Maternal Education and Academic Achievement in Schoolchildren: The Role of Cardiorespiratory Fitness

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Objectives To examine the relationship between maternal education, cardiorespiratory fitness, and academic achievement in schoolchildren, specifically whether the association between maternal education and academic achievement is mediated by cardiorespiratory fitness.

Study design This is a secondary analysis of a cross-sectional study including 478 Spanish schoolchildren aged 8-11 years. ANOVA was used to test differences in cardiorespiratory fitness by maternal education level. ANCOVA was used to test the differences in academic achievement by the educational level of mothers and the cardiorespiratory fitness of children, controlling for each other. A mediation analysis was used to test if the relationship between maternal education and academic achievement was explained by cardiorespiratory fitness.

Results A higher level of maternal education was associated with a higher cardiorespiratory fitness level and academic achievement in children; moreover, the cardiorespiratory fitness level in children was associated with better academic achievement ($P < .05$). Finally, cardiorespiratory fitness acted as a partial mediator of the relationship between maternal education and academic achievement in boys ($z = 1.81$; $P = .03$) but not in girls ($z = 0.86$; $P = .19$), explaining 6.54% of this relationship for the total sample and 6.67% for boys.

Conclusions This study suggests that the benefits of maternal education on academic achievement are partially explained by the mediating role of cardiorespiratory fitness. *(J Pediatr 2021;232:109-17)*.

The family environment is one of the main determinants of academic achievement in children.[1,2] Within the family context, in addition to lifestyle (including physical activity, nutrition behaviors, or substance use) and health status of parents, the traditional measures to assess socioeconomic status are occupation, education, and income.[3,4] Of these factors, maternal education is among the most frequently used when examining the socioeconomic status with a child's academic achievement, in part because parents with higher education may emphasize school success, and may be better able to help with children's studies.[5-7] Furthermore, it has been shown that maternal education has a stronger relationship with academic achievement than paternal education.[8] Moreover, maternal education is also closely related to children's health.[9]

Exercise, along with genetic background, is one of the main determinants of cardiorespiratory fitness in children.[10] In addition, in resource-rich settings, it has been reported that children of higher socioeconomic status participated in sports more frequently and had better fitness than did children of lower status.[11] Studies analyzing the relationship between parental education and fitness, although scarce, consistently note that higher maternal education is associated with life-long increases in physical activity and cardiorespiratory fitness.[12]

Cardiorespiratory fitness has been positively associated with academic achievement through improvements in executive functions.[13-15] Children with a higher level of cardiorespiratory fitness have better grades than their less fit peers.[16-18] Therefore, both physical activity and cardiorespiratory fitness have been related to academic performance, although the influence of physical activity is considered to be mediated by cardiorespiratory fitness.[13] Thus, both academic achievement and cardiorespiratory fitness are closely associated with the education level of the mother.[12,19] However, the potential role of cardiorespiratory fitness as a confounding factor or as a mediator between the education level of the mother and academic performance remains to be resolved.

The aim of this study was to explore the relationships between maternal education, cardiorespiratory fitness, and academic achievement in schoolchildren by examining the mean differences in cardiorespiratory fitness by maternal education level; the mean differences in academic grades by maternal education level and by cardiorespiratory fitness categories, controlling for each other; and whether the association between maternal education and academic achievement was mediated by cardiorespiratory fitness in schoolchildren.

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Funded by the Ministry of Economy and Competitiveness-Carlos III Health Institute and FEDER funds (FIS PI16/01919). S.R-G. (2020-PREDUCLM-15596), S.N.A-A. (2020-PREDUCLM-16704), and A.S-L. (2019-PREDUCLM-10708) are supported by a grant from the University of Castilla-La Mancha. The study sponsor has no role in study design, the collection, analysis or interpretation of data, the writing of the report, or the decision to submit the paper for publication. The authors declare no conflicts of interest.

https://doi.org/10.1016/j.jpeds.2021.01.047

Methods

We conducted a cross-sectional analysis of baseline data from the MOVI-daFIT! study, a cluster-randomized controlled trial (Clinicaltrials.gov NCT03236337) aiming to assess the effectiveness of a physical activity program to improve cardiometabolic risk, cardiorespiratory fitness, executive functions, and academic achievement in 8- to 11-year-old schoolchildren from Cuenca, Spain. The Clinical Research Ethics Committee of the "Virgen de la Luz" Hospital in Cuenca (REG: 2016/PI021) and the Board of Governors of each school approved the study. All procedures performed in this study were in accordance with Declaration of Helsinki and its later amendments or comparable ethical standards for experiments involving humans.[20,21] Parents signed informed consent for children's participation, and children provided verbal assent before the completion of each test. Further details about the rationale and design of this trial have been published elsewhere.[22]

