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

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Abstract

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 NYC middle school students enrolled between 2006–07 and 2011–12. 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 relative to other students. Opportunities for increased physical fitness may be important to support academic performance.

Keywords

Physical fitness; academic performance; obesity; physical activity

INTRODUCTION

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]

While several cross-sectional studies have found a positive relationship between physical activity or physical fitness and academic achievement in children,[3–15] few longitudinal studies have been performed enabling temporal inferences. Wittberg et al[16] 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[17] observed an academic achievement gap between persistently fit and persistently unfit students that began before their study period but did not see a change in this relationship over time. The effect was less pronounced for boys and those with a higher socioeconomic status (SES). 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 most diverse urban school system in the United States. This longitudinal study utilizes 5 consecutive years of fitness and academic data to evaluate the effects of changes in fitness on subsequent academic outcomes in NYC middle school students. By 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 FITNESSGRAM program, a fitness assessment for NYC public school students in grades K-12. For this analysis data for each individual student beginning with the 2006–07 academic year, the first year of data available, through the 2010–11 academic year, were linked by a unique identifier. To be included in the study, students had to be enrolled in NYC public schools for 6th, 7th, and 8th grade (without repeating a grade during that time) and also have non-missing 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 6th through 8th 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,[18] or if students were excluded from taking the New York State (NYS) English Language Arts (ELA) exam in the 6th 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. Since NYC FITNESSGRAM data is considered public health surveillance, IRB approval was not obtained.

For students who began 6th grade in 2007–08 or 2008–09, 5th grade scores were used to calculate the change in fitness from 5th to 6th grade when available; therefore these students contributed up to three years of data (6th, 7th, and 8th grade outcomes) to the analysis. Students who began 6th grade in 2006–07 contributed up to 2 years of data since their 5th grade scores were not in the dataset 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 NYS standardized assessments in ELA and mathematics. Mandatory mathematics and ELA tests are administered to all New York students each spring beginning in 5th 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 (2006–07 to 2010–11). 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 FITNESSGRAM fitness assessment from the Cooper Institute and Human Kinetics, and the City’s annual fitness assessment, NYC FITNESSGRAM, consists of 6 tests: body composition (BMI), aerobic capacity (PACER), muscle strength and endurance (curl-up and pushup), and flexibility (sit-and-reach and trunk-lift)[19]. To measure fitness for this study, we used 3 of the 6 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 5 remaining fitness tests, we excluded the 2 flexibility tests from our analysis due to 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 3 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 3 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 time periods: 5^{th} to 6^{th} grade, 6^{th} to 7^{th} grade, and 7^{th} to 8^{th} grade. A moderate increase was characterized as an increase of 10–20 percentile points and a substantial increase as more than 20 percentile points. A moderate decrease was characterized as a decrease of 10–20 percentile points and a substantial decrease as more than 20 percentile points. A change of less than 10 percentile points in either direction was considered a small/no change. Since raw fitness scores are expected to improve as children age, a composite percentile is better at capturing increases in fitness beyond what would be expected. Characterizing the exposure as change in fitness across consecutive years as opposed to using the continuous composite percentile improves interpretability.

Covariates

Models included the following covariates: race/ethnicity, language spoken at home, days absent from school, place of birth, student household poverty, school-area poverty, and obesity status. Parental responses to a demographic survey administered at the start of each school year were used to determine race, place of birth, and language spoken at home. Responses were then broadly categorized as follows: race – non-Hispanic white, non-Hispanic black, Hispanic, Asian, and other (including Native American, Native Hawaiian, multiracial, and parent refused); place of birth – New York City, US outside of New York City, foreign-born; language spoken at home – English, Spanish, other. Standard categories were used to characterize student household poverty: as regulated by the National School Lunch Program (NSLP), students enrolled in government-sponsored programs (e.g., Supplemental Nutrition Assistance Program) and/or students known to be living in a household with income ≤185% of federal poverty limits are eligible for free and reduced-price lunch and were classified as "high poverty"; otherwise a student is considered to be eligible for full-price lunch and classified as "low-poverty". Since the school environment may be a strong determinant of both physical fitness and academic outcomes, we included a covariate for school-area poverty. This was defined using a four-category area-based measure, a categorization of the percentage of households in the school zip code living below the federal poverty limit in the 2000 United States Census.[20] Categories were low (<10% of households), medium (10–20%), high (20–30%), and very high (≥30%).

