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Physical Fitness, Obesity, and Academic Achievement in Schoolchildren

Coral Torrijos-Niño, Sport Sci[1], Vicente Martínez-Vizcaíno, PhD, MD[1], María Jesús Pardo-Guijarro, PhD[1,2], Jorge Cañete García-Prieto, Sport Sci[1], Natalia María Arias-Palencia, Sport Sci[1], and Mairena Sánchez-López, PhD[1,3]

Objective To examine the association of physical fitness and obesity with academic achievement and the independent association between fitness and academic achievement after controlling for relevant confounders such as age, parental education, and body mass index in school aged children.

Study design Cross-sectional study including 893 schoolchildren, aged 9-11 years, from Cuenca, Spain. Data were collected from September to November 2010. We measured academic achievement (mean of the grades obtained in several core subjects), physical fitness (cardio-respiratory fitness, muscular fitness, and speed/agility), weight, height, and parental education. Multivariate logistic regression models were used to estimate the probability of being in high quartiles for academic achievement after controlling for potential confounders.

Results Overall, academic achievement scores were positively related to fitness levels. Obese boys had lower scores for academic achievement than overweight or normal weight boys. Good cardio-respiratory and speed/agility levels were associated with high academic achievement after controlling for confounders (OR 3.06; 95% CI, 1.35-6.91; P = .007 and OR 4.25; 95% CI, 1.91-9.44; P < .001, respectively).

Conclusions Academic success is associated with higher fitness levels. Schools should consider strategies to improve fitness as part of their overall strategy for improving academic achievement. *(J Pediatr 2014;■:■-■).*

Several studies have shown an inverse relationship between obesity and academic achievement[1-3]; nevertheless a study of 254 743 US schoolchildren did not find association between these variables.[4] Furthermore, it has been reported that this negative association between obesity and academic achievement disappears or is minimized when controlling for variables such as parents' socioeconomic status,[5] which has been shown to have a positive relationship with children's academic achievement[6,7] and a negative relationship with obesity in young people.[8]

Children with higher physical activity levels have also higher fitness levels.[9] A recent review has shown in children a positive relationship between levels of physical-activity and academic performance and executive function.[10] Physical activity related neurophysiological changes in the brain have been hypothesized to explain the positive influence of physical fitness on academic performance, such as that physical activity increases brain blood flow, improves neuroelectric functionality, and stimulates the release of brain-derived neurotrophic factor that facilitates learning and maintains cognitive functions by improving synaptic plasticity.[11]

However, despite the plausibility of these neurophysiological arguments, the evidence from population-based studies regarding the relationship between physical fitness and academic achievement remains weak. A notable weakness in these studies is the lack of control for important confounders such as parental education and other sociodemographic variables.[4,12,13]

In addition, studies analyzing the relationship between academic achievement and other components of physical fitness such as strength[4,12,14] or speed/agility are scarce, and in most of these studies, physical fitness has been indexed as an overall score across several fitness tests,[13,15] which makes it difficult to determine the independent association of each component of physical fitness with academic achievement.

The aims of this study were: (1) to examine in schoolchildren the association of both physical fitness and excess weight with academic achievement; and (2) to estimate, by using multivariate regression models, the independent ability of several fitness variables to predict high levels of academic achievement after controlling for relevant confounders such as age, parental education, and body mass index (BMI).

Methods

Data come from baseline measurements (September-November 2010) of a cluster-randomized trial aimed to assess the effectiveness of a physical activity program (MOVI-2) on prevention of excess weight in schoolchildren.[16] MOVI-2 is a play-based program of recreational and noncompetitive physical activity

BMI	Body mass index
CRF	Cardio-respiratory fitness
MF	Muscular fitness

From the [1]Social and Health Research Center, University of Castilla-La Mancha; [2]School of Education, University of Castilla-La Mancha, Cuenca, Spain; and [3]School of Education, University of Castilla-La Mancha, Ciudad Real, Spain

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adapted to the children's developmental level. The program consists of 2 weekly sessions of physical activity lasting 90 minutes and a 150-minute Saturday morning session. In this study, all the fourth and fifth grade primary schoolchildren attending the 17 public schools in the province of Cuenca, Spain, were invited to participate and 1070 (67%) accepted. Ultimately from this sample, we only obtained academic data from 893 schoolchildren (445 boys) who had all variables measured because some schools did not provide academic performance data. Children included in the data analysis for this study did not differ in age, sex, or parental socioeconomic status from the entire population of children participating in the trial.

