



## Physical fitness and academic performance in youth: A systematic review

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3 **Physical fitness and academic performance in youth: A systematic review**  
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20 **Short title:** Physical fitness and academic performance  
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PROOF

**Abstract**

Physical fitness (PF) is a construct of health and skill related attributes which have been associated with academic performance (AP) in youth. This study aimed to review the scientific evidence on the association among components of PF and AP in children and adolescents. A systematic review of articles using databases PubMed/Medline, ERIC, LILACS, SciELO and Web of Science was undertaken. Cross-sectional and longitudinal studies examining the association between at least one component of PF and AP in children and adolescents, published between 1990 and June 2016, were included. Independent extraction of articles by 2 authors using predefined data fields was done. From a total of 45 studies included, 25 report a positive association between components of PF with AP and 20 describe a single association between cardiorespiratory fitness (CRF) and AP. According to the STROBE guidelines: 12 were classified as low, 32 as medium risk and 1 as high risk of bias. Thirty-one studies reported a positive association between AP and CRF, six studies with muscular strength, three studies with flexibility and seven studies reported a positive association between clustered of PF components and AP. The magnitude of the associations is weak to moderate ( $\beta = 0.10$  to  $0.42$  and odds =  $1.01$  to  $4.14$ ). There is strong evidence for a positive association between CRF and cluster of PF with AP in cross-sectional studies; and evidence from longitudinal studies for a positive association between cluster of PF and AP; the relationship between muscular strength and flexibility with AP is uncertain.

**Keywords:** Physical education, physical activity, physical fitness, school performance, school attendance, students.

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3 Physical fitness (PF) is operationalized as a set of measurable health and skill  
4 related attributes including cardiorespiratory fitness (CRF), muscular strength and  
5 endurance, body composition, flexibility, balance, agility, coordination, reaction time  
6 and power (Caspersen et al., 1985; American College of Sports Medicine, 2010).  
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11 Besides the well-described association between PF with a cluster of metabolic  
12 risk factors in children, adolescents and adults (Ruiz et al., 2006; Ortega et al., 2008;  
13 Kvaavik et al., 2009; Zagout et al., 2016), there is increasing evidence of an association  
14 between PF and academic performance (AP) (Grissom, 2005; Chomitz et al., 2009).  
15 This could be due to PF's positive effects on cognitive function and performance in  
16 attention tasks, or by its effects on depression, stress and sleep quality (Blumenthal et  
17 al., 2009; Chang & Chen, 2015; Latorre et al., 2015). Cognition and motor skills in  
18 children have several common underlying processes, such as sequencing, monitoring,  
19 and planning which may positively influence AP (Roebbers & Kauer, 2009; Van der Fels  
20 et al., 2015).  
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34 AP refers to a child's success and performance in school and can be measured  
35 by grade point averages, as a cluster of achievement tests or, using specific tests for  
36 reading or arithmetic skills, such as reading speed, fluency and comprehension, and the  
37 ability to solve logical/arithmetic problems (Donnelly et al., 2016).  
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43 The components of PF with documented potential for improving health are CRF,  
44 muscular strength, and motor ability, each of which may have different effects on the  
45 brain (Ruiz et al., 2009; Ruiz et al., 2011). CRF is supposed to induce angiogenesis in  
46 the motor cortex and increases blood flow, improving brain vascularization which could  
47 affect cognitive performance (Hillman et al., 2008). Muscular strength may alter spinal  
48 motoneuron excitability and induce synaptogenesis within spinal cord (Adkins et al.,  
49 2006). It is probable that these adaptations in brain may be mediated by physical  
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3 activity (Hillman et al., 2008). Some studies have examined the association of CRF and  
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5 muscular strength with AP separately (Aberg et al., 2009; Roberts et al., 2010; Chen et  
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7 al., 2013; Coe et al., 2013) or clustered (Grissom, 2005; Castelli et al., 2007; Chomitz et  
8  
9 al., 2009). However, the results are conflicting and have not been systematically  
10  
11 reviewed until now. It has been postulated that body composition is associated with AP  
12  
13 (Huizinga et al., 2008; Schwimmer et al., 2003). It is not clear if AP can be directly  
14  
15 mediated by fatness or if it is influenced by factors associated with excessive fatness,  
16  
17 such as poor self-esteem (Fan et al., 2010), anxiety/depression (Goldfield et al., 2010),  
18  
19 teasing and social rejection (Gunnarsdottir et al., 2011), poor attendance in school  
20  
21 classes (Pan et al., 2013) and poor PF (Datar et al., 2004; Shore et al., 2008).  
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24  
25 Keeley & Fox (2009) reviewed the impact of physical activity (PA) and fitness  
26  
27 on academic achievement and cognitive performance in children and found a weak  
28  
29 relationship between PF (mainly CRF) and academic achievement. It is important to  
30  
31 note that only seven studies were reviewed and a qualitative analysis of the studies was  
32  
33 not performed. Recently, Haapala (2013) in a narrative review described a positive  
34  
35 association between CRF and AP in children. However, this review was not systematic  
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37 and did not considered all components of PF. Therefore, the aim of this systematic  
38  
39 review was to examine the scientific evidence on the associations between PF's  
40  
41 components and AP in children and adolescents.  
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## 47 **Materials and methods**

48  
49 This systematic review was reported according to the Preferred Reporting Items  
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51 for Systematic Reviews and Meta-Analyses (PRISMA) criteria (Moher et al., 2009).  
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### Criteria for Considering Studies for this Review

Cross-sectional and longitudinal studies were considered for this review.

Eligible studies were: (1) published in English; (2) conducted among children and adolescents aged <20 years; (3) those that reported an association between CRF, muscle strength or endurance (assessed either field tests or in a laboratory), flexibility and AP (assessed by objective measures, such as, grade point average, standardized test scores and teacher rated achievement); (4) published prior to June 2016. Review articles, meta-analysis, validation studies, conference abstracts, monographs, dissertations, theses, commentaries, brief reports and studies conducted with special populations, such as children or adolescents with developmental disabilities, developmental delays or cognitive impairment were not included.

### Search Methods for Identification of Studies

A two-phase search strategy was used to identify potential studies. First, five electronic data bases were systematically searched: PubMed/Medline, ERIC, LILACS, SciELO and Web of Science. The search for descriptors and terms was performed with the MeSH – Medical Subject Headings, through the portal of the U.S. National Library of Medicine (NLM) and DeCS – Descriptors in Health Science from the database Virtual Health Library (Biblioteca Virtual da Saúde- BVS). Search strategies included the combination of variations between two groups of key-words/terms including, but not limited to the following examples: (1) PF (“physical fitness”, “physical endurance”, “cardiorespiratory fitness”, “physical conditioning”, “muscular strength”, “muscular endurance”, “muscular resistance”, flexibility, pliability); and (2) AP (“academic achievement”, “academic performance”, “school performance”, “educational status”

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3 “attendance school”). Terms were combined using the logical operators available as  
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5 search tools. A detailed description of the Pubmed/Medline search is shown in  
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7 Appendix 1. The search strategy was adapted for the other databases.  
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10 In the second phase, the titles and abstracts for potentially relevant articles were  
11  
12 screened by two researchers (CCA and LPA). Afterwards, a full copy of the papers was  
13  
14 obtained for those that met the initial screening criteria and then were fully examined by  
15  
16 two researchers. If the two reviewers were unable to reach a consensus a third  
17  
18 researcher (WLP) was consulted. Furthermore, we examined references cited by each of  
19  
20 these articles in an attempt to identify other potential studies for inclusion.  
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### 23 24 25 **Data extraction**

26  
27 The following data were extracted from all eligible articles: (a) year of  
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29 publication, (b) study design, (c) location, (d) sample size, (e) age, (f) school year  
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31 (grades), (g) main outcomes (PF components and AP), (h) the main finding (i), and  
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33 control variables including socioeconomic status (SES), educational level of parents,  
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35 physical activity level, health status and others.  
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### 40 41 **Risk of bias**

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43 The risk of bias within studies was assessed using the adapted Strengthening the  
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45 Reporting of Observational Studies in Epidemiology (STROBE) statement according to  
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47 Lubans et al. (2010). A score of 0 (absent or inadequately described) or 1 (present and  
48  
49 explicitly described) was assigned to each of the following questions: (1) Does the study  
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51 describe the eligibility criteria for participant selection? (2) Are participants randomly  
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53 chosen from the population? (3) Does the study report the sources and details of the  
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55 method for measuring academic performance and did the instrument have acceptable  
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3 reliability? (4) Does the study report the sources and details of the assessment methods  
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5 for measuring obesity and did the instrument have acceptable reliability? (5) Does the  
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7 study report the power calculation and use a statistical method that is adequate to test  
8  
9 the hypothesis? (6) Does the study report the number of participants for each outcome  
10  
11 measurement and does this number represent at least 80% of the total sample?  
12

13  
14 A score for each article ranged from zero to six points. Studies with  $\leq 2$  were  
15  
16 considered high risk of bias, studies that achieved 3-4 points were classified as medium  
17  
18 risk and those that had scores of 5- 6 were classified as low risk of bias. Two  
19  
20 independent researchers performed the quality assessment (CCAS and LPA), and  
21  
22 disagreements were solved by the lead researcher (WLP).  
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25 The judgment of overall scientific evidence was based on Lubans et al. (2010)  
26  
27 using the percentage of studies that reported statistically significant relationship but also  
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29 taking into account the risk of bias: (a) *No Association*, if less than 33% of the studies  
30  
31 indicate a significant association between variables; (b) *Uncertain association*, if 34-  
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33 59% of the studies indicate a significant association between variables; (c) *Positive (or*  
34  
35 *negative) association*, if 60-100% of the studies indicated a significant association (in  
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37 the same direction); (d) *Strong evidence of positive (or negative) association*, if 60-  
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39 100% of the studies indicated a significant association between variables (in the same  
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41 direction) and more than 59% of the studies deemed low risk of bias (score  $\geq 5$ ) found a  
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43 significant association.  
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## 49 **Results**

