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The Relationship between Physical Activity Levels, Cardiorespiratory Fitness and Academic Achievement School-Age Children from Southern Spain

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Abstract: The relationship between physical activity (PA), cardiorespiratory fitness (CRF) and academic achievement in young people is unclear. The aim of this study was to analyze the relationship between PA, CRF and academic achievement in 152 children according to sex (average age of 8.6 ± 0.3 years) in southern Spain. A tri-axial accelerometer was used to measure PA; the 20-m Shuttle Run Test was performed to assess the CRF; and to know the academic achievement, the official school records were considered. The results showed a weak correlation between moderate PA and moderate-to-vigorous PA (MVPA) with CRF in boys (all, $0.2 > r < 0.4$; $p < 0.05$), whereas the vigorous PA showed a moderate and weak correlation with CRF (all, $p < 0.05$), in both boys ($r = 0.537$) and girls ($r = 0.382$), respectively. In addition, a weak inverse correlation between moderate PA and MVPA with academic achievement showed in girls (all, $0.2 > r < 0.4$; $p < 0.05$). Finally, the CRF weakly correlated with academic achievement only in boys (all, $0.2 > r < 0.4$; $p < 0.05$). Our study showed a relationship between PA and CRF in both sexes. Nonetheless, the PA was inversely related to academic achievement in girls, whereas the CRF was related to academic achievement in boys.

Keywords: physical activity levels; VO2max; academic performance; children

1. Introduction

There are improvements in health related to daily physical activity (PA), such as a reduction of cardiovascular diseases [1], mental health problems [2] and metabolic factors, such as obesity, hypertension and diabetes [3]. Specifically, in children and adolescents, lower PA levels are associated with an increased risk of obesity, cardiovascular and metabolic diseases [4], lower physical fitness [5] and poorer cognitive function, among others [6]. Despite the above-mentioned improvements in health, a recent study carried out by Thivel et al. [7] in children aged 9 to 11 years old from 12 countries showed that only 44% of them met the recommendations of 60-min moderate-to-vigorous PA (MVPA) per day proposed by the Physical Activity Guidelines Advisory Committee [8]. Another study in Spanish children showed that 30.4% complied with these recommendations [9].

In addition to PA, cardiorespiratory fitness (CRF) is another important factor related to children´s health [10] that determines the aerobic functional capacity to carry out PA or physical exercise [11]. Different studies in children have shown a positive relationship between PA and CRF. However, the correlations showed a moderate relationship between both variables [12,13].

With the benefits of PA and CRF on the health of children described previously it is hypothesized that academic achievement is associated with health status. Concretely, academic achievements, defined as the result of children's education represented by grades [14], have an impact on the health of children related to physiological factors such as self-concept and motivation [15] or social support [16]. In the last decade, different studies have independently analyzed the relationship between PA and CRF with academic achievement. The results of a systematic review of studies from 19 countries in children and adolescents showed an unclear relationship between PA and academic achievement [17]. These differences were due to the different tools used to measure PA. Specifically, most studies where PA was self-reported showed a positive relationship with academic achievement. However, when PA was objectively measured, most studies did not find a significant relationship with academic achievement or found a negative association [17]. Regarding the Spanish studies included in this systematic review [17], one observed a positive relationship between both variables [18], while the other showed a negative one [19]. In addition, another study conducted in Spanish children showed non-significant results between PA and academic outcomes [20].

On the other hand, the relationship between CRF and academic achievement has also been studied. The same systematic review focused on children and adolescents aged 6–18 years, where 22 studies were included, and found in most of them a positive association between CRF and academic achievement [17]. Regarding the Spanish studies included in this systematic review [17], CRF was associated with academic achievement in both cases [18,21]. Another study in Spanish children only showed a positive correlation between CRF and language skills, but not grade point average [20].

According to the scientific literature presented above, we observed that the relationship between CRF and PA in children needs more evidence because there are only few studies focused on children, especially Spanish children, compared with studies focused on adolescents. There are a few studies where they have divided the results by sex despite the differences between boys and girls [9,22]. Both PA levels and CRF change from childhood to adolescence. Thus, their relationship could also vary, in addition to their influence on academic achievement. In addition, there are only few studies that objectively evaluate these variables (i.e., using an accelerometer), so there could be evaluation bias. Therefore, the aim of this study was to objectively analyze the relationship between PA levels, CRF and academic achievement according to the sex of children in southern Spain.