The study protocol was approved by the Clinical Research Ethics Committee of the Virgen de la Luz Hospital in Cuenca, and by the Director and Board of Governors (*Consejo Escolar*) of each school. Following this approval, we sent a letter to parents of all children in fourth and fifth grades, inviting them to a meeting at which we outlined the objectives of the study and obtained written consent for the participation of their children in the study. Finally, we held class-by-class briefings in which we requested the collaboration of the children.

Data collection has been described in detail elsewhere.[16] Data were obtained by trained members of the research group as set forth below.

Participants in light clothing were weighed twice to the nearest 0.1 kg using a portable electronic scale (SECA Model 861; Vogel and Halke, Hamburg, Germany). Height was measured twice to the nearest 0.1 cm without shoes using a wall-mounted stadiometer. Using the mean of these measurements, BMI was calculated as kg/m^2.[17] Physical fitness refers to a set of physiological attributes largely determined by physical activity habits including aerobic capacity, muscular strength, agility, coordination, and flexibility.[18] Physical fitness can be defined as integrated measure of all the functions (skeletomuscular, cardio-respiratory, hematocirculatory, psychoneurological, and endocrine-metabolic) and structures involved in the performance of physical activity and/or physical exercise. Physical fitness, especially aerobic capacity and muscular strength, is considered an important marker of health in young people.[19]

According to Alpha Battery set of tests, we measured the components of physical fitness related to health in children.[20] Cardio-respiratory fitness (CRF) was measured by using the 20 m shuttle run test.[21] Participants were required to run between 2 lines 20 m apart, while keeping pace with audio signals emitted from a prerecorded compact disc. The initial speed was 8.5 kmh^{-1}, this was increased by 0.5 kmh^{-1} min^{-1} (stage duration = 1 minute). We recorded the last one-half stage completed as an indicator of CRF. Muscular fitness (MF), an age- and sex-specific MF index, was calculated by summing the standardized z-scores of 2 tests: the handgrip test and the standing broad jump test. The handgrip test (maximum handgrip strength assessment) used a hand dynamometer with adjustable grip (TKK 5401 Grip D; Takey, Tokyo, Japan).[22] The maximum score in kilograms was averaged across hands. In the standing broad jump test (lower limb explosive strength assessment), participants jumped horizontally to achieve maximum distance (in centimeters).[23]

Speed/agility was indexed using the 4 × 10 shuttle run test (measures speed of movement, agility, and coordination). Participants ran 4 repetitions of the 10 m distance at maximum speed. Two attempts were made.

Academic achievement was estimated from the final grades of the participants the previous year (2009/2010, third and fourth grades). We averaged the marks obtained in Mathematics, Language and Literature, Natural, Social and Cultural Sciences, and English.

Parents were asked about the highest level of education in the family (either mother or father) by using a questionnaire.[24] Highest level of parents education was classified as "primary education" if they belonged to 1 of these categories: (1) functionally illiterate; (2) without any studies; or (3) had not completed primary education; as "Middle education" if they had completed primary education, high school/secondary education, or *Bachillerato* (2 years of upper secondary education); as "university education" if they had obtained a university degree.

Data Analyses

The distribution of all variables was evaluated by both statistical (Kolmogorov-Smirnov Test) and graphical (normal probability plot) procedures. All variables were normally distributed.