Because obesity is associated with both academic performance[21,22] and physical fitness,[23] change in obesity status was included as a confounder. BMI percentiles were calculated from CDC's 2000 growth charts and students in the ≥95th percentile were classified as obese. As described elsewhere,[17] students were categorized into one of four obesity trajectories based on their obesity status in 6th and 8th grade: "consistently obese", "consistently not obese", "moved from obese to not obese" or "moved from not obese to obese".

Statistical Analysis

Descriptive statistics were calculated for sociodemographic covariates, fitness, obesity change, and academic performance. T-tests were used to compare the mean difference in academic scores between boys and girls for each grade and fitness category. Individual trajectories of academic scores were estimated using a multilevel growth model in which academic and fitness change occasions (time, level 1) were nested within students (level 2) who were nested within schools (level 3). The interclass correlation coefficient (ICC) for academic rankings at the school level was nearly 27%, indicating that the school explained more than a quarter of the variation in student academic scores.

The unadjusted growth models included a fixed effect term for an intercept (initial academic ranking for the reference group), a linear term for time (capturing the linear change in academic ranking each year), the exposure (annual fitness change included as a time-varying variable), and the interaction of the exposure with time. The beta coefficients for the exposure variable reflected the starting academic ranking for each level of fitness. The beta coefficients for the exposure and time interaction reflected the annual percentile change in academic ranking for each fitness group. To this model, the eight covariates were added. All unadjusted and adjusted models included random intercepts for student (capturing each student's departure from the overall initial average academic ranking) and school (capturing each school's departure from the overall initial average academic ranking from the population of schools) and a random slope for student (capturing each student's variation in rate of change in academic ranking). The final adjusted model also included fixed effects for the interactions of race/ethnicity and obesity change with time to account for the effects of these characteristics on students' rate of change in academic performance and was stratified by sex. Additional models stratified by student household income were also constructed.

Sensitivity analyses evaluating expanded study populations based on varying exclusion criteria were also performed to ensure exclusion of subjects with missing data did not adversely affect the findings. The first examined students who were in a NYC public school from 6–8th grade, including students with missing fitness data for 1 or 2 of those years (N=139,286). The second analysis evaluated students who were enrolled in 6th, 7th, or 8th grade at any point during the study period, including those with missing fitness data (N=168,193). Since student household poverty was a time-varying measure in the statistical models, allowing a student's meal code status to change each year, a third sensitivity analysis was conducted limited to students whose household poverty status did not change during the study period (N= 65,921). All analyses were conducted with SAS software, version 9.3 (SAS Institute, Cary, NC.). Models were run with math and English as separate outcomes. Since cardiovascular fitness has been associated with academics more strongly than other components of fitness in some studies[5,6] models were also run with only the PACER change as the exposure.

RESULTS

There were 411 schools included in the analysis, with an average of just over 202 students included per school. Descriptive statistics for baseline characteristics of the 83,111 students are presented in Table 1. There were slightly more girls (51.4%) than boys, and more Hispanic students (35.8%) than any other race/ethnic category.

Mean academic rankings at each time point for each level of fitness change are presented in Table 2. In all categories the scores for boys were significantly lower than for girls ($p<0.001$). The highest rankings in all years were among girls whose fitness did not change. This group included students with consistently high fitness, with nearly 18% of this group scoring in the 90th percentile or above in academic ranking. Among boys who had a substantial decrease in fitness from the prior year, mean academic rankings were highest among 6th graders and lowest among 8th graders.

Model Results: Girls

Female students who had a substantial increase in fitness had a significantly lower starting academic ranking than the reference group after adjusting for other variables in the model (Table 3). For girls in the reference group (small or no change in fitness), academic rankings increased over time by 0.70 percentile points per year (95% CI [0.47,0.94]). Girls who experienced a substantial increase in fitness also improved their academic test scores by 0.36 percentile points more per year than girls who experienced no change in fitness (95% CI [0.09,0.63]). Substantial decreases in fitness were associated with a significant decline of 0.40 percentile points per year compared to the reference group (95% CI [−0.68, −0.12]), while moderate decreases in fitness were associated with a trend toward a decline in academic ranking of 0.33 percentile points per year (95% CI [−0.67,0.01]) compared to the reference group.

