, teacher satisfaction survey	A PA programme led by a teacher is effective in increasing PA and improving early literacy.
3.	Determine the impact of lessons integrating PA on early literacy.	Pret-Post-Post (EG: 24; CG: 30)	6 months 300 m/wk	BMI, PA, early literacy skills, teacher satisfaction	Digital weighing scale, portable stadiometer, IGDI, SOFIT, satisfaction survey	The programme promotes daily PA, improves literacy and reduces BMI increase.
4.	Determine the effect of a low-cost, teacher-led intervention programme.	Pret-Post-Post (EG: 51; CG: 21)	6 months 30 m/day	PA, early literacy, teacher satisfaction	IGDI, SOFIT, teacher satisfaction survey	Academic lessons delivered through PA improve early literacy.
5.	Determine the effects of outdoor games prior to a learning experience on inhibitory control and attention.	Pret-Post (EG: U; CG: U)	2 weeks 2 ss/60 m	PA, inhibitory control, attention, age, gender, socioeconomic status	Behavioural coding scheme, observation scale	The intervention improved attention and inhibitory control in learning sessions.
6.	Investigate the effect of integrated PA on geography tasks and learning.	Pret-Post-Post (EG1: 28; EG2: 29; CG: 30)	3 ss/week	PA, geography learning and children enjoyment	Accelerometer, memory tests, satisfaction questionnaire	The programme improved moderate and intense PA and learning of geography content.
7.	Evaluate the effects of an integrated PA programme on the learning process of science content.	Pret-Post-Post (EG1: 30; EG2: 27; CG3: 29)	4 weeks 4 ss/10 m	PA, science learning and children enjoyment	Accelerometers, memory test, satisfaction questionnaire	Science learning in the integrated and non-integrated PA condition is greater than in the control condition.
8.	Evaluate the effects of a PA programme and body movement on Italian vocabulary learning.	Pret-Post-Post (EG1: 31; EG2: 23; EG3: 31; CG: 26)	4 weeks 2 ss/15 m	PA, foreign languages vocabulary learning	Free and key memory test, accelerometers	Children in the integrated PA condition achieved better learning results in Italian vocabulary.
9.	Evaluate the use of structured motor activities to teach mathematics and languages.	Post test (EG: 20)	30 m/4 days x week	Language comprehension and mathematics, children enjoyment	Recording, research diary, observation sheets, reflective notes, and semi-structured interview	Movement experiences can improve understanding of mathematics and languages content.

Note 1. Pre test (Pret); Post test (Post); Control Group (CG); Experimental Group (EG); Minutes (m); Sessions (ss); U: Unknown.

Table 2 (continued)
Data concerning intervention programmes.

Art.	Objective	Type of study	Time	Variables	Measuring Instruments	Conclusions
10.	Analyse the effectiveness of a programme based on PA and gestures on motivation and learning English vocabulary.	Pret-Post (EG1: 22; EG2: 38; CG: 28)	5 weeks 2 sessions/ week 1h	Vocabulary learning, motivation, socio-demographic variables	"Smiley scale", vocabulary checklist, **ad hoc** questionnaire	PA is an effective motivational resource that improves academic performance and learning English vocabulary.
11.	Examine the effectiveness of the CHAMP programme on motor skills and self-regulation.	Pret-Post (EG: 68; CG: 45)	5 weeks 15 sessions/ 40 m	Motor skills and self-regulation	TGMD-2, Kindergarten Self-Regulation Assessment reward introduction task	The CHAMP group significantly improved motor skills and maintained self-regulation scores.
12.	Prove that integrating movement into the learning environment contributes to improved academic achievement.	Pret-Post (EG1: 61; EG2: 54; CG: 45)	145 days 90 m/day	Languages, mathematics and non-verbal language	MAT, CRT, SPM Matrices, Ordinal number sequencing test	Conscious movement improves academic achievement.
13.	Examine the relations between motor and executive functions, and test the effects of an acute coordinated intervention in Physical Education.	Pret-Post (EG: 48; CG: 53)	25 minutes	PA, executive functions, motor functions and task order	Polar Watch RS800sd, H1 sensor belt, "Simon says", "hearts and flowers task", M-ABC2	No effect of an acute coordinated intervention on executive functions was revealed.
14.	Examine whether learning foreign languages vocabulary through PA and gestures leads to better results and enjoyment for children.	Pret-Post (EG1: 23; EG2: 23; CG: 21)	4 weeks 8 sessions/ 1 hour	Learning foreign languages vocabulary, children enjoyment	"Smiley scale", vocabulary checklist	Instructional methods that combine PA and gestures are learning enhancers.
15.	Verify the effects of PA on self-regulation in a sample of kindergarten children.	Pret-Post (EG1: 12; EG2: 13; EG3: 12; CG: 12)	15 minutes	PA, self-regulation, cognitive control (reactive/ proactive)	HTKS, General Dynamic Coordination Test	More demanding coordination activities improved self-regulation and cognitive control.
16.	Investigate the effectiveness of the "Walkabouts" active breaks programme on attention and behaviour.	Pret-Post (EG: 158; CG: 87)	7 weeks (20 days) 3 times/ week	PA, self-regulation, attention, student and teacher enjoyment	Teacher diary, SOSMART, SWAN	The programme facilitated learning and academic performance by increasing attention and self-regulation.
17.	Investigate the effects of the PA programme (mini-trampoline) on the development of executive functions (EF).	Pret-Post (EG: 29; CG: 28)	10 weeks 20 m/day	PA, inhibitory control, working memory and cognitive flexibility	Accelerometer, SCA, WMS, FIS	The programme was not sufficient to improve executive functions.
18.	Examine the effects of a structured PA programme on EF and perceived physical competence, compared to recess.	Pret-Post (EG: U; CG: U)	3 months 30 m/day	Demographic and anthropometric data, executive functions, perceived physical competence	Demographic questionnaire, executive function measure, Pictorial Scale of Perceived Competence and Social Acceptance	The intervention significantly increased executive functions.

