

**Relationship between aerobic fitness and academic achievement in Seattle secondary school
children**

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Abstract

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Aerobic fitness is an important measure of physical fitness and has been shown to affect academic achievement in youth. We hypothesized that aerobic fitness was positively associated with standardized test scores, independent of demographic and medical factors. Further, we hypothesized that the academic risk score, an aggregate measure of course failure rate, standardized test performance, attendance, and number of disciplinary actions, would moderate this association. This was a cross-sectional study of 18,312 Seattle Public Schools students in grades four through twelve. For every one minute students ran the one-mile distance slower, there was a 2 percentile reduction in math and reading MAP scores. Further, meeting criterion-based fitness standards was associated with a 10 and 7 percentile increase in math and reading MAP scores, respectively. The academic risk score did attenuate these associations, but all associations stayed statistically significant. Results from this study indicate that percentile test scores on standardized

tests in school-aged children are higher among children who achieve aerobic fitness standards, compared to those who do not achieve aerobic fitness standards.

Introduction

Aerobic fitness, the most common measure of physical fitness, is the capacity of the cardio-respiratory system to deliver adequate oxygen during sustained physical activity to support oxidative metabolic needs (1). This measure is highly heritable, but is also sensitive to the amount of physical activity performed by the individual (2). Studies examining aerobic fitness in youth have shown that levels can affect several common health measures, including BMI and serum insulin levels. For example, one study in 30 obese children found that both endurance training and high-intensity interval training significantly reduced body mass index (BMI) and insulinemia (3). Another study found that children with healthier BMI's, defined as below the overweight or at-risk for overweight thresholds for age and sex, had higher levels of physical fitness (4).

While most studies have investigated the health benefits of improved aerobic fitness in children, more recent studies have examined effects on factors such as academic achievement and cognitive development. For example, improvements in academic achievement, as measured by standardized test scores and GPA, were associated with participation in sports teams at the middle and high school level (5), and with aerobic fitness levels in elementary and middle school children (6-8). Also, a recent cross-sectional study found that a greater number of steps per day, an objective measure of physical activity that is associated with higher aerobic fitness in children and adolescents (9), was positively linked with tests of fluid intelligence, a measure of cognitive development (10). Related, researchers have found that youth with low aerobic fitness levels exhibited poorer overall accuracy and level of concentration during a test designed to measure cognitive control (11).

While most of the recent studies that have examined the effects of aerobic fitness on academic success have used measures such as GPA and standardized test scores, very few have examined these associations when taking school attendance into account. This is an important

limitation to address because attendance itself is an important determinant of academic success. For example, in a report of students in the Los Angeles Unified School District, children who were absent more than 14 times per year were twice as likely to drop out of high school (12). Within this same report, children with more than 10 absences per year were found to have only a 40% chance of graduating high school (12), showing that the rate of absenteeism is an important marker of academic success among school children. Thus, it is unknown whether the association between aerobic fitness and academic success is moderated by or completely independent of attendance.

In a recent pilot study using data gathered from middle-school children in Seattle Public Schools (SPS), members of our group found that children achieving normative aerobic fitness standards tended to have higher math and reading percentile scores, compared to children not meeting the aerobic fitness standards. Furthermore, students achieving aerobic fitness standards had fewer absences and a lower academic risk score, compared to students not achieving the aerobic fitness standards. The academic risk score is an aggregate measure of course failure rate, standardized test performance, attendance, and number of disciplinary actions. Students with a risk score of 10 or more are thought to be at higher risk of not graduating. In the present study, we re-examined these preliminary associations in greater detail. Specifically, we investigated the association among aerobic fitness, the academic risk score, and standardized math and reading tests. We hypothesized that aerobic fitness was positively associated with standardized test scores in secondary school-aged children, independent of demographic factors and medical conditions that would affect aerobic fitness. We further hypothesized that the academic risk score would moderate this association.

Methods

Context

This is a cross-sectional study using data gathered from students enrolled in schools of the SPS District in Seattle, Washington. Selected data were culled from a large repository of data that was originally gathered as part of an NIH funded project titled “Collaborative Research Infrastructure to Transform School Health”. The larger parent study gathered several diverse datasets representing both individual and school-level data from the district and that were subsequently combined for secondary analyses, pilot studies, and preliminary data for grant applications.