Model Results: Boys

Among boys in the reference group, academic rankings decreased over time by 0.44 percentile points per year (95% CI [−0.69, −0.20]). The effects of substantially increasing fitness resulted in an improvement in academic ranking of 0.38 percentile points per year compared to the reference group (95% CI [0.09,0.66]). For boys with a substantial decrease in fitness, academic ranking declined over time by 0.55 percentile points per year compared to the reference group (95% CI [−0.85, −0.25]).

Figure 1 shows the predicted trajectories of academic composite percentile by level of fitness change based on the fitted adjusted model. The largest improvement in academic rankings (1.06 percentile points per year) occurred in girls who had a substantial increase in fitness with an increase of 0.36 percentile points per year more than the reference group. Among both girls and boys, mean academic rankings declined most steeply among children who declined in fitness over time.

Model Results: Stratified by Student Household Poverty

Table 4 presents results of the fully-adjusted models separately for high- and low-poverty students. High-poverty boys who had a substantial increase in fitness improved 0.65 percentile points per year more than the reference group (95% CI[0.27,1.03]), resulting in a 1.3 percentile point increase during the middle school years compared to students with no change in fitness. This effect was not observed among low-poverty boys. Similar academic benefits of a substantial increase in fitness were observed in high-poverty girls, where a substantial increase in fitness was associated with an improvement of 0.47 percentile points per year relative to the reference group(95% CI[0.10,0.84]). Conversely, a substantial decrease in fitness was associated with a subsequent decline in academic rankings for both high-poverty boys and high-poverty girls. The magnitude of the effect was larger in boys (adjusted beta=−0.81 95% CI[−1.21, −0.41) than in girls (adjusted beta = −0.53 95%CI[−0.91, −0.16]).

Sensitivity Analysis

The analysis presented here included only students who completed three years of middle school with complete fitness data for each year. However, students may move in and out of NYC public schools or miss fitness tests and as a result only provide a single year of data. These students had lower mean academic rankings (data not shown). To determine whether this affected the findings, 2 sensitivity analyses were performed, using the larger study populations described previously. Including these additional students did not affect the findings for either sex (data not shown). Since student household poverty was a time-varying variable and a single student could contribute individual years of data to both the low- and high-poverty models, an additional analysis was conducted limited to students whose household poverty status did not change during the study period. Results for these analyses were similar to those for the larger sample (data not shown).

Sustained improvement in academics for students whose fitness improved at the beginning of middle school was explored by comparing mean academic scores in 6th, 7th, and 8th grade by level of fitness change from 5th–6th grade. There was no evidence that an increase in fitness from 5–6th grade was associated with improved academics beyond 6th grade (data not shown). Supplementary Table 2 presents results of the effects of fitness change category on math and English test percentiles separately, and Supplementary Table 3 presents results of the effect of PACER change only as the exposure. Results of these analyses were consistent with the primary findings.

DISCUSSION

The results presented in this study of over 83,000 urban middle school students provide new evidence in support of the association between physical fitness and academic achievement in middle school students. Specifically, academic rankings improved in the subsequent year for both boys and girls who increased their fitness level by more than 20 percentile points relative to the other students whose fitness did not change. Conversely, male and female students whose fitness level decreased by more than 20 percentile points relative to other students had a decline in academic achievement compared with their peers whose fitness did not change.

Previous longitudinal studies of children's physical fitness and academic achievement have mixed results. London and Castrechini[17] did not observe a statistically significant effect of fitness trajectory on either mathematics or English test scores in both boys and girls. Conversely, Wittberg et al[16] noted persistent academic achievement among students who remain in the healthy fitness zone for physical fitness. By incorporating multiple exposure groups based on a continuous measure of fitness, the current study is able to assess the effects of fitness changes that may be relevant but do not result in students moving in or out of standard fitness categories.

