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RESEARCH ARTICLE

# Poverty Status Moderates the Relationship between Cardiorespiratory Fitness and Academic Achievement

RUSSELL R. PATE, PhD[a] MORGAN CLENNIN, PhD[b] EMILY R. SHULL, MS, PhD[c] JULIAN A. REED, EdD, MPH[d] MARSHA DOWDA, DrPH[e]

## ABSTRACT

**BACKGROUND:** The purpose of the study was to examine the associations among cardiorespiratory fitness (CRF), weight status and academic achievement in youth, and to determine if these relationships are moderated by poverty status.

**METHODS:** The sample included 5th (N = 27,791) and 8th grade (N = 16,047) South Carolina students. Academic achievement was assessed using a state-wide assessment and classified into 2 categories (ie, does not meet/approaches standards vs meets/exceeds standards). CRF was assessed and expressed as Healthy Fitness Zone (HFZ) or Needs Improvement/Needs-Improvement-Health Risk. Students' demographics and poverty status were reported. Multilevel logistic regression analyses were used to examine the association between CRF, weight status and academic achievement. Interaction terms were introduced into the final models. Analyses were performed separately by grade level and academic subject.

**RESULTS:** The CRF was significantly associated with the odds of meeting/exceeding academic standards after controlling for covariates and adjusting for weight status. The relationship between CRF and academic achievement varied significantly by poverty status. After adjustment for CRF, weight status was not significantly associated with academic achievement.

**CONCLUSIONS:** The odds of achieving academic standards were significantly higher among students achieving CRF HFZ regardless of poverty status. CRF may partially mitigate the adverse effect of poverty on academic achievement.

**Keywords:** socioeconomic status; schools; physical fitness; children.

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Cardiorespiratory fitness (CRF) reflects a person's ability to perform whole-body physical activities like brisk walking, stair climbing and demanding occupational and recreational tasks.[1-4] The health effects of CRF are well-documented among adults and youth.[5-9] In youth, CRF is associated with physiologic risk factors for cardio-metabolic diseases in later life as well as adiposity levels and psychosocial health.[4,10-12] More recently, research has indicated the potential influence of CRF on indicators of brain health in children and youth.[13-15] In both experimental and observational studies, higher levels of CRF have been observed to be associated with better executive function, brain structure, and cognitive abilities in school-aged youth.[14,15] In addition, several studies have reported positive associations between CRF and academic achievement in large samples of children and adolescents.[16-22]

Whereas the association between CRF and academic achievement in youth has been reported frequently,

[a]Professor, (rpate@mailbox.sc.edu), Department of Exercise Science, University of South Carolina, Arnold School of Public Health, 921 Assembly St., Suite 212, Columbia, SC 29208.

[b]Postdoctoral Research Fellow, (clennin@email.sc.edu), Kaiser Permanente of Colorado, Institute of Health Research, 2550 S. Parker Rd., Ste 200, Aurora, CO 80014.

[c]PhD Candidate, (ershull@email.sc.edu), Department of Exercise Science, University of South Carolina, Arnold School of Public Health, 921 Assembly St., Suite 212, Columbia, SC 29208.

[d]Professor, (julian.reed@furman.edu), Department of Health Sciences, Furman University, 3300 Poinsett Hwy, Greenville, SC 29613.

[e]Biostatistician, (mdowda@mailbox.sc.edu), Department of Exercise Science, University of South Carolina, Arnold School of Public Health, 921 Assembly St., Suite 212, Columbia, South Carolina 29208.

Address correspondence to: Russell R. Pate, (rpate@mailbox.sc.edu), Department of Exercise Science, University of South Carolina, Arnold School of Public Health, 921 Assembly St., Suite 212, Columbia, SC 29208.

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the factors that may influence that association have not been studied extensively. It is well established that weight and adiposity tend to be negatively associated with CRF,[4,23,24] and some evidence suggests that adiposity may be negatively associated with academic achievement.[17,25] But few studies have examined the independence of the associations of CRF and weight status with academic achievement. Furthermore, CRF has been frequently shown to vary across demographic groups based on sex,[10,24,26] age and race/ethnicity,[24,26] and socioeconomic status.[10,26-29] However, little previous research has examined those factors as possible moderators of the association of CRF and academic achievement.

Over the past decade, several states in the United States have administered physical fitness tests to large, state-wide samples of school children.[21,22,30] Previous state-wide assessments have reported associations between CRF and academic achievement,[16,18,21,22] but few of those studies have considered the independent and joint influences of these associations. Furthermore, a limited number of studies have examined the influence of demographic factors, such as poverty status, on the associations between CRF, weight status, and academic achievement.[18,30] In South Carolina, CRF, and weight status have been measured in state-wide samples of students attending public schools, and those data have been linked to students' demographic characteristics and academic test scores. Accordingly, the purposes of this study were: (1) to examine the associations between CRF, weight status, and academic achievement in a large, diverse sample of school children; and (2) to determine if these relationships are moderated by poverty status.