CRF, MF index, and speed/agility were categorized by using quartiles (poor, Q1; satisfactory, Q2-Q3; good, Q4) by sex. For boys, mean values for CRF were: poor <2.5 stages; satisfactory 2.5-5.5 stages; good >5.5 stages; for MF index: poor < -1.12 z-score; satisfactory ≥ -1.12 to 1.16 z-score; good >1.16; and for speed/agility: poor >14 seconds; satisfactory = 14-13 seconds; good <13 seconds. For girls, mean values for CRF were poor <2 stages; satisfactory 2-3.5 stages; good >3.5 stages; for MF index: poor < -1.03 z-score; satisfactory ≥ -1.03 to 1.09 z-score; good >1.09; and for speed/agility: poor >15 seconds; satisfactory = 15-14 seconds; good <14 seconds. ANCOVA models were used to test differences in the mean scores of academic achievement by categories of CRF, MF index, speed/agility, and weight status, controlling for confounders, by sex. Post-hoc pairwise comparisons were tested using the Bonferroni correction for multiple comparisons. Effect size was calculated using the estimated marginal means, and was categorized as small (0.20-0.50), moderate (0.51-0.80), or large (>0.80).[25]

In Spanish schools, the top quartile of marks generally include the good and very good marks; academic achievement was categorized by quartiles and dichotomized (fourth quartile: 1; quartiles first-third: 0). Multivariate logistic regression models were used to evaluate whether fitness categories and obesity were independently associated to the likelihood of being in the higher quartiles of academic achievement, controlling for age and parental education (model 1); with further adjustment for BMI or CRF depending on the fixed factor (model 2 and model 2*), by sex.

All statistical analyses were performed using IBM SPSS statistics v.19 software (SPSS Inc, Armonk, New York). The criterion for statistical significance was $P \leq .05$.

Results

Table I summarizes participants' characteristics by sex. We did not find differences in age, anthropometrics variables, and parental education. Overall, boys scored higher than girls in all fitness tests, and girls higher than boys in all the academic subjects evaluated.

Table II shows mean differences in academic achievement by categories of CRF, MF index, speed/agility, controlling for age and parental education, by sex. Academic achievement was lower in children with poor fitness levels, with the exception that for boys no significant effect of MF categories was found. Overall, effect sizes for the differences in academic achievement by categories of physical fitness were small or moderate in both sexes, but large for boys on academic achievement scores by CRF categories. No significant differences in academic achievement were observed between children born in immigrant families and those born in Spanish families.

Table I. Characteristics of the study sample

	Total (n = 893)	Boys (n = 445)	Girls (n = 448)	P
Age (y)	9.49 (0.71)	9.51 (0.73)	9.48 (0.69)	.479
Height (m)	139.57 (6.99)	139.52 (6.90)	139.61 (7.09)	.821
Weight (kg)	37.35 (9.22)	37.67 (9.61)	37.02 (8.79)	.228
BMI (kg/m^2)	19.00 (3.68)	19.16 (3.81)	18.84 (3.54)	.142
BMI z-score	0.001 (0.98)	−0.033 (0.97)	0.032 (1.01)	.257
CRF: 20-m shuttle run (stage)	3.48 (1.69)	4.10 (1.83)	2.86 (1.25)	<.001
Handgrip (kg)	14.59 (3.37)	15.38 (3.45)	13.78 (3.08)	<.001
Standing broad jump (cm)	114.53 (19.67)	119.63 (19.57)	109.28 (18.37)	<.001
MF index*	−0.0001 (1.70)	−0.0001 (1.72)	−0.0001 (1.68)	1.00
Speed/agility: Shuttle run 4 × 10 m (s)†	14.07 (1.39)	13.66 (1.29)	14.49 (1.36)	<.001
Parent's education:				.344
Primary	7.9%	5.6%	8.4%	
Middle	73.8%	76.6%	71.0%	
University	18.3%	17.8%	20.6%	
Mathematics	7.46 (1.69)	7.41 (1.70)	7.52 (1.67)	.373
Language and Literature	7.75 (1.68)	7.50 (1.71)	7.99 (1.62)	<.001
Natural, Social and Cultural Sciences	7.34 (1.81)	7.18 (1.83)	7.50 (1.77)	.008
Foreign language (English)	7.51 (1.78)	7.28 (1.83)	7.74 (1.69)	<.001
Mean academic achievement‡	7.52 (1.59)	7.34 (1.61)	7.69 (1.54)	.001

Values are means (SD) except for parent's education.
*Muscle fitness index = age-sex standardized z-scores (handgrip/weight) and standing broad jump test.
†The lower the score (time in seconds) the better performance.
‡Mean of the scores in Mathematics, Language and Literature, Natural, Social and Cultural Sciences, and Foreign language (English).