The effects of fitness change on changes in academics were stronger in high-poverty students than in low-poverty students, a finding consistent with previous analysis by London and Castrechini. As the authors suggest, low-poverty students may have additional resources at home to help mitigate the potential negative academic effects of poor fitness.[17] Multiple studies have documented an association between increased physical activity and cognitive skills important for learning such as memory and concentration.[2,24–26] Studies of school-based physical activity interventions have shown some evidence of improved test scores and other academic measures with increased physical activity, but these trials have generally focused on physical activity rather than fitness as an exposure.[27] Further studies are necessary to determine the levels of physical education and activity that are most beneficial for maintaining and improving academic performance.

Limitations and Strengths

Administrative databases such as NYC FITNESSGRAM were not created for research purposes; thus student and school-level information that can be used to control for confounding are often not available. Unmeasured individual-level factors that may be responsible for part of the association between fitness and academic outcomes, such as changes in a student's motivation, self-control, or characteristics of their home life, could not be included in the model. There may also be unmeasured confounding by household factors such as parental education not captured in the student household poverty measure[28,29] or residual confounding by school-level factors if the school-area poverty measure does fully capture the effects of school socioeconomic status. Finally, these results cannot be generalized to all NYC children in this age range because certain groups of students were excluded from the analysis (those who moved, had limited English proficiency, or repeated a grade during middle school). The exclusions were applied to improve model validity. Additional analyses are needed to characterize the relationship between fitness and academics for students excluded from the current study.

To date, this study is one of the largest to assess the longitudinal relationship between changes in fitness and academic outcomes among school children. This study evaluated a heterogeneous mix of more than 83,000 students in a diverse metropolitan area, thereby enabling a detailed gender sub-group analysis. Furthermore, the measurement of fitness change from the year that preceded academic testing ensured the temporal relationship between fitness and academic testing remained intact.

Conclusions

This study provides evidence demonstrating the benefit of physical fitness on academic performance among girls and boys in middle school. These results provide further support for national, state and local policies aimed to improve physical fitness through increased physical education and physical activity in school. Future research should explore whether these associations are maintained as students transition to high school.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Abbreviations

NYC	New York City
CDC	Centers for Disease Control and Prevention
SES	Socioeconomic Status
PACER	Progressive aerobic cardiovascular endurance run
NYS	New York State
ELA	English Language Arts
BMI	Body Mass Index
NSLP	National School Lunch Program

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IMPLICATIONS AND CONRIBUTION

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 low-income students.

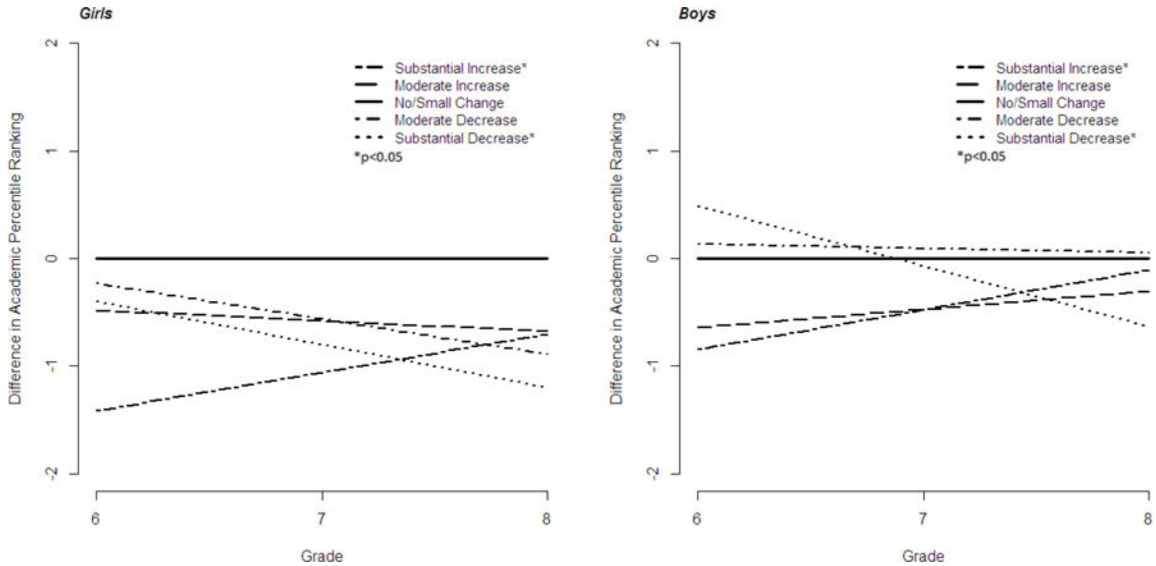
Girls
Boys
Substantial Increase*
Moderate Increase
No/Small Change
Moderate Decrease
Substantial Decrease*
*p<0.05
Difference in Academic Percentile Ranking
Grade

Figure 1.