Participants

All schools in Cuenca province, Castilla-La Mancha region, Spain, with at least 1 full classroom of fourth and fifth grades (n = 19) were invited to participate. From those that agreed to participate (n = 18), 10 were randomly selected and, from these schools, a total of 923 schoolchildren aged 9-11 years were invited to participate. Children were excluded if they had Spanish learning difficulties (as reported by parents or teachers) or had serious physical or mental disorders that could prevent their participation in the activities of the physical activity program (as reported by their pediatricians). Finally, 570 schoolchildren participated in this trial, 478 of whom were included in this analysis, because they had data on all study variables of interest.

Variables

The measurement procedures have been extensively described elsewhere.[22] The baseline variables were measured in September-October 2017 in each school by trained researchers following standardized conditions.

Anthropometric variables, namely, height and weight, were measured twice and averaged for analyses. Body mass index was calculated as weight (kg)/height $(m)^2$. Cardiorespiratory fitness is the maximal capacity of the respiratory and cardiovascular systems to provide oxygen during exercise and was assessed using the Course Navette test (20-m shuttle run test, validated to estimate aerobic capacity).[22-24] Participants were encouraged to run between 2 lines separated by 20 m, following the audio signals of a pre-recorded tape. The speed was initially 8.5 km/h and increased 0.5 km/h at each stage (each stage lasted 1 minute). If children did not reach the lines before the signal sounded twice, they were considered as having failed the test. The last one-half stage completed was considered, and maximal oxygen intake (VO_2 max; mL/kg/h) was calculated by applying the Leger formula.[25]

Maternal education level was assessed with a validated scale describing the maximum level of education achieved using 6 mutually exclusive categories: (1) no literacy, (2) no studies, (3) elementary studies, (4) secondary studies, (5) high school, and (6) university studies.[26] These 6 categories were collapsed into 3: primary education, including functionally illiterate mothers with no formal education or those who had not completed primary education (categories 1-3); secondary education, including complete primary or high school/secondary education (categories 4 and 5); and university education, including university degrees, master's or doctoral degrees (category 6).

Academic achievement, determined using data provided by the schools, consisted of final grades from the previous year (2016/2017, ie, third and fourth grades) for language and mathematics. In the primary education stage of the Spanish educational system, language and mathematics are the curricular areas that have the greatest relevance, because they are considered instrumental subjects underlying other areas of the curriculum. In Spain, final grades represent the student's work in a whole academic year, and academic achievement is measured on a scale of 1-10, with 10 the highest grade.

Statistical Analyses

Normal distribution of continuous variables was checked using both graphical (normal probability plot) and statistical (Kolmogorov-Smirnov) procedures. All variables fitted to a normal distribution. Differences by sex were analyzed using the Student t test for continuous variables and the Pearson χ^2 test for categorical variables. Equality of variances was assessed with the Levene test.

Correlation coefficients were estimated to examine the relationship between cardiorespiratory fitness, maternal education level, and academic achievement by sex using Pearson correlation coefficients when there was at least 1 continuous variable, and Kendall tau-b correlation coefficients when both variables were discrete or categorical. Mean differences in cardiorespiratory fitness by maternal education categories were tested using ANOVA. ANCOVA models were used to examine differences in academic achievement by maternal education categories, controlling for cardiorespiratory fitness, and by cardiorespiratory fitness categories controlling for maternal education. For this analysis, cardiorespiratory fitness was categorized as poor (first quartile), medium (second and third quartiles), and good (fourth quartile), as has been done in previous studies.[27,28] Pairwise post hoc hypotheses were tested using the Bonferroni correction for multiple comparisons.

Mediation analysis models were estimated to examine whether the association between maternal education and academic achievement was mediated by cardiorespiratory fitness. In these models, academic achievement was represented by an index calculated as the mean of mathematics and language grades. The first equation regressed the mediator (cardiorespiratory fitness) on the independent variable (maternal education), the second equation regressed the independent variable on the dependent