Obese boys had lower academic achievement scores than those categorized as overweight or normal weight. However, in girls no differences by BMI categories were found (Table III).

Logistic regression models predicting high academic achievement (top quartile), by sex, using as predictors physical fitness levels and BMI categories, and controlling for age and parental education are shown in Table IV. Boys with good CRF and speed/agility had, after controlling for potential confounders, respectively, a 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. Schoolchildren of both sexes with high strength scores and normal weight, and girls with good CRF did not have a higher probability of a good academic achievement score after controlling for relevant confounders (Table IV).

Discussion

Although it is still difficult to draw definitive conclusions regarding the relationship between physical activity and academic achievement, the overall findings show a positive relationship; as physical activity (including fitness, sports participation, and physical education) increases, cognitive function and academic achievement generally improve. In line with other recent findings,[4,26-28] our data support the hypothesis that academic achievement is better in children with higher levels of physical fitness, especially in boys where the largest effect size (0.811) was seen. There are currently 3 hypotheses about the mechanisms by which aerobic exercise might influence some cognitive measures[29]: (1) vascular changes, including an increase in oxygen saturation, promote angiogenesis and increased cerebral blood flow to cognition-related brain areas; (2) increased cerebral levels of neurotransmitters such as serotonin and/or norepinephrine facilitate information processing; and (3) changes to the regulation of neurotrophins influencing neurogenesis.

Alternative explanations have been advanced for the positive relationship between aerobic capacity and academic achievement, namely that it may reflect the achievement orientation of motivated students as follows: (1) motivated students may strive for achievement in both academic subjects and physical fitness; (2) students' physical fitness is associated with better health, which may contribute positively to academic achievement; (3) physical activity and higher physical fitness may improve students' attention and behavior in the classroom; and (4) physical activity may improve mental health and self-esteem. Regular exercise can alleviate stress, anxiety, and depression problems that can affect school performance and can even boost self-esteem.[13] The relationship between speed/agility and academic achievement is less well documented, mainly because in most studies, physical fitness was

Table II. Mean differences of academic achievement* by physical fitness categories, in ANCOVA models controlling for age and parent's education, by sex

	Physical fitness categories						
	Poor Mean (SD)	Satisfactory Mean (SD)	Good Mean (SD)	*P*	Effect size Poor/S	S/G	Poor/G
CRF‡							
Total (n = 388)	7.25 (1.72)	7.88 (1.35)	8.16 (1.22)	**<.001**	**0.407**	0.218	**.610**
Boys (n = 175)	7.06 (1.70)	7.61 (1.42)	8.23 (1.13)	**.001**	0.351	0.483	**.811**
Girls (n = 213)	7.47 (1.74)	8.09 (1.26)	8.06 (1.30)	**.029**	**0.408**	0.023	.384
P	.234	**.014**	.406				
Muscle strength index†,‡							
Total (n = 398)	7.53 (1.65)	7.88 (1.34)	8.02 (1.39)	**.031**	**0.233**	0.103	**.321**
Boys (n = 183)	7.49 (1.78)	7.55 (1.41)	8.05 (1.32)	.081	0.037	0.366	.357
Girls (n = 215)	7.55 (1.56)	8.18 (1.20)	8.02 (1.46)	**.014**	**0.453**	0.120	.311
P	.679	**<.001**	.675				
Speed/agility‡							
Total (n = 396)	7.26 (1.54)	7.90 (1.41)	8.19 (1.34)	**<.001**	**0.433**	0.211	**.644**
Boys (n = 181)	7.10 (1.63)	7.68 (1.46)	8.13 (1.36)	**.003**	**0.375**	0.319	**.686**
Girls (n = 215)	7.46 (1.46)	8.10 (1.34)	8.22 (1.32)	**.009**	**0.457**	0.090	**.546**
P	.428	**.024**	.849				