Table 1

Demographic characteristics of New York City public school students enrolled in grades 6–8 from 2006–2011

		All Students		Girls		Boys	
		N	%	N	%	N	%
Study Population		83,111	–	42,718	51.4	40,393	48.6
Race/Ethnicity							
	Non-Hispanic white	16,444	19.79	8,113	18.99	8,331	20.63
	Non-Hispanic black	20,645	24.84	11,086	25.95	9,559	23.66
	Hispanic	29,823	35.88	15,410	36.07	14,413	35.68
	Asian/Pacific Islander	15,966	19.21	7,990	18.7	7,976	19.75
	Other[f]	232	0.28	119	0.28	114	0.28
Place of Birth							
	NYC Born	65,931	79.33	33,807	79.14	32,124	79.53
	Foreign Born	12,924	15.55	6,718	15.73	6,206	15.36
	US (not NYC) Born	4,256	5.12	2,193	5.13	2,063	5.11
Language Spoken at Home							
	English	45,605	54.87	23,584	55.21	22,021	54.52
	Spanish	19,727	23.74	10,275	24.05	9,452	23.4
	Other Language	17,779	21.39	8,859	20.74	8,920	22.08
Student Household Poverty[a]							
	High	52,955	63.7	27,301	63.9	25,657	63.5
	Low	30,154	36.3	15,416	36.1	14,736	36.5
School Area Poverty[b]							
	Low	17,011	20.47	8,654	20.26	8,357	20.69
	Medium	30,994	37.29	16,082	37.65	14,912	36.92
	High	16,306	19.62	8,257	19.33	8,049	19.92
	Very high	18,800	22.62	9,725	22.77	9,075	22.47
Obesity Trajectory[c]							
	Consistently Obese	11,986	14.42	5,268	12.33	6,718	16.63
	Not Obese to Obese	3,418	4.11	1,663	3.89	1,755	4.34
	Obese to Not Obese	5,840	7.03	2,526	5.91	3,314	8.2

	All Students		Girls		Boys	
	N	%	N	%	N	%
Consistently Not Obese	61,867	74.44	33,261	77.86	28,606	70.82

	All Students		Girls		Boys	
	Mean	SD	Mean	SD	Mean	SD
Days Absent[d]	9.54	9.52	9.26	9.36	9.83	9.68
Starting Fitness Score[e]	0.61	28.37	0.62	28.41	0.60	28.32

SD=standard deviation

[a]Household poverty is measured by participation in the National School Lunch program. Students are eligible for reduced/free price meals and considered ‘high poverty’ if household income is within federally-defined poverty limits[30]. Some students changed meal code during the study period, values in the table represent starting meal code values.

[b]Within the school postal code area, levels of poverty were classified as low (<10% of residents living below the federal poverty level as defined by the U.S. Census 2000), medium (10 to <20%), high (20 to <30%), and very high (≥30%).

[c]Students were characterized based on their obesity status in 6[th] and 8[th] grade.

[d]Mean and standard deviation for days absent are based on all person-years of data for sample population (N=207,726 person-years).

[e]The starting fitness score is grand mean centered (52.4) and should be added to the value presented to get starting fitness score.

