Effect of physical activity and fitness on executive functions and academic performance in children of elementary school. A systematic review

Efectos de la actividad física y condición física sobre funciones ejecutivas y rendimiento académico en niños de Educación Primaria. Una revisión sistemática

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Abstract

This systematic review sought to investigate the influence of physical activity and physical fitness on cognitive functions and academic performance. Studies were identified in four databases from January 2010 through January 2021. A total of 26 studies were selected after meeting the established criteria. Nine studies showed an association between physical activity and physical fitness variables and academic performance. Cardiorespiratory fitness, speed-agility, motor coordination, and perceptual-motor skill had the strongest association with executive function, including attention, memory, inhibition and shifting in 17 studies. High levels of physical activity and physical fitness are associated with higher academic performance and executive function. More hours of Physical Education are needed to more effectively develop the cognitive aspects and physical fitness of children in elementary school.

Keywords: Physical performance, cognitive functions, academic achievement, school-aged children..

Resumen

Esta revisión sistemática buscó investigar la influencia de la actividad física y la aptitud física en las funciones cognitivas y el rendimiento académico. Los estudios se identificaron en cuatro bases de datos desde enero de 2010 hasta enero de 2021. Se seleccionaron un total de 26 estudios después de cumplir con los criterios establecidos. Nueve estudios mostraron una asociación entre la actividad física y las variables de aptitud física y el rendimiento académico. La aptitud cardiorrespiratoria, la velocidad-agilidad, la coordinación motora y la habilidad perceptivo-motora tuvieron la asociación más fuerte con la función ejecutiva, incluida la atención, la memoria, la inhibición y el cambio en 17 estudios. Los altos niveles de actividad física y aptitud física están asociados con un mayor rendimiento académico y función ejecutiva. Se necesitan más horas de Educación Física para desarrollar de manera más efectiva los aspectos cognitivos y la aptitud física de los niños en la escuela primaria.

Palabras clave: Desempeño físico, funciones cognitivas, rendimiento académico, niños en edad escolar.

Introduction

The importance of physical activity (PA) for health and quality of life is well known and researched. Children experience both physical and psychological benefits when participating in PA (Ahn and Fedewa, 2011; Janssen and Leblanc, 2010; Lobelo et al., 2020). Moreover, previous studies have shown that PA influences cognitive functions (Ellemberg and St-Louis-Deschênes, 2010; Gallotta et al., 2014; Gunnell et al., 2019; Verburgh et al. 2014). A recent review showed that physical fitness (PF), single bouts of PA, and PA interventions benefit children's cognitive functioning (Donnelly et al., 2016). Children who demonstrated to have high physical aptitudes exhibited greater cortical activation and corresponding cognitive functions than less fit children (Álvarez-Bueno et al., 2017; Latorre Román et al., 2017; Lemes et al., 2021). Chaddock, Pontifex, Hillman and Kramer (2011) demonstrated how PA improved brain health and cognitive functions during child development. Chang et al. (2012) and Gallotta et al. (2014) showed that several variables associated with PA such as PA duration, PA intensity and specific types of PA performed during a training programme were significant moderators in the association between cognitive functions and PA.

The terms PA and PF are often confused. Although these terms are closely related, they should not be treated as synonyms. PA refers to any bodily movement produced by skeletal muscle which requires consumption of energy. PF in turn is interpreted as a measure of the capacity to perform PA that include the majority of the physical functions (skeletomuscular, CRF, hematocirculatory, endocrine-metabolic, and psycho-neurological) involved in PA. PF is made up of 3 components: cardiorespiratory fitness (CRF), strength, and agility (Martínez-Vizcaíno and Sánchez-López, 2008). The close relationship between these terms is what justifies attending to both in this systematic review.

Previous studies have found several associations between PA and cognitive functions on specific factors such as academic performance (AP), executive function (EF), memory, intellectual maturity, concentration, and creativity in children (Donnelly et al., 2016; Latorre-Román et al., 2016; Lees and Hopkins, 2013; Soga, Shishido and Nagatomi, 2015). These studies analysed both acute and chronic effects of PA on cognitive actions. In addition, literature reviews (e.g. Marques et al., 2018) show how higher cardiorespiratory fitness (CRF) may be important to enhance academic performance.

Academic performance can be improved through PA at school (Carriedo and González, 2019). Wittberg et al. (2012) demonstrated how students who have healthy PF had significantly higher scores in different school subjects than students who had a low level of PF. In addition, current research has shown that AP was higher when children completed an intervention dedicated to doing more PA at school (Resaland et al., 2015; Donnelly et al., 2013).

Aerobic exercises have the potential to promote multiple facets of development through its direct impact on EF (Best, 2010). The term EF makes reference to capabilities we utilise when we formulate our goals and objectives, organise and plan, and when we carry out a series of adjusted and effective behaviours to achieve a goal (Lezak, Howieson and Loring, 2004). Multiple cognitive functions such as inhibiting dominant responses, updating working memory representations, shifting between task sets and attention are included in EF (Friedman et al., 2008). Working memory is an important element which belongs with EF. Pesce et al. (2009) investigated the effects of PA on memory performance in children through two sessions immediately following a PE class (aerobic circuit training vs. team games). They found that memory improved in both experimental groups compared to the control group. In addition, Berrios Aguayo et al. (2019) demonstrated the effectiveness of two PE classes (team game exercise and aerobic exercise) on memory. Additionally, attentional control and selective attention are other components of EF (Anderson, 2002). Mahar (2011) showed how after a break from a PE class, attention on a task was better. Syväoja et al. (2014) found that sedentary behaviour was associated with weaker flexibility of attention.

Different variables for PA have been associated with childhood neurocognition, however how cognitive aspects in children are developed through their physical development are still poorly understood. Further research is necessary to understand the relationship between PA and cognition performance during development. Mahar et al. (2006) claimed opportunities to be physically active at school are limited by pressure on scholastic performance. The incorporation of PA time into the school day is needed (Kibbe et al., 2011; Segura-Martínez et al., 2020).

Considering all previous evidence about how the practice of PA is related to greater cognitive and academic development in school-aged children, the research question focuses on: is there enough research literature that analyse this issue? Therefore, the objective of this systematic review was to analyse research that investigated the relationship and/or influence of PA and the level of PF on AP and EF in school-age children.

Method

The study was designed following the structure and recommendation of other systematic reviews (Ruiz-Ariza et al., 2017; García-Pinillos et al., 2016), the protocol used by PRISMA guidance for reports and studies (Moher, Liberati, Tetzlaff, Altman and PRISMA Group, 2009) and the Cochrane Manual of systematic reviews of interventions (Higgins and Green, 2011).

Search strategy

A comprehensive search of 4 databases (Medline, Pubmed, Eric ProQuest and Web of Science) from January 2010 through to January 2021 was undertaken. The principal categories of search terms were identified and employed in different combinations using "AND" (combining terms by retrieving the records in which all the searched terms appear) and "OR" (joining different terms by retrieving the records in which any of the terms appear) (Table 1).