The effect size corresponding to mean pairs that showed statistical significance (*P* values less than .05 for post hoc hypothesis 2-sided testing with the Bonferroni correction for multiples comparisons are set in bold).
*Mean of the scores in Mathematics, Language and Literature, Natural, Social and Cultural Sciences, and Foreign language (English).
†Muscle fitness index = age-sex standardized z-scores (handgrip/weight) standing broad jump test.
‡Categories of CRF, muscle fitness index and speed/agility are category poor, satisfactory (S), and good (G) representing the first, second and third, and fourth quartiles, respectively. For boys, mean values for CRF were poor <2.5 stages; satisfactory ≥2.5-5.5 stages; good >5.5 stages; for MF index: poor < −1.12 z-score; satisfactory ≥ −1.12 to 1.16 z-score; good >1.16; and for speed/agility: poor >14 seconds; satisfactory = 14-13 seconds; good <13 seconds. For girls, mean values for CRF were poor <2 stages; satisfactory ≥2-3.5 stages; good >3.5 stages; for MF index: poor < −1.03 z-score; satisfactory ≥ −1.03 to 1.09 z-score; good >1.09; and for speed/agility: poor >15 seconds; satisfactory = 15-14 seconds; good <14 seconds.

measured using the Fitnessgram battery,[4,15] which does not include a test of speed/agility; and because a global measure of fitness has generally been used as a predictor rather than the fitness components independently. Because speed/agility depends largely on the neuromotor system, which ensures that commands in the brain are communicated to the muscles, a possible explanation of the relationship between speed/agility and academic achievement could be related to an improvement in the speed of nerve impulse conduction of children with higher levels of speed/agility.

The relationship between MF and academic achievement remains controversial; although some studies have found a positive relationship,[4,14] others[12] failed to establish this association. Our data did not show any significant relationship between strength and academic achievement. Possible explanations for these discrepancies include the use of different measures to evaluate both MF and academic achievement.

Thus, our data support that cardiovascular fitness is the physiological mediator that explains the relationship between physical exercise and improved cognitive performance, in the same way that our data support that positive associations with academic achievement are restricted to cardiovascular fitness and not muscular strength. These findings are also consistent with the notion that cardiovascular fitness improves cognition through increased amounts of circulating factors that positively influence brain plasticity and cognitive function.[30]

In our study, mean scores for academic achievement by BMI categories show significant differences in boys, even after controlling for confounders; however, the influence of BMI on academic achievement disappeared in logistic models predicting the probability of getting higher grades, particularly when fitness variables were included in the models. Consistent with other studies, our data show that physical fitness is more closely related to academic achievement than obesity.[4,15]

The limitations of our study include its cross-sectional design, which prevents us from establishing causal relationships. In addition, controls for other potential confounders

Table III. Mean of academic achievement* by weight status categories, in ANCOVA models controlling for age and parent's education, by sex

	Normal weight Mean (SD)	Overweight Mean (SD)	Obesity Mean (SD)	*P*	Effect size NW/OV	OV/OB	NW/OB
Total (n = 403)	7.90 (1.39)	7.95 (1.32)	7.06 (1.81)	**.001**	0.037	**0.562**	**0.521**
Boys (n = 186)	7.64 (1.45)	8.02 (1.22)	6.70 (1.96)	**.001**	0.284	**0.809**	**0.545**
Girls (n = 217)	8.09 (1.32)	7.90 (1.44)	7.50 (1.57)	.162	0.138	0.266	0.407
P	**.012**	.638	.201				

BMI, body mass index; *NW*, normal weight; *OV*, overweight; *OB*, obesity.
The effect size corresponding to mean pairs that showed statistical significance (*P* values of less than .05 for post hoc hypothesis 2-sided testing with the Bonferroni correction for multiples comparisons are set in bold).
*Mean of the marks in Mathematics, Language and Literature, Natural, Social and Cultural Sciences, and Foreign language (English).