Note 1. Pre test (Pret); Post test (Post); Control Group (CG); Experimental Group (EG); Minutes (m); Sessions (ss); U: Unknown.

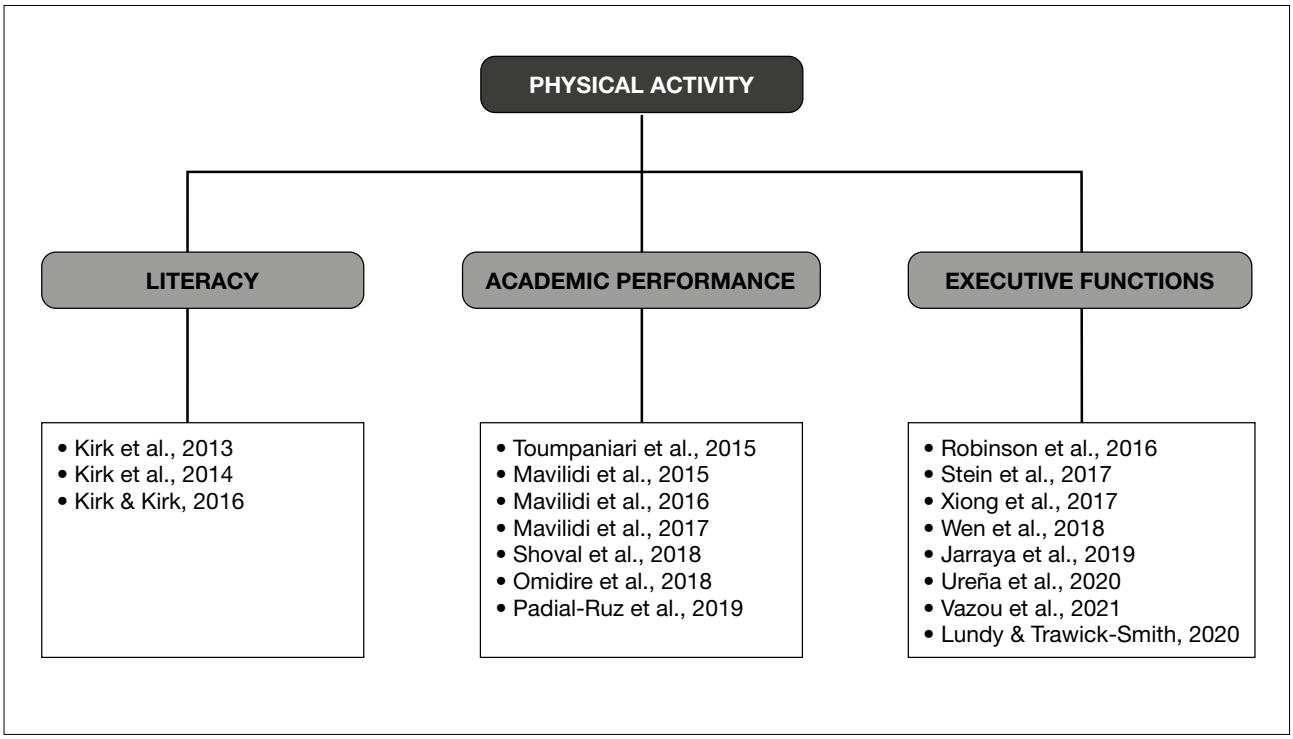

Figure 3
Central themes analysed in the sample.