Table 1. *Searcher strategy in databases*

Databases	Research Strategy	Limits	Filters
Medline (EBSCO)	(physical education OR physical fitness OR physical activity) AND (cognitive performance OR academic performance OR attention OR executive function OR memory) AND (children OR childhood)	Publication date: 2010-2021 English language Age: 6-12 years Free full text	5623
Pubmed	(physical education OR physical fitness OR physical activity) AND (cognitive performance OR academic performance OR attention OR executive function OR memory) AND (children OR childhood)	Publication date: 01/01/2010-01/01/2021 Humans Age: 6–12 years. English language Linked full text	2343
Eric Proquest	(physical fitness OR physical education OR physical activity) AND (cognitive performance OR academic performance OR attention OR executive function OR memory) AND (children OR childhood)	Publication date: 01/01/2010-01/01/2021 English language Journal Articles Elementary education	143
Web of Science	((physical education' OR' physical activity' OR 'physical fitness') (cognitive performance' OR 'academic performance' OR attention OR executive function OR memory) (children OR childhood))	Publication date: 2010-2021 English language Articles Open access	1783

Inclusion and exclusion criteria

The relevant papers selected for inclusion in the review were checked against the following criteria:

(1) There were no exclusion criteria with regard to sex or ethnic origin; (2) There was exclusion with children with physical or intellectual disabilities. (3) Age: children aged between 6-12 years old; (4) Language: English; (5) Year of publication: 2010-2021; (6) The systematic review uses cross-sectional, repeated measures or interventional studies; (7) Review articles were not included in this systematic review.

Reliability and data extraction

Based on the inclusion and exclusion criteria, two independent reviewers screened the citations of potentially relevant publications. If the citation showed any potential relevance, it was screened at the abstract level. When abstracts indicated potential inclusion, full-text articles were reviewed. A third-party consensus meeting was held with a third author (APV) if the 2 reviewers were not able to reach agreement. In conclusion, authors reviewed the studies resulting from the systematic review and agreed on their inclusion.

Quality assessment and level of evidence

The quality assessment of the study has carried out on the basis of other standardised assessment lists. Cross-sectional studies were assessed using the modified version of the Quality Index developed by Downs and Black (Downs and Black, 1998) (Table 2). The original scale was reported to have good test-retest (. = 0.88) and inter-rater (. = 0.75) reliability and high internal consistency (Kuder-Richardson Formula 20 (KR-20) = 0.89). Reliability of the subscales varied from good to poor validity. The Quality Index correlated highly with an existing, established instrument for assessing randomised studies r = 0.90. The modified version of the Downs and Black Quality Index is scored from 1 to 14, with higher scores indicating higher-quality studies. Those items that corresponded to the selected studies were selected based on the needs of the study, as well as relevant systematic reviews already published, such as the one by Ruiz-Ariza et al. (2017).

Table 2. *List of included studies with quality score (Down and Black scale modified)*

Authors and variables	Item 1	Item 2	Item 3	Item 6	Item 7	Item 10	Item 12	Item 15	Item 16	Item 18	Item 20	Item 22	Item 23	Item 25	Total Score (out of 14)
Wittberg, Northrup and Cottrell (2012)	1	1	1	1	1	1	1	1	1	1	1	1	0	0	12
Lambourne et al. (2013)	1	1	1	1	1	1	1	1	1	1	1	1	0	1	13
Hansen et al. (2014)	1	1	1	1	1	1	1	1	1	1	1	1	0	1	13
Haapala et al. (2014)	1	1	1	1	1	1	0	1	1	1	1	1	1	1	13
Syväoja et al. (2014).	1	1	1	1	1	1	0	1	1	1	1	1	1	1	13
van der Niet et al. (2015)	1	1	1	1	1	1	0	1	1	1	1	1	1	0	12
van den Berg et al. (2016)	1	1	1	1	1	0	0	1	1	1	1	1	1	0	11
Pontifex et al. (2012)	1	1	1	1	1	1	0	1	1	1	1	1	1	1	13
Gallotta et al. (2015)	1	1	1	1	1	1	0	1	1	1	1	1	1	1	13
Ma, Le Mare and Gurd (2015)	1	1	1	1	1	1	0	1	1	1	1	1	1	1	13
Raine et al. (2013)	1	1	1	1	1	1	0	1	1	1	1	1	1	1	13
Jäger et al. (2015)	1	1	1	1	1	1	0	1	1	1	1	1	1	0	12
Schmidt et al. (2015)	1	1	1	1	1	1	0	1	1	1	1	1	1	0	12
Pirrie and Lodewyk (2012)	1	1	1	1	1	1	0	1	1	1	1	1	1	1	13
Schmidt et al. (2017)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14

Note: 0 = no; 1 = yes; Item 1: clear aim/hypothesis; Item 2: outcome measures clearly described; Item 3: patient characteristics clearly described; Item 6:main findings clearly described; Item7:measures of random variability provided; Item10: actual probability values reported; Item12: participants prepared to participate representative of entire population; Item 15: Blinding of outcome measures; Item 16: analysis completed was planned; Item 18: appropriate statistics; Item 20: valid and reliable outcome measures; Item 22: participants recruited over same period; Item 23: Randomised; Item 25: adjustment made for confounding variables.

The methodological quality of interventional studies was assessed using the Physiotherapy Evidence Database (PEDro) scale (Maher et al., 2003) (Table 3). This 11-item scale rates randomised controlled trials from 0 to 10, with 6 representing the cut off score for high-quality studies. Studies scoring 9-10 on the PEDro scale were considered to be of "excellent" methodologically quality, 6-8 of "good" quality, 4-5 of "fair" quality, and below 4 of "poor" quality.

Table 3. *List of included longitudinal studies with quality scores (PEDro scale)*

Authors and variables	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11	Total Score	Quality level
Mullender-Wijnsma et al. (2015)	1	1	0	1	1	0	0	1	1	1	1	8	GQ
Erwin, Fedewa and Ahn (2012)	1	0	0	1	1	0	0	1	1	1	1	7	GQ
Käll, Nilsson & Lindén (2014)	1	0	0	1	1	0	0	1	1	1	1	7	GQ
Sardinha et al. (2016)	1	0	0	1	1	0	0	1	1	1	1	7	GQ
Hillman et al. (2014)	1	1	0	1	1	0	0	1	1	1	1	8	GQ
Fisher et al. (2011)	1	0	0	1	1	0	0	1	1	1	1	7	GQ
Kamijo et al. (2011)	1	1	0	1	1	0	0	1	1	1	1	8	GQ
Ou et al. (2016)	1	1	0	1	1	0	0	1	1	1	1	8	GQ
de Greeff et al. (2016)	1	1	0	1	1	0	0	1	1	1	1	8	GQ
Kvalø et al. (2017)	1	1	0	1	1	0	0	1	1	1	1	8	GQ
Lind et al. (2018)	1	1	1	1	1	0	0	1	1	1	1	9	EQ
Chaddock-Heyman et al. (2020)	1	1	1	1	1	0	0	1	1	1	1	9	EQ
Layne et al. (2021)	1	1	1	1	1	0	0	1	1	1	1	9	EQ

Note. 0 = item was not satisfied; 1 = item was satisfied Excellent quality (EQ)= 9-10; Good quality (GQ)= 6-8; Fair quality(FQ)= 4-5; Poor quality (PQ)= <4; Item 1: eligibility criteria were specified; Item 2: subjects were randomly allocated to groups; Item 3: allocation was concealed; Item 4:The groups were similar at baseline regarding the most important prognostic indicators; Item 5:There was blinding of all subjects; Item 6:There was blinding of all therapists who administered the therapy; Item 7: There was blinding of all assessors who measured at least one key outcome; Item 8: measurements of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups; Item 9: all subjects for whom outcome measuments were available received the treatment or control condition as allocated, or where this was not the case, data for at least one key outcome were analyzed by "intention to treat"; Item 10: the results of between groups statistical comparisons are reported for at least one key outcome; Item 11: the study provides both point measurements and measurements of variability for at least one key outcome.

