Original article

The Effects of Changes in Physical Fitness on Academic Performance Among New York City Youth

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A B S T R A C T

Purpose: To evaluate whether a change in fitness is associated with academic outcomes in New York City (NYC) middle-school students using longitudinal data and to evaluate whether this relationship is modified by student household poverty.
Methods: This was a longitudinal study of 83,111 New York City middle-school students enrolled between 2006—2007 and 2011—2012. Fitness was measured as a composite percentile based on three fitness tests and categorized based on change from the previous year. The effect of the fitness change level on academic outcomes, measured as a composite percentile based on state standardized mathematics and English Language Arts test scores, was estimated using a multilevel growth model. Models were stratified by sex, and additional models were tested stratified by student household poverty.
Results: For both girls and boys, a substantial increase in fitness from the previous year resulted in a greater improvement in academic ranking than was seen in the reference group (girls: .36 greater percentile point improvement, 95% confidence interval: .09—.63; boys: .38 greater percentile point improvement, 95% confidence interval: .09—.66). A substantial decrease in fitness was associated with a decrease in academics in both boys and girls. Effects of fitness on academics were stronger in high-poverty boys and girls than in low-poverty boys and girls.
Conclusions: Academic rankings improved for boys and girls who increased their fitness level by >20 percentile points compared to other students. Opportunities for increased physical fitness may be important to support academic performance.

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IMPLICATIONS AND CONTRIBUTION

This study shows a relationship between changes in physical fitness and changes in academic performance among middle-school students. Opportunities for improving physical fitness may be an important part of efforts to improve academic performance, particularly for high-poverty students.

In 2010, the Centers for Disease Control and Prevention (CDC) reviewed a growing body of evidence evaluating the relationship between physical activity in schools and academic performance and concluded that both physical education and physical activity may help improve academic performance and are unlikely to impede a student's academic progress [1]. Improved cognition

including better concentration and emotional behavior may drive the positive association of physical activity and fitness with academic performance [2].

Although several cross-sectional studies have found a positive relationship between physical activity or physical fitness and academic achievement in children [3–14], few longitudinal studies have been performed enabling temporal inferences. Wittberg et al. [15] found that students who remained in the "healthy fitness zone" over time scored higher in mathematics and English than students who stayed in the "needs improvement zone". London and Castrechini [16] observed an academic achievement gap between persistently fit and persistently unfit students that began before their study period but did not change over time. The effect was less pronounced for boys and those with a higher socioeconomic status. Although limited evidence suggests a relationship between academic achievement and fitness status, more research is needed to describe how changes in fitness may be related to subsequent changes in academic outcomes and how this relationship might vary across sociodemographic subgroups.

The New York City (NYC) public school system is the largest and the most diverse urban school system in the United States. This longitudinal study uses five consecutive years of fitness and academic data to evaluate the effects of changes in fitness on subsequent academic outcomes in NYC middle-school students. Using data from a large and heterogeneous population, this study was able to assess the impact of sex on the fitness–academic relationship and also whether the relationship between fitness and academics varies across levels of student household poverty.

Methods

Study population

Data for this analysis were obtained from the NYC FITNESS-GRAM program, a fitness assessment for NYC public school students in grades K-12. For this analysis, data for each individual student beginning with the 2006–2007 academic year, the first year of data available, through the 2010–2011 academic year were linked by a unique identifier. To be included in the study, students had to be enrolled in NYC public schools for sixth, seventh, and eighth grade (without repeating a grade during that time) and also have nonmissing fitness measurements for the progressive aerobic cardiovascular endurance run (PACER), push-up, and curl-up fitness tests from each year (N = 109,536 students). Students who were above or below the normal age for their grade by more than 2.9 years or repeated a grade during middle school were excluded as the relationship between fitness and academics might differ in these students. Analysis was restricted to students who did not change schools for sixth through eighth grades to avoid school-level effects that cannot be adjusted for in the analysis. Restricting the analysis to middle-school students allowed focus on a population undergoing significant developmental changes where variations in fitness may be particularly influential. Individual years of student data were excluded if students had invalid body mass index (BMI) data identified using the CDC growth chart guidelines [17] or if students were excluded from taking the New York State English Language Arts (ELA) examination in the sixth grade because it was their first year in the United States (indicating possible limited English proficiency). After these exclusions, 83,111 students were included in the final analysis. Because NYC

FITNESSGRAM data are considered public health surveillance, institutional review board approval was not obtained.

For students who began sixth grade in 2007–2008 or 2008–2009, fifth-grade scores were used to calculate the change in fitness from fifth to sixth grade when available; therefore, these students contributed up to 3 years of data (sixth-, seventh-, and eighth-grade outcomes) to the analysis. Students who began sixth grade in 2006–2007 contributed up to 2 years of data because their fifth-grade scores were not in the data set and only two fitness change values could be calculated. Demographic characteristics of the two cohorts were similar. The numbers of students in each grade for each year of data available included in the final analysis are presented in Supplementary Table 1.

Outcome measure: academic performance

The primary outcome was a composite measure of academic test performance, based on New York State standardized assessments in ELA and mathematics. Mandatory mathematics and ELA tests are administered to all New York students each spring beginning in fifth grade. To create the outcome measure, raw scores were used to calculate grade-specific percentile scores separately for mathematics and ELA for each year of data (2006–2007 to 2010–2011). Mathematics and ELA percentiles for each student were summed, and a new grade-specific percentile was calculated based on the sum. This standardized score allows students to be compared across grades and years, which cannot be done with raw test scores alone.

Exposure measure: fitness

The NYC Department of Education has licensed the FITNESS-GRAM fitness assessment from the Cooper Institute and Human Kinetics, and the City's annual fitness assessment, NYC FITNESS-GRAM, consists of six tests: body composition (BMI), aerobic capacity (PACER), muscle strength and endurance (curl-up and push-up), and flexibility (sit-and-reach and trunk-lift) [18]. To measure fitness for this study, we used three of the six tests. Because we were interested in evaluating the effects of fitness independent of BMI, we included body composition (BMI) as a covariate rather than a component of the overall fitness score. Of the five remaining fitness tests, we excluded the two flexibility tests from our analysis because of limited data. For all students, scores from the PACER, pushup, and curl-up tests were used to determine student fitness. The primary exposure in this study was change in fitness percentiles measured over consecutive years.

For each of these three NYC FITNESSGRAM tests, an age- and sex-specific percentile score for a student was calculated, representing the percentage of all students that student outperformed. The three separate percentiles were summed, and a new age- and sex-specific percentile was determined based on this summation. Thus, each student's overall empirical composite percentile score represented a measure of fitness relative to students of the same age and sex.

Students were categorized into levels of fitness change based on the change in their overall percentile from the previous school year. For each student, the change in fitness was calculated for three periods: fifth to sixth grade, sixth to seventh grade, and seventh to eighth grade. A moderate increase was characterized as an increase of 10 to <20 percentile points and a substantial increase as ≥20 percentile points. A moderate decrease was characterized as a decrease of 10 to <20 percentile points and a