For the result synthesis, a grouping of the different articles was made, distinguishing between studies in which PA is directly related to literacy, integration of PA in curriculum content and academic performance, and those relating PA to other performance determining factors, such as executive functions (figure 3).

Physical activity and literacy

n = 3 studies (16.7% of the total sample) linking PA to literacy in kindergarten were found. All used the same research design, as shown in table 2, with a longer intervention time (8 months) in the Kirk & Kirk (2016) study.

The first two studies (Kirk et al., 2013; Kirk et al., 2014) were designed to cover half of the recommended PA time per day (half an hour divided into two 15-minute slots), while the last one (Kirk & Kirk, 2016) reached 60 minutes per day divided into two 30-minute slots. Regarding the type of PA used for the experimental condition, it only states that they are activities of moderate intensity, such as walking or jumping. Results showed improvement in PA levels of the children who participated in the experimental condition, with 90% adherence (Kirk et al., 2014) and over 95% for the recommended exercise, and also indicated increased PA intensity (Kirk & Kirk, 2016). The literacy lessons were aimed at improving the areas of picture naming, rhyming and alliteration (phonological awareness). All made significant improvements in the areas of alliteration and rhyme, although there was not much difference in picture naming.

Physical activity integrated to the curriculum and academic performance

n = 7 studies (38.9% of the total sample) were found to add PA to teaching curriculum content such as languages (Mavilidi et al., 2015; Padial et al., 2019; Toumpaniari et al., 2015), geography (Mavilidi et al., 2016), Spanish (Omidire et al., 2018), mathematics (Omidire et al., 2018; Shoval et al., 2018) and science (Mavilidi et al., 2017; Shoval et al., 2018).

Studies that aimed to determine the effects of incorporating PA and the use of gestures for learning vocabulary in a foreign language (*n* = 3) used a similar design, with a minimum of two experimental conditions. One was based on the integration of PA and gestures for teaching vocabulary (Padial et al., 2019; Toumpaniari et al., 2015). The second, in which they learned new vocabulary through gestures. And a third, in the study by Mavilidi et al. (2015), in which an additional experimental group was included, and movement was used, but not integrated to vocabulary learning.

PA, both in terms of intensity improvement and time in minutes, was only measured objectively in the study by Mavilidi et al. (2015) through the use of accelerometers, a larger number of minutes of PA and a longer time of moderate to vigorous PA were recorded, both in the integrated and non-integrated PA condition, with no significant differences. Generally, results on academic performance show an improvement with the use of integrated PA for learning vocabulary in both English (Padial et al., 2019; Toumpaniari et al., 2015) and Italian (Mavilidi et al., 2015).

As for the rest of the curriculum contents studied (n = 4), PA was only measured objectively in the studies by Mavilidi et al. (2016) and Mavilidi et al. (2017) through accelerometers. These revealed that, in the first study, those who accumulated the most PA were those in the non-integrated condition, while in the second study, the integrated PA condition obtained the best results in the tests. The results, in terms of content learning, indicated that both the integrated and non-integrated conditions showed better results in learning geography content, but it could not be demonstrated that the integrated PA condition performed better than the non-integrated condition (Mavilidi et al., 2016). However, Mavilidi et al. (2017) did obtain better results in science tests using the integrated PA condition than the non-integrated and control conditions. The Shoval et al. (2018) study shows the same result for learning mathematics and that of Omidire et al. (2018), in which they concluded that when learning was performed through games, comprehension, listening, language and mathematics results were much better.

Physical activity and executive functions

n = 8 studies (44.4% of the total sample) were obtained which analyse the effects of motor and PA programmes on EF (figure 4), and a variety of components were studied: Inhibitory control (n = 4); Flexibility (n = 3); Self-regulation (n = 3) and Attention (n = 3); Working memory (n = 2). Only n = 2 of these articles measured the validity of the programmes used for PA improvement in terms of practice time, measured by accelerometers (Wen et al., 2018); and PA time and intensity, measured by SOSMART (Vazou et al., 2021). PA time was significantly increased in the study by Wen et al. (2018), while in the Vazou et al. (2021) study, there was an increase in practice time, but not in activity intensity, which was predominantly low.