Result

The flow of search results through the systematic review process is shown in Figure 1. Firstly, 9892 papers from the different databases were extracted based on the language, type of document, age and date. Secondly, duplicate papers were excluded (4562 duplicate papers). Then, the titles of the articles were read to exclude those that were not related with our bibliographical search (123 papers were selected). Specifically, population, age, language, design, variables, and other excluding factors were meticulously inspected. Finally, 123 papers were read in full in order to select the final sample (28 papers) (Table 4).

A meticulous analysis was conducted with the final papers. Nine papers (32,14%) were cross-sectional studies (Wittberg et al. 2012; Lambourne et al., 2013; Hansen et al., 2014; Haapala et al., 2014; Syväoja et al., 2014; van der Niet et al., 2015; Pontifex et al., 2012; Raine et al., 2013; Schmidt et al. 2017); six papers (21,42%) were repeated measures studies (van den Berg et al., 2016; Gallotta et al., 2015; Ma et al., 2015; Jäger et al., 2015; Schmidt et al., 2015; Pirrie and Lodewyk, 2012). Both cross-sectional studies and repeated measures studies were methodologically assessed through the *modified Down and Black scale* providing an adequate assessment of the articles based on the scale scores. Finally, 13 papers (46.42%) were interventional studies (Mullender-Wijnsma et al., 2015; Käll et al., 2014; Erwin et al., 2012; Hillman et al., 2014; Fisher et al., 2011; Kamijo et al., 2011; Ou et al., 2016; de Greeff et al., 2016; Sardinha et al., 2016; Kvalø et al. 2017; Lind et al., 2018; Chaddock-Heyman et al., 2020; Layne et al., 2021) . These articles were assessed through the PEDro scales obtaining an evaluation of *Good Quality* or *Excellent Quality*.

The main findings of the studies analyzed in the systematic review agree that PA has an acute and chronic effect on the cognitive and academic performance of primary school children. The results will mainly depend on the intensity and the time of development of the PA.

Table 4. Characteristic of the studies analysed

Authors	Physical/ Cognitive Variables	Study design/ Duration Sample/ Age/ Country	Procedure and physical activities measures.	Cognitive function measures	Result
Wittberg et al. (2012)	CRF/AP	Cross-sectional study/ 1725 students/ 5th grade and 7th grade/ Virginia, USA	Cardiorespiratory fitness: Students did the Progressive Aerobic Cardiovascular Endurance Run (PACER) used in FitnessGram. This test measures the time it takes the child to run or walk 1 mile. With the PACER assessment, the student is expected to run back and forth across a 20-metre space at a pace defined on a beep-only or music audiotape, which gets faster each minute.	Academic performance: WESTEST (West Virginia Educational Standards Test) 4 test areas: mathematics, science, social studies, and reading and language arts.	Students who had better marks on the CRF test obtained significantly higher WESTEST scores than students who had lower CRF capacity.
Lambourne et al. (2013)	PA and CRF/AP	Cross-sectional study/ 687 students/ 2nd and 3rd grades/ Kansas, USA	Daily PA assessed: Children wore a portable Accelerometer on a belt over the non-dominant hip for at least 10 hours on 3 days or more. Cardiovascular fitness: children did the PACER.	Academic performance: Weschsler Individual Achievement Test-Third Edition (WIAT-III). It assessment reading comprehension and oral reading fluency, spelling, and mathematics problem solving and numerical operations.	Findings showed a direct effect of PA on AF ($b = 0.009$, $p < 0.001$) and an indirect effect (mediation) of PA via fitness on math achievement ($b = 0.003$, $p < 0.01$). However, PA nor AF were correlated with WIAT-III reading or spelling scores.

Note: PA = Physical activity; PF = Physical fitness; PE = Physical education; MVPA = moderate to vigorous physical activity; AF = Aerobic fitness; CRF = Cardiorespiratory fitness; PLACER = Progressive Aerobic Cardiovascular Endurance Run; BMI = Body mass index; AP = Academic performance; EF = Executive function

Table 4 (cont.) Characteristic of the studies analysed

Hansen, at al. (2014)	CRF/AP	Cross-sectional study/ 687students/ Mean age = 7.8 ± 0.6 years from 2nd and 3rd grades/ Kansas USA	Physical activity: To measure PA, children wore an ActiGraph GT3X+ portable accelerometer on a belt over the non-dominant hip for 4 consecutive days (including 1 weekend day) Cardiorespiratory fitness: To measure progressive cardiovascular fitness, PACER was used.	Academic performance: The WIAT-III is comprised of 16 subtests. For this study, five subtests were selected: reading comprehension, oral reading fluency, spelling, mathematics problem solving, and numerical operations.	Multilevel regression results for AF indicated there was no significant linear or non-linear association between fitness and reading achievement ($p > 0.05$), but a significant quadratic association between fitness and both spelling and math achievement (both p's < 0.01).
Haapala et al. (2014)	Motor performance, cardiovascular performance/AP	Cross-section study/ 341 students/ 6-8 years from 1st and 3rd grades/ Kuopio, Finland	Body composition: Body fat mass was assessed using a Lunar dual-energy x-ray absorptiometry device. Body weight was measured using a calibrated InBod. BMI (body weight (kg) divided by height (m) squared). Cardiorespiratory fitness: The PA test protocol included a 3-min warm-up period, a 1-min steady-state period, a PA period with a workload increase every 6 s until exhaustion, and a 4-min cooldown period. Motor performance: The shuttle run test was used to assess speed and agility. The flamingo balance test was used to assess static balance. The box and block test was used to assess manual dexterity.	Academic performance: Reading fluency and reading comprehension were assessed using a group-administered timed subtest of the nationally normed reading achievement battery (ALLU). Arithmetic skills were assessed using a basic arithmetic test, with a set of visually presented addition and subtraction tasks.	A worse overall motor performance in grade 1, was associated with poorer reading fluency ($F2,161 = 5.94$, $p = 0.003$), reading comprehension ($F2,161 = 3.95$, $p = 0.021$), and arithmetic skills ($F2,161 = 10.01$, $p = 0.001$) in grades 1–3 after adjustment for age. Children who had lower motor performance in grades 1-3 had poorer reading fluency ($p = 0.003$) and reading comprehension ($p = 0.025$).