variable (academic achievement) without controlling for the mediator (total effect), and the third equation regressed the academic achievement on both maternal education and cardiorespiratory fitness, the independent and mediator, which estimated the direct effect of both the independent and mediator variables on the dependent. The indirect effect represents how the dependent variable is influenced by the independent through a causal sequence in which the independent influences the mediator, which in turn influences the dependent variable. It is calculated as the product of both direct effects from the third equation. The Sobel test was used to assess the statistical significance of the mediation effect, which is calculated as the ratio of the indirect effect by its standard error, and performing a Z test under the null hypothesis that the indirect effect was equal to zero.[29] To estimate the percentage of the total effect explained by the mediation path, the percentage of mediation was calculated as follows: (indirect effect/total effect) × 100. The following assumptions were used to establish mediation: the independent variable must be significantly related to the dependent and mediator variables; the mediator variable must be significantly related to the dependent variable; and the association between the independent and dependent variables must be decreased when the mediator is included in the model. Mediation models were estimated using PROCESS macro v.3.3. for SPSS v.25.0., with resample procedure of 10 000 bootstrap samples as recommended by Preacher and Hayes.[30,31]

All analyses were conducted for the total sample and by sex and performed using IBM SPSS Statistics for Windows software (Version 25.0. IBM Corp), and the statistical significance was set at a *P* value of less than .05.

Results

The characteristics of the study sample are shown in Table I. Of the 478 schoolchildren involved in the study, 227 were boys (47.49%), and the mean age was 9.57 ± 0.70 years. Regarding the education level of the mothers, 71.1% had a secondary education, 17.2% had a university education, and 11.7% had a primary education.

Relationship Between Study Variables

Table II (available at www.jpeds.com) shows the correlation coefficients between cardiorespiratory fitness, maternal education, language and mathematics grades, and the index of academic achievement. Correlations for academic achievement and language and mathematics grade coefficients with cardiorespiratory fitness ranged from 0.197 to 0.342 ($P < .05$), and those with maternal education ranged from 0.281 to 0.311 ($P = .001$). Maternal education was also significantly correlated ($P < .05$) with cardiorespiratory fitness for boys (0.184) and the total sample (0.145) but not girls (0.096; $P = .129$).

Cardiorespiratory Fitness of Children by Maternal Education Categories

Overall, children of mothers with a university education had higher cardiorespiratory fitness level than those of mothers with other education level, and these differences were significant for the total sample ($P = .012$ and $P = .002$) and in boys when comparing those of mothers with university education vs those of mothers with secondary education ($P = .001$). Differences in girls were not significant (Figure 1).

Table I. Characteristics of the study sample, by sex

Variables	Total (n = 478)	Boys (n = 227)	Girls (n = 251)	*P* value
Age (years)	9.57 ± 0.70	9.52 ± 0.72	9.62 ± 0.68	.098
Height (cm)	140.74 ± 7.06	140.82 ± 6.82	140.67 ± 7.28	.821
Weight (kg)	36.34 ± 9.40	36.35 ± 9.16	36.34 ± 9.64	.991
BMI (kg/m^2)	18.18 ± 3.70	18.19 ± 3.72	18.17 ± 3.70	.970
CRF (VO_2 max; mL/kg/h)	46.06 ± 4.59	47.58 ± 4.90	44.69 ± 3.81	.001
Poor	(n = 85)	(n = 49)	(n = 36)	
	37.18-43.01	37.18-43.90	37.18-41.51	
Medium	(n = 287)	(n = 124)	(n = 163)	
	43.01-48.67	43.90-51.06	41.51-48.00	
Good	(n = 106)	(n = 54)	(n = 52)	
	48.67-59.55	51.06-59.55	48.00-54.93	
Maternal education level, No. (%)				
Primary education	56 (11.7)	26 (11.5)	30 (12.0)	.758
Secondary education	340 (71.1)	159 (70.0)	181 (72.1)	
University education	82 (17.2)	42 (18.5)	40 (15.9)	
Mean academic achievement	7.16 ± 1.70	7.16 ± 1.70	7.17 ± 1.70	.988
Language	7.30 ± 1.71	7.17 ± 1.75	7.41 ± 1.66	.127
Mathematics	7.03 ± 1.83	7.15 ± 1.77	6.92 ± 1.88	.163

BMI, body mass index; *CRF*, cardiorespiratory fitness; *VO_2* max, maximal oxygen intake.
Data are mean ± SD, except for CRF categories presented as minimum-maximum. CRF indicates VO_2 max (mL/kg/h) values calculated with the Leger formula. Categories of cardiorespiratory fitness are poor (first quartile), medium (second and third quartiles), and good (fourth quartile). Academic achievement is the mean of language and mathematics grades. *P* values are from parametric test as all variables are normally distributed.