## METHODS

### Participants

Data in the present study were obtained from the South Carolina Departments of Health and Environmental Control (DHEC) and Education (SCDE). Health-related fitness data for the study were obtained from South Carolina's FitnessGram project conducted during the 2016-2017 school year. FitnessGram is a physical fitness test battery that is widely used in US schools. The project is a state-wide observational study designed to evaluate health-related fitness among South Carolina students, grades K-12. During the 2016-2017 school year, approximately 700 (56%) South Carolina public schools within 60 (58%) school districts participated in the FitnessGram project. Student academic achievement information was obtained from standardized test data provided by the SCDE. De-identified student-level fitness and academic achievement data were used to examine the relationship between health-related fitness and academic achievement among students in South Carolina. The original sample included 37,283 5th graders and 22,756 8th graders. Deletions were made for missing data for weight status, cardiorespiratory fitness, measures of academic achievement, race/ethnicity, and/or poverty status. The final analytic sample included 43,838 students with complete data (5th grade, N = 27,791 and 8th grade, N = 16,047 students).

### Instrumentation and Procedure

***Academic achievement.*** Academic achievement was assessed using data from the South Carolina College-and Career-Ready Assessment (SC READY). This state-wide standardized test is used to measure students' achievement of academic standards in mathematics and English language arts (ELA). Test items are aligned with the South Carolina College- and Career-Ready Standards for English Language Arts and Mathematics.[31] During each school year, SC READY is administered to students in grades 3 to 8 during the last 30 days of the school year. Students' test scores in mathematics and ELA are then classified into one of 4 academic achievement categories using established scoring standards: does not meet, approaches, meets, and exceeds. For the current analyses, academic achievement categories were combined to model the odds of meeting academic achievement standards (ie, does not meet/approaches standards vs meets/exceeds standards).

***Cardiorespiratory fitness.*** As part of FitnessGram, CRF was assessed by the Progressive Aerobic Cardiovascular Endurance Run (PACER) test, a 1-mile run test, or a 1-mile walk test. The PACER test is a multistage, progressive fitness test that involves running across a 15 or 20-m space at an increasing pace for as long as possible. The objectives of the 1-mile run and walk tests were to run/walk as fast as possible for 1 mile.[32] For each fitness field test, CRF was estimated using established protocols.[32] CRF was reported as estimated $VO_2$max and expressed as $mL \cdot kg^{-1} \cdot min^{-1}$. Relative to age- and sex-specific standards, estimated $VO_2$max was categorized into one of 3 health zones: (1) Healthy Fitness Zone (HFZ); (2) Needs Improvement; and (3) Needs Improvement—Health Risk. These fitness field tests have been found to be reliable and valid assessments of CRF.[32] Fitness testing was conducted by school staff (primarily physical education teachers) during physical education classes. School staff received training support through the President's Youth Fitness Program prior to administering the FitnessGram test items.[32]

***Weight status.*** Using height and weight measurements obtained by trained school staff, body mass index (BMI) was calculated and participants were classified into weight status categories using CDC growth charts.[33] These categories consisted of normal weight

(5th percentile to <85th percentile), overweight (85th percentile to <95th percentile), and obese (≥95th percentile). Using a calculated z-score[34], children with implausible BMI values were not used for the analysis.

***Student characteristics.*** Student demographic characteristics were obtained from school staff via the FitnessGram software or the SC DHEC. Sex was reported as male or female. Race/ethnicity groups included non-Hispanic white, non-Hispanic black, Hispanic or Latino, and other (including multiracial). Student poverty status was assessed at day 135 of the 2016-2017 school year. This was defined by the SCDE as student enrollment in Medicaid, Supplemental Nutrition Assistance Program (SNAP), Temporary Assistance for Needy Families (TANF), or Foster Care Services within the past 3 years (February 2014 to January 2017) and/or student homelessness/migrant status during the 2016-2017 school year. For the current analyses, student poverty status was expressed categorically as Yes (living in poverty) based on the aforementioned criteria or No.

### Data Analysis

Descriptive statistics were applied to the analytic sample. Multilevel logistic regression was used to examine the relationship between FitnessGram components and academic achievement. Specifically, the odds of achieving academic standards (ie, meeting/exceeding standards) were modeled. Separate logistic regression models (PROC GLIMMIX using SAS 9.4 statistical software) were conducted for each academic subject (mathematics and ELA) by FitnessGram component (CRF and weight status) and grade level (5th grade and 8th grade). First, the unadjusted association between academic achievement and the health-related fitness component was examined. Then student-level covariates were added to the model to examine the adjusted relationship. The models for weight status were adjusted for cardiorespiratory fitness, expressed as a continuous variable (maximal aerobic power), and the models for cardiorespiratory fitness were adjusted for weight status expressed as a continuous variable (BMI). Finally, interaction terms were introduced into the final models to examine the potential moderating role of demographic variables. To interpret significant interactions, the analytic sample was stratified by covariate of interest and the final models were rerun. Odds ratios and p-values for linear trends were produced. All models accounted for nesting of students within schools. Model fit and assumption were checked for each model; Akaike's Information Criteria (AIC), Bayesian Information Criteria (BIC), and −2 Loglikelihood (−2LL) were used to assess model fit. An alpha < .05 was used to denote statistical significance for 2-sided statistical tests.

