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Cardiorespiratory Fitness and Muscular Strength as Mediators of the Influence of Fatness on Academic Achievement

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Objective To examine the combined association of fatness and physical fitness components (cardiorespiratory fitness [CRF] and muscular strength) with academic achievement, and to determine whether CRF and muscular strength are mediators of the association between fatness and academic achievement in a nationally representative sample of adolescents from Chile.

Study design Data were obtained for a sample of 36 870 adolescents (mean age, 13.8 years; 55.2% boys) from the Chilean System for the Assessment of Educational Quality test for eighth grade in 2011, 2013, and 2014. Physical fitness tests included CRF (20-m shuttle run) and muscular strength (standing long jump). Weight, height, and waist circumference were assessed, and body mass index and waist circumference-to-height ratio were calculated. Academic achievement in language and mathematics was assessed using standardized tests. The PROCESS script developed by Hayes was used for mediation analysis.

Results Compared with unfit and high-fatness adolescents, fit and low-fatness adolescents had significantly higher odds for attaining high academic achievement in language and mathematics. However, in language, unfit and low-fatness adolescents did not have significantly higher odds for obtaining high academic achievement. Those with high fatness had higher academic achievement (both language and mathematics) if they were fit. Linear regression models suggest a partial or full mediation of physical fitness in the association of fatness variables with academic achievement.

Conclusions CRF and muscular strength may attenuate or even counteract the adverse influence of fatness on academic achievement in adolescents. *(J Pediatr 2017;187:127-33).*

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Successful academic development during adolescence underpins potential occupational success later in life.[1] Obesity might have a detrimental effect on academic achievement in adolescents[2-6]; however, this influence seems weak,[7] and other factors, such as socioeconomic status,[8] screen time,[9] or physical fitness,[10] might be interrelated.

Physical fitness is a marker of health in children and adolescents.[11] The main components of physical fitness are cardiorespiratory fitness (CRF), muscular strength, and motor ability; however, CRF and muscular strength are the components with the greatest potential to improve health.[12] Previous studies have shown that CRF and muscular strength may prevent the development of cardiovascular and metabolic diseases, obesity, and mental illness. In addition, a growing body of evidence suggests that physical fitness is associated with better academic achievement,[13] although this association may differ among specific components of physical fitness. More specifically, evidence for a relationship between muscular strength and academic achievement is scarce, but there is evidence of a positive association with CRF.[14,15]

Most previous studies did not take into consideration the combined association of physical fitness and fatness. Sardinha et al[3] found that aerobically fit and normal-weight students were more likely to have better school performance. When examining the interdependence among fitness, fatness, and academic achievement, previous studies usually performed multiple linear regression, logistic regression, or analysis of covariance to adjust for confounding or mediator variables; however, these multivariate methods did not account for the percentage of the total effect explained by the potential covariates.

BMI	Body mass index
CRF	Cardiorespiratory fitness
SIMCE	System for the Assessment of Educational Quality
TEM	Technical error of measurement
WC	Waist circumference
WHtR	Waist-to-height ratio

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The purpose of this study was twofold: to examine the combined association of fatness and physical fitness components with academic achievement and to determine whether CRF and muscular strength are mediators of the association between fatness and academic achievement.

Methods

The methodology of this study is described in detail elsewhere.[16] In brief, this cross-sectional analysis is based on data drawn from a national sample of students (the Chilean Agency of Quality for Education [Agencia de Calidad de la Educación, Gobierno de Chile]), including all students enrolled in eighth grade (mean age, 13.83 years) who completed a standardized test, the System for Assessment of Educational Quality (SIMCE) and the SIMCE in physical education, administered by the Chilean Ministry of Education in November 2011, 2013, and 2014.[17] The SIMCE test was not carried out in 2012.

The sample was stratified by 15 regions in Chile (with the exception of Easter Island, the Juan Fernández archipelago, and the Antarctic) and by 3 school types (public, private subsidized, and private nonsubsidized). Within each stratum, schools were the primary sampling unit, and all students in the selected schools were sampled.

A total of 50 549 students participated in the SIMCE in physical education. After exclusion of students because of erroneous data entry, disability, temporary illness or injury, chronic illness, absenteeism, age ≥18 years, missing body mass index (BMI) data, missing waist circumference (WC) data, or missing academic data, the present series comprised a total of 36 870 adolescents (72.94 % of the original sample) from 3 different cohorts and 669 schools.