### 50 **Study selection**

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52 The initial search identified a total of 1,404 potential papers. After adjusting for  
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54 duplicates, 1,369 remained. Of these, 1,315 studies did not meet the criteria after  
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3 examination of the title and abstract. The full texts of the 54 remaining papers were  
4  
5 examined. Reference tracking identified two additional studies (Kantomaa et al., 2013;  
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7 Hansen et al., 2014), resulting in total of 56 papers. Of these, 11 studies did not meet the  
8  
9 inclusion criteria. Two papers did not use an objective measure for AP (Padilla-Moledo  
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11 et al., 2012; Raine et al., 2013). Two papers were conducted in adults (Saavedra et al.,  
12  
13 2008; Valkeinen et al., 2013). One paper was a meta-analysis (Fedewa & Ahn, 2011).  
14  
15 Two papers were commentaries (Feiden, 2011; Hupert, 2015). Three were dissertations  
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17 (Hanna, 2009; Hannigan, 2010; Mobilia-Jones, 2010). One paper was published in  
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19 Spanish (Cumillaf et al., 2015). Therefore, 45 studies met all inclusion criteria and were  
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21 included in this systematic review (Figure 1).  
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27 Figure 1 here  
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### 32 **Characteristics of included studies**

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34 Table 1 shows that 77.8% of the studies had a cross-sectional design, 22.2% had  
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36 prospective design and 51.1% of the studies were conducted in the United States.  
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40 Table 1 here  
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45 Risk of bias assessment indicated that a single study (2.2%) was classified as  
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47 high risk (Du Toit et al., 2011), 32 (71.1%) as medium risk (Kim et al., 2003; Castelli et  
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49 al., 2007; Chomitz et al., 2009; Eveland-Sayers et al., 2009; Wittberg et al., 2009;  
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51 Roberts et al., 2010; Wittberg et al., 2010; Blom et al., 2011; Davis and Cooper, 2011;  
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53 London and Castrechini, 2011; Van Dusen et al., 2011; Wingfield et al., 2011; Wittberg  
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55 et al., 2012; Bass et al., 2013; Chen et al., 2013; Coe et al., 2013; Kantomaa et al., 2013;  
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3 Lambourne et al., 2013; Liao et al., 2013; Rauner et al., 2013; Greeff et al., 2014;  
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5 Haapala et al., 2014; Hansen et al., 2014; Scudder et al., 2014; Srikanth et al., 2014;  
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7 Torrijos-Niño et al., 2014; Chaddock-Heyman et al., 2015; Desai et al., 2015; Pellicer-  
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9 Chenoll et al., 2015; García-Hermoso, 2016; Morita et al., 2016; Pindus et al., 2016)  
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11 and 12 (26.7%) as low risk (Dwyer et al., 2001; Kwak et al., 2009; Welk et al., 2010;  
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13 Telford et al., 2012; Bezold et al., 2014; Esteban-Cornejo et al., 2014; Janak et al.,  
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15 2014; Sardinha et al., 2014; Aguilar et al., 2015; Huang et al., 2015; Kalantari et al.,  
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17 2016; Sardinha et al., 2016) (Table 2).

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20 Table 2 here

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23 Reporting how participants were randomly chosen from the population was the  
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25 main limiting factor in terms of risk of bias, a criterion that only 8 (17.8%) studies  
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27 fulfilled (Dwyer et al., 2001; Kim et al., 2003; Kwak et al., 2009; Lambourne et al.,  
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29 2013; Hansen et al., 2014; Sardinha et al., 2014; Kalantari et al., 2016; Sardinha et al.,  
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31 2016). This was followed by reporting statistical power as only 13 (28.9%) studies  
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33 fulfilled this criterion (Dwyer et al., 2001; Kwak et al., 2009; Welk et al., 2010;  
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35 Wittberg et al., 2010; Blom et al., 2011; Telford et al., 2012; Rauner et al., 2013; Bezold  
36  
37 et al., 2014; Esteban-Cornejo et al., 2014; Janak et al., 2014; Aguilar et al., 2015; Huang  
38  
39 et al., 2015, Morita et al., 2016). All studies present acceptable standards of quality of  
40  
41 reliable measurement from both exposure and outcome variables. However, no study  
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43 fulfilled all criteria to achieve the maximum quality score.  
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## 49 **Participants**

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51 The sample size ranged from 42 to 2,550,114 students. Participants were  
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53 enrolled in 1<sup>st</sup> grade to senior high school and aged from 6 to 18 years old. Seven studies  
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55 did not report the age of participants (Blom et al., 2011; Wittberg et al., 2012; Coe et al.,  
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3 2013; Rauner et al., 2013; Bezold et al., 2014; Janak et al., 2014; Pellicer-Chenoll et al.,  
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5 2015). Studies were conducted in both genders, except Kalantari et al. (2016) which  
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7 was conducted in boys.  
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### 10 11 12 **Dependent variable outcome: academic performance**

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14 AP was measured by standardized tests to assess knowledge in reading, writing,  
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16 mathematics and general knowledge in 37 studies (82.2%). Seven studies (16.7%) used  
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18 measures of AP through by scores given by the teachers (Kim et al., 2003; Kwak et al.,  
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20 2009; Chen et al., 2013; Kantomaa et al., 2013; Kalantari et al., 2016; Morita et al.,  
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22 2016; Sardinha et al., 2016). One study (2.4%) only utilized a math test (Huang et al.,  
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24 2015).  
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### 30 31 **Independent variable outcomes**

32 Ten studies (22.2%) used the FITNESSGRAM test to assess body composition,  
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34 CRF, muscular strength, muscular endurance and flexibility, (Castelli et al., 2007;  
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36 Chomitz et al., 2009; Wittberg et al., 2009; Blom et al., 2011; Du Toit et al., 2011;  
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38 London & Castrechini, 2011; Van Dusen et al., 2011; Bass et al., 2013; Coe et al., 2013;  
39  
40 Bezold et al., 2014). Three studies (6.7%) utilized the Alpha battery tests to asses CRF,  
41  
42 agility and muscular fitness (Esteban-Cornejo et al., 2014; Torrijos-Niño et al., 2014;  
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44 García-Hermoso, 2016). Thirty-seven studies (82.2%) examined the association  
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46 between CRF and AP, seven (15.6%) looked at the association between muscular  
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48 strength and AP, ten studies (22.2%) between flexibility and AP and eight studies  
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50 (17.8%) examined the association between PF components clustered and AP.  
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54 Twenty studies (44.4%) assessed only CRF (Kwak et al., 2009; Roberts et al.,  
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56 2010; Welk et al., 2010; Wittberg et al., 2010; Davis & Cooper, 2011; Telford et al.,  
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3 2012; Wittberg et al., 2012; Kantomaa et al., 2013; Lambourne et al., 2013; Rauner et  
4 al., 2013; Haapala et al., 2014; Hansen et al., 2014; Janak et al., 2014; Sardinha et al.,  
5 2014; Scudder et al., 2014; Srikanth et al., 2014; Chaddock-Heyman et al., 2015; Huang  
6 et al., 2015; Pindus et al., 2016; Sardinha et al., 2016).

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11 Some studies also measured motor skills. Three studies (6.7%) assessed motor  
12 proficiency (Du Toit et al., 2011), static balance or manual dexterity (Haapala et al.,  
13 2014) and motor ability (Esteban-Cornejo et al., 2014) and 1 study added measures of  
14 gross motor skills (Kantomaa et al., 2013).  
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### 23 **Main results**