Data from three datasets were obtained and combined for the present study, including the Research, Evaluation and Assessment department (REA) database, the WelNet database, and the Nurse Encounter Database (NED). The REA database is a central database where data is stored for every child enrolled in SPS. Demographic data is entered upon the child’s enrollment, and other data, such as the number of times they have been disciplined, attendance rate, and standardized tests scores, among others, are gathered and entered on an ongoing basis as the student progresses through different grade levels. The Welnet database is used by SPS Physical Education (PE) instructors to document how well students perform in standardized physical fitness performance and knowledge tests. The PE curriculum and all tests were developed by Focused Fitness (Focused Fitness, Spokane, WA); specifically “Five for Life” is the curriculum and testing program while WelNet is the central database repository. These programs were developed to provide PE instructors with guidelines for age-appropriate fitness instruction, as well as to document the students’ fitness level and allow for longitudinal data access. Finally, the NED database is used to record medical conditions. It is used to log any International Classification of Diseases, Ninth Edition (ICD9) codes present for each child, including those for asthma, allergies, anaphylaxis, attention-deficit disorder, and the presence of any mood disorder(s).

Predictors

Estimated Aerobic Fitness

Aerobic fitness levels were estimated using various fitness tests and normative data provided by FitnessGram (The Cooper Institute for Aerobics Research, Dallas, TX). Assessment is done through a criterion-based system, instead of a norm-based system, that compares children's fitness scores to a range of acceptable values rather than percentile ranks from similarly aged cohorts of children. Minimum standards are set for each type of activity measured; if the child meets the minimum standard then they are deemed to meet the Healthy Fitness Zone (HFZ) for that measure, regardless of how the child's peers have performed.

The aerobic fitness measure used for this study is the one-mile run, measured in minutes and seconds. Standards were set in the 2009-2010 school year for each grade, starting with grade 4, for how quickly a child must run the one mile in order to meet the HFZ standard.

Academic Risk Score

The academic risk score is a cumulative score using multiple factors that have been linked to poor academic success among SPS students (see Table 1). The risk score was expressed as a binary value, indicating if the child has a total risk score of less than 10 vs. 10 or more, where a score of 10 or more has been associated with an increased risk of not graduating from high school according to research performed by the Johns Hopkins University Everyone Graduates Center (13).

Outcomes

MAP Scores

Measures of Academic Progress (MAP), MAP for Science and MAP for Primary Grades in Reading and Mathematics, are standardized tests developed for secondary school grade levels, developed by the Northwest Evaluation Association (NWEA). The tests are designed to be adaptive

enough to match the national, state, county, and district requirements, while adjusting for the child's individual level of knowledge. In addition to the actual testing, NWEA also provides information on how each child scored in each goal area so that instruction can be tailored to the child's current level. The exams used for the present study were MAP for Reading and Mathematics, taken in spring 2010 and obtained from the central REA database.

Data Analysis

Descriptive information was presented as means and standard deviations or percentages where appropriate. All associations were tested using linear regression in three separate models. Two sets of regressions were performed based on the expression of aerobic fitness (the independent variable), one examining the association between one-mile run time and MAP scores and the other the association between HFZ status and MAP scores. A binary variable was created to indicate whether a child met HFZ standards, taking into account age, one-mile run time, and sex. The first model examined the associations between one-mile run time or HFZ status (predictors) and MAP scores (outcomes); one-mile run time was adjusted for grade level in this first model but HFZ status was not because this expression of aerobic fitness is already adjusted for age and sex. The second model adjusted for relevant demographic and health covariates, including age, sex (for one-mile run time only), race, school level socioeconomic status, and having asthma. Socioeconomic status was approximated at the school level, rather than the individual level, by determining the percentage of children eligible for free/reduced price lunch. Of the student encounters with the school nurse that are recorded, we hypothesized based on the literature that poorly controlled asthma can have a profound effect on the primary predictor of interest, aerobic fitness (14), thus asthma status was controlled for in the adjusted analyses. Finally, the third model additionally adjusted for the academic risk score to examine if the hypothesized association between aerobic fitness and academic test scores was independent of the academic risk score. Analyses were

conducted using STATA 12 (StataCorp LP, College Station, TX); significance was set at p-value <0.05.

Results

Demographics

The study sample consisted of pooled data available from students in 92 distinct SPS schools, including 12 high schools, 9 middle schools, 57 elementary schools, and 10 K-8 schools. The total student enrollment for the SPS district in 2010-2011 was 54,659, but only 38,617 students had both demographic and FitnessGram information available. Due to lack of FitnessGram standards for children under ten, 20,302 additional students were eliminated from the study. An additional 3 students were eliminated due to not having specific demographic information necessary for statistical adjustment. This left a final analytic sample of $n = 18,312$ students. The racial and ethnic distribution of the sample was 38% White, 22% Black, 21% Asian, 13% Hispanic students, 4% multi-racial, 2% American Indian and <1% Pacific Islander, and grade level was roughly normally distributed across grades 4 through 12 (three students were in third grade).