## RESULTS

Table 1 presents descriptive characteristics for the sample of South Carolina students. Approximately 63% of the overall sample was enrolled in 5th grade and the remaining 37% was enrolled in 8th grade. Sex was distributed equally between boys and girls. The sample was racially/ethnically diverse, and approximately 55% were living in poverty (poverty status = yes). Approximately 40% of the sample was overweight/obese and just over half achieved the HFZ for CRF. For academic achievement, about 40% of the sample met and/or exceeded academic standards for mathematics and ELA. Furthermore, we examined the distribution of academic achievement categories across race/ethnicity and poverty groups, and the findings of that analysis are presented in Table 2. While meeting the academic standards was unevenly distributed across race/ethnicity and poverty groups, substantial percentages of students in non-White and poverty groups met the academic standards.

Table 3 presents results from logistic regression analyses examining the odds of meeting/exceeding academic standards in mathematics and ELA by weight status categories among 5th- and 8th-grade students. In each model, the unadjusted association between weight status, and academic achievement was significant regardless of grade level or academic subject. Among 5th-grade students, the odds of meeting/exceeding academic achievement standards in mathematics and ELA were 23% and 34% greater among normal-weight students compared to obese students, respectively (odds ratio [OR] = 1.23, 95% confidence interval [CI] = 1.16-1.31; OR = 1.34, 95% CI = 1.25-1.43). Similarly, the odds of meeting/exceeding academic achievement standards in 8th grade for mathematics and ELA were 62% and 54% greater among normal-weight students compared to obese students (OR = 1.62, 95% CI = 1.48-1.77; OR = 1.54, 95% CI = 1.41-1.68). However, the relationship was attenuated after adjusting for student-level characteristics. Specifically, the adjusted odds of meeting/exceeding academic standards were not significantly associated with weight status after accounting for sex, race/ethnicity, poverty status, and CRF. The only exception was a significant association between the adjusted odds of meeting/exceeding mathematics standards by weight status categories in 5th grade.

Next, the unadjusted and adjusted associations between CRF and academic achievement in mathematics and ELA were examined among 5th- and 8th-grade students. Table 4 depicts the odds of meeting/exceeding academic standards in mathematics and ELA stratified by CRF categories and grade level. After adjusting for student-level covariates, the association between CRF and academic achievement

Table 1. **Student Characteristics for the Overall Sample and by Grade Level**

| | Total (N = 43,838) | | 5th Grade (N = 27,791) | | 8th Grade (N = 16,047) | |
|---|---|---|---|---|---|---|
| | N | % | N | % | N | % |
| Sex | | | | | | |
| Boys | 22,267 | 50.8% | 13,889 | 50.0% | 8378 | 52.2% |
| Girls | 21,571 | 49.2% | 13,902 | 50.0% | 7669 | 47.8% |
| Race/ethnicity | | | | | | |
| Non-Hispanic White | 23,933 | 54.6% | 14,850 | 53.4% | 9083 | 56.6% |
| Non-Hispanic Black | 12,768 | 29.1% | 8190 | 29.5% | 4578 | 28.5% |
| Hispanic/Latino | 4590 | 10.5% | 3090 | 11.1% | 1500 | 9.4% |
| Other | 2547 | 5.8% | 1661 | 6.0% | 886 | 5.5% |
| Poverty status | | | | | | |
| No | 19,579 | 44.7% | 11,748 | 42.3% | 7831 | 48.8% |
| Yes | 24,259 | 55.3% | 16,043 | 57.7% | 8216 | 51.2% |
| Cardiorespiratory fitness | | | | | | |
| Cardiorespiratory fitness (mean, SD) | 43,838 | 42.0 (6.0) | 27,791 | 42.0 (5.4) | 16,047 | 41.9 (7.1) |
| Healthy fitness zone | 22,806 | 52.0% | 14,875 | 53.5% | 7931 | 49.4% |
| Needs improvement | 11,593 | 26.5% | 8524 | 30.7% | 3069 | 19.1% |
| Health risk | 9439 | 21.5% | 4392 | 15.8% | 5047 | 31.5% |
| Weight status | | | | | | |
| Body mass index (mean, SD) | 43,838 | 21.6 (5.3) | 27,791 | 20.8 (5.0) | 16,047 | 23.0 (5.5) |
| Normal weight | 26,111 | 59.6% | 16,200 | 58.3% | 9911 | 61.8% |
| Overweight | 7819 | 17.8% | 4960 | 17.9% | 2859 | 17.8% |
| Obese | 9908 | 22.6% | 6631 | 23.9% | 3277 | 20.4% |
| English language arts | | | | | | |
| Does not meet | 10,869 | **24.9%** | 6808 | **24.5%** | 4061 | **25.4%** |
| Approaches | 14,828 | **33.9%** | 9531 | **34.4%** | 5297 | **33.1%** |
| Meets | 12,600 | **28.8%** | 8102 | **29.2%** | 4498 | **28.1%** |
| Exceeds | 5447 | **12.5%** | 3297 | **11.9%** | 2150 | **13.4%** |
| Mathematics | | | | | | |
| Does not meet | 10,994 | **25.1%** | 6574 | **23.7%** | 4420 | **27.5%** |
| Approaches | 14,677 | **33.5%** | 9012 | **32.4%** | 5665 | **35.3%** |
| Meets | 9458 | **21.6%** | 6218 | **22.4%** | 3240 | **20.2%** |
| Exceeds | 8709 | **19.9%** | 5987 | **21.5%** | 2722 | **17.0%** |