Table IV. Logistic regression models predicting high quartiles of academic achievement from fitness and weight status, by sex

	Academic achievement*					
	Boys		Girls		Total	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
CRF						
Model 1						
Satisfactory	2.05 (0.68; 6.12)	.198	1.51 (0.68; 3.36)	.310	1.69 (0.89; 3.19)	.106
Good	5.59 (1.70; 18.29)	**.004**	1.84 (0.71; 4.74)	.207	3.06 (1.48; 6.32)	**.002**
Model 2						
Satisfactory	2.33 (0.73; 7.35)	.148	1.40 (0.61; 3.21)	.417	1.68 (0.87; 3.27)	.122
Good	7.34 (1.83; 29.41)	**.005**	1.59 (0.56; 4.49)	.376	3.06 (1.35; 6.91)	**.007**
Muscle fitness index†						
Model 1						
Satisfactory	0.56 (0.22; 1.41)	.220	2.01 (0.95; 4.25)	.066	1.25 (0.71; 2.21)	.432
Good	1.84 (0.69; 4.89)	.223	2.29 (0.98; 5.36)	.055	2.08 (1.10; 3.92)	.023
Model 2						
Satisfactory	0.54 (0.20; 1.45)	.225	1.91 (0.87; 4.20)	.107	1.18 (0.65; 2.16)	.577
Good	1.70 (0.51; 5.67)	.382	2.11 (0.83; 5.38)	.115	1.89 (0.92; 3.87)	.082
Speed/agility						
Model 1						
Satisfactory	2.78 (0.98; 7.84)	.053	3.85 (1.51; 9.77)	**.005**	3.21 (1.63; 6.31)	**.001**
Good	4.26 (1.26; 14.35)	**.019**	5.10 (1.77; 14.69)	**.003**	4.56 (2.09; 9.94)	**<.001**
Model 2						
Satisfactory	2.73 (0.96; 7.72)	.058	3.78 (1.48; 9.62)	**.005**	3.15 (1.59; 6.21)	**.001**
Good	4.00 (1.48; 13.96)	**.029**	4.72 (1.61; 13.85)	**.005**	4.25 (1.91; 9.44)	**<.001**
BMI						
Model 1						
Overweight	2.08 (0.50; 8.68)	.312	2.42 (0.62; 9.45)	.202	2.23 (0.84; 5.90)	.105
Normal weight	2.21 (0.58; 8.36)	.242	2.62 (0.72; 9.47)	.140	2.44 (0.98; 6.09)	.054
Model 2*						
Overweight	1.58 (0.36; 6.95)	.543	2.19 (0.55; 8.70)	.262	1.84 (0.68; 4.98)	.228
Normal weight	0.82 (0.18; 3.75)	.805	1.70 (0.44; 6.57)	.437	1.27 (0.47; 3.41)	.635

Model 1: predictors adjusted for age and parent's education, taking poor fitness and obesity as reference model; Model 2: further adjustment for BMI; Model 2*: adjusted for CRF.
*Academic achievement is the mean of the score between Mathematic, Language and Literature, Natural, Social and Cultural Sciences and Foreign language (English) categorized by quartiles and dichotomized (1 = fourth quartile; 0 = first-third quartiles).
†Muscle fitness index was calculated as the sum of the standardized z scores of reason dynamometry/weight and standing broad jump test.

which were not measured, such as stress or ethnicity, are lacking.[5,31] Using final academic grades to index academic achievement provided objective information on the children's progress, but it makes it difficult to compare our findings with other studies that have used standardized tests. Because there is no consensus on whether paternal or maternal education has more influence on the academic performance of their children,[32-34] it would have been interesting to show the mother and father's results separately. Unfortunately, because we asked for the parent's highest level of education, we cannot provide any information regarding this concern. Finally, the relationship between physical fitness and academic achievement may also be influenced (confounded or mediated) by personal factors such as self-esteem, self-efficacy, or self-image that have not been considered in the present study. However, our study quantifies the relationship between specific components of physical fitness—objectively measured—and obesity with academic achievement, controlling for sociodemographic variables and CRF in a large sample of schoolchildren.

Because our data suggest that physical fitness are a determinant of academic achievement, we should consider fitness rather than weight control as the main goal in programs aimed at promoting physical activity in schools. ■

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Reprint requests: Mairena Sánchez-López, PhD, Centro de Estudios Sociosanitarios, Universidad de Castilla-La Mancha, C/Santa Teresa Jornet s/n, 16071 Cuenca, Spain. E-mail: mairena.sanchez@uclm.es

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