The Association between Aerobic Fitness and Academic Achievement among Elementary School Youth

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ABSTRACT

Physical activity (PA) and fitness are important for both healthy physical and mental development in youth, including positive effects for academic achievement. Several studies have shown positive associations between PA and academic achievement or cognitive function. However, fewer studies have examined these associations with large representative samples of youth with objective measurement of aerobic fitness and body composition. Therefore, the present study examined the association between aerobic fitness and academic achievement in a large sample of fourth and fifth grade youth from a large southeastern school district. In 2013, objectively measured aerobic capacity via FitnessGram® Progressive Aerobic Cardiovascular Endurance Run was collected for all fourth and fifth grade youth (n = 8641) in a southeastern US county, along with several demographic characteristics. Students also completed the Palmetto Assessment of State Standards test for the following subjects: writing, English/language arts, math, science, and social studies. Multilevel linear regression models were used to examine associations between aerobic fitness and all subject test scores while controlling for demographic characteristics. Results from multilevel linear regression indicate that even after controlling for important covariates, including sex, race/ethnicity, school lunch status, grade level, and youth body mass index, there was a significant positive association between aerobic fitness and academic achievement in writing, English/language arts, math, science, and social studies. Further analysis indicated that the association between increased aerobic fitness and subject test scores was not modified by sex. In conclusion, these findings are supported by previous research highlighting the important role that aerobic fitness for elementary school youth plays in healthy brain development during this rapid period of growth and acquisition of cognitive skills, thus impacting lifelong academic achievement and educational attainment.

INTRODUCTION

Health promotion research has long documented the healthful benefits of regular participation in physical activity (PA) for youth, including enhanced aerobic fitness, reduction in chronic disease risk factors, maintaining a healthy weight status, and improved mental health (19,26,35). Despite this knowledge of the numerous health benefits of PA, data from the 2012 National Health and Nutrition Examination Survey National Youth Fitness Survey indicate that as few as one quarter of US youth meet the Centers for Disease Control and Prevention's (CDC) recommendations for 60 min or more of moderate-to-vigorous PA each day (17).

Considering the significant number of total waking hours youth spend at school and in school-related activities (23), schools are an excellent environment to promote healthy behaviors such as participation in regular PA; however, less than 4% of elementary schools nationwide provide access to daily physical education (PE), and less than half offer regular recess (25). One of the possible barriers to increasing the time youth spend in PE or recess each day is the emphasis of the federal government on academic progress in schools, leading many school districts to focus only on curricula directed at improving performance in core subject areas including writing, English, math, and science (1,11,34).

In 2001, the passage of the No Child Left Behind (NCLB) Act brought intense scrutiny on schools' standardized testing performance through the allocation of national school dollars based on school-level academic progress (15,38). In a 2006 nationwide school survey, conducted to assess changes in PA policies in response to the NCLB Act, 14% of school administrators reported reducing the time spent in PE and recess by an average of 40 min each week in exchange for increased instructional time in math and English (33). No conclusive

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research to date, however, indicates that increased classroom instruction time has positively impacted standardized testing scores. Rather, a 2010 synthesis of literature conducted by the CDC found that few studies documented a negative relationship between academic achievement and increased time spent in PA or PE (5). Similar findings were reported in an earlier study by Sallis et al. (31), in that school participation in an intervention designed to increase time spent in PE did not decrease standardized testing scores; rather, preliminary findings from the study suggested that increased time spent in PE enhanced academic performance (15,30,31). Most recently, a systematic review on the links between PA, fitness, cognition, and academic achievement found connections between single and multiple PA bouts and cognition among youth (3,15).

On the basis of the concept that physically active and aerobically fit children are healthier children, educators and researchers across multiple disciplines, including child development, public health, and neurosciences, have acknowledged the vital role that PA and fitness play in learning and healthy brain development (1, 9,15,27,28,30,35). Over three decades ago, Gabbard and Barton (20) first documented the positive correlation between levels of youth PA and school academic performance. In this landmark study of 106 elementary school male and female youth, researchers found that physical exertion both immediately after and 1 h postactivity improved the ability of students to solve mathematical equations compared with pre-PA participation (20). Since then, positive associations between measures of PA and fitness and academic achievement have been reported by a variety of epidemiological studies (7,11,22,39).