The SIMCE test for physical education consists of a fitness and anthropometric assessment using a standardized battery of fitness tests administered in November of each test year. The full protocol and battery of tests have been described previously.[16]

For the anthropometric measurements, the students wore light clothing and were barefoot. Data were recorded on paper by Ministry of Education evaluators.[17] Weight was measured to the nearest 0.1 kg, and height was measured to the nearest 0.1 cm. BMI was calculated as body weight in kilograms divided by the square of height in meters. Weight status and increased adiposity were defined as a BMI above the age- and sex-specific thresholds of the International Obesity Task Force.[18]

WC was measured by placing a nonelastic tape measure midway between the lowest rib margin and the iliac crest and recorded to the nearest 0.1 cm. WC was classified using criterion-referenced, health-related cutpoints derived from de Ferranti et al[19] because of the large size, age-specificity, and relatively generalizable ethnicity (ie, the Chilean population is roughly 59% non-Hispanic white) of the sample. WC and height were used to calculate waist-to-height ratio (WHtR); central obesity was defined as a WHtR ratio ≥0.5.[20]

Testing procedures were consistent with guidelines for school-based physical fitness assessment.[21] At each school, a team of trained Ministry of Education evaluators (n = 5 each year) administered the tests with the same instruments in partnership with the physical education instructor. Tests were administered in the school gymnasium or on another available hard surface.[17] Consistent with recommendations,[22,23] our analysis was limited to health-related, valid, and reliable field-based tests, such as the 20-m shuttle run and standing long jump test.

The 20-m shuttle run was used to assess CRF. The test was performed as described by Léger et al.[24] Each participant ran in a straight line between 2 lines 20 m apart while keeping pace with prerecorded audio signals. The initial speed of 8.5 km/hour was increased by 0.5 km/hour each minute. The test was completed when the participant failed to reach the end lines keeping pace with the audio signals on 2 consecutive occasions or when he or she stopped because of fatigue. Results were recorded to the nearest stage completed. The Léger equation was used to determine peak oxygen uptake (mL/kg/minute) in each adolescent.[24] Fit adolescents were defined using the age- and sex-specific cutoffs listed for the healthy fitness zone in the 2011 FITNESSGRAM.[25]

The standing long jump was used to assess muscular strength. In this test, the participant stood behind the starting line and was instructed to push off vigorously and jump as far as possible. The participant had to land with the feet together and remain upright. The test was repeated twice, and the longer distance was recorded to the nearest 0.1 cm. To classify muscular strength, we considered the risk group to be the age- and sex-specific 20th percentile of standing long jump for European adolescents,[26] because the lower quintile in this sample had the strongest association with a poor cardiometabolic risk profile.[27]

All measurements in a subsample of 50 adolescents (28 girls, 22 boys; mean [SD] age, 13.7 [1.0] years; mean [SD] weight, 56.2 [10.4] kg; mean [SD] height, 1.60 [7.0] m; mean [SD] BMI, 20.9 [3.5]) were repeated by administering the tests again 1 week later with several physical education instructors from the last SIMCE (2015). Technical errors of measurement (TEMs) for weight, height, and ANOVA-based intraclass correlations (*R*) and corresponding 95% CIs were used to estimate test-retest reliability. For anthropometric measures, TEMs were 0.1 cm for height, 0.1 kg for weight, and 0.2 cm for WC. For physical fitness tests, *R* ranged from 0.89 (95% CI, 0.84-0.92) for the 20-m shuttle run to 0.96 (95% CI, 0.94-0.98) for the standing broad jump.

The SIMCE measures national curricular objectives for language and mathematics as established by the Chilean Ministry of Education. The language test evaluates reading and writing ability. The mathematics test evaluates the ability to understand concepts and numerical operations, ability to use simple nonfractional algebraic expressions and apply them to solve problems using the correct approach, and ability to solve first-degree equations with a single unknown quantity. The test, administered by the Ministry of Education evaluators, comprises both multiple-choice items and open-ended questions, and is scored on a scale of 0-400.

In the present study, scores were categorized according to the achievement levels established by the Ministry of Educa-