2. Materials and Methods

2.1. Participants

The data were obtained from the PREVIENE Project (Promoting Healthy Lifestyles for the School Environment) [23]. The study protocol was approved by the Ethics Committee on Human Research of the University of Granada (Reference: 57/CEIH/2015). More specific information on the protocol of this study can be found in the methodological study of the PREVIENE project [23].

A total of six schools (five public and one private) of Granada (Spain) were invited to participate in the study. All schools were invited by phone call and email. The research team conducted an initial meeting with the teachers of the schools to explain the objectives and evaluation process of the study. After the participation approval from the schools, the families received an invitation to an initial meeting to receive information and to encourage their participation. Parents signed an informed consent for the inclusion of their children in the study. Of the initial 300 children invited to participate, 148 children were excluded from data analysis; 79 did not give informed consent, 7 did not attend the evaluation day, 48 did not wear the accelerometer for at least five days and 14 did not deliver the sleep log. Finally, a sample composed of 152 children (average 8.6 ± (0.3) years old, 80 boys).

2.2. Instruments

2.2.1. Anthropometry

The children's weight and height were assessed wearing shorts, a short sleeve shirt and bare feet. Weight was measured with a 0.1 kg approximation using a Seca 876 weighing system (Seca, Ltd., Hamburg, Germany). Height was measured in the Frankfort plane with an approximation of 0.1 cm using a Seca 213 stadiometer (Seca, Ltd., Hamburg, Germany). Height and weight were measured twice and the average of both measurements taken. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. To determine the weight status of children we used the age and gender BMI cut-off points proposed by the International Obesity Task Force [24].

2.2.2. Physical Activity

PA was measured using a tri-axial accelerometer (Actigraph wGT3X-BT, Pensacola, FL, USA), considered to be a valid and reliable tool to measure objectively PA in children [25]. Participants were instructed to wear the accelerometer attached to the non-dominant wrist for seven consecutive days, 24 h a day [26]. Parents were also asked to complete a log to determine the time that their children were out of bed, bathing/showering or involved in other water activities. The minimum amount of time considered acceptable for the inclusion in the sample was at least five days and a minimum of 10 h per day, including one weekend day.

The accelerometers were initialized at 6:00 AM. To estimate the PA levels the Chandler´s algorithm was used [27]. The data were collected at a sampling rate of 90Hz, set to record in 5-s epochs. The cut points to determine the type of intensity were: sedentary time ($<$ 305 counts per 5 s), light PA (306–817 counts per 5 s), moderate PA (818–1968 counts per 5 s) and vigorous PA ($>$ 1969 counts per 5 s). The outcomes were analyzed using the ActiLife software (version 6.8.1).

2.2.3. Cardiorespiratory Fitness

The 20-m Shuttle Run Test was applied to assesses children´s CRF [28]. The children ran from one line to another line placed 20 m apart. The speed was increased progressively and announced with a sound signal. The initial speed of the signal was 8.5 km/h and it was increased by 0.5 km/h per minute (1 min was 1 stage). The test ended when the child was not able to reach one of the lines before the audio signal. The outcome test was obtained taking into account the time, running meters, the last stage reached and the speed of the last stage. To estimate the maximal oxygen consumption ($VO_{2\,máx}$), Leger´s equation was used for children aged 6 to 17.9 years [$VO_{2máx} = 31.025 + (3.238 \times \text{Speed}) - (3.248 \times \text{Age}) + (0.1536 \times \text{Speed}) \times \text{Age})$] [29].

To determine the CRF status of the children, we used the age and gender CRF cut-off points proposed by the IDEFICS study [30]; being considered healthy CRF in children from 8 to 8.5 years old [(50.8 mL/kg/min) in boys; (47.9 mL/kg/min) in girls] and in children from 8.5 to 9 years old [(50.9 mL/kg/min) in boys; (47.7 mL/kg/min) in girls].

2.2.4. Academic Achievement

Academic achievement was obtained through the official first period school records (September to December). The school records are designed by specialists in school curriculum and teachers of each subject to evaluate the student's knowledge, skills and attitudes [31].