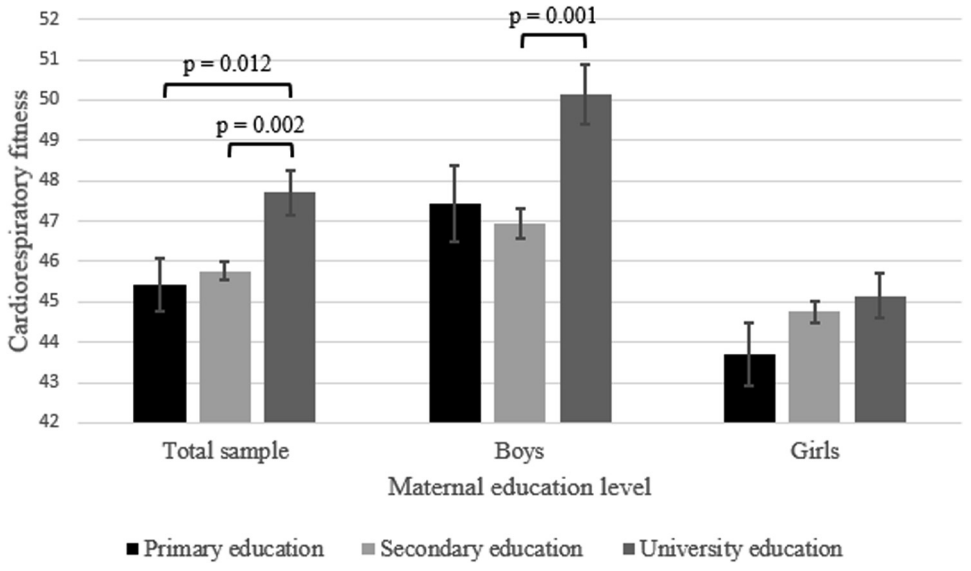

Figure 1. Mean differences in cardiorespiratory fitness by maternal education level categories, by sex. Brackets indicate significant differences in mean ($P < .05$) between categories in the Bonferroni multiple comparison post hoc test. Error bars represent standard error.

Academic Achievement of Children by Maternal Education and Cardiorespiratory Fitness Categories

The mean differences in academic achievement by maternal education level (controlling for cardiorespiratory fitness) were significantly higher ($P < .05$) for children whose mothers had a higher education level for the total sample and by sex (Figure 2, A). In all cases, children whose mothers had a university education had better academic achievement than did children whose mothers had an education level in other categories, and those whose mothers had a secondary education had better academic achievement than those whose mothers had a primary education ($P < .05$). Finally, the differences in academic achievement by cardiorespiratory fitness categories controlling for maternal education level were higher for children with better cardiorespiratory fitness, although the differences only reached statistical significance for the total sample and for girls ($P < .05$) (Figure 2, B). In both cases, pairwise post hoc Bonferroni tests showed that children with a good or medium level of cardiorespiratory fitness had significantly higher academic achievement than did those with a poor level of cardiorespiratory fitness.

Mediation Analysis

The mediation analysis to test whether the relationship between maternal education level and academic achievement was mediated by cardiorespiratory fitness is depicted in Figure 3. For the total sample (Figure 3, A), in the first regression equation, the relationship between maternal education level and cardiorespiratory fitness was positive ($\beta = 1.01$; 95% CI, 0.26-1.76; $P = .01$). In the second equation, maternal education level was also positively associated with academic achievement ($\beta = 1.07$; 95% CI, 0.80-1.33; $P = .001$). Finally, in the third equation, when maternal education level and cardiorespiratory fitness were simultaneously included in the model, both variables were positively associated with academic achievement, and the regression coefficient decreased ($\beta = 1.00$; 95% CI, 0.73-1.26; $P = .001$). Thus, cardiorespiratory fitness acted as a partial mediator of the relationship between maternal education level and academic achievement, as confirmed by the Sobel test values ($z = 2.12$; $P = .02$). The percentage of the total effect mediated by cardiorespiratory fitness in the relationship between maternal education level and academic achievement for the total sample was 6.54%.

When we tested mediation analysis by sex (Figure 3, B), the results for boys were similar to those described for the total sample. In girls, the indirect effect was not significant ($\beta = 0.06$; 95% CI, −0.06 to 0.17); thus, cardiorespiratory fitness did not mediate the relationship between maternal education level and academic achievement for girls.

Discussion

A higher education level of mothers is associated with better academic attainment of their children, as well as with higher cardiorespiratory fitness; however, the fact that the cardiorespiratory fitness is also associated with academic achievement adds complexity to the relationships between the 3 variables. Overall, our data confirm the positive association between maternal education and academic achievement and cardiorespiratory fitness, and builds on this literature by demonstrating that cardiorespiratory fitness partially mediates the relationship between maternal education and school performance in boys but not in girls.