Table 4 (cont.) Characteristic of the studies analysed

Syväoja et al. (2014)	PF/EF (visual memory, working memory, attention).	Cross-sectional study/ 224 children/ Mean age 12.2 years/ Jyväskylä, Finland	Physical activity and sedentary time: The ActiGraph GT1M/GT3X accelerometers with vertical axel were used to measure children's MVPA and sedentary time. The accelerometer was worn on the right hip with an elastic waistband during waking hours for seven consecutive days.	Visual memory: Pattern Recognition Memory test (PRM) assessed recognition memory and visual patterns. Executive functions Spatial Span (SSP) and Intra-Extra Dimensional Set Shift (IED) tests assess the length of the visuospatial working memory span based on the Corsi blocks task. Attention: Reaction Time (RT) and Rapid Visual Information Processing (RVP) measured children's reaction time and speed of response to a visual target.	Girls spent more of their waking hours being sedentary than boys. Objectively measured MVPA was negatively associated with the RTI five-choice test score (ms), whereas sedentary time was not associated with the RTI five-choice test score. Sedentary time was positively associated with RVPA, whereas objectively measured MVPA was not associated with RVPA. Self-reported playing of computer/video games was negatively associated with SSP span length.
van der Niet et al. (2015)	PF/EF (inhibition, working memory, cognitive flexibility and planning)	Cross-sectional study/ 80 students/ 8-12 years old	Physical activity: An accelerometer was used (The ActiGraph GT1M/GT3X) over seven consecutive days.	Executive functions: Inhibition: Was measured with Stroop test. Working memory: Was measured with the Visual Memory Span test. Cognitive flexibility: Was measured with Trailmaking. Planning: Children used Tower of London test in order to measure planning.	More time spent in sedentary behaviour was related to worse inhibition ($r = -0.24$). A higher total volume of PA was associated with better planning ability ($r = 0.24$) and a shorter total execution time ($r = -0.29$). A significant correlation was found between time spent in MVPA and the total execution time of the Tower of London ($r = -0.29$).
Pontifex et al. (2012)	Poor CRF/ EF(attention)	Cross-sectional study/ 62 students/ 9-10 years old/ East-central Illinois region, USA	Cardiorespiratory fitness: Maximal oxygen consumption (VO_2max) was measured using a computerised indirect calorimetry system with averages for oxygen uptake (VO_2) and respiratory exchange ratio (RER; $VC0_2\backslash V0_2$) assessed every 20 seconds.	Poor attention: The ADHD Rating Scale IV is an 18-item inventory completed by the parent/legal guardian based upon the diagnostic criteria for attention deficit hyperactivity disorder Pubertal status: The Tanner Pubertal Timing Scales use self-ratings based upon schematic drawings of secondary sexual characteristics. Intelligent: The K-BIT assessed the verbal and nonverbal intelligence in individuals.	Findings showed that lower-fit children exhibited poorer overall response accuracy during a task requiring aspects of cognitive control relative to their higher-fit counterparts, with a disproportionately greater number of errors of omission, and longer, more frequent sequential errors of omission.

Table 4 (cont.) Characteristic of the studies analysed

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Raine et al. (2013)	CRF/AP and EF (way of learning and memory)	Cross-sectional study/ 3 days/ 48 students/ children 7-9 years old/ Illinois, USA	Day 1: participants completed maximal oxygen consumption (VO2max) test to assess their level of AF. Cardiorespiratory fitness: Sessions occurred on consecutive days and involved a mobile application on an iPad (Apple Inc., Cupertino, CA). The task involved remembering names of specific regions comprised of four letters each from a map	Learning and recall: Day 2: children learned the names and locations of the regions. Participants learned two different maps using two different learning strategies: a study only (SO) strategy and a test study (TS) strategy. Day 3: Participants returned one day after studying the maps to complete the recall test.	There were no differences in performance at initial learning between higher fit and lower fit participants. However, during the retention session higher fit children outperformed lower fit children, particularly when the initial learning strategy involved relatively poor recall performance. Fitness can boost learning and memory of children and these fitness-associated performance benefits are largest in conditions in which initial learning is the most challenging.
Schmidt et al. (2017)	Motor ability(aerobic endurance, motor coordination, muscular strength)/EF (updating, inhibitions, shifting) and academic performance	Cross-sectional study/10 week/236 students/children 10-12 years old/Magglingen, Switzerland	The first 4 week the motor ability was evaluated. Aerobic endurance: The Shuttle run test was used to assess cardiorespiratory endurance. Next 6 week the motor coordination and muscular strength was assessed Motor coordination: Motor coordination was measured by jumping sideways, a subtest of the Körperk oordinations test für Kinder Muscular strength The standing long jump was used to measure strength	Executive function Updating A non-spatial n-back task was used to assess updating Inhibition A child-adapted Eriksen flanker task was used Shifting An additional block ("mixed" block) included in the flanker task was employed Academic performance Math	A mediation analysis was used to show how EF was a mediator variable for the three physical variables . However, there was only one direct path from motor coordination and the AP. It concludes by showing an indirect path of physical skills and the AP through the EF

Table 4 (cont.) Characteristic of the studies analysed

				Arithmetic, geometry, and solving written math problems Task was considered Reading The Salzburger Lese-Screening für die Klassenstufen 5–8 was used Spelling Hamburger Schreib-Probe test was employed	
Jäger et al. (2015)	Team games and aerobic exercise /EF (inhibition and shifting)	Repeated measure study/ acute effect/ 12 years old/ Bern, Switzerland	Team games group (floorball and basketball): These two team games were chosen because they are appropriate to induce MVPA intensity. Both control and complex eye-hand coordination and require goal-directed behaviour. Third, these team games were suitable for combining sport-specific skill development. Aerobic exercise group: Children were instructed to run a marathon as an entire class, whereby each child was allowed to cross off one box from a joint list after each circuit. With a circuit of 200 m. Control group: normal classes of PE	Executive functions Inhibition Was measured by means of a child-adapted Flanker task consisting of a block with 20 congruent trials ("pure" block) and a block with 20 congruent and 20 incongruent trials in a randomised order ("standard" block). Shifting Was assessed by an additional block ("mixed" block) included in the Flanker task.	Both interventions (team games and aerobic exercise) have a positive acute effect on children's AF (4–5% increase in estimated VO2 max). Importantly, an improvement in shifting performance was found only in the team games and not in the aerobic exercise or control condition. Thus, the inclusion of cognitive engagement in PA seems to be the most promising type of chronic intervention to enhance EF in children.

Table 4 (cont.) Characteristic of the studies analysed

van den Berg et al. (2016)	Aerobic, coordination, and strength classes/EF (information processing speed and selective attention)	Repeated measures study / acute effect/ 195 students/ 10-13 years old/ The Netherlands	Three types of exercises in the classroom 12 minutes for each (the first 1½ min warming-up and last 30 s cooling-down were equal for all exercise types). Heart rates: during the exercise session, students wore a HR monitor: Aerobic exercise: Various well-known, easy and repetitive movements Coordination exercise: More complex movements that stressed coordinative skills, including bilateral movements and movements in which the body mid line was crossed Strength exercise: Dynamic and static body-weight exercises Control group Normal sessions in the classroom	Information processing speed: The Letter Digit Substitution Test (LDST) requires students to match letter-number pairs according to a key, which is presented on top of the sheet. The key contains nine boxes with letters and associated numbers, between 1-9. Selective attention: Students performed the D2 test. It consists of one page with 14 lines, each consisting of 47 letters 'd' and 'p'. Above and/or below each letter are 1–4 dashes displayed, either individually or in pairs.	There were no significant acute effects of exercise on information processing speed [$F(1,174) = 0.71$, $p = 0.40$, $\eta 2p = 0.00$] and selective attention [$F(1,172) = 0.91$, $p = 0.34$, $\eta 2p = 0.01$]. Likewise, type of PA did not moderate effects on information processing speed [$F(1,174) = 1.75$, $p = 0.18$, $\eta 2p = 0.02$] and selective attention [$F(1,172) = 0.60$, $p = 0.55$, $\eta 2p = 0.01$]. Pre- and post-test scores showed similar patterns on the exercise and control day, and did not differ between exercise types.
Gallotta et al. (2015)	Physical exertion, cognitive exertion, mixed cognitive and physical exertion/EF (attention)	Repeated measures study / acute effect/ 116 students/ 8-11 years old from 3rd-5th grades/ Rome, Italy.	Physical exertion (PE): The PE consisted of continuous aerobic circuit training followed by a submaximal shuttle run exercise. This lesson was focused on the improvement of cardiovascular endurance by performing different types of gaits (fast walking, running…) without any specific coordinative request	Attention: Children, before the intervention classes and just after these, used the D2 test in order to assess pre- and post selective attention.	Exertion type × time interaction indicates the likely presence of differential effects of the exertion type on TR (total responses) and E% (precision index) variables change after intervention. Children improved their performances from pre- to post-, and to 50′ post-intervention to a lower degree when exerted in CPE condition as compared with both CE and PE conditions. These results revealed that CPE exertion type led to a