for mathematics and ELA remained significant across both grade levels. More specifically, the odds of meeting/exceeding academic standards increased across CRF categories, with the greatest odds of meeting/exceeding academic standards observed among students that achieved the HFZ compared to students in the health risk category. For example, the odds of meeting/exceeding the academic standards for ELA were 88% and 41% greater among 5th-grade students achieving the CRF HFZ and CRF needs improvement categories compared to 5th-grade students achieving the CRF health risk category, respectively (HFZ: OR = 1.88, 95% CI = 1.71-2.07; needs improvement: OR = 1.41, 95% CI = 1.29-1.55). Similar associations and patterns were observed among 8th-grade students and for mathematics. Notably, the magnitude of the association between CRF and academic achievement was stronger for mathematics than ELA across both grade levels.

Given the observed association between CRF and academic achievement, interaction terms were introduced into the adjusted CRF and academic achievement models to determine whether the relationship varied by sex, race/ethnicity, and poverty status. A consistent significant interaction between CRF and poverty status was observed across each grade level and academic subject ($p < .05$). To further examine the odds of meeting/exceeding academic achievement standards by poverty status, the sample was stratified by poverty status and the final models were rerun, adjusting for interactions of CRF*Race and CRF*Sex. Figures 1 and 2 depict the odds of meeting/exceeding academic standards in mathematics and ELA across CRF categories by poverty status and grade level. Across the CRF categories, the odds of meeting/exceeding academic standards in mathematics and ELA increased significantly as CRF increased, regardless of poverty status (linear trend: $p < .001$). However, the magnitude of the observed associations was weaker among students living in poverty. For example, among 8th-grade students not in poverty (poverty status = no), the odds of meeting academic standards in ELA among students achieving the CRF HFZ was 2.49 times the odds the of meeting/exceeding the academic standards for ELA among students achieving the CRF health risk category (OR = 2.49, 95% CI = 2.02-3.08). Comparatively, among 8th-grade students living in poverty (poverty

Table 2. **Distribution of Student Demographic Characteristics within and across Academic Achievement Categories**

| | 5th Grade | | | 8th Grade | | |
|---|---|---|---|---|---|---|
| | Does Not Meet, Approached, N = 15,586 | Meets, Exceeds N = 12,205 | p-value* | Does Not Meet, Approached, N = 10,085 | Meets, Exceeds N = 5962 | p-value* |
| Mathematics | | | | | | |
| Sex | | | .80 | | | <.001 |
| Boys | 49.9% | 50.1% | | 53.4% | 50.2% | |
| Girls | 50.1% | 49.9% | | 46.6% | 49.8% | |
| Race/ethnicity | | | <.001 | | | <.001 |
| Non-Hispanic White | 41.5% | 68.7% | | 46.9% | 73.1% | |
| Non-Hispanic Black | 40.5% | 15.4% | | 37.7% | 13.1% | |
| Hispanic/Latino | 12.7% | 9.1% | | 10.7% | 7.1% | |
| Other | 5.3% | 6.8% | | 4.8% | 6.7% | |
| Poverty status | | | <.001 | | | <.001 |
| No | 29.0% | 59.3% | | 38.6% | 66.1% | |
| Yes | 71.0% | 40.7% | | 61.5% | 33.9% | |
| English language arts | | | | | | |
| Sex | | | <.001 | | | <.001 |
| Boys | 53.5% | 45.1% | | 57.5% | 55.4% | |
| Girls | 46.6% | 54.9% | | 64.5% | 44.7% | |
| Race/ethnicity | | | <.001 | | | <.001 |
| Non-Hispanic White | 42.2% | 69.8% | | 46.3% | 71.3% | |
| Non-Hispanic Black | 39.3% | 15.5% | | 38.2% | 15.1% | |
| Hispanic/Latino | 13.0% | 8.3% | | 10.5% | 7.4% | |
| Other | 5.6% | 6.5% | | 5.0% | 6.3% | |
| Poverty status | | | <.001 | | | <.001 |
| No | 29.0% | 61.2% | | 37.0% | 65.4% | |
| Yes | 71.0% | 38.8% | | 63.1% | 34.6% | |

status = yes), the odds of meeting academic standards in ELA for students achieving the CRF HFZ was 1.68 times the odds of meeting/exceeding the academic standards for ELA among students achieving the CRF health risk category (OR = 1.68, 95% CI = 1.41-1.99).