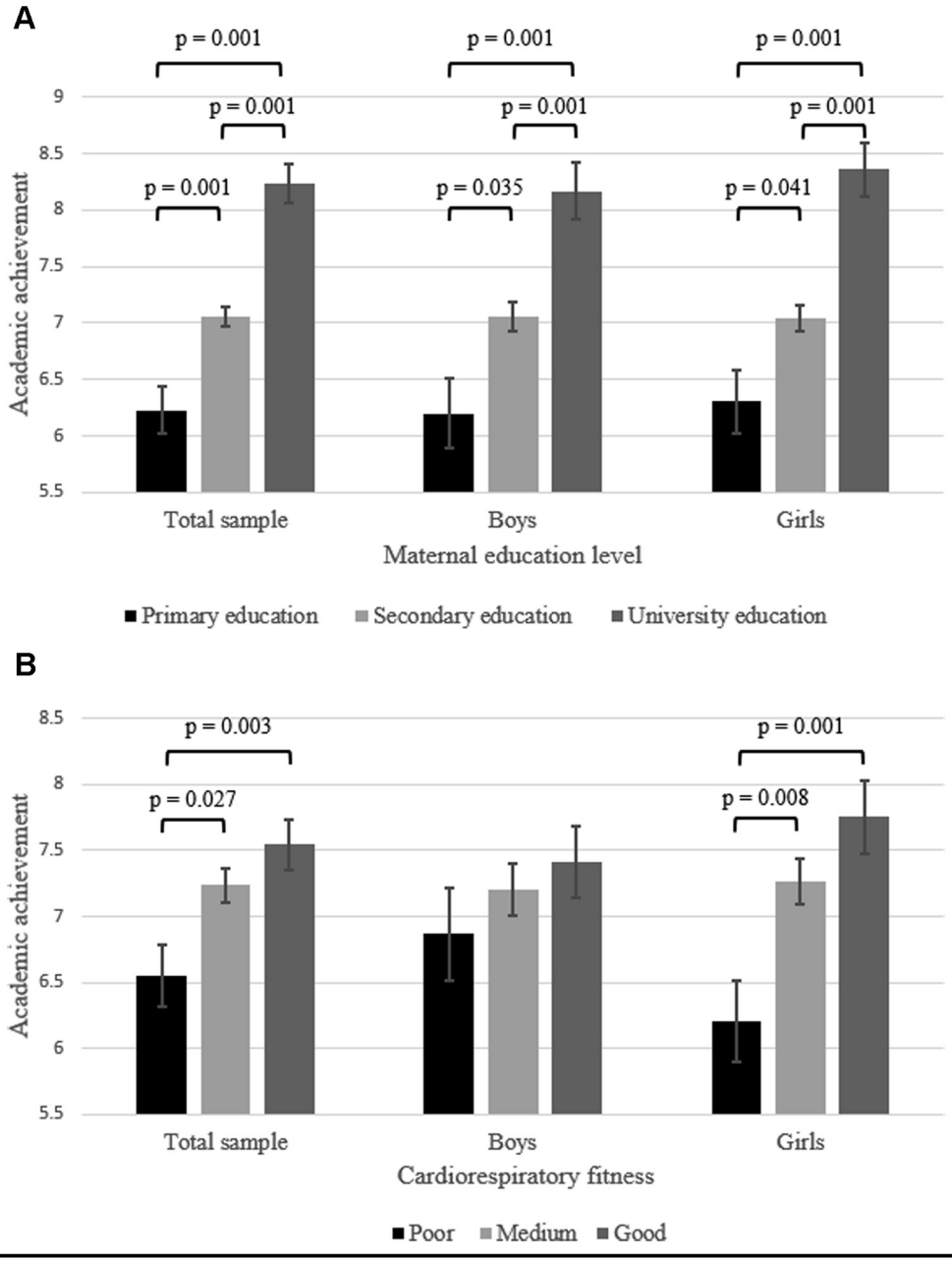

Figure 2. Mean differences in academic achievement by, **A,** maternal education level and **B,** cardiorespiratory fitness categories controlling for each other, by sex. Categories of cardiorespiratory fitness are poor (first quartile), medium (second and third quartiles), and good (fourth quartile). Brackets indicate significant differences in mean ($P < .05$) between categories in the Bonferroni multiple comparison post hoc test. Error bars represent standard error.