Table 4 (cont.) Characteristic of the studies analysed

			Cognitive exertion (CE): It consisted of a 50-min academic class about humanistic subject matters. Mixed physical and cognitive exertion (CPE): Basketball was used in the context of mini-games. The basketballs were used in unconventional ways with varying game rules (use of foot-eye coordination techniques with basketballs)		lower improvement of CP values over time than the two other exertion conditions
Ma et al. (2015)	A 4-minute high-intensity exercise/EF (attention).	Repeated measures study/ 3 weeks/ 168 students/ Children 9-11 years old from 3rd -5th grades/ South eastern Ontario, Canada	FUNterval activity intervention: This physical technique requires only 4 min to complete. Consists of 20 s of high-intensity activity separated by 10 s of rest, repeated 8 times. FUNterval is performed in the classroom before the academic lessons. Control group: normal academic lessons	Attention: Children did a pre-test and a post-test using the D2 test to assess selective attention.	A comparison of the D2 test performance on no-activity days demonstrated that males made a higher number of total errors (E) and E Omission than females. The effect of the intervention on attention was good. All measures of the D2 test improved from week 1 to week 2 ($p < 0.05$).

Table 4 (cont.) Characteristic of the studies analysed

Schmidt et al. (2015)	Physical games, aerobic exercise and cognitive games sessions/EF (updating, inhibition and shifting)	Repeated measures study / Acute effect/ 219 students/ children 10-12 years/ Bern, Switzerland	Physical games session: Children played three different cooperative and competitive physical games that required the activation of one or more EF dimensions. Aerobic exercise condition: PA without cognitive engagement. This condition consisted of short tasks and games requiring different forms of running Cognitive games group: The games required the activation of all EF dimensions and the level of difficulty was increased twice during the game by introducing new rules. Control group: Children made themselves comfortable on a mat and listened to an age-appropriate story.	Executive function: Updating Was assessed by a non-spatial n-back task. Several pictures of fruits were presented one after another on the screen. Inhibition Was measured by a Flanker task consisting of a block with 20 congruent and 20 incongruent trials in a randomised order. Shifting Was assessed by an additional block (shifting block) included in the Flanker task. In this block, again 20 congruent and 20 incongruent trials were shown with additional rule cued.	No significant effect was found in children with lower academic achievement. In children with higher academic achievement, a significant main effect for PA (F (1,104) = 12.55, $p < .01$) and also for cognitive engagement (F (1, 104) = 4.86, p = .03) emerged indicating that children with higher academic achievement benefitted from all interventions relative to the control condition. Post-tests showed that children with higher academic achievement in the physical games ($p < .01$, d = 1.12), in the aerobic exercise ($p < .01$, d=.89), and in the cognitive games group (p = .02, d = .57) improved significantly more than children in the control group.

Table 4 (cont.) Characteristic of the studies analysed

Pirrie and Lodewyk (2012)	MVPA/EF (planning, attention, simultaneous process and successive process).	Repeated measures study / 2 weeks/ 40 students/ Children from 4th grade/ Southwestern Ontario, Canada	Experimental group: They completed the cognitive function tests after an hour MVPA lesson. Testing began approximately 10 min after the end of the PE lesson and all students were tested within one hour after the end of the PE class. Control group: This group was tested first after PA and eight days later after no activity. Cardiorespiratory fitness measurement: Heart rate monitors were used to measure the intensity of PA for a randomly selected, gender-matched group of ten students in each class.	Children completed an independent reading task assigned by their regular teacher. Executive function: The PASS theory has been operationalised using the Cognitive Assessment System (CAS) which measures planning, attention, simultaneous processing, and successive processing.	Performance on the planning test significantly improved after PA ($p <$ 0.001), controlling for sequence and habituation/retesting effects. No improvement was observed for attention, simultaneous processing, or successive processing.
Sardinha et al. (2016)	CRF/AP	Interventional study/ 3 years/ 1286 students/ Mean age=11.3 from 5th, 6th and 7th grades/ Portugal	Participants were part of the PA and Family-Based Intervention in Paediatric Obesity Prevention in the School Settings (PESSOA project). This intervention lasted 3 years. CRF measurement: The CRF was assessed by PACER Body mass index (BMI): Was calculated by the Quetelet index (weight (kg)/height (m)2)	Academic performance Children were assessed at baseline and at the end of 3 years by student marks (Mathematic, Portuguese, English and Science)	Being persistently fit (fit–fit), compared with those classified unfit–unfit, increased the odds of having high levels of academic achievement in Portuguese (odds ratio (OR) = 3.49; 95% CI, 1.97–6.20; p = 0.001) and foreign language (OR = 2.41; 95% CI, 1.39–4.14; p = 0.01) at follow-up. Students that improved their CRF and became fit (unfit–fit) also had higher odds of achieving better marks than those persistently unfit–unfit in Portuguese (p = 0.01) and foreign language (p = 0.01).

Table 4 (cont.) Characteristic of the studies analysed

Käll et al. (2014)	Increasing PE classes/AP	Interventional study / 1965 students/ elementary school/ Sweden	Experimental group: Children were carrying out a Swedish government programme (Handslaget), using group play, and other activities. Control group: Student did not increase PA sessions.	Academic performance: National goals in Swedish, Mathematics, and English. Academic results from the years prior to and during the intervention programme were analysed.	Higher proportions of students in the experimental group achieved the national goals in all 3 subjects compared with the control group which obtain lower results.
Mullender-Wijnsma et al. (2015)	Active academic lesson/AP	Interventional study/ 1 year/ 228 children (122 boys and 106 girls) /Mean age: 8.1 from 2nd or 3rd grades/ Netherlands	Experiment group: Children have to do MVPA during F&V lessons (Fit & Vaardig op school; Fit and academically proficient at school) in the classroom (jumping while spelling words, moving around the class saying exercise results, etc.) Control group: Normal lesson without PA	Academic performance: Observations were done during the lesson. Investigators observed whether children performed the basic exercise (on-task), the specific exercise (on-task) or no/other exercise (off-task) of maths and languages.	The third-grade children in the intervention group scored significantly higher on both mathematics ($F[1,99] = 11.72$, $p < .05$) and reading ($F[1,98] = 6.97$, $p < .05$) in comparison with the third-grade children in the control group. On the other hand, the second-grade children in the intervention group scored significantly lower on mathematics in comparison with the second-grade children in the control group ($F[1,109] = 12.40$, $p < .05$). No differences were found on the reading test in grade 2 ($F[1,109] = 0.72$, $p = .40$)
Erwin et al. (2012)	Active academic lessons/AP	Interventional study/ 20 week/ 29 students/ Mean age: 8.87 from 3rd grade/ Kentucky, USA	Experimental group: Intervention children had PA breaks for 20+ minutes per day. Children combined different PA like teacher-directed instruction, partner or group exercises around the classroom, etc. To measure school day PA, participants wore a pedometer for five consecutive school days Control group:	Academic performance Reading fluency was curriculum-based while mathematical fluency was assessed with short progress measures designed to assess children's reading and mathematical abilities. At the beginning and end of the intervention, students carried out the Test of Primary Reading Outcomes (T-PRO), which	The intervention group ($M = 24.56$, $SD = 2.21$) scored significantly higher in mathematics than the control group ($M = 13.69$, $SD = 2.45$). The scores in reading were statistically higher than standardised test scores ($p < .001$).