The academic indicators were the grades (ranging from 0 to 10) from selected subjects (Arts, Physical Education, Language (Spanish), Foreign language (English, French), Math, Natural Science, Social Sciences and Religion) and the average grade point (the sum of the grades obtained in each subject divided by the total number of subjects). All subjects were grouped into three categories according to the curriculum of Primary Education in Andalucía (Spain) [32]. Core subjects were all those subjects that are common throughout the country due to their importance. Specific subjects were all those subjects that are not common throughout the country; however, the Government establishes evaluation criteria that can be complemented by the autonomous communities. Finally, instrumental subjects were all those subjects that contribute to the learning of other subjects. Therefore, the subjects were grouped accordingly to Spanish curricula as follows: Core subjects (Natural Science, Social Sciences, Language, Spanish and Foreign language, English); specific subjects (Physical Education, Religion, Arts and Foreign language, French) and Instrumental subjects (Math, Language, Spanish and Foreign language, English).

2.3. Data Analysis

Descriptive statistics were reported for all measured variables as a mean (SD). To know the normality of all variables the Kolmogorov–Smirnov test was used. To examine the differences by sex, independent *t*-tests were conducted for variables with a normal distribution (height, light PA and MVPA) and the Mann–Whitney *U* test for the rest of the variables (age, weight, BMI, normal weight, overweight, obesity, waist circumference, moderate PA, vigorous PA, all variables of cardiorespiratory fitness and academic achievement). For discrete variables a Chi-squared test was used. The Spearman correlation coefficient was used to calculate the strength of the relationship between PA levels, CRF and academic achievement; classified as very week (0–0.19), weak (0.20–0.39), moderate (0.40–0.59), strong (0.60–0.79) and very strong (0.80–1.0) [33]. To analyze the association between PA and CRF (healthy and unhealthy), binary logistic regressions were used for the total sample and by sex. Data were reported establishing statistical significance at $p \leq 0.05$. All statistical analyses were performed using SPSS (version 23.0; SPSS, Chicago, IL, USA).

3. Results

Table 1 presents the results of the descriptive data of participants by sex. Boys spent 35.66 min more in vigorous PA than girls during a whole week ($p < 0.001$). Regarding CRF, boys completed 0.82 more stages than girls. The final speed reached was higher in boys as well (both, $p = 0.001$). Likewise, the maximal oxygen consumption was 1.66 mL/kg/min higher in boys ($p = 0.003$). Nonetheless, the percentage of a healthy CRF was 4.31% higher in girls, while the percentage of unhealthy CRF was 4.31% higher in boys (both, $p < 0.001$). Girls had an average score in academic achievement 0.36 higher than boys ($p = 0.041$).

Table 1. Descriptive data of physical activity (PA) levels, cardiorespiratory fitness (CRF) levels and academic achievement of the participants.

	Total Mean (SD)	Boys' Mean (SD)	Girls' Mean (SD)	*p*-Value
N	152	80	72	
Age	8.5 (0.42)	8.6 (0.42)	8.5 (0.42)	0.125
Weight (Kg)	30.94 (6.34)	31.56 (6.38)	30.24 (6.25)	0.200
Height (m)	1.32 (0.05)	1.34 (0.05)	1.30 (0.05)	**< 0.001**
BMI (Kg/m^2)	17.47 (2.81)	17.37 (2.62)	17.58 (3.02)	0.776
Normal weight	75% (114)	38.2% (58)	36.8% (56)	0.467
Overweight	18.4% (28)	11.2% (17)	7.2% (11)	0.088
Obesity	6.6% (10)	3.3% (5)	3.3% (5)	0.119
Waist circumference (cm)	58.34 (6.72)	59.09 (6.61)	57.50 (6.78)	0.079
Physical activity				
Light (min/week)	1630.02 (212.63)	1614.74 (206.90)	1646.99 (219.03)	0.352
Moderate (min/week)	641.87 (158.36)	633.67 (152.25)	650.98 (165.47)	0.521
Vigorous (min/week)	77.69 (45.21)	94.53 (49.60)	58.97 (30.56)	**< 0.001**
MVPA (min/week)	719.56 (183.31)	728.21 (181.12)	709.96 (186.50)	0.542