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25 According to established criteria of overall scientific evidence (Lubans et al.  
26 2010), 27/30 cross-sectional studies (90%), and 4/7 longitudinal studies (57%) report a  
27 positive association between CRF and AP (Table 3). The results suggest strong  
28 evidence of positive associations between CRF and AP for cross-sectional studies and  
29 uncertain evidence for longitudinal ones.  
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36 Sixteen studies (35.5%) investigated the association between muscular strength  
37 and AP, 5/14 cross-sectional studies (35.7%) and 1/2 longitudinal studies (50%)  
38 reported a positive association between muscular strength with AP. There is uncertain  
39 evidence about the association between muscular strength and AP for both cross-  
40 sectional and longitudinal studies. Ten studies focused on the association between  
41 flexibility and AP (22.2%), 2/8 cross-sectional studies (25%) and 1/2 longitudinal  
42 (50%) described a positive association between flexibility and AP. There is no evidence  
43 from cross-sectional, and uncertain evidence for longitudinal association between  
44 flexibility and AP. Eight studies (17.8%) investigated the association between a  
45 clustered of PF components and AP, from this, 4/5 cross-sectional studies (80%) and  
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3 3/3 longitudinal studies (100%) reported a positive association. For cross-sectional  
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5 studies there is a positive association between cluster of PF and AP, for longitudinal  
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7 studies there is a strong evidence of positive association (table 3).  
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12 Table 3 here  
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14 Three studies found that the association between CRF and AP is stronger in girls  
15  
16 than boys. Eveland-Sayers et al. (2009) verified that time in a 1-mile run test was  
17  
18 negatively associated with performance in reading/language ( $r=-0.31$ ) and math ( $r=-$   
19  
20  $0.36$ ) in girls. Du Toit et al. (2011) found that relationship between PF components and  
21  
22 AP was stronger among girls (CRF  $r=0.63$ ; knee push-ups  $r=0.62$ ; wall sitting  $r=0.54$ ;  
23  
24 strength total  $r=0.62$ ) than boys (CRF  $r=0.40$ ; knee push-ups  $r=0.45$ ; wall sitting  $r=0.16$ ;  
25  
26 strength total  $r=0.51$ ). Van Dusen et al. (2011) showed a higher effect size in the  
27  
28 association between CRF and reading skills in girls (effect size = 0.27 -CI:0.25-0.29)  
29  
30 compared to boys (effect size = 0.17 - CI:0.15-0.19). A single study described an  
31  
32 association between anaerobic power and flexibility with AP only in girls (Liao et al.,  
33  
34 2013). Four studies found no or weak association between PF and CRF with AP after  
35  
36 adjusting for SES, BMI, motor performance, and screen time (Wingfield et al., 2011;  
37  
38 Haapala et al., 2014; Janak et al., 2014; Aguilar et al., 2015). Kantomaa et al. (2013) did  
39  
40 not find a relationship between compromised motor function in childhood, CRF and  
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42 AP in adolescents.  
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47 The association between PF with AP was assessed by multivariate linear  
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49 regression analyses in 21 studies (46.6%) (Dywer et al., 2001; Kim et al., 2003; Kwak  
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51 et al., 2010; Castelli et al., 2007; Roberts et al., 2010; London and Castrechini, 2011;  
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53 Wingfield et al., 2011; Chen et al., 2013; Coe et al., 2013; Liao et al., 2013; Esteban-  
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55 Cornejo et al., 2014; Greeff et al., 2014; Haapala et al., 2014; Janak et al., 2014;  
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3 Srikanth et al., 2014; Aguilar et al., 2015; Huang et al., 2015; García-Hermoso, 2016;  
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5 Kalantari et al., 2016; Morita et al., 2016; Pindus et al., 2016), 8 (17.8%) used logistic  
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7 binomial regression (Chomitz et al., 2009; Welk et al., 2010; Blom et al., 2011; Bass et  
8  
9 al., 2013; Sardinha et al., 2014; Torrijos-Niño et al., 2014; Desai et al., 2015; Sardinha  
10  
11 et al., 2016). Five (11.1%) studies utilized mixed models regression (Van Dusen et al.,  
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13 2011; Telford et al., 2012; Lambourne et al., 2013; Rauner et al., 2013; Bezold et al.,  
14  
15 2014). One study (2.4%) utilized structural equation to test mediation (Kantomaa et al.,  
16  
17 2013), and 1 study (2.2%) used multilevel regression (Hansen et al., 2014). Three  
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19 studies (6.6%) utilized analyses of variance (ANOVA) (Wittberg et al., 2009; Wittberg  
20  
21 et al., 2012; Chaddock-Heyman et al., 2015). Four studies (8.9%) did simple  
22  
23 correlation (Eveland-Sayers et al., 2009; Wittberg et al., 2010; Davis and Cooper 2011;  
24  
25 Du toit et al., 2011). One (2.2%) study utilized Student t-test (Scudder et al., 2014), and  
26  
27 1 study (2.2%) utilized the SOM equation (Peliccer-Chenoll et al., 2015).  
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32 Few studies provided details of the statistical analysis, when using linear  
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34 regression analysis and logistic regression (Dwyer et al., 2001; Castelli et al., 2007;  
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36 Chomitz et al., 2009; Kwak et al., 2010; London & Castrechini, 2011; Chen et al., 2013;  
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38 Liao et al., 2013; Esteban-Cornejo et al., 2014; Greeff et al., 2014; Sardinha et al., 2014;  
39  
40 Morita et al., 2016; Pindus et al., 2016). Another important consideration about the  
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42 analysis was how the covariates were incorporated in the final model. Considering that  
43  
44 the covariates are potentially related to one another, only the study of Esteban-Cornejo  
45  
46 et al. (2014) performed the final model analysis using multicollinearity using variance  
47  
48 inflation factors (VIFs). Two studies reported analysis of normal distribution of error  
49  
50 terms and outliers; however, the authors do not report details of the analysis, such as,  
51  
52 influence analysis of the fitted model, studentized residuals, Cook's Distance and  
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3 distributions of unweighted and weighted models (London & Castrechini, 2011; Pindus  
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5 et al., 2016).  
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8 Most population-based studies showed an association between PF and AP, and  
9  
10 these findings can be extrapolated to other populations due external validity. However,  
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12 the magnitude and power of the results were small in some studies (Dwyer et al., 2001;  
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14 Roberts et al., 2010; Welk et al., 2010; Blom et al., 2011; Van Dusen et al., 2011; Liao  
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16 et al., 2013; Rauner et al., 2013; Bezold et al., 2014). Van Dusen et al. (2011) with a  
17  
18 sample size of 254,743 students found an association between CRF and performance in  
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20 reading (effect size = 0.27) and performance in math (effect size = 0.33) in girls, for  
21  
22 boys the reported effect size was 0.17 for reading and for math 0.34, respectively. Liao  
23  
24 et al. (2013) with size sample of 149, 240 students verified that a 1 Standard Deviation  
25  
26 (SD) increase on the anaerobic power and flexibility Z-scores from high school in girls  
27  
28 was associated with an increase in the university entrance exam score by 0.018 and  
29  
30 0.010 SD, respectively. Dwyer et al. (2001) found a very weak correlation between time  
31  
32 to complete the 50-meter run ( $r=-0.15$ ), sit-ups repetitions ( $r=0.14$ ), and distance leaped  
33  
34 in the standing long jump ( $r=0.10$ ) and AP. Welk et al. (2010) with a sample size of  
35  
36 36,835 students also found a weak association between CRF and AP (OR=1.014;  
37  
38 CI=1.011-1.016), indicating that for each 1% increase in CRF, AP increases.  
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44 Regarding studies with lower size sample, some utilized direct measure to asses  
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46 CRF and added measures of cognition, electroencephalographic and magnetic resonance  
47  
48 imaging, which increases the internal validity of the studies (Davis & Cooper, 2011;  
49  
50 Haapala et al., 2014; Scudder et al., 2014; Chaddock-Heyman et al., 2015; Pindus et al.,  
51  
52 2016). Although some studies did not use more elaborate statistical tests due to limited  
53  
54 sample size, the authors found significant associations between CRF and performance  
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56 in reading ( $r=0.29$ ) and math ( $r=0.25$ ) (Davis & Cooper, 2011). Scudder et al. (2014)  
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3 verified that more fit children had greater reading achievement scores ( $123.1 \pm 2.8$ )  
4  
5 compared to less fit children ( $112.9 \pm 2.1$ ), with a larger effect size  $d= 0.8$ . A similar  
6  
7 finding was observed for spelling (higher fit:  $117.6 \pm 2.6$ ; lower fit:  $108.0 \pm 3.0$ ;  $d=$   
8  
9  $0.7$ ). Chaddock-Heyman et al. (2015) reported that higher fit children showed decreased  
10  
11 cortical thickness in the superior frontal cortex ( $3.76 \pm 0.15$ ;  $d=0.62$ ), superior temporal  
12  
13 cortex ( $3.17 \pm 0.24$ ;  $d= 0.64$ ) and lateral occipital cortex ( $2.46 \pm 0.10$ ;  $d= 0.68$ ) when  
14  
15 compared to lower fit children ( $3.85 \pm 0.14$ ;  $3.11 \pm 0.18$ ;  $2.56 \pm 0.19$ ), respectively.  
16  
17 Therefore, these methodological discrepancies should be considered when interpreting  
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19 the results.  
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## 24 25 Discussion

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27 From this systematic review, we conclude that there was strong evidence for a  
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29 positive association between CRF and AP in cross-sectional studies; a positive  
30  
31 association with the cluster of PF and AP; and a strong evidence from longitudinal  
32  
33 studies for a positive association between cluster of PF and AP. These results support  
34  
35 the conclusion of a recent review from Donnelly et al. (2016) demonstrating cross-  
36  
37 sectional and longitudinal associations between PF, AP and cognition in youth.  
38  
39 However, those authors state that these conclusions should be cautiously interpreted as  
40  
41 they are based on cross-sectional, acute/short-term, nonrandomized trials and from  
42  
43 randomized trials with a high risk of bias. Many of the studies had relatively small  
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45 samples or used correlational methodologies that cannot provide evidence of cause and  
46  
47 effect. Because most of the existing studies are cross-sectional or correlational, there is  
48  
49 a need for intervention studies to determine whether this relationship is causal. If the  
50  
51 relationship is causal, there would be a strong reason to promote physical activity in  
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53 schools as a means of increasing academic achievements.  
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3 The quality of existing studies was uneven and future studies could be  
4 strengthened by longitudinal research and follow-up assessments for RCT designs to  
5 provide a better understanding of the longevity of PF effects on cognition and academic  
6 achievement. Although the best evidence will come from RCT designs, in cases where  
7 cross-sectional data are still collected, it is recommended that researchers study the  
8 contribution of each component of PF on AP in order to determine whether another  
9 component of PF is really more important than other.  
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18 Most of the studies showed weak to moderate associations between PF and AP;  
19 the magnitude ranged from 0.10 (Kim et al., 2003) to 0.42 (Castelli et al., 2007) and  
20 odds ratio from 1.01 (Welk et al., 2010) to 4.14 (Blom et al., 2011). The magnitude of  
21 the association might not be clinically meaningful at individual level, but might be at  
22 population level. This systematic review expands a previous review by Keeley & Fox by  
23 including studies since 2009, and by including a qualitative assessment of the studies.  
24 We found 45 studies that met our criteria for inclusion in the systematic review. Of  
25 these, 30 (66.6%) with medium and low risk reported a positive association between  
26 CRF with AP and 7 studies that measured PF as cluster found a positive association  
27 between PF and AP.  
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40 PF has been associated with improvement in cognitive function in children and  
41 better performance in attention tasks. It is possible that those children who have higher  
42 cognitive ability may have both better AP and better PF compared to those with lower  
43 level of cognitive ability (Hillman et al., 2005; Hillman et al., 2009). This may be  
44 related to parents' cognitive ability and SES (Tucker-Drob & Harden, 2012; Heberle &  
45 Carter, 2015), which are not taken into account in some studies (Eveland-Sayers et al.,  
46 2009; Wittberg et al., 2010; Du Toit et al., 2011; Wittberg et al., 2012; Pellicer-Chenoll  
47 et al., 2015).  
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3 The mechanism of the association between academic performance and CRF  
4  
5 remains unclear. It is hypothesized that improvements in CRF, as induced by changes in  
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7 physical activity levels, may have a positive influence on cognition mediated by  
8  
9 increased levels of brain-derived neurotrophic factor (BDNF) (Hillman et al., 2008). In  
10  
11 a systematic review, Knaepen et al. (2010) suggested that the BDNF response to  
12  
13 exercise is most probably a phenomenon of what happens centrally, and exercising  
14  
15 regularly could induce central effects without elevating peripheral basal BDNF  
16  
17 concentration. However, the association between CRF and AP might be influenced by a  
18  
19 number of confounding factors affecting CRF. Some studies reported an inverse  
20  
21 association between obesity and CRF (Pahkala et al., 2013; Díez-Fernández et al.,  
22  
23 2014), and others suggested that due to growth and maturation the relationship between  
24  
25 these two variables might be more complex in children and adolescents (Rowland,  
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27 2013). It has been reported that CRF and body fat contribute equally to endurance  
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29 performance in field tests (Rowland et al., 1999).  
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34 The relationship between CRF and AP has been investigated mainly by CRF  
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36 field-based exercise tests (Roberts et al., 2010; Welk et al., 2010; Wittberg et al., 2010;  
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38 Lambourne et al., 2013; Rauner et al., 2013; Telford et al., 2012; Janak et al., 2014;  
39  
40 Sardinha et al., 2014; Srikanth et al., 2014; Huang et al., 2015; Sardinha et al., 2016).  
41  
42 There is evidence that the association between CRF and AP might be protocol/test  
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44 dependent (Dwyer et al., 2001), however it's suggested that this association may be  
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46 influenced by motor skills and running efficiency (Haapala et al, 2014; Van Der Niet et  
47  
48 al., 2014) rather than CRF itself (Kantomaa et al., 2011; Kantomaa et al., 2013).  
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52 The different association between boys and girls were also explored in a few  
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54 studies. Kwak et al. (2009) found that fitness was associated with AP in boys but not in  
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56 girls. On the other hand, others reported strong associations in girls (Eveland-Sayers et  
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3 al., 2009; Du Toit et al., 2011; Van Dusen et al., 2011; Liao et al., 2013). Haapala et al.  
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5 (2014) reported that in girls maturation may, at least partly, explain the relationships of  
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7 shuttle run performance and AP. Differences could be attributed to the age of the  
8  
9 subjects, such as, adolescents (Kwak et al., 2009; Van Dusen et al., 2011; Liao et al.,  
10  
11 2013), children (Eveland-Sayers et al., 2009; Du Toit et al., 2011; Haapala et al., 2014),  
12  
13 or assessment of PF and sex (Kalantari et al., 2016).  
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17 Considering the results presented in this review, studies are needed to develop  
18  
19 effective strategies for improving AP in school age children. Nevertheless, education  
20  
21 professionals are under pressure to improve the AP of students and historically, the  
22  
23 physical education classes are supposed to be less valuable than other disciplines in an  
24  
25 education setting. As a result, many schools have reduced or neglected children's  
26  
27 opportunities for PA at school (Chaddock et al., 2010). Reductions in time devoted to  
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29 PA and an increased amount of time in sedentary behaviors may not only affect weight  
30  
31 status but could also reduce HRPF, which could negatively affect AP (Tokmakidis et  
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33 al., 2006; Brunet et al., 2007; Korsten-Reck et al., 2007; Cantell et al., 2008; Nevill et  
34  
35 al., 2009).  
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39 The present study has some limitations that should be considered. A literature  
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41 search was performed only in journals indexed in the electronic databases ERIC,  
42  
43 PubMed / Medline, LILACS, Web of Science and SciELO. Therefore, it is possible that  
44  
45 some studies were not retrieved. Besides, the inherent limitations of cross-sectional  
46  
47 study designs, which were noted the most in this review, preclude making definitive  
48  
49 conclusions regarding causality relating to the development of AP and PF. Another  
50  
51 important limitation to consider is publication bias (e.g. studies which found no  
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53 association may not been published), which might affect the findings of this review.  
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3 Finally, there was only a small proportion of the studies (28.9%) meeting the criterion  
4  
5 of estimating statistical power.  
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7 In summary, the findings encourage carefully controlled intervention studies to  
8  
9 determine if increasing PF could improve AP of students.  
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### 11 12 13 **Perspectives**