The type of PA that was designed for the interventions used motor games in most of the studies. Specifically, coordination games of moderate intensity with little or no movement (Stein et al., 2017), motor games for motor skill development (Xiong et al., 2017), outdoor motor play sessions (Lundy & Trawick-Smith, 2021) and trampoline PA (Wen et al., 2018). The results regarding the improvement of inhibitory control, in n = 2 studies, reveal that children who participated in the intervention condition improved this EF (Lundy & Trawick-Smith, 2021; Xiong et al., 2017), while in the other two groups, the intervention showed no effect on EF (Stein et al., 2017; Wen et al., 2018).

Regarding the observation of effectiveness of PA on Self-regulation, pre and post test designs with a control and experimental group were carried out, except for Ureña et al. (2020), which used 3 experimental groups. The samples of kindergarten pupils (3-7 years) ranged from 49 pupils in the study by Ureña et al. (2020) to 245 in the Vazou et al. (2021) study. The intervention time was of 15 minutes, delivered in a single intervention (Ureña et al., 2020), at 7 weeks / 3 times per week (Vazou et al., 2021). The type of PA designed for the experimental conditions were: motor skills and tasks (Robinson et al., 2016); walking obstacle course, cycling obstacle course and motor story (Ureña et al., 2020); Walkabouts (commercial web-based programme that includes fundamental movements such as jumping, hopping, walking and stretching) (Vazou et al., 2021). Regarding the improvement of self-regulation, results show that the children who participated in the intervention condition improved this EF (Robinson et al., 2016; Vazou et al., 2021). In the first part, all intervention groups improved, while in the second part, in which a new standard was added, significant improvements were only seen in the groups where coordination demand was higher (Ureña et al., 2020).

Regarding the effectiveness of PA on *Attention*, the intervention time was of 12 weeks, with a total of 24 sessions of 30 minutes. The type of PA designed for the interventions was: yoga sessions for one group, and moderate-intensity generic PA for the other. Results on attention indicate an improvement in two of the studies (Lundy & Trawick-Smith, 2021; Vazou et al., 2021) and in the case of Jarraya et al. (2019), the results showed an improvement in attention for the yoga condition over the remaining conditions.

For the observation of effectiveness of PA on the *Working memory* of the two studies that evaluated this component, one obtained improvements in participants from the experimental condition (Xiong et al., 2017), while Wen et al. (2018) found no significant improvements.

Figure 4 summarises the research (n = 18) that obtained improvements or not on the different variables studied.