Analysis by One-Mile Run Time

The results using one-mile run time as the independent variable are shown in Table 3. In model 1, a 1-minute increase in one-mile run time was associated with significant reductions in math and reading percentile scores ($p < 0.05$). In model 2, the strength of association was reduced with adjustment for demographic factors, although the association was still large and significant ($p < 0.05$). Additional adjustment for academic risk score further attenuated the relationship, however, an increase in one-mile run time was still significantly associated with a reduction in MAP percentile scores ($p < 0.05$).

Analysis by Healthy Fitness Zone Status

The results using Healthy Fitness Zone status as the independent variable are shown in Table 4. In model 1, meeting the HFZ criteria was associated with a large percentile increase in math and reading scores ($p < 0.05$). In model 2, the strength of association was reduced with adjustment for demographic factors, although the association was still large and significant ($p < 0.05$). Additional adjustment for academic risk score further attenuated the relationship, however, meeting the HFZ status was still associated with large percentile increases in MAP scores ($p < 0.05$).

Discussion

The findings from this study demonstrate that increased aerobic fitness in children is associated with higher percentile test scores on standardized reading and math tests, among a large sample of students in the SPS district. The associations between aerobic fitness and percentile test scores were attenuated, but still significant, after controlling for demographic factors and academic risk scores. Not only were the results statistically significant, but of a magnitude that would suggest a tangible difference in academic achievement. For example, for every 1-minute increase in one mile run time, indicating a slower run time and lower aerobic fitness level, there was a roughly 2 percentile reduction in math and reading MAP scores, even after adjustment of all demographic covariates and the academic risk score. Similarly, when FitnessGram standards for aerobic fitness were achieved, reflected by students in the HFZ, there was a nearly 10 and 7 percentile increase in math and reading MAP scores, respectively, even after accounting for all covariates and the academic risk score.

The academic risk score did attenuate the association between percentile test scores for both the math and reading MAP exams and aerobic fitness as predicted. Because it is an aggregate score of several academic risk factors, most notably attendance and course failure, it is understandable that this measure would attenuate the association between aerobic fitness and academic test scores. For example, studies examining the role of attendance on academic

achievement in middle and high school students have shown that attendance by itself is a key factor in a student's likelihood of graduating high school (12,15). Although low attendance is a major risk factor for poor academic achievement, the results of the present study demonstrate that being aerobically fit is associated with improved standardized test performance independent of academic risk score. However, the cross-sectional nature of this study cannot establish causality between aerobic fitness and standardized test performance, and the possibility of biases in the data still exist despite controlling for important demographic factors and the academic risk score. Most notably, it is possible that students with poor attendance yet high levels of aerobic fitness simply did not show up to PE class on the day(s) of testing, or were allowed to opt out of PE all together, and thus were not included in the analysis.

The findings of this study are generalizable to the general student population of other large metropolitan areas with demographics similar to Seattle, WA. Findings from this study could be used to support greater emphasis on PE instruction, and more specifically on improving physical fitness, among students enrolled in SPS. In turn, such an initiative might lead to improvements in standardized test scores across the SPS district. The SPS school district has been working hard to improve its rate of graduation, with an increase from 62% to 73% in the 2010-2011 school year compared to the 2007-2008 school year (16). The present data adds to similar initiatives in SPS and emphasizes that attention to physical fitness may produce tangible academic benefits.

Limitations

There are a few limitations to this study worth noting. The most important limitation is that the risk score includes the most recent MAP scores, including those that are the primary outcome of this study. Using the combined risk score variable as a covariate against the MAP scores introduces collinearity that cannot be controlled. While the aggregate risk score matrix is not a validated tool, it is based on a large body of research from the Johns Hopkins University Everyone Graduates

Center (13). Grade level was used as a covariate instead of age because it was easy to define and equated directly to the time when the one-mile run and MAP standardized tests were performed and documented. In addition, it should be noted that the one-mile run time is being used as a proxy for true aerobic fitness, and is highly subject to each child's motivation to run. This proxy does not capture students who are motivated for class or for PE/ sports and not for the other. Finally, the only indicator of socioeconomic status available was the percent of children receiving free/reduced lunch. This indicator is at the school level and not at the individual level, and therefore not a true indicator of each child's socioeconomic status.