14  
15 The present review aimed to examine the scientific evidence on the association  
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17 between PF and AP in children and adolescents. Based on the results of this review, we  
18  
19 suggest the focus of future interventions should be directed at promoting PF in an  
20  
21 environment that is developmentally appropriate for children and adolescents as this  
22  
23 may be the most advantageous path to promote overall functional capabilities, as well as  
24  
25 improvements on motor skill due to gender-specific games, equipment and spaces  
26  
27 (Hardy et al., 2012). Both PF and motor skill may promote positive and sustainable  
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29 trajectories of health, cognition and AP leading to long term positive health outcomes.  
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*Fig. 1.* Flow chart of the study selection process..

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Table 1. Main results of studies about Physical fitness and academic performance in children and adolescents.

References	Study design and location	Participants characteristics	Assessment of PF	Assessment of academic performance	Control variables	Main results
Du Toit et al. (2011)	Cross-sectional/ South Africa	212 students/ 9 to 12 age/ 4 <sup>th</sup> to 5 <sup>th</sup> grades	Battery of physical tests of the Fitnessgram (body composition, CRF-PACER, muscular strength, muscular endurance and flexibility) and Bruininks-Oseretsky Test of Motor Proficiency II.	The average of the end-of-the-year academic marks, as recorded in school schedules and children's report cards according to the prescriptions of the National Department of Education for learners in the Intermediate Phase (Grade 4, 5 and 6), was used as a measure of academic achievement.	No utilized	Significant positive correlation between total strength scores and AP in girls ( $r=0.35$ ; $p=0.05$ ). A positive relationship between physical fitness components and academic achievement was found with more significant correlations among girls (CRF $r=0.63$ ; $p<0.05$ , knee push-ups $r=0.62$ ; $p<0.05$ , wall sitting $r=0.54$ ; $p<0.05$ ; strength total $r=0.62$ ; $p<0.05$ ) than boys (CRF $r=0.40$ ; $p>0.05$ , knee push-ups $r=0.45$ ; $p>0.05$ , wall sitting $r=0.16$ ; $p>0.05$ ; strength total $r=0.51$ ; $p<0.05$ ), as well as among older boys and girls.
Kim et al. (2003)	Cross-sectional/ South Korea	6,463 students/ 10 to 14 age/ 5 <sup>th</sup> to 8 <sup>th</sup> grades	BMI, Sprint (100m) and long (600-1000m) distance race, standing broad jump, back up exercise throwing, and chin-ups for boys or hanging on the bar for girls.	Reading, math, social studies, science, physical education, music, arts and ethics.	Parental education level was used to represent the SES. Dietary behaviour and food frequency was collected.	Physical fitness score was positively associated with AP in boys ( $\beta=0.101$ ; $p<0.001$ ) and girls ( $\beta=0.050$ ; $p<0.01$ ). There was no association between AP and body mass.
Eveland-Sayers et al. (2009)	Cross-sectional/ United States	134 students/ 9 to 11 age/ 3 <sup>th</sup> to 5 <sup>th</sup> grades	BMI, Test of a mile, abdominal and flexibility.	Terra Nova achievement test (assessment in reading, language and mathematics)	No utilized	There was a statistically significant negative relationship ( $r=-0.31$ ; $p<0.001$ and $r=-0.36$ ; $p<0.05$ , respectively) among 1-mile run times and reading/language arts and mathematics test scores for girls. There was no relationship

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between BMI and academic performance.

Wittberg et al. (2009)	Cross-sectional/ United States	741 students/ 9 to 13 age/ 5 <sup>th</sup> grade	Battery of physical tests of the Fitnessgram (body composition, CRF-PACER or one mile run, muscular strength, muscular endurance and flexibility).	West Virginia Educational Standards Test (WESTEST) which assesses language, reading, math, science and social studies.	Meal program status (whether the child received a free lunch, a reduced cost lunch, or paid for their lunch) served as a proxy for SES.	All children who were in the Healthy Fitness Zone (HFZ) for CRF and abdominal strength scored significantly higher on reading (3.34; 3.31), math (3.51; 3.46), Science (3.47; 3.43) and social studies (3.40; 3.38) than those children who were in the Needs Improvement Zone (NIZ) (3.09; 2.97 reading), (3.14; 2.98 math), (3.25; 3.20 science) and (3.20; 3.07). Math scores were significantly higher among children who were in the HFZ for the upper body strength test (3.44) and flexibility test (3.43) than children in the NIZ (3.26; 3.13). Science scores were also significantly higher for students in the HFZ for flexibility (3.43) than students in the NIZ (3.20). There was no association between BMI and academic performance.
Roberts et al. (2010)	Cross-sectional/ United States	1,989 students/ 10 to 16 age/ 5 <sup>th</sup> to 9 <sup>th</sup> grades	Test of a mile	Achievement Tests version e o California Standards Test (CST), using math and language.	Parental education, child ethnicity, and eligibility for free or reduced-price lunch status were determined by parent self-report information collected by the school district.	Mile run/walk time was a significant predictor of performance in math such that the math score dropped 1.9 points for every additional minute required to complete the 1-mile run/walk ( $\beta=-1.94$ ; CI=-2.37, -1.53). Reading test score dropped 1.1 points for every additional minute required to complete the 1-mile run/walk ( $\beta=-1.13$ ; CI=-1.56, -0.70). Negative associations between overweight and academic performance.
Davis & Cooper (2011)	Cross-sectional/ United States	170 students/ 7 to 11 age/ 1 <sup>st</sup> to 5 <sup>th</sup> grades	Incremental treadmill test	Woodcock-Johnson test (assessment in reading and math) and cognitive skills.	Race, gender, and primary caregiver's education level.	CRF was positively associated with cognition (planning $r=0.26$ ; $p<0.001$ , attention $r=0.22$ ; $p<0.001$ ), performance in reading ( $r=0.29$ ; $p<0.001$ ) and math ( $r=0.25$ ; $p<0.001$ ). Body fat (planning $r=-0.22$ ; $p<0.001$ , attention $r=-0.16$ ; $p<0.05$ ; math $r=-0.23$ ; $p<0.001$ ; reading $r=-$

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London & Castrechini (2011)	Longitudinal/prospective cohort/ United States	1,410 students/ 9 to 15 age/ 4 <sup>th</sup> to 9 <sup>th</sup> grades	Battery of physical tests of the Fitnessgram (body composition, CRF- one mile run, muscular strength, muscular endurance and flexibility).	California standardized test (CST), assessment in reading and math.	School context, SES, ethnicity, proximity to fast food restaurants, and opportunities for PA.	0.20; p<0.05) and WC were negatively related (planning r=-0.16; p<0.05; math r=-0.28; p<0.001; reading r=-0.21; p<0.05).  For the younger cohort, students who go on to pass in physical fitness tests and students who fail in the first year but pass in the second have higher math scores in the fourth grade compared to students who go on to fail both tests ( $\beta=0.244$ ; $p<0.001$ and $\beta=0.147$ ; $p<0.01$ , respectively). Similarly, both these 2 groups of students have significantly higher scores on the reading than those who fail both tests ( $\beta=0.115$ ; $p<0.05$ and $\beta=0.129$ ; $p<0.05$ , respectively). For the older cohort, an initial CST gap is present between those passing and failing both tests ( $\beta=0.218$ ; $p<0.001$ in math, $\beta=0.154$ ; $p<0.01$ in reading). Models that focus on the most challenging of the tests-the mile run and the push-up test and find no conclusive evidence that one of these tests, rather than the combination of all of them, is responsible for the link with academic achievement. There were no associations between BMI and academic performance.
Van Dusen et al. (2011)	Cross-sectional/ United States	254,743 students/ 9 to 16 age/ 3 <sup>th</sup> to 11 <sup>th</sup> grades	Battery of physical tests of the Fitnessgram (body composition, CRF-PACER or one mile run, muscular strength, muscular endurance and flexibility).	Texas Assessment of Knowledge and Skills (TAKS), (assessment in reading and math).	Gender, age, grade ethnicity, economic disadvantage (measure by school lunch status), school number, and special educational status.	CRF was found to have the strongest direct associations with academic achievement, with a standardized mean difference effect size of 0.17 (CI:0.15-0.19) for boys-reading, 0.34 (CI:0.32-0.35) for boys-math, 0.27 (CI:0.25-0.29) for girls reading, 0.33 (CI:0.31-0.35) for girls-math. The next largest associations were with curl-ups, followed by push-ups, sit and reach, and trunklift which registered the lowest effect size of .07 (CI:0.05-0.08).