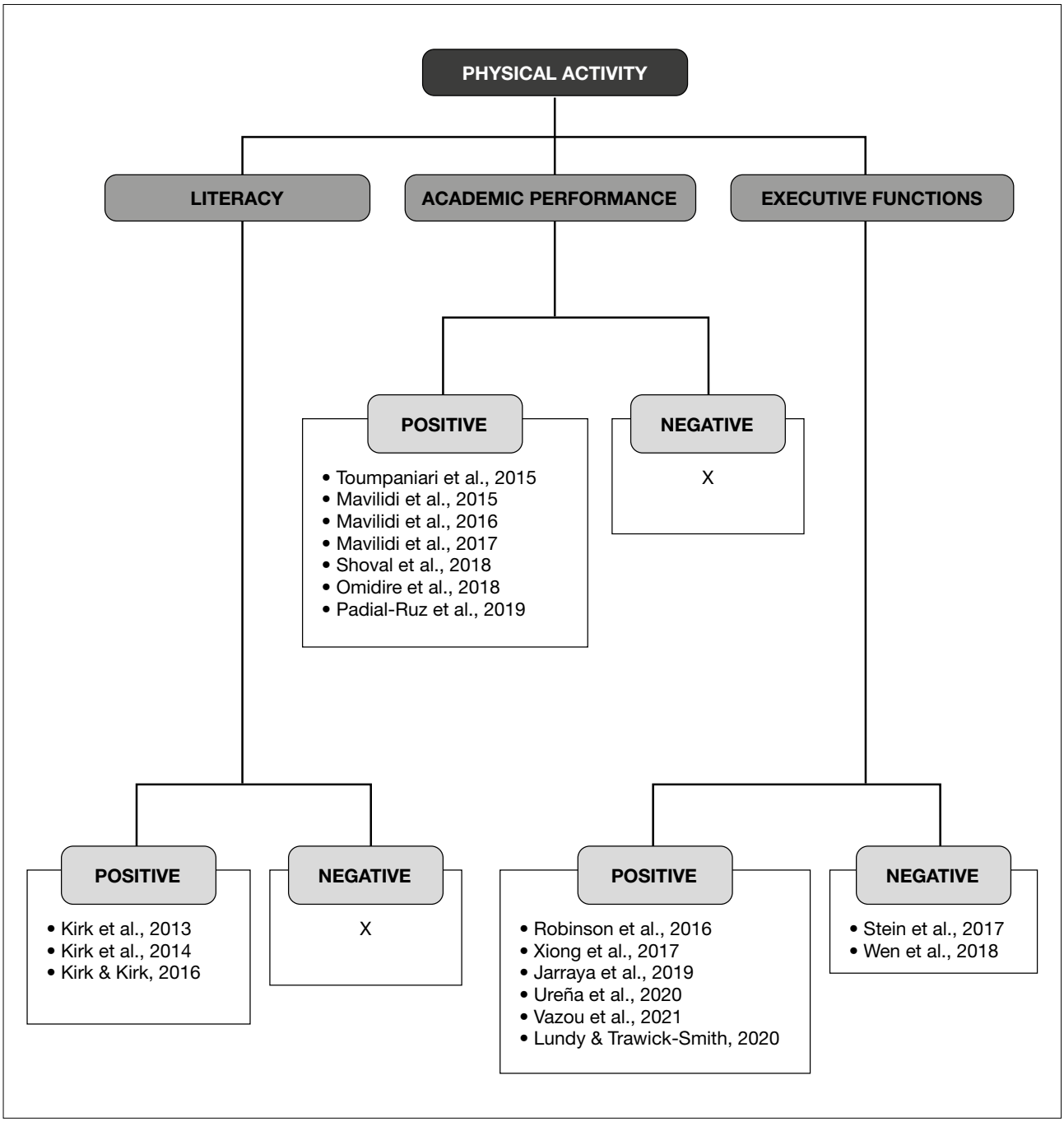

Figure 4
Effect of PA interventions on academic achievement and executive functions.

Discussion

Based on the main objective of this study, it was found that, in the case of *literacy*, the studies reviewed suggest that PA can have a significant influence on children's early literacy skills. Possible reasons, as indicated by Kirk & Kirk (2016), are the improved attention to a task, better long-term memory, children's increased ability to think and process information, and improved classroom behaviour (Davis et al., 2007; Miller & Votruba-Drzal, 2013). Moreover, the idea of incorporating PA to academic content can be a strategy to increase PA in a kindergarten setting (Castelli et al., 2007; Coe et al., 2006). This is important, as improved literacy skills development in early childhood contributes to children's long-term academic success. Children who lack basic skills such as phonological awareness, letter and print knowledge may have difficulty learning to read when they start school (Kirk & Kirk, 2016).

With regard to PA being integrated into the curriculum, for the improvement of academic performance and PA time during classes, all the interventions carried out in the kindergarten stage provide positive results, regardless of the curriculum content studied (foreign languages, mathematics, science, language,...) and the type of PA. Similarly, children who participated in this type of intervention were more physically active (Mavilidi et al., 2016; Toumpaniari et al., 2015) and showed improved cognition, classroom performance and academic results, supporting the theory that PA integrated to the curriculum is educational and can promote health, social and cognitive benefits to students (Omidire et al., 2018). One explanation for this improvement is that children could have been more enthusiastic about the new active teaching methods. Consequently, not only could they have put more physical effort into the exercise, but they could also have been able to invest more mental effort in learning (Sebastiani, 2019). Thus, although few studies exist, there is a positive association between physically active classes and academic results compared to traditional sedentary classes (Omidire et al., 2018; Shoval et al., 2018). Beyond health benefits, they also have positive effects on brain development and learning ability, as well as facilitate children's executive function, which is important for academic achievement (Milne et al., 2018; Tomporowski et al., 2008). Therefore, when considering the integration of PA in the teaching of different curriculum contents as a form of cognitive demand exercise, it is possible that these lessons could result in improved cognitive and academic results, especially when they add psychosocial mechanisms, which increase students' motivation and interest towards learning (Diamond & Ling, 2016; Viciana et al., 2017).

