Physical Fitness, Obesity, and Academic Achievement in Schoolchildren

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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;165:104-9)*.

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

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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.