Higher parental education is associated with increased physical activity and fitness of children.[12] This relationship is stronger for maternal education level, which may be because, due to higher unemployment in women than men, mothers may spend more time with their children, resulting in a greater involvement in their activities.[32,33] A systematic review showed that people in higher socioeconomic strata had a higher level of moderate-vigorous intensity physical activity than did those at the bottom, and this was related to the education level.[34] Previous evidence suggests that people from neighborhoods with lower socioeconomic characteristics have fewer physical activity resources, and may have less free time, contributing to this relationship.[35] Moreover, a positive association between the physical activity level of parents and their children has also been reported.[36] Our data are in accordance with these previous findings, because they show that children whose mothers have university education have a higher cardiorespiratory fitness level. However, differences in cardiorespiratory fitness between children of mothers with primary education and those of mothers with

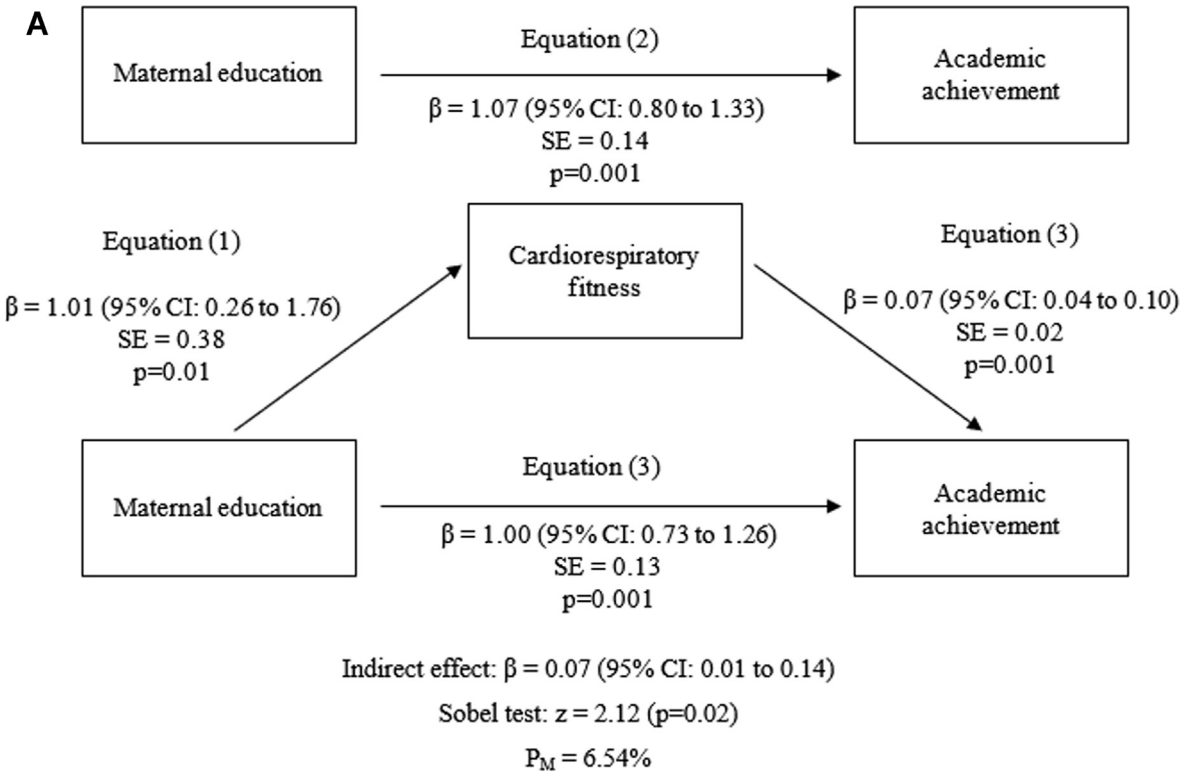

Figure 3. Mediation model of the relationship between maternal education and academic achievement using cardiorespiratory fitness as a mediator and controlling for age, for **A,** total sample and **B,** by sex. The results showed unstandardized beta coefficients, 95% CI, and standard error of beta estimate. *na*, not applicable; P_M, percentage of mediation. Data in italics refer to girls (♀). *(Continues)*

secondary education were negligible, and there was no relationship between maternal education and cardiorespiratory fitness in girls.