[f]Includes American Indian, Native Hawaiian, multiracial, and parent refused

Table 2

Academic rankings for New York City public school students in grades 6–8, by level of fitness change from the previous year, 2006–11

	Grade 6			Grade 7			Grade 8		
	N	**Mean**	**Standard Deviation (SD)**	**N**	**Mean**	**(SD)**	**N**	**Mean**	**(SD)**
Girls (N=42,718)[a]									
Change in Fitness[b]									
Substantial Increase[c]	6089	56.74	27.40	8138	56.96	27.36	6918	56.81	27.50
Moderate Increase	2595	59.01	27.45	5306	59.51	27.49	5304	59.81	27.38
No/small change	6260	59.13	27.92	16081	60.03	27.72	17934	60.66	27.83
Moderate Decrease	2274	56.48	27.88	4942	56.84	27.36	5293	57.24	27.73
Substantial Decrease	4844	54.56	27.81	7724	52.29	27.36	7229	53.02	27.51
Boys (N=40,393)[a]									
Change in Fitness[b]									
Substantial Increase[c]	5430	52.37	27.93	7570	53.95	28.37	6936	52.90	28.09
Moderate Increase	2468	54.18	27.75	5074	55.12	28.48	5229	53.37	28.36
No/small change	6387	54.89	28.30	15110	55.13	28.38	16773	54.42	28.69
Moderate Decrease	2228	53.02	28.69	4781	53.16	28.31	4884	52.03	27.90
Substantial Decrease	4393	52.94	28.47	7125	49.42	28.00	6548	48.51	28.30

SD=standard deviation

[a]Sum of students does not equal row or column totals because student can appear in each group more than once.

[b]T-tests comparing means between boys and girls for each fitness category and grade were significant (all $p<0.001$).

[c]Substantial Increase: >20 percentile point increase, moderate increase: 10–20 percentile point increase, moderate decrease: 10–20 percentile point decrease, substantial decrease: >20 percentile point decrease

Table 3

Effects of fitness change on academic rankings by sex in New York City public school students in grades 6–8, 2006–11

Girls (N=42,718)	Unadjusted[a]		Adjusted[b]	
	Beta	**95% CI**	**Beta**	**95% CI**
Starting Academic Ranking by Fitness Change				
Reference	50.74***	(49.59,51.88)	66.12***	(63.90,68.34)
Substantial Increase[c]	−0.59**	(−0.97, −0.21)	−0.44*	(−0.81, −0.08)
Moderate Increase	0.13	(−0.35,0.61)	0.28	(−0.19,0.75)
Moderate Decrease	−0.18	(−0.68,0.32)	−0.08	(−0.56,0.41)
Substantial Decrease	−0.56**	(−0.97, −0.21)	−0.26	(−0.66,0.13)
Academic Change by Fitness Change[d]				
Reference[e]	0.91***	(0.75,1.08)	0.70***	(0.47,0.94)
Substantial Increase	0.34*	(0.06,0.62)	0.36*	(0.09,0.63)
Moderate Increase	−0.07	(−0.41,0.28)	−0.10	(−0.43,0.23)
Moderate Decrease	−0.33	(−0.68,0.02)	−0.33	(−0.67,0.01)
Substantial Decrease	−0.25	(−0.54,0.04)	−0.40**	(−0.68, −0.12)

Boys (N=40,393)	Unadjusted[a]		Adjusted[b]	
	Beta	**95% CI**	**Beta**	**95% CI**
Starting Academic Ranking by Fitness Change				
Reference	46.94***	(45.77,48.11)	62.15***	(59.75,64.55)
Substantial Increase[c]	−0.37	(−0.77,0.02)	−0.27	(−0.66,0.12)
Moderate Increase	−0.32	(−0.82,0.18)	−0.19	(−0.67,0.30)
Moderate Decrease	−0.03	(−0.48,0.54)	0.10	(−0.40,0.60)
Substantial Decrease	0.15	(−0.26,0.57)	0.32	(−0.09,0.73)
Academic Change by Fitness Change[d]				
Reference[e]	−0.10	(−0.27,0.07)	−0.44***	(−0.69, −0.20)
Substantial Increase	0.41**	(0.12,0.70)	0.38*	(0.09,0.66)

Boys (N=40,393)	Unadjusted[a]		Adjusted[b]	
	Beta	95% CI	Beta	95% CI
Moderate Increase	0.26	(−0.09,0.61)	0.18	(−0.17,0.52)
Moderate Decrease	−0.04	(−0.40,0.32)	−0.05	(−0.40,0.31)
Substantial Decrease	−0.47**	(−0.78, −0.17)	−0.55***	(−0.85, −0.25)

[a] Unadjusted fitness results are based on a model that included fixed effects for time, fitness change, and an interaction of fitness by time. Random effects are included for intercept and time at the student level, and intercept at the school level.