Because studies identifying the positive associations between aerobic fitness and PA have continued to emerge, increased attention has been paid to the potential causal pathways in this observed relationship. One such explanation is the role of PA and aerobic fitness in the acquisition and maintenance of healthy brain function and processing skills during the sensitive period of childhood, which is marked by rapid growth in not only physical size and stature but also brain growth (7,11–13, 18). Specifically, studies have indicated that increased aerobic fitness may positively impact important learning centers of the brain by increasing blood and oxygen supply, improving neuroelectric conductivity, and changing brain physiology, particularly in learning and memory centers of the brain (7, 11,18,25). These positive changes in brain function and structure may improve cognitive function and processing by enhancing memory processing, speed, and capacity, as well as attention to task, which in turn have great potential to positively impact youth academic achievement (7,18,39,40).

Educators and child health researchers would be remiss not to examine the complex interaction of factors that extend beyond youth fitness in determining youth academic achievement and lifelong learning outcomes (1,3,15,23,30). Numerous contextual factors, including school attendance, parental involvement, and sociodemographic factors, have been linked to youth academic achievement (3,23). One such factor is the role that sex plays in the relationship between PA and fitness with academic achievement (23). Numerous studies have explored the relationship of PA and aerobic fitness with academic achievement with differing results (15). Donnelly et al. (15) found evidence in the literature of positive associations between activity, fitness, academic achievement, and cognition; however, a gap in the literature remains. Most published studies have found that the relationship between aerobic fitness and academic achievement is stronger for female versus male youth, yet little research has addressed the causal pathways for this difference by sex (10,29,30).

Previous research linking aerobic fitness and PA to improved academic achievement has shown great promise within the last decade; however, there is still a lack of consensus among study findings (15). Within the literature, findings are inconsistent by sex, weight status, socioeconomic status, and subject area (21). These inconsistencies may stem from the fact that these same studies often lack strong methodologies including sufficient sample sizes, standardized measures, and lack of attention to potential confounders including socioeconomic status, race/ethnicity, weight status, and sex (1,5,15,23). To support evidence-based practices for the important role of PA in youth health and development within the school setting, LiveWell Greenville, a community coalition whose mission is to prevent and reduce youth obesity through PA and healthy eating policy and systems change, partnered with a local school district to assess the school PA and obesity environment of elementary school youth. To address some of the gaps in the literature, this study examined the relationship between aerobic fitness and academic achievement among fourth and fifth grade youth in writing, English/language arts, math, science, and social studies standardized subject area tests. In addition, the study explored whether sex (male vs female) moderated the relationship between aerobic fitness and academic achievement.

Specifically, the researchers hypothesized that there will be a positive association between aerobic fitness levels and academic achievement. Furthermore, the researchers hypothesized that the strength of the relationship between aerobic fitness and academic achievement will differ for female versus male youth, with female youth experiencing greater improvements in academic achievement with increasing aerobic fitness. Lastly, the present study provides an important opportunity to examine the role that potential confounders (i.e., race/ethnicity, socioeconomic status, and weight status) play in the relationship between physical fitness and academic achievement using a large data set with standardized and objective measures.

METHODS

Study Setting and Sample

The study setting was a large school district located within a southeastern county in the United States that covers almost 800 square miles and has a population of approximately 491,863. Specifically, the county population is composed of 69.5% white (not Hispanic or Latino), 18.5% African American, 8.7% Latino or Hispanic, and 2.2% Asian residents (36). Youth younger than 18 years make up 23.7% of the population (36). The annual median household income is $49,022, and 15.8% of residents live below the poverty line (36).

The participating school district, which serves the entire county, is the largest within the state and the 49th largest in the nation with eight public elementary, middle, and high schools serving more than 75,000 youth. Specifically, the school district contains 52 elementary schools with approximately 36,000 kindergarten through fifth grade students. The student population of the school district is predominantly non-Hispanic white (57.8%), followed by non-Hispanic black (22.8%) and Hispanic (12.7%), and approximately 50.2% of youth are eligible to receive free or reduced lunch from the National School Lunch Program.

Eligibility criteria for the study sample included fourth and fifth grade youth enrolled in PE classes with complete measurements of

standardized test scores, aerobic fitness, body weight and height, and demographic characteristics. Demographic characteristics included grade level, sex, race/ethnicity, and school lunch status. The final sample size for writing (n = 8641), English/language arts (n = 8654), math (n = 8662), social studies (n = 6490), and science (n = 6504) subject area tests varied by the number of youth with standardized testing scores for each of the five subject area tests that also had complete data on aerobic fitness, height and weight status, and demographic characteristics. Youth with biologically implausible height and weight data, as determined by the CDC's youth body mass index (BMI) growth charts, were excluded from the study sample using casewise deletion (4).