Table 4 (cont.) Characteristic of the studies analysed

			They did normal academic classes in the classroom	assesses phonics, vocabulary, comprehension, and research skills.	
Hillman et al. (2014)	Afterschool PA/ Behaviour (accuracy and reaction time) and EF (modulated attentional, inhibition and cognitive flexibility).	Interventional study/ 9 months/ 221 students/ 7-9 years old/ East Central Illinois	Aerobic fitness: A test of maximal oxygen consumption (VO2max) was used to measure AF. Afterschool PA programme: The 2-hour PA intervention occurred after each school day, and focused on improvement of AF. Children intermittently participated in at least 70 minutes of MVPA. The intervention included 30-40 minutes at PA stations. Next, a healthy snack and educational component were provided as a rest period, and children then engaged in low organisational games (45–55 minutes) centred on a skill theme.	Attentional inhibition Assessed using a modified flanker task. Cognitive flexibility was assessed by using a colour-shape switch task. A modified flanker task is a method to measure inhibition in which children are engaged in a series of trials that, in this case, have arrays of fish that either match (congruent arrays) or do not match (incongruent arrays).	Response accuracy increased in both groups, however, the intervention group demonstrated greater improvement from pre-test to post-test than the wait-list control group (3.2%, 95% CI: 0.0 to 6.5, $d = 0.27$ for group difference in pre-to-post change score. The improvement in performance on the heterogeneous task was greater among intervention participants (4.8%, 95% CI: 1.1 to 8.4, $d = 0.35$ for group difference in pre-to-post change score.
Fisher et al. (2011)	Increasing hours of PE/EF (spatial memory, working memory) and attention	Interventional study/ 10 week/ 185 students/ Mean age: 6.2/ Glasgow, Scotland	Physical activity: Data were collected at week 0 with the Actigraph GT1M accelerometer for 7 days. Actigraphs were worn over the right hip on a waist belt. Experimental group: It increased 2 classes per week of PE.	Cognitive function: The Cognitive Assessment System (CAS), the Cambridge Neuropsychological Test Battery (CANTAB). Attention:	Total PA was significantly greater during the intervention than control sessions (median difference 649 counts per minute; $p < 0.001$). There were no significant between group differences in any of the CAS scales (all $p > 0.05$). The CANTAB Spatial Working Memory Error rate was significantly reduced in the intervention group. Scores on subscales which measure the risk of

Table 4 (cont.) Characteristic of the studies analysed

			Control group: Only 1 class of PE per week	The Attention Network Test (ANT). Memory: The test of Spatial Memory Span (SSP) and the test of Spatial Working Memory (SWM).	suffering cognitive Problems/ Inattention, Hyperactivity and ADHD index were significantly lower post intervention than in the control group.
Kamijo et al. (2011)	Afterschool PA/EF (working memory)	Interventional study/ 9 months/ 43 students/ children 7-9 years old/ Illinois, USA	Physical activity intervention: It occurred for a 2-hour period following each school day, and focused on improvement of CRF. Muscle fitness was addressed at least 2 days a week, with the participants using their own Thera-bands®. The sessions were around 40 min, however there were lessons lasting 70 min. Cardiorespiratory fitness: Maximal oxygen consumption (VO_{2max}) was measured using a motor-driven treadmill and a modified Balke protocol.	Working memory: A modified Sternberg task asked participants to encode a memory set containing an array of one, three, or five letters and press one of two buttons with their thumbs corresponding to whether a single probe letter was present (right) or absent (left) in the encoded letter array.	The PA intervention led to increases in CRF and improved Sternberg task performance. Further, the beneficial effects of the PA intervention were greater for a task condition requiring greater working memory demands. In addition, the intervention group exhibited larger initial contingent negative variation (CNV) at the frontal electrode site, relative to the control group.
Ou et al. (2016)	Afterschool PA/EF(working memory)	Interventional study/ 10 weeks/ 71 students/ Mean age: 9.4 years/ Westphalia, Germany	The experimental groups had 3 afterschool sessions per week for 45 min. The cardiovascular exercise group (CE): Children focused on improvement of cardiovascular fitness through running and running-based games of MVPA (recorded on three occasions by F1 Polar HR monitors). The motor exercise group (ME):	Working memory: Children used The Letter Digit Span (LDS). The task involves a standardised auditory presentation of an increasing mixed series of alternating numbers and letters. After an acoustic signal, each participant was asked to respond by first writing the numbers in order from the smallest to the largest,	Improvements in working memory from pre- to post-test in the two exercise groups were found with large effect sizes (CE: $F(1,26) = 19.709$, $p = 0.001$, $r = 0.66$; ME: $F(1,22) = 62.718$, $p = 0.001$, $r = 0.86$), but not in the CO ($F(1,20) = 0.769$, $p = 0.391$, $r = 0.19$). In the post measurement, only the ME differed significantly from the CO ($t(68) = 2.521$, $p = 0.014$, $r = 0.29$), but not from the CE ($t(68) = 0.746$, $p = 0.458$, $r = 0.09$), nor did the CE

Table 4 (cont.) Characteristic of the studies analysed

			Children focused on the improvement the bilateral coordination, hand–eye coordination, and leg–arm coordination exercises as well as spatial orientation and reaction to moving objects/persons Control group (CO): normal PE classes	followed by writing the letters in alphabetical order.	differ significantly from the CO ($t(68) = 1.887$, $p = 0.063$, $r = 0.22$).
de Greeff et al. (2016)	Active academic lesson/EF (inhibition, cognitive flexibility and working memory).	Intervention study/ 2 years/ 499 students/ Mean age: 8.1 years from 2nd and 3rd grades/ Northern Netherlands	Intervention group: Three F&V lessons per week. The F&V lessons had a duration of 20–30 min, with 10–15 min spent on solving mathematical problems and 10–15 min spent on language. They had MVPA intensity. During the F&V lessons all children started with performing a basic exercise, such as jogging, hopping in place or marching. A specific exercise was performed when the children solved an academic task. Control group: Normal lesson in the classroom	Executive function measurement: Inhibition: The Golden Stroop test was used to measure inhibition. Cognitive flexibility: Measured using a modified version of the Wisconsin card sorting test (M-WCST) Working memory: The Digit span backward and Visual span backward were used.	A great improvement in speed-coordination ($B = -0.70$, $p = 0.002$) and a lower improvement in static strength ($B = -0.92$, $p < 0.001$) were found for the intervention group. There was no significant result between intervention group and EF.
Kvalø et al. (2017)	Active academic lesson/EF (inhibition, cognitive flexibility and working memory).	Intervention study/ 10 months/ 449 students/ children 10-11 years old/ Stavanger, Norway.	Aerobic fitness: A 10-minute interval running test was using to assess AF Interventional group:	Executive function measurement: Inhibition: This EF was measured by The Golden Stroop test.	No significant differences were found between aerobic capacity and EF $F(1,344)=3.64$, $P=.057$. However, the results were positive.