Similarly, children whose mothers had university education had marks approximately 2 points higher (on a scale of 1-10) than those whose mothers did not have this level of education. There is consistent evidence on the importance of parental education level on the academic achievement of their children.[37,38] Several reasons are proposed to explain the parental influence (maternal in our case) on both cardiorespiratory fitness and academic achievement. Apart from genetics or other nonmodifiable factors, there is evidence of greater parental involvement in both physical and academic activities.[10,39,40] Some studies have suggested differences in the relationship between sport participation and academic achievement between children whose parents have had some college experience and those who did not.[41]

Current evidence supports a positive relationship between cardiorespiratory fitness and academic achievement.[42-44] Cardiorespiratory fitness has been demonstrated to elicit functional and structural changes in the brain that are positively associated with executive functions such as attention capacity and memory, which are predictors of academic success.[9,45-49] Our results, in line with these prior findings, indicate that children with a good cardiorespiratory fitness level had better academic achievement than did their peers with a poor cardiorespiratory fitness level, even after controlling for mother's education level. Therefore, in some cases, it seems plausible that the negative effect of lower maternal education level on the academic achievement of their children could be mitigated by improving their cardiorespiratory fitness level.

The potential mediating role of cardiorespiratory fitness in the relationship between maternal education and academic achievement is of interest for families and educators. Our study revealed a partial mediation role of cardiorespiratory fitness in the relationship between maternal education level and academic achievement in schoolchildren. There is a lack of studies reporting the influence of this relationship in children by sex, and we only found a relationship for boys. We were unable to demonstrate a relationship between maternal education and cardiorespiratory fitness in girls. This result may be because mothers themselves have less cardiorespiratory fitness as perceived by girls sharing similar interests, or that parents have greater expectations for sports participation for sons than for daughters.[50,51] There may be other unmeasured environmental and genetic factors responsible, although one would expect a lesser contribution of genetic differences in the prepubertal age group.[52]