Conclusion

Results from this study indicate that percentile test scores on standardized tests in school-aged children are higher among children who achieve aerobic fitness standards compared to those who do not achieve aerobic fitness standards. These findings corroborate the evidence regarding aerobic fitness and standardized test scores from studies conducted both in the U.S. and abroad (17-21). Future research could examine individual factors that make up the academic risk score and their association with aerobic fitness, allowing specific interventions to be developed for altering that risk factor or risk factors. In addition, longitudinal studies could examine changes in MAP scores and changes in aerobic fitness levels to strengthen causal links between fitness and academic achievement.

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Table 1. Individual factors that are integrated into the academic risk score.

Risk Factor		Definition	High	Medium	Low
			2 points	1 point	0 points
Repeated Grade		Same grade in 2011-2012 as 2010-2011	5 points if yes, 0 points if no.		
2011-2012 Course Taking	Core Course Failure Rate	Percent of courses in Math, Language, Arts, Science, Social Studies, and World Languages with final marks of Ns or Es* in the last two semesters	> 20%	10-20%	< 10%
	Math Course Failure	No. of Math courses with Ns or Es* in last two semesters	2 or more	1	0
	LA Course Failure	No. of Language Arts courses with Ns or Es* in last two semesters	2 or more	1	0
Most Recent State Test Performance	Math MSP/EoC	Most recent and highest score among Math,	Level 0 or Level 1	Level 2	Met Standard

		Algebra EoC, Geometry EoC state test performance			
	Reading MSP	Most recent Reading state test performance	Level 0 or Level 1	Level 2	Met Standard
	Writing MSP	Most recent Writing state test performance	Level 0 or Level 1	Level 2	Met Standard
2011-2012 Attendance & Discipline	Attendance	Attendance rate (%)	< 80%	80-90%	>90%
	Unexcused Absences	Number of unexcused absences	5 or more	2 to 4	Less than 2
	Discipline	Number of disciplinary actions	2 or more	1	0
				TOTAL SCORE =	

* Ns = Not passed; Es =Failed

Table 2. Select demographic characteristics of study participants (n=18,312).

Age (years)	13.3 (2.36)
Gender (% male)	46.1 (0.50)
Asthma (%)	10.3 (0.30)
Free/Reduced Lunch (%)	45.2 (23.2)
Risk Score (%)	7.4 (26.2)
One Mile Run (minutes)	10.2 (2.8)
Healthy Fitness Zone (%)	46.9 (49.9)

Continuous measures are presented as mean (standard deviation); categorical measures are presented as percentages (standard deviation). The Healthy Fitness Zone measure indicates the percentage of children achieving the aerobic fitness standard based on one mile run time for that age and sex.

Table 3. Association between MAP* scores and one-mile run time.

	Model 1	Model 2	Model 3
Math MAP Score	-2.97 (-3.17,-2.77)	-2.36 (-2.57,-2.16)	-2.24 (-2.48,-2.00)
Reading MAP Score	-2.37 (-2.57,-2.17)	-1.75 (-1.96,-1.55)	-1.66 (-1.90,-1.41)

Data presented as regression coefficients with 95% confidence intervals (95% CI).

Model 1 is MAP score regressed by one-mile run time and grade; Model 2 adjusts for sex, race, percent free/reduced lunch and asthma; Model 3 adjusts additionally for academic risk score[†].

* MAP = Measures of Academic Progress, expressed as a percentile score.

† Academic risk score is an aggregate measure of total academic risk indicating ≥ 10 points; included in calculation is presence of repeated grade, core course failure, MAP test performance, and attendance & discipline.

All analyses are statistically significant at $p < 0.05$.

Table 4. Association between MAP* score and HFZ* status.

	Model 1	Model 2	Model 3
Math MAP Score	14.20 (13.20,15.19)	10.66 (9.69,11.62)	9.54 (8.41,10.66)
Reading MAP Score	11.79 (10.81,12.78)	7.54 (6.59,8.49)	6.60 (5.53,7.79)

Data presented as regression coefficients with 95% confidence intervals (95% CI).

Model 1 is MAP score regressed by HFZ status; Model 2 adjusts for race, percent free/reduced lunch and asthma; Model 3 adjusts additionally for academic risk score[†].

* MAP = Measures of Academic Progress expressed as a percentile score; HFZ = Healthy Fitness Zone based on FitnessGram sex and age-based fitness standards.

[†] Academic risk score is an aggregate measure of total academic risk indicating ≥ 10 points; included in calculation is presence of repeated grade, core course failure, MAP test performance, and attendance & discipline.

All analyses are statistically significant at $p < 0.05$.