During the spring and fall of the 2013 calendar, as part of a data sharing agreement between the school district and a local university, the school district Office of Research and Compliance merged standardized testing scores, aerobic fitness, height and weight data, and student-level sociodemographic data. The data were de-identified and coded before being released to researchers. The study was reviewed and approved by the Institutional Review Board at Furman University.

Instruments and Measures

Academic Achievement

The main dependent variable of youth academic achievement was assessed using continuous, absolute scores of standardized test scores across three subject areas from the Palmetto Assessment of State Standards subject area tests: writing, English/language arts, math, science, and social studies. Subject area tests were administered to all fourth and fifth grade youth in the spring of 2013. Each subject area test consists of multiple choice items that are scored as right or wrong and have a raw score value of one point. If a student chooses the wrong answer, does not answer the item, or marks more than one answer for an item, the item is scored as wrong and the student receives no point for that item. Students receive a continuous score ranging from a minimum of 300 to a maximum of 900 (32).

Youth Aerobic Fitness

The main predictor variable of individual youth aerobic fitness was assessed using the number of Progressive Aerobic Cardiovascular Endurance Run (PACER) laps completed. PACER is a 15- or 20-m shuttle run that has been previously validated as an acceptable estimate of a youth's maximum oxygen intake for aerobic performance, or what is commonly known as $\dot{V}O_{2max}$ (38). During the fall of the 2013 academic year, trained PE teachers administered and entered PACER results for fourth and fifth grade youth enrolled in PE classes. PE teachers entered results into the FitnessGram database, a computer program used to assess, record, and track youth activity and fitness (i.e., aerobic capacity, BMI, curl-ups, etc.). The 20-m PACER shuttle run is the standardized procedure; however, because of the shortened length of some elementary school gymnasiums, standards for the alternative 15 m were created. To standardize measures across all youth, the FitnessGram PACER conversion chart was used by researchers to convert 15-m PACER results to the corresponding number of laps for the 20-m PACER before data analysis.

Youth Weight Status

Youth weight status was assessed using BMI calculated from height and weight measures collected as part of annual student FitnessGram assessments. Individual youth height and weight data were collected by trained PE teachers for all fourth and fifth grade students enrolled in PE classes during fall of 2013. Height and weight were assessed using a Seca 769 measuring station (Seca Corporation, Hanover, MD). The digital scale has a maximum capacity of 200 kg (450 lb) with accuracy within 0.2 lb. The Seca 769's stadiometer has a range of 60–200 cm (24–78 inches) with accuracy within 1 mm (1/25 inch). New Seca 769 measuring stations were provided for each elementary school in the summer of 2012. PE teachers were instructed to measure fourth and fifth grade youths' height and weight during a 3-wk period in October 2013. At the end of each 3-wk period, PE teachers entered height and weight data into the FitnessGram database.

In addition to variation by weight for height, youth BMI varies by age and sex; therefore, before data analysis, youth BMI percentiles were calculated. Initial inspection of the youth BMI percentiles indicated that the data were not normally distributed. To create a normal distribution, BMI z-scores were calculated using the CDC protocol and source code (4).

Youth Sociodemographic Characteristics

Sociodemographic information including sex, race/ethnicity, school lunch status, grade level, and birth date were obtained for each youth through the school district database. Race/ethnicity was categorized as "non-Hispanic white," "non-Hispanic black," "Hispanic," and "Other." School lunch status, used as a proxy for socioeconomic status, was categorized by the school district as "free," "reduced," or "full-pay." As part of the National School Lunch Program, eligibility for free or reduced lunch status is determined by household income and size (37). Sex was categorized as "male" or female," and grade level was categorized as "fourth" or "fifth" grade.