## DISCUSSION

The key finding of this study was that, in a large and diverse sample of elementary and middle school students, CRF was consistently and independently associated with academic achievement as assessed by standardized tests of mathematics and ELA. Higher CRF was associated with a greater likelihood of meeting academic achievement standards in both 5th- and 8th-grade students, and these associations remained significant after adjustment for sex, race/ethnicity, poverty status, and BMI. A unique finding was that the observed associations between CRF and academic achievement varied by students' poverty status. Students living in poverty were less likely than their more affluent peers to meet academic standards. However, higher CRF was associated with better academic achievement in both poverty status groups. Importantly, in both groups, dose-response relationships were observed between CRF category and academic achievement category. The present study extends this line of research by demonstrating that higher CRF is robustly associated with better academic achievement after consideration of student's poverty status. This finding is important because poverty status has been shown consistently to exert a negative influence on academic achievement.[35] The cross-sectional design of the present study precludes concluding that the association between CRF and academic achievement is causal. This possibility should be considered in future research using experimental or prospective, observational study designs.

Similar to existing literature, our findings demonstrate a positive association between CRF and academic achievement.[18-20,22,30,36-38] In the past decade, evidence examining the relationship between components of CRF and academic achievement has grown substantially. More recently, several systematic reviews have concluded that strong evidence supports the relationship between CRF and academic achievement.[37,38] While most of these studies have controlled for individual-level confounders, the present study is one of the first to show that the relationship between CRF and academic achievement varies by poverty status. Another study that examined these relationships in 11,7443 students in grades 4 to 8 also concluded that higher CRF was associated with greater odds of achieving academic standards and that the effect was significantly lower among students receiving free/reduced price lunch.[36] However, several

Table 3. **Academic Achievement and Weight Status: Odds of Meeting/Exceeding Academic Standards Based on Weight Status and Individual-level Covariates**

| | Grade | | | |
|---|---|---|---|---|
| | 5th Grade | | 8th Grade | |
| **Variables** | **Unadjusted Model OR (95% CI)** | **Adjusted Model OR (95% CI)** | **Unadjusted Model OR (95% CI)** | **Adjusted Model OR (95% CI)** |
| Mathematics | | | | |
| Weight status | | | | |
| Normal weight | **1.23 (1.16, 1.31)** | **0.81 (0.75, 0.87)** | **1.62 (1.48, 1.77)** | 0.99 (0.90, 1.10) |
| Overweight | **1.14 (1.05, 1.23)** | **0.91 (0.84, 0.99)** | **1.33 (1.19, 1.49)** | 1.03 (0.91, 1.16) |
| Obese | Reference | Reference | Reference | Reference |
| Sex | | | | |
| Girls | | **1.15 (1.09, 1.22)** | | **1.56 (1.44, 1.69)** |
| Boys | | | | Reference |
| Race/Ethnicity | | | | |
| Black | | **0.33 (0.30, 0.35)** | | **0.28 (0.25, 0.31)** |
| Hispanic | | **0.59 (0.54, 0.65)** | | **0.52 (0.45, 0.59)** |
| Other | | **0.86 (0.77, 0.96)** | | **0.90 (0.77, 1.04)** |
| White | | Reference | | Reference |
| Poverty | | | | |
| No | | **2.33 (2.19, 2.47)** | | **2.07 (1.91, 2.23)** |
| Yes | | Reference | | Reference |
| Cardiorespiratory fitness | | **1.06 (1.05, 1.07)** | | **1.05 (1.05, 1.06)** |
| Model fit | | | | |
| −2LL | 35,587.83 | 32,804.75 | 20,041.37 | 18,258.93 |
| AIC | 35,595.83 | 32,826.75 | 20,049.37 | 18,278.93 |
| BIC | 35,611.36 | 32,863.58 | 20,061.33 | 18,308.84 |
| English language arts | | | | |
| Weight status | | | | |
| Normal weight | **1.34 (1.25, 1.43)** | 0.94 (0.87, 1.01) | **1.54 (1.41, 1.68)** | 1.01 (0.91, 1.11) |
| Overweight | **1.24 (1.15, 1.35)** | 1.02 (0.94, 1.11) | **1.26 (1.13, 1.40)** | 0.98 (0.87, 1.10) |
| Obese | Reference | Reference | Reference | Reference |
| Sex | | | | |
| Girls | | **1.69 (1.60, 1.79)** | | **2.41 (2.23, 2.61)** |
| Boys | | Reference | | Reference |
| Race | | | | |
| Black | | **0.33 (0.31, 0.36)** | | **0.28 (0.26, 0.31)** |
| Hispanic | | **0.54 (0.49, 0.59)** | | **0.55 (0.48, 0.62)** |
| Other | | **0.78 (0.70, 0.87)** | | **0.75 (0.65, 0.88)** |
| White | | Reference | | Reference |
| Poverty | | | | |
| No | | **2.47 (2.33, 2.62)** | | **2.23 (2.06, 2.40)** |
| Yes | | Reference | | Reference |
| Cardiorespiratory Fitness | | **1.04 (1.04, 1.05)** | | **1.04 (1.04, 1.05)** |
| Model fit | | | | |
| −2LL | 35,256.22 | 32,307.12 | 20,877.83 | 18,756.68 |
| AIC | 35,264.22 | 32,327.12 | 20,885.83 | 18,776.68 |
| BIC | 35,279.76 | 32,365.96 | 20,897.79 | 18,806.59 |