[b] Fully adjusted models include fixed effects for fitness change, obesity change, starting fitness score, school-area poverty, ethnicity, student poverty, language spoken at home, place of birth, ethnicity by time, fitness change by time, and obesity change by time.

[c] Substantial Increase: >20 percentile point increase, moderate increase: 10–20 percentile point increase, moderate decrease: 10–20 percentile point decrease, substantial decrease: >20 percentile point decrease.

[d] Fixed effect for exposure and time interaction are the values for rate of change in exposure groups.

[e] Fixed effect for time is the value of the reference group rate of change.

* p<0.05,

** p<0.01,

*** p<0.001.

Table 4

Relationship between changes in fitness and changes in academics among high and low-poverty students in New York City Public Schools in grades 6–8, 2006–11[a]

Girls	High Poverty[b] (N=66,697 person-years)		Low Poverty (N= 40,234 person-years)	
	Beta	**95% CI**	**Beta**	**95% CI**
Starting Academic Ranking by Fitness Change				
Reference	60.94***	(58.17,63.72)	70.26***	(67.77,72.75)
Substantial Increase[c]	−0.54*	(−1.03, −0.04)	− 0.38	(−1.01,0.24)
Moderate Increase	0.43	(−0.21,1.06)	0.21	(−0.57,1.00)
Moderate Decrease	−0.16	(−0.81,0.49)	0.23	(−0.61,1.08)
Substantial Decrease	−0.18	(−0.69,0.34)	− 0.48	(−1.18,0.22)
Academic Change by Fitness Change[d]				
Reference[e]	1.36***	(0.93,1.79)	0.46**	(0.14,0.78)
Substantial Increase	0.47*	(0.10,0.84)	0.29	(−0.18,0.75)
Moderate Increase	−0.18	(−0.63,0.28)	0.06	(−0.50,0.61)
Moderate Decrease	−0.32	(−0.78,0.14)	− 0.51	(−1.10,0.07)
Substantial Decrease	−0.53**	(−0.91, −0.16)	− 0.36	(−0.86,0.14)

Boys	High Poverty (N = 62,381 person-years)		Low Poverty (N = 38,552 person-years)	
	Beta	**95% CI**	**Beta**	**95% CI**
Starting Academic Ranking by Fitness Change				
Reference	56.34***	(53.53,58.15)	68.01***	(65.25,70.77)
Substantial Increase[c]	−0.39	(−0.90,0.13)	0.16	(−0.52,0.83)
Moderate Increase	−0.08	(−0.73,0.57)	− 0.25	(−1.10,0.59)
Moderate Decrease	0.31	(−0.36,0.99)	− 0.14	(−0.99,0.72)
Substantial Decrease	0.77**	(0.23,1.31)	− 0.38	(−1.10,0.34)
Academic Change by Fitness Change[d]				
Reference[e]	0.14	(−0.28,0.57)	− 0.63	(−0.97, −0.29)
Substantial Increase	0.65***	(0.27,1.03)	− 0.14	(−0.64,0.36)

Boys	High Poverty (N = 62,381 person-years)		Low Poverty (N = 38,552 person-years)	
	Beta	95% CI	Beta	95% CI
Moderate Increase	0.13	(−0.33,0.59)	− 0.02	(−0.61,0.57)
Moderate Decrease	−0.20	(−0.68,0.28)	0.00	(−0.60,0.60)
Substantial Decrease	−0.81 ***	(−1.21, −0.41)	− 0.33	(−0.84,0.18)

[a]Models include fixed effects for fitness change, obesity change, starting fitness score, school-area poverty, race/ethnicity, language spoken at home, place of birth, fitness change by time, and obesity change by time.

[b]Student household poverty is measured by participation in the National School Lunch program. Students are eligible for reduced/free price meals and considered 'high-poverty' if household income is within federally-defined poverty limits.[24]

[c]Substantial Increase: >20% improvement, moderate increase: 10–20 percentile improvement, moderate decrease: 10–20 percentile decline, substantial decrease: >20% decrease.

[d]Fixed effect for exposure and time interaction are the values for rate of change in exposure groups.

[e]Fixed effect for time is the value of the reference group rate of change.

*p<0.05,

**p<0.01,

***p<0.001