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Wingfield et al. (2011)	Cross-sectional/ United States	132 students/ 10 years old/ 4 <sup>th</sup> to 5 <sup>th</sup> grades	BMI, Curl-ups, 20-meter shuttle run test, one mile run, pull-ups, flexed arm hang, and V-sit reach.	Florida Comprehensive Assessment Tests (FCAT), to assess reading and math.	Sex, age, race, and SES.	In girls, only BMI marginally predicted AP ( $\beta=-0.40$ ; $p<0.05$ ), fitness no longer significantly predicted AP when BMI was in the model ( $\beta=0.21$ ; $p=0.34$ ).
Chen et al. (2013)	Longitudinal/ prospective cohort/ Taiwan	669 students/ 13 to 15 age/ 7 <sup>th</sup> to 9 <sup>th</sup> grades	BMI, 1,600-Meter run (boys), 800-meter run (girls), sit-and-reach test, curl-ups.	Mean score of Language, Mathematics, Science, and Social Studies.	Measures of SES, parental education and ethnicity.	CRF exhibits stronger longitudinal associations with AP than other forms of fitness or BMI for adolescents. CRF slope to the academic slope was significant, showing the rate of change in CRF was related to the rate of change in AP over this period ( $z=6.98$ ; $p<0.05$ ).
Coe et al. (2013)	Cross-sectional/ United States	1,701 students/ No age available/ 3 <sup>rd</sup> , 6 <sup>th</sup> , 9 <sup>th</sup> grades	Battery of physical tests of the Fitnessgram (BMI, CRF-PACER, muscular strength, muscular endurance and flexibility).	Michigan Education Assessment Program (MEAP) that assess English/language mathematics and social studies.	Student eligibility for a free and reduced lunch program was used as a proxy for SES, based on household income and number of family members in the home.	In 6 <sup>th</sup> , Muscular strength and endurance were significantly associated with performance in math ( $r=0.149$ ; $p<0.001$ ), English ( $0.106$ ; $p<0.001$ ) and social studies ( $r=0.144$ ; $p<0.001$ ). However, compared with all other variables, SES had the strongest association with academic achievement in 6 <sup>th</sup> and 9 <sup>th</sup> , respectively ( $r=0.183-0.324$ ; $p<0.05$ ). Regression analysis yielded similar results, with SES accounting for a large portion of the variance in standardized test percentiles (18.6-32.2%; $p<0.001$ ). This was true for all subject areas in all grades, except for Math in ninth-grade students. In this group, curl-ups were the best predictor of academic achievement (accounting for 20.9% of the variance; $p<0.001$ ), but SES was also significant in this model (accounting for 6.2% of the variance; $p<0.001$ ).
Lambourne et al. (2013)	Cross-sectional/ United States	401 students/ 6 to 9 age/ 2 <sup>nd</sup> to 3 <sup>rd</sup> grades	20-meter shuttle run test, accelerometer to assess daily PA.	Weschler Individual Achievement Test-Third Edition.	Grade, age, gender, ethnicity, and race, as well as the education level of the mother and	PA had a direct effect on CRF ( $0.009$ ; $p<0.01$ ), which in turn had a direct effect on math scores ( $-0.007$ ; $p<0.05$ ). The effect of PA on math achievement was partially mediated by CRF ( $0.003$ ; $p<0.05$ ).

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Haapala et al. (2014)	Longitudinal/prospective/Finland	167 students/ 6 to 8 age/ 1 <sup>st</sup> to 3 <sup>th</sup> grades	Maximal exercise test (cycle ergometer). Shuttle run test was used to assess speed and agility, the flamingo balance test was used to assess static balance and box and block test was used to assess manual dexterity.	Reading fluency and comprehension were assessed using a group-administered speeded subtest of the nationally-normed reading achievement battery. Arithmetic skills were assessed using a basic arithmetic test with a set of visually presented addition and subtraction tasks.	Measures of parental education, PA level, pubertal status and risk of reading disabilities.	Among boys, overall motor performance in grade 1 was positively associated with reading fluency in grades 1–3 ( $\beta=0.40$ ; $p<0.001$ , $\beta=-0.41$ ; $p<0.001$ ), reading comprehension in grades 1 and 2 ( $\beta=0.39$ ; $p<0.001$ , $\beta=0.25$ ; $p<0.05$ ), and arithmetic skills in grades 1–3 ( $\beta=0.41$ ; $p<0.001$ , $\beta=0.39$ , $p<0.001$ ) after adjustment for age, parental education, and other measures of cardiovascular and motor performance. Maximal workload in grade 1 was not associated with academic skills in grades 1–3.
Srikanth et al. (2014)	Cross-sectional/ United States	1,211 students/ 12 to 13 age/ 6 <sup>th</sup> to 8 <sup>th</sup> grades	Progressive Aerobic Cardiovascular Endurance Run (PACER)	Texas Assessment of Knowledge and Skills (TAKS), (assessment in reading and math).	SES was based on federal guidelines for determining students' status for free or reduced lunch based on family income. PA and psychosocial variables, general self-concept and social support.	Boys being more aerobically fit were associated with better performances in the TAKS reading exam ( $\beta=0.24$ ; $p<0.005$ ) and math ( $\beta=0.26$ ; $p<0.005$ ). Girls more aerobically fit were associated with better performances in the TAKS reading exam ( $\beta=0.23$ ; $p<0.005$ ) and math ( $\beta=0.17$ ; $p<0.005$ ).
Pindus et al. (2016)	Cross-sectional/ United States	74 students/ 7 to 9 age/ No data grades available	Graded treadmill test using a computerized indirect calorimetry system.	Kaufman Test of Educational Achievement, Second Edition (assessment in reading and math) and standardized score for spelling subscale were included.	Age, gender, Intelligence quotient, PA, SES and clinical diagnosis of attention deficit hyperactivity disorder.	CRF was positively associated with spelling ( $\beta=-0.22$ ; $p= 0.04$ ; $F(2, 71) = 12.8$ , $P < .001$ ) after adjusted by covariates.

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Castelli et al. (2007)	Cross-sectional/ United States	259 students/ 9 to 11 age/ 3 <sup>th</sup> to 5 <sup>th</sup> grades	Battery of physical tests of the Fitnessgram (BMI, CRF-PACER, muscular strength, muscular endurance and flexibility).	Illinois Standards Achievement Test (ISAT) (assessment in reading and math).	Age, gender and SES measures.	There were significant effects for BMI and for CRF ( $\beta=-0.15$ ; $p<0.01$ ), ( $\beta=0.40$ ; $p<0.001$ ) indicating that lower BMI and higher CRF were positively related to reading achievement and math ( $\beta=-0.13$ ; $p<0.05$ ), ( $\beta=0.42$ ; $p<0.001$ ).
Chomitz et al. (2009)	Cross-sectional/ England	2,217 students/ 10 to 14 age/ 4 <sup>th</sup> to 8 <sup>th</sup> grades	Physical tests adapted from the Amateur Athletic Union and Fitnessgram (BMI, CRF test, abdominal strength test, flexibility, upper body strength test, and agility test).	MCAS tests (assessment in reading and math).	Gender, SES, weight status, grade, and ethnicity.	The logistic regression analysis estimated that the odds of passing the Math MCAS increased by 38% for each 1-unit increase in the number of fitness tests passed, holding gender, ethnicity, weight status, grade, and SES constant (OR=1.379; CI=1.234-1.541) the odds of passing the reading MCAS test increased by 24% for each 1-unit increase in the number of fitness tests passed (OR=1.236; CI=1.003-1.522).
Wittberg et al. (2010)	Cross-sectional/ United States	1,740 students/ 9 to 13 age/ 5 <sup>th</sup> grade	Test of a mile and Progressive Aerobic Cardiovascular Endurance Run (PACER).	West Virginia Educational Standards Test (WESTEST) which assesses language, reading, math, science and social studies.	No utilized	In boys, faster students in mile test had higher average in reading (3.75; $p<0.001$ ), math (3.37; $p<0.001$ ), science (3.69; $p<0.01$ ) and social studies (3.48; $p<0.001$ ) when compared with slower students, respectively, (3.26; 2.91; 3.39; 3.12). The same was not found when the CRF was measured by shuttle run test. In girls, faster student in the PACER test had higher average in reading (3.43; $p<0.001$ ), math (3.37; $p<0.001$ ) and social studies (3.22; $p<0.01$ ) when compared with slower students (3.18; 3.20; 3.16). However, when CRF was measured by the test of a mile there were no associations.
Blom et al. (2011)	Cross-sectional/ United States	2,992 students/ No age reported/	Battery of physical tests of the Fitnessgram (BMI, CRF-PACER, muscular strength,	Mississippi Curriculum Test (MCT2) that assesses performance in language arts	Academic behavior data on absences and disciplinary	A linear trend was observed between language arts, Math and overall fitness level, indicating the odds of high academic achievement increased