*Note:* Bolded values indicate significant odds ratios ($p < .05$).
CI, confidence interval; OR, odds ratio; 2LL, − 2 Loglikelihood.

studies also contradict our finding that poverty status moderates the relationship between CRF and academic achievement.[18,30] For example, Chomitz et al. examined poverty status as a potential moderator of the relationship between CRF and academic achievement among 3990 K-8th-grade students and reported no significant interaction.[18] Given the existing discrepancies across a limited number of studies, the present study extends current literature and has important implications for public health efforts. These findings highlight the influential role of CRF on academic achievement outcomes and support implementation of evidence-based strategies to improve academic achievement among students, especially those living in poverty.

Approximately 19% of children in the United States are obese,[39] and our data indicate that students with normal-weight status were more likely to achieve academic standards. However, this relationship was attenuated by the addition of demographic variables and CRF. Also, BMI was not significant when

Table 4. **Academic Achievement and Cardiorespiratory Fitness: Odds of Meeting/Exceeding Academic Standards Based on Cardiorespiratory Fitness Healthy Fitness Zone and Individual-level Covariates**

| | Grade | | | |
|---|---|---|---|---|
| | 5th Grade | | 8th Grade | |
| **Variables** | **Unadjusted Model OR (95% CI)** | **Adjusted Model OR (95% CI)** | **Unadjusted Model OR (95% CI)** | **Adjusted Model OR (95% CI)** |
| Mathematics | | | | |
| Cardiorespiratory fitness health fitness zone | | | | |
| Healthy fitness zone | **2.31 (2.13, 2.51)** | **2.34 (2.12, 2.58)** | **2.32 (2.13, 2.52)** | **2.12 (1.92, 2.35)** |
| Needs improvement | **1.54 (1.41, 1.67)** | **1.55 (1.42, 1.70)** | **1.51 (1.36, 1.68)** | **1.37 (1.23, 1.54)** |
| Health risk | Reference | Reference | Reference | Reference |
| Sex | | | | |
| Girls | | **1.09 (1.03, 1.15)** | | **1.33 (1.24, 1.44)** |
| Stress | | Reference | | Reference |
| Race | | | | |
| Black | | **0.32 (0.30, 0.35)** | | **0.27 (0.25, 0.30)** |
| Hispanic | | **0.58 (0.53, 0.64)** | | **0.52 (0.46, 0.60)** |
| Other | | **0.84 (0.76, 0.94)** | | 0.89 (0.76, 1.03) |
| White | | Reference | | Reference |
| Poverty | | | | |
| No | | **2.34 (2.21, 2.48)** | | **2.08 (1.93, 2.25)** |
| Yes | | Reference | | Reference |
| Body mass index | | **1.02 (1.01, 1.03)** | | 0.99 (0.99, 1.03) |
| Model fit | | | | |
| −2LL | 35,171.83 | 32,786.93 | 19,767.93 | 18,262.66 |
| AIC | 35,179.83 | 32,806.93 | 19,775.93 | 18,282.66 |
| BIC | 35,195.36 | 32,845.76 | 19,775.94 | 18,312.56 |
| English language arts | | | | |
| Cardiorespiratory fitness health fitness zone | | | | |
| Healthy fitness zone | **1.95 (1.79, 2.12)** | **1.88 (1.71, 2.07)** | **1.97 (1.81, 2.13)** | **1.89 (1.72, 2.09)** |
| Needs improvement | **1.50 (1.37, 1.63)** | **1.41 (1.29, 1.55)** | **1.57 (1.42, 1.73)** | **1.34 (1.21, 1.50)** |
| Health risk | Reference | Reference | Reference | Reference |
| Sex | | | | |
| Girls | | **1.62 (1.54, 1.72)** | | **2.11 (1.96, 2.27)** |
| Boys | | Reference | | Reference |
| Race | | | | |
| Black | | **0.33 (0.31, 0.36)** | | **0.28 (0.26, 0.31)** |
| Hispanic | | **0.53 (0.48, 0.58)** | | **0.55 (0.48, 0.63)** |
| Other | | **0.77 (0.69, 0.86)** | | **0.74 (0.64, 0.87)** |
| White | | Reference | | Reference |
| Poverty | | | | |
| No | | **2.48 (2.34. 2.63)** | | **2.24 (2.07, 2.41)** |
| Yes | | Reference | | Reference |
| Body mass index | | 1.01 (0.99, 1.01) | | 1.00 (0.99, 1.01) |
| Model fit | | | | |
| −2LL | 35,069.06 | 32,285.98 | 20,717.34 | 18,753.07 |
| AIC | 35,077.06 | 32,305.98 | 20,722.34 | 18,773.07 |
| BIC | 35,092.59 | 32,344.81 | 20,722.34 | 18,802.97 |