Table 4 (cont.) Characteristic of the studies analysed

			A weekly intervention was carried out of 2×45 minutes physically active academic lessons, 5×10 minutes physically active breaks and 5×10 minutes physically active homework. Control group: Children followed a normal routine	Cognitive flexibility: Measured using the Trail Making Test Working memory: The Digit span was used to measure attention capacity	
Lind et al. (2018)	Increasing hours of PE /Psychomotor function and EF (attention, working memory)	Intervention study/11 week / 931 children 10-11 years old/ Southern Denmark	Intervention group: Two weekly PE sessions based on The "FIFA 11 for Health" were added: a 45-minute "play football" session (teaching football skills and playing small-sided football) and a 45-minute "play fair" session (teaching a health message and health behaviours) Control group: This group performed the obligatory daily school-based PA (5 × 45 minutes per week).	Cognitive assessment: English version of the Cogstate® Brief Battery, which is an objective computer-based cognitive test battery addressing psychomotor function, attention, working memory and visual learning in children.	This study provided evidence that the school-based physical activity programme "FIFA 11 for Health" for Europe can improve cognitive performance in schoolchildren: psychomotor function (56, sx– = 22 ms, p < .001), attention (39, sx– = 17 ms, p = .012) and working memory (79, sx– = 35 ms, p = .020)
Chaddock-Heyman et al. (2020)	Afterschool PA/EF (cognitive flexibility) and AP	Intervention study / 9 months/ 150 children 8-9 years old / East-Central Illinois	Intervention group: Two hours daily afterschool development the FITKids2 program based on improving aerobic fitness through engagement in a variety of developmentally appropriate physical activities. Control group: They completed all facets of the baseline and post-intervention without carrying out the program.	Cognitive assessment: Children completed subtests from the Woodcock–Johnson III Tests of Cognitive Abilities. The cognitive performance clusters assess executive processes, thinking ability, cognitive efficiency and verbal ability. Academic performance: The scholastic performance was assessed with subtests from the	The Experimental group better outcomes than control group in cognitive and academic performance after intervention: Executive Processes: F=36.441, p<0.001; Cognitive Efficiency: F=23.764, p<0.001; Thinking Ability: F=35.564, p<0.001; Verbal Ability: F=7.595, p=0.007; Mathematics: F=9.022, p=0.003; Reading: F=2.566, p=0.111).

Table 4 (cont.) Characteristic of the studies analysed

				Kaufman Test of Educational Achievement School performance was assessed with subtests of the Kaufman Test for Educational Achievement evaluating word recognition, reading comprehension, math concepts, applications and math computation.	
Layne et al. (2021)	Active academic lesson/EF (reaction time, response inhibition) and AP.	Intervention study / 4 week / 40 children 8-9 years / mid-south United States	Intervention group The intervention group played FitNexx active video game 10-minutes daily before mathematics classes. Control group	Cognitive assessment: The Go/No-Go test for inhibitory control (reaction time, overall error, decision error, and omission error) were conducted. Academic performance: Mathematics test for performance for mathematics. This test were regularly scheduled given to the students each week to examine their knowledge obtainment of the material being learned.	The findings showed that the intervention had a positive effect on students' reaction time (F[2,39] = 29.98, p < .001, η2 = .45) and response inhibition control (F[2,39] = 21.02, p < .001, η2 = .36). No effect was found on mathematics performance (F[2, 35] = .51, p = .479, η2 = .02).

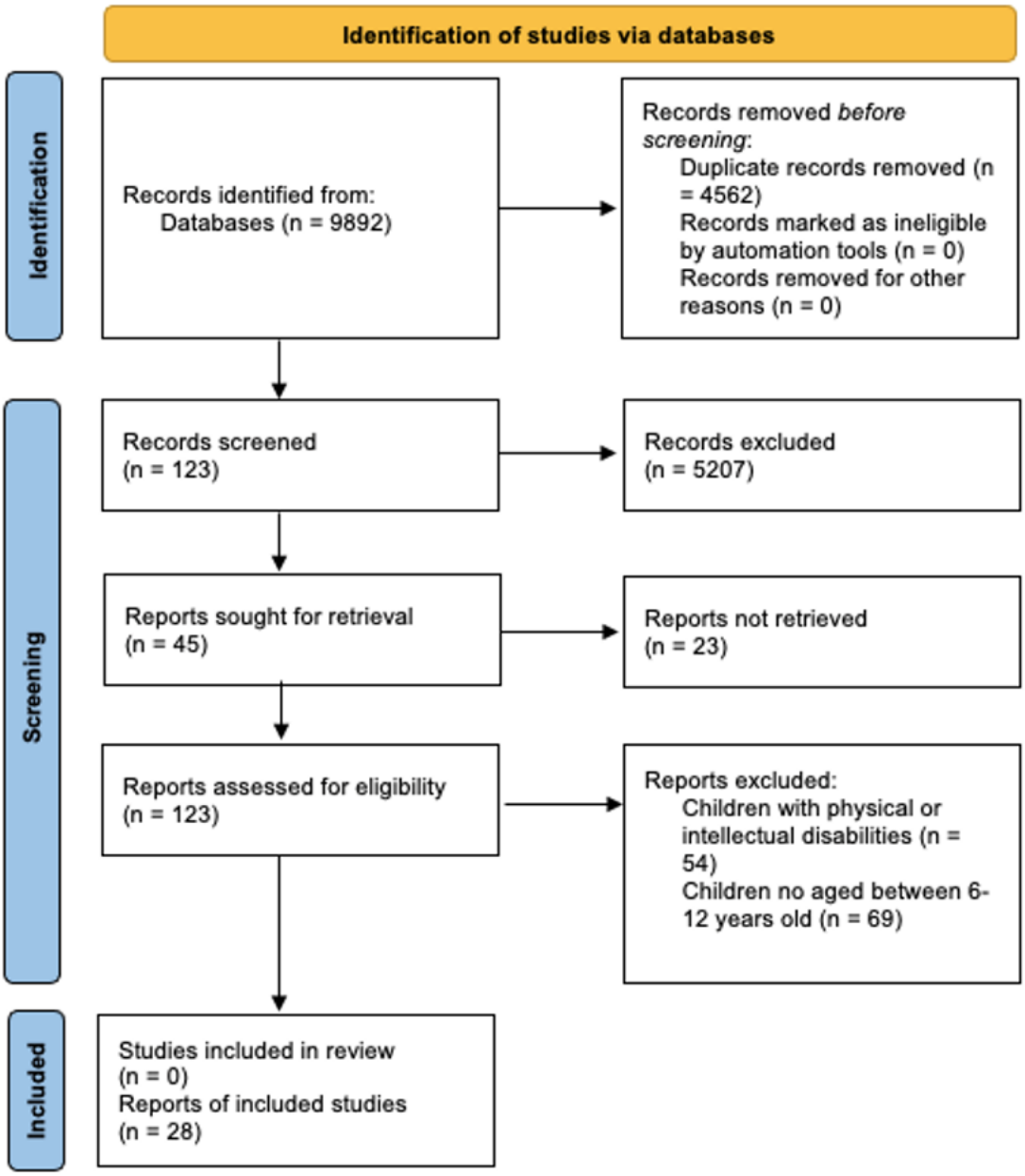

Figure 1. Flowchart illustrating the different phases of the search and selection of the studies
Note: PRISMA (2020) flow diagram for new systematic reviews which included searches of databases and registers only.

Discussion

This systematic review has explored the association between PA and PF on AP and EF in elementary school children (6-12 years old). Studies from January 2010 to January 2021 were obtained from 4 databases. A total of 26 articles met the inclusion criteria: 9 studies used a cross-sectional design, 6 were repeated measures studies and 11 were intervention studies. PA and levels of PF were assessed by CRF, muscular strength, speed-agility, motor coordination, perceptual-motor skill and other physical variables.