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6		3 <sup>th</sup> to 8 <sup>th</sup>	muscular endurance and	and mathematics.	actions, and socio-	with the number of healthy fitness zones achieved
7		grades	flexibility).		demographic	(OR=3.31; CI=1.66-6.57), (OR=4.14; CI=2.01-
8					information of	8.55), respectively. The relationships remained
9					gender,	significant while controlling for gender, race, and
10					race/ethnicity, and	SES.
11					SES (via lunch	
12					status), gender and	
13					race.	
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15	Wittberg et al.	Longitudinal/	1,725	West Virginia Educational		Students at the beginning of the cohort had CRF
16	(2012)	prospective	students/ No	Standards Test (WESTEST)	No utilized	in Healthy Fitness Zone and those during follow-
17		cohort/ United	date age	which assesses language,		up can achieve it have higher AP (0.133;
18		States	available/ 5 <sup>th</sup>	reading, math, science and		p<0.001, 0.127; p<0.01) than students who
19			to 7 <sup>th</sup> grades	social studies.		started outside of this zone (-0.276; -0.284).
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21	Bass et al.	Cross-sectional/	838 students/	Illinois Standards	Age, sex,	Boys in the Healthy Fitness Zone (HFZ) for CRF
22	(2013)	United States	13 years old/	Achievement Test (ISAT)	participation in the	or muscular endurance had higher odds in
23			6 <sup>th</sup> to 8 <sup>th</sup>	which assesses math and	National School	Reading performance (3.15; CI= 1.90-5.21),
24			grades	reading	Lunch Programme,	(2.56; CI=1.22-5.38) than boys not in the HFZ.
25					providing free or	Girls in the HFZ for CRF had higher odds in
26					reduced lunch to	reading and math test performance (2.08;
27					economically	CI=1.10-3.93, 2.58; CI=1.39-4.78) than girls not
28					disadvantaged	in the HFZ, respectively. There were no
29					students, was used	associations between body composition and
30					as an indicator for	academic performance.
31					socio-economic	
32					status.	
33			8,061	The GPA was calculated as a		
34	Kantomaa et al.	Longitudinal	students/ 7 to	measure of academic	Mother's	Compromised motor function in childhood had a
35	(2013)	prospective/	16 age follow-	achievement based on the	education, BMI,	negative indirect effect on academic achievement
36		Finland	up/ No data	grades in the following	PA and motor	via lower levels of PA ( $\beta$ = -0.023; p<0.001) and
37			grades	school subjects: mother	function.	obesity ( $\beta$ =-0.025; p<0.001), but not via CRF
38			available	tongue, first foreign language		( $\beta$ =0.004; p=0.314).
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				grade 7), math, biology, geography, physics, chemistry, religion or ethics, history, music, visual arts, physical education, crafts, and home economics.		
Liao et al. (2013)	Longitudinal/prospective/ Taiwan	149,240 students/ 17 to 18 age/ Senior high school	1,600-meter run (boys), 800-meter run (girls), sit-and-reach test, curl-ups.	General Scholastic Ability Test (GSAT) that assesses chinese, english, mathematics, science and social studies.	SES and age.	On average, 1 Standard Deviation (SD) increase on the anaerobic power and flexibility Z-scores from the first to third year of senior high school in girls are associated with an increase in the university entrance exam by 0.018 and 0.010 SD, respectively.
Rauner et al. (2013)	Cross-sectional/ United States	11,742 students/ No date age available/ 3 <sup>th</sup> to 8 <sup>th</sup> grades	20-meter shuttle run test	Nebraska State Accountability (NESA) which assesses math and reading.	BMI percentile, SES, sex, ethnicity, grade level, and school type.	Aerobically fit students receiving free/reduced lunch had 1.68 times greater odds of passing the NeSA math test and 1.56 times greater odds of passing the NeSA reading test compared with aerobically unfit students receiving free/reduced lunch. BMI was not associated with academic performance.
Greeff et al. (2014)	Cross-sectional/ Netherlands	544 students/ 7 to 10 age/ 2 <sup>nd</sup> to 3 <sup>rd</sup> grades	Physical fitness was evaluated with items of the Eurofit physical fitness test battery (BMI, CRF, explosive strength, abdominal muscle endurance and static strength)	AP was evaluated with scores on mathematics and two domains of language, namely spelling and reading.	Age, grade, gender and SES.	Results showed a positive association between CRF and mathematics ( $\beta=0.23$ ; $p<0.01$ ), regardless of SES. A positive association was found between CRF and spelling performance ( $\beta=0.16$ ; $p<0.05$ ). However, lower SES did moderate the relationship between CRF and spelling.
Hansen et al. (2014)	Cross-sectional/ United States	687 students/ 7 to 8 age/ 2 <sup>nd</sup> to 3 <sup>rd</sup> grades	Progressive Aerobic Cardiovascular Endurance Run (PACER)	Weschler Individual Achievement Test-Third Edition (WIAT-III) was used to assess academic achievement in reading,	PA, gender, race, ethnicity, mother's education, SES and BMI.	No significant linear or non-linear association between CRF and reading achievement ( $\beta=0.06$ ; $p=0.46$ ), however, a significant quadratic association between CRF and spelling ( $\beta=0.32$ ; $p<0.01$ ) and math achievement ( $\beta=0.55$ ;

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				spelling and math.		p=<0.01).
				Reading, spelling, and arithmetic achievement were determined using the WRAT3. Hand dominance, intelligence quotient and academic achievement were also determined using Edinburgh Handedness Inventory and Kaufman Brief Intelligence Test 2 (K-BIT2). Additionally, measures of Event-related brain potentials (ERPs) were realized through electroencephalographic (EEG) and electrooculographic (EOG)		Higher fit children had greater reading achievement scores ( $123.1 \pm 2.8$ ) compared to lower fit children ( $112.9 \pm 2.1$ ), $t(44)=2.8$ , $p=0.007$ , $d=0.8$ . A similar finding was observed for spelling (higher fit: $117.6 \pm 2.6$ ; lower fit: $108.0 \pm 3.0$ ), $t(44)=2.4$ , $p=0.02$ , $d=0.7$ . Higher fit children have faster neuroelectric responses and perform better on cognitive tests including those linked to language skills.
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39	Scudder et al. (2014)	Cross-sectional/ United States	46 students/ 9 to 10 age/ No data grades available	Computerized indirect calorimetry system.	SES and pubertal stage.	
				Alpha Battery tests (BMI, CRF, muscular fitness handgrip test, speed/agility and standing broad jump test)	Age, sex, and parental education.	Boys with good CRF and speed/agility had, after controlling for potential confounders, showed 7.3 and 4.0 times higher probability of score in the top quartile of academic achievement than children with poor CRF and speed/agility levels. Girls with satisfactory or good speed/agility had a higher probability of scoring in the top quartile of academic achievement (3.8 and 4.7 times, respectively) than girls with poor speed/agility after controlling for confounders. Physical fitness is more closely related to academic achievement than BMI.
				Wide Range Achievement Test-3rd edition (WRAT-3) was used to assess academic achievement in reading,	Pubertal timing and SES.	Higher fit children showed decreased cortical thickness in superior frontal cortex ( $F(1, 46)=4.80$ , $p=0.034$ ), superior temporal cortex ( $F(1,$

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				spelling and math. T1-weighted structural brain images were acquired using a 3D MPRAGE (Magnetization Prepared Rapid Gradient Echo).		46) = 5.39, p = 0.025) and lateral occipital cortex (F (1, 46) = 5.67, p = 0.021), relative to lower fit children. Higher fit children showed superior mathematics achievement compared to lower fit children (t (46) = 1.98, p = 0.05) on the WRAT-3. No fitness differences were found for reading or spelling performance (t < 1.1, p > 0.3).
Desai et al. (2015)	Cross-sectional/India	273 students/7 to 10 age/ No data grades available	BMI, body composition and 20-m shuttle run test.	School-wide exams administered by school-teachers. Subject areas assessed included mathematics, Kannada (the official language of the Indian state of Karnataka), English, science, and social science. Only math and Kannada scores, reported as percentages, were used as final academic outcome measures because these two subjects were assessed in all participants.	Physical activity, diet, age, SES and micronutrient status.	After standardizing scores across grade levels and adjusting for school, gender, SES, and BMI, children with greater CRF had greater odds of scoring above average on math and Kannada exams (OR=1.08; CI: 1.02-1.15 and OR=1.11; CI: 1.04-1.18, respectively).
Pellicer-Chenoll et al. (2015)	Longitudinal/Spain	700 students enrolled in the first year of secondary education/ No age reported	BMI, Jump power was measured from the data obtained in a countermovement jump (CMJ), CRF was measured using the Cooper test, handgrip isometric strength was measured with a Takei dynamometer.	Academic achievement was obtained from the student's transcripts using the GPAs. The procedure was as follows: the mean value of 10 academic topics corresponding to an academic year (GPA) was obtained for each of the 4 years that the students spent at secondary school. The score of the mean value ranged from 0 (worst rating)	No utilized	Students with lower energy expenditure (~1000 METs week <sup>-1</sup> ) and lower physical fitness exhibited higher BMI and low AP below 5 out of 10 points. whereas those adolescents with higher energy expenditure exhibited better physical fitness, lower BMI and higher AP.

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				to 10 (best rating). Students' grades in the core subjects (mathematics and language) were collected from the official school records at four moments in the first semester (March, April, May and June 2014). Grade scores in Chile range from 1 (worst) to 7 (best).	Physical activity, sedentary behavior, mother's education and SES.	Higher birth weight was associated with better AP independent of current BMI. These differences disappeared after controlling for CRF, which also mediated the association between birth weight and AP (13.4%; z=2.33; p=0.012). The relationship between birth weight and AP was not mediated by muscular strength.
García-Hermoso (2016)	Cross-sectional/ Chile	395 students/ aged 12/ 7 <sup>th</sup> grades	BMI, Alpha Battery tests (20 m shuttle run test and standing broad jump test).			
Morita et al. (2016)	Cross-sectional/ Japan	315 students/ 12 to 13 age/ 7 <sup>th</sup> grades.	BMI, 50-m sprint, standing broad jump, repeated side-steps, sit and reach, sit-ups, hand grip strength, handball throw, and 20-m shuttle run.	Academic achievement was assessed by the total grade point (GP) of school subjects evaluated by school teachers; individual grades were reported for 8 school subjects (Japanese, Mathematics, Social Studies, Sciences, English, Music, Arts, and Home Economics/Vocational Technology).	BMI, SES, mother's education and time spent on electronic devices.	After adjusting for covariates, total physical fitness was positively associated with AP in boys ( $\beta=0.13$ ; $p<0.001$ ). In girls, obesity status, but not physical fitness, was significantly associated with AP after adjusting for the confounders ( $\beta=-1.61$ ; $p=0.04$ ).
Dwyer et al. (2001)	Cross-sectional/ Australia	9,000 students/ 7 to 15 age/ 1 <sup>st</sup> a 9 <sup>th</sup> grades	BMI, Long jump, abdominal, push-ups, flexibility, handgrip, cardiopulmonary exercise test and sprint 50 yards.	Evaluation overall accomplished through scale: excellent, above average, average, below average or poor.	Height, BMI, body fat, SES, time to be and length of sleep.	There were weak but consistent associations between field tests of muscular force, endurance and power. Students with higher AP took less time to complete the 50-meter run ( $r=-0.15$ ; $p<0.001$ ), completed more sit-ups ( $r=0.14$ ; $p<0.001$ ), and leapt greater distances in the standing long jump ( $r=0.10$ ; $p<0.001$ ). BMI was negatively associated with AP.
Kwak et al. (2009)	Cross-sectional/ Sweden	232 students/ 15 to 16 age/ 9 <sup>th</sup> grade	Incremental test on a cycle ergometer and accelerometer 4 consecutive days	17 school subjects.	Mother's education, family structure, parental monitoring, sex, pubertal phase, PA,	Vigorous PA was the only intensity level that significantly correlated with academic achievement ( $\beta=0.23$ ; $p<0.05$ ), solely in girls, whereas in boys only fitness was associated positively with academic achievement ( $\beta=0.25$ ;