Table 1. *Cont.*

	Total Mean (SD)	Boys' Mean (SD)	Girls' Mean (SD)	*p*-Value
Cardiorespiratory fitness				
Stage	2.90 (1.56)	3.29 (1.67)	2.47 (1.32)	**0.001**
Final speed	9.81 (0.77)	10 (0.80)	9.61 (0.68)	**0.001**
$VO_{2máx}$. (mL/kg/min)	47.89 (3.52)	48.68 (3.67)	47.02 (3.14)	**0.003**
Healthy (%)	28.3% (43)	26.25% (21)	30.56% (22)	**< 0.001**
Unhealthy (%)	71.7% (109)	73.75% (59)	69.44% (50)	**< 0.001**
Academic Achievement				
Arts	7.99 (1,11)	7.56 (1.15)	8.46 (0.83)	**< 0.001**
Physical Education	8.47 (0,86)	8.44 (0.88)	8.50 (0.83)	0.484
Language (Spanish)	7.41 (1.42)	7.29 (1.39)	7.54 (1.44)	0.194
Foreign language (English)	7.99 (1.59)	7.85 (1.67)	8.15 (1.50)	0.286
Math	7.06 (1.64)	6.90 (1.62)	7.24 (1.65)	0.244
Religion	8.09 (1.12)	7.62 (1.08)	8.67 (0.87)	**< 0.001**
Natural Science	7.15 (1.33)	7.06 (1.32)	7.25 (1.34)	0.397
Social Science	7.44 (1.44)	7.46 (1.44)	7.42 (1.45)	0.861
Foreign language (French)	7.76 (1.56)	7.52 (1.72)	8.03 (1.33)	0.082
Average grade point score	7.72 (1.04)	7.55 (1.06)	7.91 (0.99)	**0.041**

SD: standard deviation; BMI: body mass index; MVPA: moderate-to-vigorous physical activity; Healthy CRF status in children from 8 to 8.5 years old (50.8 mL/kg/min in boys and 47.9 mL/kg/min in girls) and children from 8.5 to 9 years old (50.9 mL/kg/min in boys and 47.7 mL/kg/min in girls). Significant values are highlighted in bold.

Table 2 presents the correlations between PA levels, CRF and academic achievement (average grade point score) adjusted for sex. On the one hand, the moderate PA presented a weak correlation with CRF in boys ($r = 0.265$; $p = 0.018$) and an inverse weak one with academic achievement in girls ($r = 0.274$; $p = 0.020$). The vigorous PA showed a weak ($r = 0.382$) and moderate ($r = 0.537$) correlation with CRF in both girls and boys, respectively (all, $p \leq 0.001$). The MVPA showed a weak correlation with CRF in boys ($r = 0.306$; $p = 0.006$) and an inverse weak correlation with academic achievement in girls ($r = -0.249$; $p = 0.035$). On the other hand, only CRF was positively related to mean grade point ($r = 0.282$), core subjects ($r = 0.240$), specific subjects ($r = 0.295$) and instrumental subjects ($r = 0.280$) in boys (all, $p < 0.05$).

Table 2. Correlations between PA levels, CRF and academic achievement adjusted for sex.

	Cardiorespiratory Fitness				Academic Achievement			
	Boys		Girls		Boys		Girls	
	R	*p*	R	*p*	R	*p*	r	*p*
Physical Activity Levels								
Light (min/week)	0.194	0.084	-0.106	0.375	0.173	0.126	−0.153	0.199
Moderate (min/week)	**0.265**	**0.018**	0.076	0.525	0.015	0.897	**−0.274**	**0.020**
Vigorous (min/week)	**0.537**	**0.000**	**0.382**	**0.001**	0.179	0.113	−0.050	0.679
MVPA (min/week)	**0.306**	**0.006**	0.178	0.135	−0.016	0.889	**−0.249**	**0.035**
Academic Achievement								
Mean grade point	**0.282**	**0.011**	0.056	0.640	-	-	-	-
Core subjects	**0.240**	**0.032**	0.036	0.764	-	-	-	-
Specific subjects	**0.295**	**0.008**	0.097	0.419	-	-	-	-
Instrumental subjects	**0.280**	**0.012**	0.056	0.639	-	-	-	-

MVPA: moderate-to-vigorous physical activity; Significant values are highlighted in bold.

Figure 1 presents the association between CRF (healthy and unhealthy categories) with PA levels for the total sample and by sex. The vigorous PA and MVPA were positively related to CRF (OR 1.015; CI 95% 1.006 to 1.023; $p = < 0.001$ and OR 1.002; CI 95% 1.000 to 1.004; $p = 0.020$, respectively). By sex, the vigorous PA was related to CRF in both girls (OR 1.037; CI 95% 1.016 to 1.058; $p = 0.001$) and boys (OR 1.014; CI 95% 1.003 to 1.024; $p = 0.010$).