*Note:* Bolded values indicate significant odds ratios ($p < .05$).
CI, confidence interval; OR, odds ratio; 2LL, − 2 Loglikelihood.

added to analyses of the relationship between CRF and academic achievement. Across existing studies, there have been mixed findings regarding the relationship between weight status and academic achievement.[17,18,20,40] A study of 259 3rd- and 5th-grade students reported that CRF was positively associated with academic achievement and BMI was significantly inversely associated.[17] In another study of 1478 children (mean age $11.73 \pm 1.58$), fitness achievement (ie, passing scores from number of fitness tests passed) was significantly related to academic achievement using logistic regression models, while BMI z-score was not related after adjustment for race, sex, grade, and socioeconomic status.[18] Fair et al. reported similar results using fourth and fifth graders ($N = 8641$) and CRF (PACER laps) and 5 subject area tests.[20] There were significant positive relationships between PACER laps and academic achievement for each study area after adjustment for grade, race, sex, free/reduced lunch, and BMI z-score. BMI z-score,

Figure 1. **Adjusted Odds of Meeting/Exceeding Mathematics Academic Standards by Cardiorespiratory Fitness Healthy Fitness Zone and Poverty Status[a]**

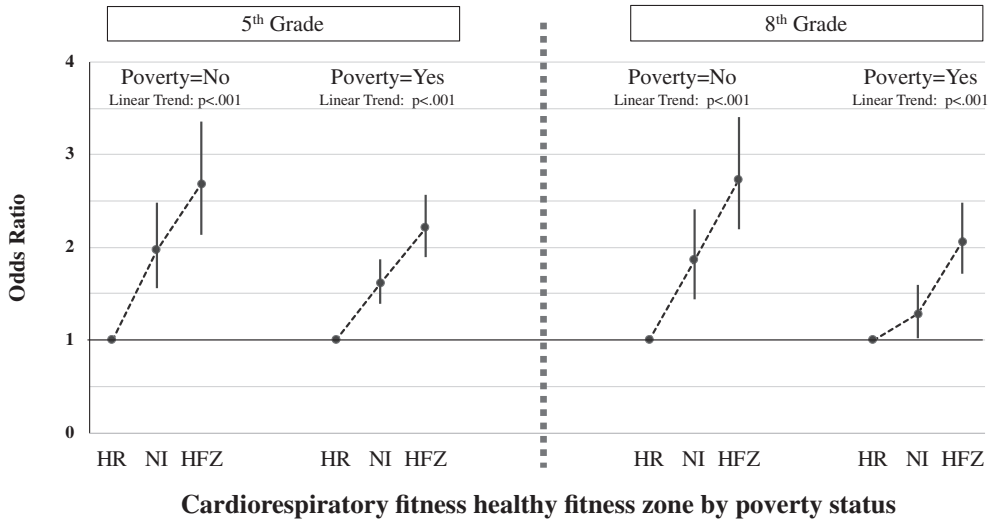
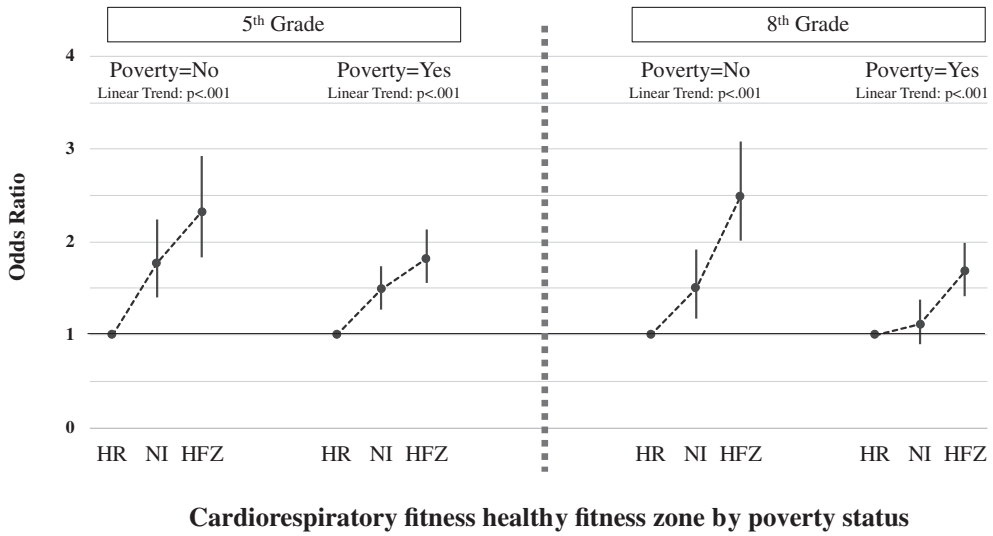