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					and sum of skinfolds.	p=<0.05).
					Grade level (elementary, middle, secondary), school size (number of students), gender, minority status, and SES.	Positive association between CRF and performance in TASK (OR=1.014; CI=1.011-1.016), indicating that for each 1% of higher CRF increase AP.
Welk et al. (2010)	Cross-sectional/ United States	36,835 students/ 9 to 16 age/ 3 <sup>th</sup> to 11 <sup>th</sup> grades	20-meter shuttle run test	Texas Assessment of Knowledge and Skills (TAKS), (assessment in reading and math).		
Telford et al. (2012)	Cross-sectional/ Australia	757 students/ 8 to 10 age/ 3 <sup>th</sup> to 5 <sup>th</sup> grades	20-meter shuttle run test, pedometers to assess daily PA.	Texas Assessment of Knowledge and Skills (TAKS), (assessment in reading and math).	PA, body fat % and SES.	School reading scores were positively associated with both the school CRF ( $\beta=0.143$ ; $p<0.001$ ) and PA ( $\beta=4.7$ ; $p=0.01$ ) and there was evidence that reading score was negatively related to % body fat at the school level ( $\beta=-5.5$ ; $p=0.05$ ). School numeracy scores were positively associated with school CRF levels ( $\beta=0.142$ ; $p<0.001$ ) and PA ( $\beta=4.11$ ; $p=0.02$ ) and associated negatively with % body fat ( $\beta=-6.5$ ; $p=0.02$ ). School writing scores were associated with the school CRF ( $\beta=0.145$ ; $p<0.001$ ) with little evidence of any association with PA ( $\beta=1.5$ ; $p=0.17$ ) or % body fat ( $\beta=-3.0$ ; $p=0.23$ ).
Bezold et al. (2014)	Longitudinal/ United States	83,111 students/ No data age available/ 6 <sup>th</sup> to 8 <sup>th</sup> grades	Battery of physical tests of the Fitnessgram (BMI, CRF-PACER, muscular strength and muscular endurance).	Measure of academic test performance, based on New York State standardized assessment in English Language Arts and Math.	Race and/or ethnicity, language spoken at home, days absent from school, place of birth, student household poverty, school-area poverty, and obesity status.	Girls who experienced an increase in fitness improved their academic test scores by 0.36 percentile points more per year than girls who experienced no change in fitness ( $\beta=0.36$ ; CI:0.09-0.63). Substantial decreases in fitness were associated with a decline of 0.40 percentile points per year compared with the reference group ( $\beta=-0.40$ ; CI=-0.68,-0.12), whereas moderate decreases in fitness were associated with a trend toward a decline in academic ranking

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						<p>of 0.33 percentile points per year (<math>\beta=-0.33</math>; CI=-0.67,-0.01) compared with the reference group. In boys, increasing fitness resulted in an improvement in academic ranking of 0.38 percentile points per year compared with the reference group (<math>\beta=0.38</math>; CI=0.09-0.66). A substantial decrease in fitness, academic ranking declined over time by 0.55 percentile points per year compared with the reference group (<math>\beta=-0.55</math>; CI=-0.85,-2.25).</p>
<p>Esteban-Cornejo et al. (2014)</p>	<p>Cross-sectional/ Spain</p>	<p>2,038 students/ 6 to 18 age/ No data grades available</p>	<p>Physical fitness was assessed following the ALPHA (Assessing Levels of PA) health-related fitness test battery for youths (BMI, body composition, Muscular strength, motor ability and CRF.</p>	<p>Four indicators were used to define AP: individual grades for the core subjects (math and language), an average for math and language, and Grade Point Average (GPA) score.</p>	<p>Sex, age, city, maternal education, pubertal status and waist circumference.</p>	<p>CRF and motor ability, both independently and combined, were related positively to AP in youths, independent of potential confounders, including fatness (<math>\beta=0.136</math>; <math>p&lt;0.001</math>). Muscular strength was not associated with AP independent of the other 2 physical fitness components (<math>\beta=-0.005</math>; <math>p=0.882</math>).</p>
<p>Janak et al. (2014)</p>	<p>Cross-sectional/ecologic study/ United States</p>	<p>2,550.114 students/ No data age available/ 3<sup>th</sup> to 12<sup>th</sup>grades</p>	<p>Progressive Aerobic Cardiovascular Endurance Run (PACER) and the 1-mile run.</p>	<p>Texas Essential Knowledge and Skills curriculum (TAKS) that assesses performance in English language arts, reading, writing, mathematics, science, and social studies.</p>	<p>SES and grade category stratified by sex.</p>	<p>The magnitude of effect for CRF (<math>\beta=0.56</math>; <math>p&lt;0.001</math>), BMI (<math>\beta=1.14</math>; <math>p&lt;0.001</math>), and SES (<math>\beta=-0.30</math>; <math>p&lt;0.001</math>) in the univariate models were reduced by 61% (<math>\beta=0.13</math>; <math>p=0.02</math>), 77% (<math>\beta=0.45</math>; <math>p=0.001</math>), and 43% (<math>\beta=-0.17</math>; <math>p&lt;0.001</math>), respectively in the multivariable model. SES explained the largest percent of the variance in academic achievement with BMI having the largest magnitude of effect.</p>
<p>Sardinha et al (2014)</p>	<p>Longitudinal/prospective cohort/ Portugal</p>	<p>1,531 students/ 12 to 14 age/ 3<sup>rd</sup> to 9<sup>th</sup> grades</p>	<p>Aerobic Cardiovascular Endurance Run (PACER).</p>	<p>AP was assessed using the marks students had, at the end of their academic year, in math, language (Portuguese), foreign language (English) and</p>	<p>Gender, weight status, and different cohorts.</p>	<p>CRF and weight status were independently and combined related to academic achievement independent of the different cohorts. The odds of having high or average academic achievement versus low academic achievement of normal weight students was higher than overweight in</p>

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				sciences. Student marks range from 1 to 5 (very poor to very good).		both unadjusted (OR=4.98; CI:2.53-9.81) and adjusted analysis (OR=3.72; CI:1.85-7.49). Fit students, compared with unfit students, had higher odds for having a high academic achievement, in both the unadjusted (OR=2.27; CI:1.57-3.26), and adjusted model (OR=2.27; CI:1.46-3.52).
Aguilar et al. (2015)	Cross-sectional/ Chile	395 students/ 12 years old/ 7 <sup>th</sup> grades	BMI, 20-meter shuttle run test, muscular strength was measured with the standing broad jump test. Questionnaire employed to assess PA	Academic attainment was assessed using the students' grades in the core subjects (mathematics and language).	Mother's and father's education, SES and screen time.	CRF was related to AP in both genders independent of potential confounders. However, these associations did not remain significant after adjusting for screen time. CRF was positively associated with language ( $\beta=0.272$ , CI=0.658-2.365, $\beta=0.153$ ; CI=0.048-1.885 in boys and girls, respectively) and mean academic attainment ( $\beta=0.192$ ; CI=0.021-0.210, $\beta=0.156$ , CI=0.049-0.251 in boys and girls, respectively), however, after adjusting by screen time these associations disappeared.
Huang et al. (2015)	Cross-sectional/ Denmark	525 students/12 to 13 age/ 6 <sup>th</sup> to 7 <sup>th</sup>	Andersen intermittent shuttle-run test.	A modified Eriksen flanker task was used to assess inhibitory control. Academic skills were assessed by a math test according to curriculum of Danish schools.	Sex, age, ethnicity, pubertal stage, parental education level, school year, and attending special teaching.	CRF was positively associated with both inhibitory control and math score ( $\beta=0.23$ ; CI=0.15-0.32), irrespective of weight status.
Kalantari et al. (2015)	Cross-sectional/ Iran	580 students boys/ 15 to 17 age/ No data grades	BMI, body composition, One-mile walk/run test, sit and reach, hand grip strength test, 40-m sprint, push-ups and Illinois agility test.	Cumulative grade point averages (CGPA) were recorded from the school record of the previous semester (middle of the current year) and end of the current year and divided to 2	PA, pubertal maturation status, age and SES.	CRF (but not PA and muscular fitness) was significantly correlated to better academic achievement in the adolescent boys. Time in the one-mile run/ walk is significantly correlated to CGPA ( $\beta=-0.19$ ; $p<0.01$ ).

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				for obtaining mean CGPA of the year.		
				Academic achievement was assessed using students' marks at the end of the academic year at baseline and at follow-up 3 year later, in Portuguese, mathematics, foreign language (English), and science.	Age, BMI z-score and AP at baseline.	Students consistently fit increased the likelihood of having high levels of academic achievement in Portuguese (OR= 3.49; CI, 1.97–6.20) and foreign language (OR= 2.41; CI, 1.39–4.14) compared with those consistently unfit. Those that were unfit at baseline and improved their CRF and became fit at follow-up had also higher odds of achieving better marks than those consistently unfit in Portuguese (OR = 2.52; CI, 1.42–4.45) and foreign language (OR =2.13; CI, 1.23–3.67).

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CRF= cardiorespiratory fitness; PA= physical activity; BMI= body mass index; AP= academic performance; SES= socioeconomic status; OR= odds ration; CI= confidence interval

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Table 2 Risk of bias assessment of the included studies.