Analytic Approach

Descriptive information was obtained on standardized test scores, number of PACER laps completed, BMI z-score, and relevant demographic characteristics (Table 1). Then, for each academic subject area (i.e., writing, language arts, math, social studies, and science), a series of four two-level linear models were used to examine the research questions. Multilevel linear models were used to account for the nesting of youth within schools. First, an unconditional model with no predictors was estimated to determine the between-school variation, or intraclass correlation, for each subject area followed by a model that included all three individual-level youth demographic characteristics and BMI z-score as fixed effects (not shown). To answer the main research question, PACER laps was added to the model (Table 2, model 1 for each subject area). For the final model, we examined whether sex moderated the associations between PACER laps and each subject test score by including an interaction term between sex and PACER laps (Table 2, model 2 for each subject area). Model fit was assessed throughout the model-building process by examining the changes in –2 log-likelihood and applying the χ^2 likelihood ratio test to examine statistical significance between each model. We also examined the changes in Akaike Information Criterion and Bayesian Information Criterion between statistical models in which lower values indicate better model fit. For example, for writing, we compared model 1 with the unconditional model (not shown) and model 2 to model 1. Interpretation of results was based on significant statistical tests ($P < 0.05$) and model fit statistics. All analyses were completed in SAS v9.4 using PROC MIXED with maximum likelihood estimation and Satterthwaite degrees of freedom.

RESULTS

Sample Characteristics

Sample characteristics for fourth and fifth grade youth are presented in Table 1. Youth included in the final analytic sample were predominantly white (64%), followed by black (20%) and Hispanic (13%). About half of the students were male (51%). Slightly

TABLE 1.
Sample Characteristics for Fourth to Fifth Grade Youth, Including Mean Standardized Test Scores and Percentages of Race/Ethnicity, Sex, and Lunch Status Among Studied Population.

	Mean or Pct.	SD	Range
Test score			
Writing (n = 8641)	638.4	48.0	467 to 860
English (n = 8654)	656.5	50.6	485 to 858
Math (n = 8662)	651.6	55.3	480 to 859
Social studies (n = 6490)	661.7	53.4	376 to 900
Science (n = 6504)	636.1	49.3	300 to 841
Number of pacer laps (cardiorespiratory fitness, n = 8882)	22.0	13.4	0 to 125
BMI z-score	0.3	1.2	−4.5 to 7.0
Grade level			
Fourth grade (n = 5095)	50.3%		
Fifth grade (n = 5069)	49.7%		
Sex			
Male	51.6%		
Female	48.5%		
School lunch status			
Full priced	55.3%		
Free or reduced price	44.7%		
Race/ethnicity			
White	64.1%		
Black	20.1%		
Hispanic	13.0%		
Other[a]	2.9%		

[a]All other races/ethnicities were combined because of the small sample size.

more youth were eligible full-pay lunch (55.3%), and about 45% of students were eligible for free or reduced lunch. The highest mean score by test subject area was in English/language arts ($\bar{X}$ = 656.9, SD = 50.5), followed by math ($\bar{X}$ = 652.6, SD = 55.2), social studies ($\bar{X}$ = 661.7, SD = 53.4), writing ($\bar{X}$ = 638.9, SD = 47.8), and science ($\bar{X}$ = 636.1, SD = 49.3). The total number of PACER laps completed by youth ranged from 0 to 125, with youth completing an average of 22.0 laps (SD = 13.4), and BMI z-score ranged from –4.4 to 7, with an average score of 0.28 (SD = 1.21).

In null models, the level 2 units (i.e., schools) accounted for 11.1%, 8.9%, 10.5%, 9.7%, and 9.8% of the variation in writing, English/language arts, math, social studies, and science, respectively, suggesting some variance in the dependent variable across level 2 units and justifying the use of multilevel modeling analyses. Table 2 reports the results from the multilevel linear regression models assessing the association between youth aerobic fitness and academic achievement. Model 1 estimates the association between aerobic fitness and academic achievement while controlling for important covariates including youth BMI z-score, sex, grade level, race/ethnicity, and income. There was a significant and negative association between BMI z-score and academic achievement for social studies (b = 1.7, P < 0.05). In addition, results indicate that there is a small but positive association between the number of PACER laps completed and standardized testing scores in writing (b = 0.54, SD = 0.04), English/language arts (b = 0.3, SD = 0.05), math (b = 0.61, SD = 0.05), science (b = 0.3, SD = 0.05), and social studies (b = 0.3, SD = 0.06). Model 2 includes an interaction term between aerobic fitness and sex for each subject area test. No statistically significant interactions were found between sex and aerobic fitness for any of the subject areas.