Figure 2. **Adjusted Odds of Meeting/Exceeding English Language Arts Academic Standards by Cardiorespiratory Fitness Healthy Fitness Zone and Poverty Status[a]**




however, was not consistently related to academic achievement, with a significant relationship occurring in only one out of the 5 subject areas.

A major strength of this study is the analytic technique used to examine the independent associations of CRF and weight status on academic achievement, with poverty status as a moderating variable. Furthermore, we accounted for nesting of students within school in all models. Much of the previous literature has failed to control for confounding variables, such as poverty status, and many previous studies had substantial limitations in research designs (eg, small sample sizes and use of non-standardized fitness and academic tests).[19] Additional strengths of this study include a large, racially and ethnically diverse sample, very similar to the population of the children attending public schools in the state of SC, as well as the use of standardized testing protocols. However, this study also had some important limitations. The cross-sectional design does not allow inference of a causal relationship between CRF and academic achievement. Also, while teachers received training in administration of the FitnessGram protocol, it is likely that there was variability across teachers in the manner in which these items were

administered and scored. Furthermore, the analysis samples of 5th- and 8th-grade students were well distributed across sex, race/ethnicity, poverty, fitness categories, and academic achievement categories. However, academic achievement was unevenly distributed across the race/ethnicity and poverty groups. While the analyses were adjusted for demographic factors, those adjustments may not have eliminated the influence of those potential confounding factors.

### Conclusions

In summary, this study examined associations among CRF, weight status, and academic achievement in a state-wide sample of public school students. Furthermore, the study considered the potential moderating effect of children's poverty status on the relationship between CRF and academic achievement. It found that a positive association between CRF and academic achievement was robust and was evident in both children living in poverty and those living in more favorable socioeconomic conditions. These findings suggest that levels of physical activity that produce and maintain higher levels of CRF in children may positively influence their academic achievement. However, because of this study's cross-sectional design, a causal inference cannot be made. Future research on these issues should employ longitudinal, observational, or experimental study designs.

## IMPLICATIONS FOR SCHOOL HEALTH

The findings of this study indicate that schools should adopt policies and practices that provide students with the types and amounts of physical activity that are known to improve and maintain good levels of physical fitness in children and adolescents. Current federal physical activity guidelines recommend that school-age children engage in moderate-to-vigorous physical activity for 60 minutes per day and that vigorous-intensity exercise and muscle-strengthening activities be included at least 3 days per week.[41] Given the substantial amounts of time that youth spend in school, experts have recommended that, on school days, students attain at least one-half of the recommended amount of daily physical activity while at school.[42] Surveillance data suggest that most American students do not attain that goal at the present time.[43] Accordingly, there is a need for school policymakers, administrators, and teachers to modify their policies and practices so that students are physically active enough during the school day to develop and maintain adequate levels of physical fitness.

The Comprehensive School Physical Activity Program is an evidence-based model that can be used by school personnel in identifying practices aimed at providing students with recommended types and amounts of physical activity.[44] Key elements of the model include:

- **Physical education.** Schools should provide students with physical education programs that are delivered by a certified physical educator and that meet national standards for quantity and quality.
- **Physical activity before and after the school day.** Schools can provide students with structured physical activity programs and informal physical activity opportunities in the morning before classes start and during the afterschool time block.
- **Physical activity during the school day.** Structured classroom exercise breaks and physically active instructional strategies can be incorporated into the classroom routine. Such activities have the effect of breaking up extended periods of sedentary behavior as well as contributing to students' physical activity needs.
- **Active transport to and from school.** Students who walk or ride bicycles to school have been shown to receive important doses of physical activity by doing so. Schools can adopt policies and practices that encourage students and their parents to use active transport modalities.
- **Interscholastic and intramural sports and recreation programs.** Students who engage in structured school sports programs, whether those are competitive (eg, varsity sports teams) or recreational (eg, dance clubs), typically receive substantial doses of physical activity through those programs. Schools can adopt policies and programs that encourage all students to engage in such programs.

Schools that adopt policies and practices aimed at insuring that students meet current federal physical activity guidelines contribute importantly to the health of their students. The findings of this study suggest that such schools also increase the likelihood that students will meet important academic standards.

### Human Subjects Approval Statement

The data analyzed in the study were provided through a data sharing agreement with the South Carolina Department of Education and were completely de-identified. The University of South Carolina IRB determined that the study was not human subjects research.

### Conflict of Interest

All authors declare no conflicts of interest.

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