The complex composition of *executive functions* increases the measurement difficulty, particularly among kindergarten children. The positive relation between PA and academic performance has been demonstrated, and its use in teaching is an effective tool for the development of cognitive content (Singh et al., 2012), as games and movement are significant resources for students, which help improve attention and motivation for learning (Janssen et al., 2014). However, not all the articles analysed in this review demonstrated positive effects on some of the EF components, such as cognitive flexibility and working memory, matching previous research such as that of Mierau et al. (2014). These results contradict studies reporting the positive effects of coordinated interventions and aerobic exercise interventions on inhibition (Barenberg et al., 2011; Jäger et al., 2014) and cognitive flexibility (Ellemberg & St-Louis-Deschênes, 2010; Chen et al., 2014), obtained in children over 6 years, adolescents and adults. This may be caused by the attentional and cognitive resources of kindergarten children being more limited than those of older children and because the intensity of the activities performed was not high enough to stimulate cognitive development. Other reasons could have been insufficient sample size and intervention time (Wen et al., 2018).

As in previous reviews carried out at the primary school stage (Chacón-Cuberos et al., 2020), most of the studies analysed in this review show how the practice of PA improves academic performance and the development of executive functions; and although no conclusions can be drawn about the type of PA, its intensity and duration from the articles included in this review, some of the characteristics of PA (table 3) that can produce positive effects on these parameters at the kindergarten stage are:

Table 3
Type of PA used with positive effect on executive functions and academic performance.

Authors	Characteristics
Kirk & Kirk (2016); Mavilidi et al. (2017); Shoval et al. (2018); Ureña et al. (2020)	Integration of PA into lessons; PA integrated into the curriculum; Conscious movement; Physical education with cognitive involvement.
Lundy & Trawick-Smith (2021); Stein et al. (2017)	Exercises and activities of high intensity and duration. Gross motor skills exercises. Motor games.
Padial et al. (2019); Toumpaniari et al. (2015)	Combination of PA and gestures for learning curriculum content.
Jarraya et al. (2019)	Yoga activities.
Mavilidi et al. (2016).	Group games (observing the movements of others can activate neurons related to the same actions).
Omidire et al. (2018); Xiong et al. (2017).	Structured physical activity.
Ureña et al. (2020)	Complex motor skills.

This review contributes to the existing evidence base, to our knowledge it is the first systematic review on physical activity programmes implemented in the kindergarten stage for improving academic performance. The findings must be understood bearing in mind the following limitations. Firstly, the high level of heterogeneity detected in the included studies limits the strength of these findings. Secondly, the limited amount of research measuring the improvement of PA in interventions, the characteristics of this PA being fundamental to support the validity of the results in terms of academic performance and the development of executive functions. Thirdly, methodological limitations, which prevent from making a valid conclusion because of the variety in the sample and the different activities that comprise the interventions, or the duration of implementations. Some interventions were implemented for a short period of time, which is why only short-term results could be observed, without having the possibility to verify the possible continuation of these results or the potential long-term benefits.

Despite all these limitations, the review reflects the efficiency of the interventions conducted, with 88.9% of the studies demonstrating their effectiveness. One of the main advantages of these PA programmes is that they are minimal interventions that can easily be brought into the classroom, since they require little change in the methodology of the stage and a small cost in resources and investment for schools, guaranteeing their sustainability over time. Thus, we consider that the practical application of this review focuses on two areas: The first is the utility for schools, as it provides active methodologies, allowing the physical and motor improvement of the child, enables more adherence to PA from an early age and favours the learning and cognitive development of kindergarten pupils. And the second is researchers, since it provides a basis for all interventions conducted to enable their future replication.

Conclusions

The results of this systematic review indicate that there is a positive association between different strategies for the integration of PA in the classroom and academic results, regardless of the curriculum content studied (foreign languages, mathematics, science, language) and the type of PA practised for the intervention.

Although it is not possible to draw clear conclusions about the type of PA, the intensity and duration that it should have in order to achieve greater effectiveness, the research analysed reveals that the most effective interventions are those that involve a moderate level of PA and, which are also linked to the development of the different curriculum contents, and need at least a minimum of 10 minutes in order to obtain positive results. Thus, the academic lessons delivered using PA can be an important strategy for improving early literacy and curriculum content learning, all the while achieving PA levels close to those recommended daily. Programmes using moderate or vigorous PA intensity reached better scores than the others. Similarly, pupils who benefited from this type of intervention show a higher level of willingness and motivation towards the task.

Regarding the effectiveness of physically active classes, or curriculum-integrated PA on EF, not all the articles reviewed show positive effects on some components such as cognitive flexibility and working memory.

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Conflict of interest: No conflict of interest was reported by the authors.