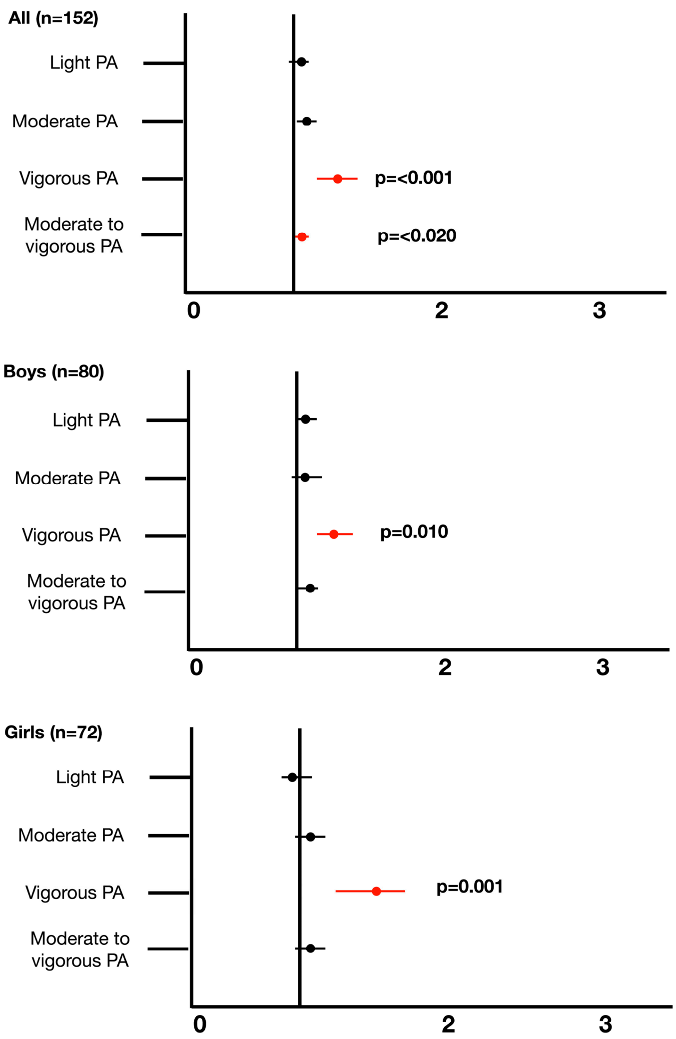

Figure 1. Association between CRF (healthy and unhealthy categories) with PA levels by total sample and sex.

4. Discussion

This study examined the relationship between PA levels, CRF and academic achievement according to sex. The main findings found in this study were: (i) there was an inverse association between PA and academic achievement only in girls; (ii) the CRF positively correlated with academic achievement only in boys; (iii) there was a significant relationship between PA and CRF in boys and girls.

Regarding the relationship between PA levels and academic achievements, the results of our study showed a weak inverse correlation between moderate PA and MVPA with academic achievements only in girls. Comparing our outcomes, previous studies have shown a positive relationship between cognitive processes and PA [34,35]. Regarding sex differences, a study carried out by Booth et al. [36] in British children and adolescents showed that a higher percentage of MVPA was related to an improvement in English in girls and to Math and Science in boys. Whereas, in the study implemented by Kwak et al. [37] in Swedish adolescents, vigorous PA was associated with academic achievement in girls, but not in boys, after controlling for fitness and maternal education. The difference in our results and the previous comparative studies may be due to the fact that in our study the subjects were grouped into three categories according to the curriculum of Primary Education in Andalucía

(Spain) [32]. However, in one of the previous studies, every subject was taken into account [37], while in the other study only the subjects of English, Math and Science were compared [36]. The inverse correlation in girls showed in our study could be related to the time of day when PA was performed. Regarding this, a study carried out in American children alternated an active period walking with rest periods. During rest periods the children performed cognitive tests. This study observed a better performance on the academic achievement test after aerobic exercise in relation to the rest session [38]. Thus, the time of day in which the girls had performed more time of PA could have conditioned the outcomes showed in girls.