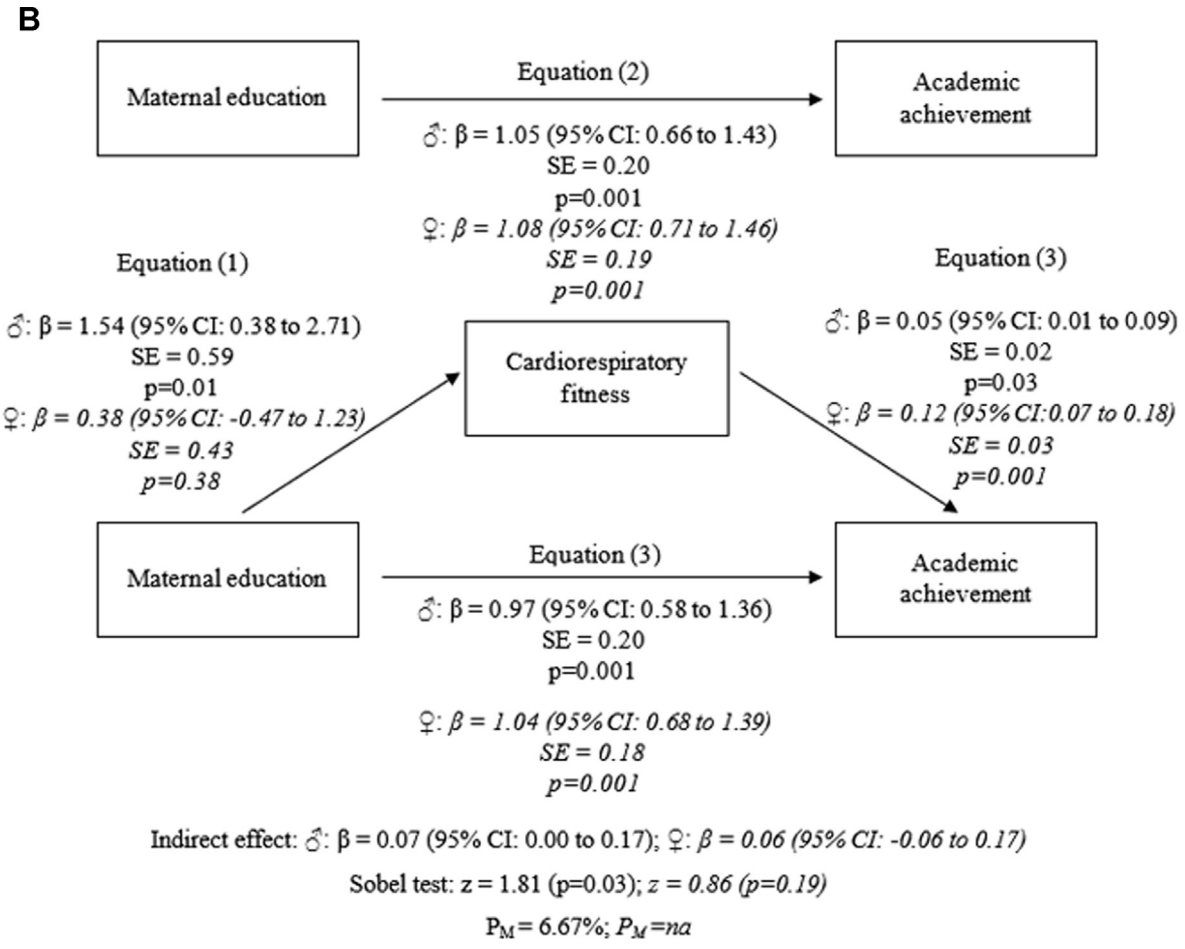

Figure 3. (Continued)

This study should be interpreted in light of several limitations. First, although it seems logical to assume that the education level of mothers preceded, in most cases, the cardiorespiratory fitness level and school grades of children, it is plausible that maternal educational attainment could change over time, influencing these associations. Thus, the cross-sectional design of this analysis prevents us from making cause-effect inferences, and prospective studies should be implemented to clearly establish the temporality of these relationships. Second, the study sample included only Spanish children from the fourth and fifth grades, so caution is necessary when extrapolating these data to another population, age range, or to children of non-Caucasian origins. Third, we used the 20-m shuttle run test to determine the cardiorespiratory fitness level, and the assessment of other physical fitness components, such as strength and speed/agility, could have different results. Fourth, it is possible that an index integrating comprehensively all areas of the curriculum would result in a more complete measure of academic achievement, but it was not possible with the current Spanish system of academic evaluations in the schools. Finally, other variables that were not controlled (such as nutritional status, physical activity level, self-concept, or sociological factors); unmeasured confounding could have influenced the relationship between maternal education level and cardiorespiratory fitness and academic achievement, particularly when considering the sex differences we describe.

Despite these limitations, our study had several strengths. We included a sample with a homogeneous age range of children that permitted us to compare differences by sex. In addition, we are unaware of previous approaches using mediation analysis to clarify these relationships.

Our findings have clinical implications because they reinforce the need for pediatricians to encourage physical activity aimed at optimizing cardiorespiratory fitness. This not only improves general health, but also may yield better academic achievement; whether this might mitigate inequities related to lower maternal education remains to be seen.[53] In our opinion, pediatricians should inform and sensitize families about the importance of physical activity in childhood, encourage and reinforce to families the value of physical activity in their children, and refer families to community resources to facilitate and provide opportunities for their children to be physically active.

In conclusion, our findings show that maternal education level is associated with a better level of cardiorespiratory

fitness in boys. Moreover, both a high level of maternal education and cardiorespiratory fitness are associated with academic success in schoolchildren, because the relationship between cardiorespiratory fitness and academic achievement remains after controlling for maternal education level. Therefore, promoting exercise activities aimed at improving cardiorespiratory fitness level in children should be a priority, especially for children whose mothers have a lower education level. ■

We thank schools, schoolchildren, teachers, and families for their collaboration and participation in the study.

Submitted for publication Aug 7, 2020; last revision received Jan 16, 2021; accepted Jan 21, 2021.

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Table II. Correlation coefficients among CRF, maternal education level, and academic achievement, by sex

	CRF		Maternal education level		Academic achievement		Language	
		P value		*P* value		*P* value		*P* value
Maternal education level								
Total	0.145*	.001						
Boys	0.184*	.005						
Girls	0.096*	.129						
Academic achievement								
Total	0.254*	.001	0.301	.001				
Boys	0.213*	.001	0.293	.001				
Girls	0.338*	.001	0.311	.001				
Language								
Total	0.234*	.001	0.292	.001	0.896	.001		
Boys	0.214*	.001	0.281	.001	0.911	.001		
Girls	0.342*	.001	0.309	.001	0.890	.001		
Mathematics								
Total	0.255*	.001	0.307	.001	0.906	.001	0.757	.001
Boys	0.197*	.003	0.305	.001	0.915	.001	0.787	.001
Girls	0.310*	.001	0.307	.001	0.908	.001	0.751	.001

CRF, cardiorespiratory fitness; *VO_2 max*, maximal oxygen intake.
CRF indicates VO_2 max (mL/kg/h) values calculated with Leger formula. Academic achievement is the mean of language and mathematics grades. Results indicate Kendall tau-b correlation coefficients, except for *Pearson correlation coefficients.