Study	Criteria						Total Score
	1	2	3	4	5	6	
Du Toit et al. (2011)	-	-	+	+	-	-	2/6
Kim et al. (2003)	+	+	+	-	-	-	3/6
Eveland-Sayers et al. (2009)	-	-	+	+	-	+	3/6
Wittberg et al. (2009)	+	-	+	+	-	-	3/6
Roberts et al. (2010)	+	-	+	+	-	-	3/6
Davis & Cooper (2011)	+	-	+	+	-	-	3/6
London & Castrechini (2011)	+	-	+	+	-	-	3/6
Van Dusen et al. (2011)	+	-	+	+	-	-	3/6
Wingfield et al. (2011)	+	-	+	+	-	-	3/6
Chen et al. (2013)	+	-	+	+	-	-	3/6
Coe et al. (2013)	+	-	+	+	-	-	3/6
Lambourne et al. (2013)	-	+	+	+	-	-	3/6
Haapala et al. (2014)	-	-	+	+	-	+	3/6
Srikanth et al. (2014)	+	-	+	+	-	-	3/6
Pindus et al. (2016)	+	-	+	+	-	-	3/6
Castelli et al. (2007)	+	-	+	+	-	+	4/6
Chomitz et al. (2009)	+	-	+	+	-	+	4/6
Wittberg et al. (2010)	-	-	+	+	+	+	4/6
Blom et al. (2011)	-	-	+	+	+	+	4/6
Wittberg et al. (2012)	+	-	+	+	-	+	4/6
Bass et al. (2013)	+	-	+	+	-	+	4/6
Kantomaa et al. (2013)	+	-	+	+	-	+	4/6
Liao et al. (2013)	+	-	+	+	-	+	4/6

Rauner et al. (2013)	-	-	+	+	+	+	4/6
Greeff et al. (2014)	+	-	+	+	-	+	4/6
Hansen et al. (2014)	-	+	+	+	-	+	4/6
Scudder et al. (2014)	+	-	+	+	-	+	4/6
Torrijos-Niño et al. 2014	+	-	+	+	-	+	4/6
Chaddock-Heyman et al. (2015)	+	-	+	+	-	+	4/6
Desai et al. (2015)	+	-	+	+	-	+	4/6
Pellicer-Chenoll et al. (2015)	+	-	+	+	-	+	4/6
García-Hermoso (2016)	+	-	+	+	-	+	4/6
Morita et al. (2016)	-	-	+	+	+	+	4/6
Dwyer et al. (2001)	+	+	+	+	+	-	5/6
Kwak et al. (2009)	+	+	+	+	+	-	5/6
Welk et al. (2010)	+	-	+	+	+	+	5/6
Telford et al. (2012)	+	-	+	+	+	+	5/6
Bezold et al. (2014)	+	-	+	+	+	+	5/6
Esteban-Cornejo et al. (2014)	+	-	+	+	+	+	5/6
Janak et al. (2014)	+	-	+	+	+	+	5/6
Sardinha et al. (2014)	+	+	+	+	-	+	5/6
Aguilar et al. (2015)	+	-	+	+	+	+	5/6
Huang et al. (2015)	+	-	+	+	+	+	5/6
Kalantari et al. (2015)	+	+	+	+	-	+	5/6
Sardinha et al. (2016)	+	+	+	+	-	+	5/6

+indicates that a criterion was satisfied; -indicates that a criterion was not satisfied.

1, Does the study describe the eligibility criteria for participant selection?; 2, Are participants randomly chosen from the population?; 3, Does the study cite the sources and details of the method for measuring academic performance and present the reliability of the instrument for the specific age group?; 4, Does the study cite the sources and details of the assessment methods for measuring physical fitness using reliable methods?; 5, Does the study present the analysis for statistical power and use a statistical method that is adequate to test the hypothesis?; 6, Does the

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2  
3 study cite the number of participants for each outcome measurement and does this number  
4 represent at least 80% of the total sample?  
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**Table 3** Distribution of the studies that investigated cross-sectional and longitudinal associations between Physical Fitness with academic performance by risk of bias and the level of scientific evidence.

Physical fitness components	Studies that demonstrated association	Study by risk of bias	Association or no association according to study risk of bias	Level of evidence
<b><i>Cross-sectional</i></b>				
Cardiorespiratory fitness (n=30)	Yes: 27 (90.0%)	Low: 9 (30.0%) Medium: 20 (66.7%) High: 1 (3.3%)	Low risk of bias: Yes: 7 (77.8%) (positive association) No: 2 (22.2%) Medium risk of bias: Yes: 19 (95.0%) (positive association) No: 1 (5.0%) High risk of bias: Yes: 1 (100.0%) (positive association) No: 0 Total: Yes: 27 (90.0%) No: 3 (30.0%)	Strong evidence of positive association
Muscular strength (n=14)	Yes: 5 (35.7%)	Low: 4 (28.6%) Medium: 9 (64.3%) High: 1 (7.1%)	Low risk of bias: Yes: 1 (25.0%) (positive association) No: 3 (75.0%) Medium risk of bias: Yes: 3 (33.3%) (positive association) No: 6 (66.7%) High risk of bias: Yes: 1 (100.0%) (positive association) No: 0 Total: Yes: 5 (35.7%) No: 9 (64.3%)	Uncertain association
Flexibility (n=8)	Yes: 2 (25.0%)	Low: 1 (12.5%) Medium: 6 (75.0%) High: 1 (12.5%)	Low risk of bias: Yes: 0 (0.0%) No: 1 (100.0%) Medium risk of bias: Yes: 2 (33.3%) (positive association) No: 4 (66.7%) High risk of bias: Yes: 0 (0.0%) No: 1 (100.0%) Total: Yes: 2 (25.0%) No: 6 (75.0%)	No association



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8			Low risk of bias: Yes: 0 (0.0%)	
9	Cluster of PF (n=5)	Yes: 4 (80.0%)	No: 0 (0.0%)	
10			Medium risk of bias: Yes: 4 (80.0%) (positive association) No: 1 (20.0%)	Positive association
11			High risk of bias: Yes: 0 (0.0%)	
12			No: 0 (0.0%)	
13			Total: Yes: 4 (80.0%) No: 1 (20.0%)	
14	<i>Longitudinal</i>			
15			Low risk of bias: Yes: 2 (100.0%) (positive association)	
16	CRF (n=7)	Yes: 4 (57.1%)	No: 0	Uncertain association
17			Medium risk of bias: Yes: 2 (40.0%) (positive association) No: 3 (60.0%)	
18			High risk of bias: Yes: 0 (0.0%)	
19			No: 0 (0.0%)	
20			Total: Yes: 4 (57.1%) No: 3 (42.9%)	
21				
22			Low risk of bias: Yes: 0 (0.0%)	
23			No: 0 (0.0%)	
24	Muscular strength (n=2)	Yes: 1 (50.0%)	Medium risk of bias: Yes: 1 (50.0%) (positive association) No: 1 (50.0%)	Uncertain association
25			High risk of bias: Yes: 0 (0.0%)	
26			No: 0 (0.0%)	
27			Total: Yes: 1 (50.0%) No: 1 (50.0%)	
28				
29			Low risk of bias: Yes: 0 (0.0%)	
30			No: 0 (0.0%)	
31	Flexibility (n=2)	Yes: 1 (50.0%)	Medium risk of bias: Yes: 1 (50.0%) (positive association) No: 1 (50.0%)	Uncertain association
32			High risk of bias: Yes: 0 (0.0%)	
33			No: 0 (0.0%)	
34			Total: Yes: 1 (50.0%) No: 1 (50.0%)	
35				
36	Cluster of PF (n=3)	Yes: 3 (100.0%)	Low risk of bias: Yes: 1 (100.0%) (positive association)	Strong evidence of
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High: 0 (0.0%)	No: 0 (0.0%) Medium risk of bias: Yes: 2 (100.0%) (positive association) No: 0 (0.0%) High risk of bias: Yes: 0 (0.0%) No: 0 (0.0%) Total: Yes: 3 (100.0%) No: 0 (0.0%)	positive association
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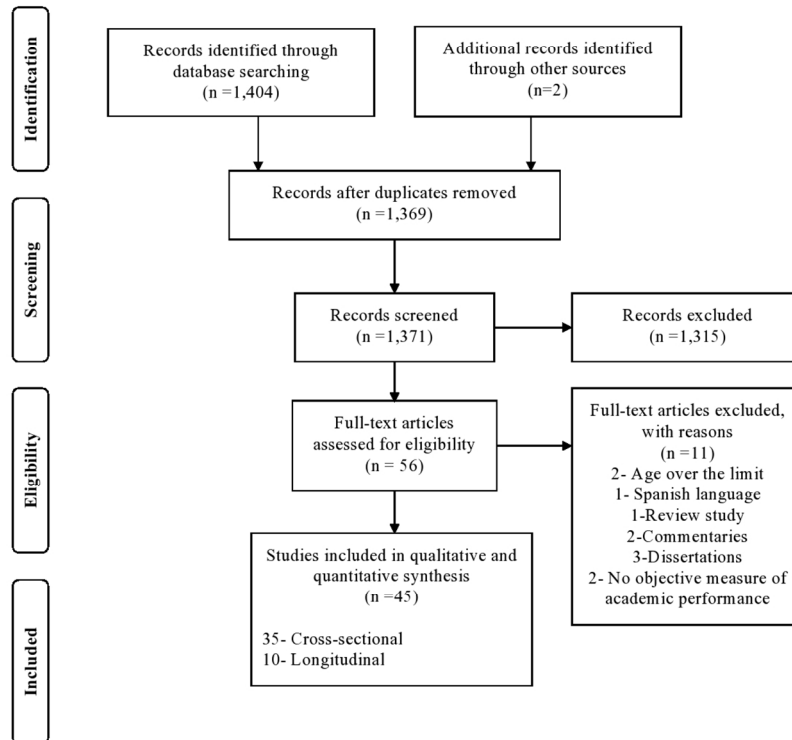


Fig. 1. Flow chart of the study selection process.

449x582mm (72 x 72 DPI)

**Appendix 1. Search strategy for MEDLINE (Pubmed)**

Independent variable:

# “Physical fitness” [DeCS]

# “Physical fitness” [MeSH]

# “Cardiorespiratory fitness”

# “Physical endurance” [MeSH]

# “Physical conditioning” [MeSH]

# “Muscle strength” [MeSH]

# “Muscular endurance”

# “Muscular resistance”

# Pliability [MeSH]

# Pliability [DeCS]

# 23 (((“physical fitness”) OR “cardiorespiratory fitness”) OR “physical endurance”)

OR “physical conditioning”

# 24 ((“muscular strength”) OR “muscular endurance”) OR “muscular resistance”

# 25 (flexibility) OR pliability

Outcome:

# academic achievement (MeSH)

# educational status (MeSH)

# attendance school

# academic performance

# school performance

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3 #26 (((("academic achievement") OR "academic performance") OR "school  
4  
5 performance") OR "attendance school") OR "educational status"  
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7 (#23) AND #26  
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9 (#24) AND #26  
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