One of the main findings in our study was the relationship between CRF and academic achievement. Specifically, the CRF was positively but weakly correlated with academic achievement only in boys. This positive correlation is also presented in other studies in children and adolescents where higher CRF was related to increased mean academic attainment in both boys and girls [39,40]. Nevertheless, in a study in Brazilian children, CRF was only positively associated with Math in girls [41], while in another study in Chilean children it was negatively related to reading/language arts and math scores in girls [42]. However, the higher CRF in boys than in girls could mediate this association. Consequently, it may be possible that some level of CRF is needed for higher academic achievement to have an impact on physiological and psychological factors [42]. These factors have been used to explain the relationship between CRF and academic achievement. Physiological factors such as an increase in cerebral blood flow that improves brain vascularization [21] or alterations in brain neurotransmitter activity [42,43] positively affect cognitive performance, which could have had a greater impact on boys in our study. Other mechanisms are psychological factors; high levels of stress and anxiety are associated with higher cortisol and related to poor academic achievement, especially in girls [44]. On the other hand, the association between PA levels and better CRF could also influence academic achievement [45]. Both variables have been associated with angiogenesis and neurogenesis in areas of the brain related to attention and memory and consequently to improved cognitive performance [46]. Likewise, this association has also been positively related to executive functions, which are the cognitive functions responsible for initiating, adapting, regulating, monitoring and controlling information processes essential for learning in children [17,46]. More studies taking into account sex are necessary to obtain a more precise conclusion about the results shown.

Based on the outcomes of the relationship between PA and CRF obtained in our study, it was observed that vigorous PA and MVPA levels were the only intensities that were related to a healthy CRF level. This observation agrees with a previous review conducted in children and adolescents, which also observed that high-intensity exercise provided more favorable changes on cardiometabolic outcomes than moderate-intensity exercise [47]. A possible hypothesis of these results could be the relationship between PA and blood hemoglobin concentration levels, which are increased with high intensities and therefore could be correlated with CRF [48]. Regarding the differences by sex in our study, data showed moderate and weak correlations between vigorous PA and CRF. It could be related to the amount of PA performed where different studies have shown that boys are physically more active than girls [9,49], as more PA time is related to better CRF [50]. In this sense, it is possible that the boys in our study who were more physically active obtained improvements in systolic blood pressure and heart rate, resulting in an improvement in aerobic capacity and therefore, in better cardiorespiratory fitness than girls [51]. Regarding the girls in our study, it only showed a weak correlation between vigorous PA and CRF due to the fact that vigorous PA was significantly lower in girls. It is possible that a minimum required threshold of vigorous PA was necessary to elicit favorable changes in the results obtained and to reduce the differences between boys and girls [36,52]. Therefore, high PA intensity had a greater effect on CRF compared with lower PA intensities. It is necessary to develop intervention programs that encourage high intensity activities (i.e. jumping, running, etc.) contributing to a better CRF for both boys and girls [53]. However, more studies are necessary to corroborate these results.

We must highlight that this study offered novel results in Spanish children from 8 to 9 years old taken from objective tools such as the accelerometer. Nonetheless, some limitations must be acknowledged. First, the current cross-sectional design did not allow us to explain the direction of the relationship between the variables of the study. Second, the academic achievement was obtained through official school records, which present a component of subjectivity that other standardized tests do not present (i.e., Wechsler Individual Achievement Test, Canadian Achievement Test) [54]. Third, we used the 20 m Shuttle Run Test, which has been validated and recommended to assess cardiorespiratory fitness in children [30]. Nevertheless, it is less accurate compared with other more objective tools. Finally, the schools were recruited by convenience sampling, hence, we cannot generalize our results to the general population.

5. Conclusions

Our study showed an inverse relationship between PA and academic achievement only in girls, whereas the CRF was related to academic achievement only in boys. Furthermore, there was a significant relationship between PA levels and CRF in both sexes. In addition, this study provided results divided by sex and used objective measurement, such as accelerometers, in order to offer new data on the relationship between PA levels, CRF and academic achievement. Therefore, we believe that this study is novel mainly due to the age of the sample participants and the use of objective PA assessment. Consequently, more studies should take into account differences by sex between PA and CRF, which may influence academic achievement. Also, studies should develop PA strategies and intervention programs in the school environment in response to these differences to increase the PA time and intensity and contribute to improving CRF and academic achievement.

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