A large number of studies have examined, through cross-sectional designs, the association between the level of PF and various cognitive functions at school. The detailed analysis of the influence of each physical fitness component revealed that CRF has the greatest influence on AP and EF. To evaluate CRF, some studies used the 20-m shuttle run test PACER (Wittberg et al., 2012; Lambourne et al., 2013; Hansen, et al., 2014) and two studies used a formula to calculate the maximal oxygen consumption (VO.max) (Pontifex et al., 2012; Raine et al., 2013). Wittberg et al. (2012), Lambourne et al. (2013) and Hansen et al. (2014) found that children with more CRF had a higher AP. On the other hand, Pontifex et al. (2012) and Raine et al. (2013) used a computerised indirect calorimetry system with averages for oxygen uptake (VO.) and respiratory exchange ratio to assess CRF, showing how children with a high level of CRF had better memory ability. A suitable PF is an

possible condition for better inhibition, working memory and cognitive flexibility in children (Syväoja et al., 2014; van der Niet et al., 2015). In addition, a good CRF, an adequate body composition, and a higher motor performance are associated better AP (Haapala et al., 2014). However, Jansen et al. (2019) did not find relationship between PF (body coordination and speed) and working memory in school-aged children.

Some research has focused on determining the acute and chronic effect of PA on children's cognitive abilities. The type of effect depended on the duration of the intervention carried out. Several research has shown a acute effect when children perform PA before academic subjects on AP and EF. Different PE classes in which children have to activate their brain function, lead to they are more prone to obtain better scores on AP, memory, attention or concentration (Yanagisawa et al., 2010). MVPA performed in a PE session has an acute effect on different EF like planning, attention, simultaneous processing and successive processing and school performance in children during elementary school (Pirrie and Lodewyk, 2012). Moreover, short periods of aerobic exercise (20 seconds of high-intensity activity separated by 10 seconds of rest and repeated 8 times) have an important acute effect on attention in the next academic classes (Ma et al., 2015). Team game sessions, which demand control and complex eye-hand coordination and require goal-directed behaviour, and aerobic exercises, based on high-intensity cardiomyopathy, help students to better develop inhibition, shifting and memory update of themselves to face scholary activities in an appropriate way (Jäger et al., 2015). This was also supported by authors such as Mezcua et al. (2019) who showed that short-term training of C-HIIT has benefits in cognitive functions. However, a team game session had a better result in cognitive function than a class in aerobic exercise because it is producing a cognitive compromise when the frontal lobe is activated in the execution (Yanagisawa et al., 2010). This statement attempts to explain how PE sessions which include a cognitive compromise can have an acute effect on the cognitive capacities of children. Thus, Gallotta et al. (2015) demonstrated in an experiment that those sessions that require cognition exercises like playing mini-games with coordination, meant students were able to develop their cognitive skills more effectively. However, van den Berg et al. (2016) did not find any improvement on memory, attention or the PA in children who did aerobic, coordination or strength sessions in comparison with children who were in the control group.

On the other hand, current research has demonstrated the chronic effect of PA on AP and EF for elementary school children. Most of them have performed PA programmes in which children increased the time dedicated to PA at school (Lind et al., 2018). Käll et al. (2014) carried out a controlled interventional study in a Swedish government programme (Handslaget) based on group play and other activities which increased the proportion of students who achieved national learning compared with three reference schools. Higher proportions of students in the intervention school achieved the national goals in all three subjects compared with the reference schools after initiation of the intervention programme. Sardinha et al. (2016) also performed an intervention study to assess AP of children after a three-year intervention dedicated to avoiding childhood obesity. The result of this intervention was positive regarding the national goals. On the other hand, active lessons of MVPA in the classroom for several weeks improved the AP and EF of students due to the fact that they exercise not only the body but also the cognitive processes reflected in the AP (Mullender-Wijnsma et al., 2015; Erwin et al., 2012; Layne et al., 2021). Hillman et al. (2009) showed that an intervention over 9 months where children do short periods of moderate-intense aerobic exercise can improve cognitive control and attention. Increasing the number of hours of PE at school (two hours), over at least 10 weeks, is a suitable method to enhance the students' marks and cognitive aspects such as working memory and attention (Fisher et al., 2011). Children who have physical afterschool sessions for two hours per week (over 9 months) performing MVPA achieve better results on their behaviour (analysing accuracy and reaction time) and on executive control such as modulated attentional, inhibition and cognitive flexibility (Hillman et al., 2014). Moreover, afterschool sessions based on aerobic exercises (Kamijo et al., 2011; Chaddock-Heyman et al., 2020) and cardiovascular and motor exercises (Ou et al., 2016) showed improvements in some EF such as memory work or inhibitory control and AP. Continuing with afterschool sessions performing MVPA is a good way to enhance children's cognitive functions. In addition, it is relevant to determine not only whether team games and aerobic exercises have an acute effect on PA, but also whether it has a chronic effect if carried out for several weeks on EF such as inhibition, shifting and update (Schmidt et al., 2015). However, de Greeff et al. (2016) did not find improvements in mathematical and language activities for the experiment group after a two-year intervention dedicated to active MVPA classes.

Limitations of research and implications for research and practice

The limitations of the study are manifested in the selected databases. Although relevant databases were used, others such as Scopus were ignored. In addition, all types of studies that met the inclusion criteria were attended without paying attention to factors that could determine the quality of the study, such as the sample size.

Finally, based on the measurement instruments of the different variables, the suitability of the same can be confirmed in consideration of the context where the measurement was carried out and the age of the sample. All reflect an appropriate degree of reliability and are tailored to the sample. Certainly, more innovative and effective techniques such as image analysis could have been used, however, in the educational field, which has a fairly large sample, the use of such instruments is very complicated.

The literature suggests that cognitive and academic performance of children not improved by limiting the time allocated to PE and PA (Trudeau and Shephard, 2008). Therefore, increasing the amount of time devoted to PA and so improving their PF can promote acute and chronic cognitive benefits on EF such as working memory, attention, inhibition and shifting have important implications for AP (Fisher et al., 2011). In addition, activity breaks can produce positive, chronic cognitive response. This literature review serves as the basis for future research in the field of educational psychology that promotes PA programs in the school context in primary education.

Conclusion

The present review found a total of 26 articles that analysed the association between PA with AP and EF in children. Nine articles focused on AP and fifteen on EF. Thirteen of those focused on attention and working memory and two on other EF like inhibition, shifting, cognitive flexibility, update

or planning. Most studies showed a positive relationship between PA on AP and EF. In the nine studies which analysed the effect of PA and PF on AP, only one did not find an association. Regarding EF, in two studies PA did not produce any effects. CRF was the physical variable that was correlated with better AP and EF. On the other hand, active classes of MVPA and PE classes when children had to perform coordination exercises revealed a better acute effect. In addition, a large chronic effect was found mainly in children who carried out PE sessions over several weeks which involved cognitive compromises by means of coordination exercises. Finally, confounders could have played a pivotal role in these associations. Sex, age, BMI, sociodemographic factors, and previous marks must be taken into account. More research is needed to explain the effect of different types of PA on AP and EF to clarify the role of confounders and better predict the relationship between physical and cognitive variables. Intervention studies in which children have to move more at school or outside school are necessary in order to enhance cognitive processes which are used during the school day. Integrating educational departments, the school and the families can guarantee the cognitive and physical health of children. Promoting PA in children as a tool for improving cognitive aspects is everyone's responsibility.

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