DISCUSSION

Previous research demonstrates that increased aerobic fitness is correlated with academic achievement among youth (2,3,11,15,22,39). Using cross-sectional data from a large south eastern school district, results from this study indicate that increased aerobic fitness, as measured by the number of PACER laps completed, was positively associated with raw continuous standardized testing scores in writing, English/language arts, math, social studies, and science subject area tests. Furthermore, findings remained significant after controlling for the covariates of sex, age, race/ethnic, school lunch status, grade level, and youth BMI. Specifically, these findings indicate that if the youth were able to increase the number of PACER laps they run by 10, this would result in an average corresponding increase in standardized testing score of 5.0, 3.0, 6.0, 3.0, and 3.0 for writing, English/language arts, math, social studies, and science, respectively.

These findings are similar to previous research that indicates that the strongest effect sizes for the relationship between aerobic fitness and academic achievement are seen most frequently in math and writing/reading subject areas (10,34). Reasons behind the strength of the relationship with math and reading/writing scores compared with other subject areas, however, remain unclear. Some researchers hypothesize that the specific neurocognitive pathways associated with acquiring and executing these skills may be more sensitive to the positive effects of PA on the brain (10,16,22,28). Future studies should also incorporate measures of cognitive function while still exploring differences in academic achievement by subject area tests to further elucidate the observed differences in the relationship between aerobic fitness and academic achievement.

One of the most interesting findings in the present study was the observed differences in the relationship between aerobic fitness and academic achievement by sex. Female youth performed significantly better than male youth on writing, English/language arts, and math standardized tests, net of all other factors (P < 0.001). Although boys scored higher on social studies (5.9, P < 0.005), the difference in standardized testing scores in science between male and female youth was not significant. The greatest difference was observed for the area scores in the writing subject, with female youth scoring on average 22.2 points higher than male youth, followed by an average of 11.1 points higher on English/language and 5.0 points higher on math subject area tests. The current study also explored the moderating effect of sex on the relationship between youth aerobic fitness and academic achievement. Findings indicate, however, that sex is not a moderator in the relationship

TABLE 2.
Results of the Multilevel Regression Models Indicate an Association Between Aerobic Fitness and Academic Achievement in Fourth and Fifth Grade Youth.

	Subject Area Tests									
	Writing (n = 5478), b (SE)		English/Language Arts (n = 5484), b (SE)		Math (n = 5489), b (SE)		Social Studies (n = 4411), b (SE)		Science (n = 4456), b (SE)	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Fixed effects										
Intercept	635.7 (3.0)**	635.4 (3.0)**	684.0 (3.0)**	684.6 (3.1)**	642.4 (3.6)**	642.5 (3.7)**	650.6 (4.2)**	651.4 (4.3)**	630.7 (3.7)**	631.2 (3.7)**
Grade level	−3.6 (1.2)**	−3.6 (1.2)**	−16.3 (1.3)**	−16.3 (1.3)**	7.8 (1.4)**	7.8 (1.4)**	12.6 (1.7)**	12.5 (1.7)**	8.3 (1.5)**	8.3 (1.5)**
Race/ethnicity										
Black	−18.1 (1.6)**	−18.1 (1.6)**	−25.1 (1.8)**	−25.1 (1.8)**	−31.3 (1.9)**	−31.3 (1.9)**	−23.2 (2.1)**	−23.2 (2.1)**	−27.5 (1.9)**	−27.5 (1.9)**
Hispanic	−11.8 (2.0)**	−11.8 (2.0)**	−16.8 (2.1)**	−16.8 (2.1)**	−12.6 (2.3)**	−12.6 (2.3)**	−12.0 (2.6)**	−12.0 (2.6)**	−14.0 (2.3)**	−14.0 (2.3)**
Other	−1.3 (2.7)	−1.3 (2.7)	−4.1 (2.9)	−4.1 (2.9)	−7.6 (3.2)*	−7.6 (3.2)*	−7.1 (3.6)*	−7.1 (3.6)*	−4.4 (3.1)	−4.4 (3.1)
Free/reduced lunch	−21.9 (1.3)**	−21.9 (1.3)**	−22.7 (1.4)**	−22.7 (1.4)**	−24.8 (1.6)**	−24.8 (1.6)**	−22.7 (1.8)**	−22.7 (1.8)**	−22.3 (1.6)**	−22.3 (1.6)**
Female	21.3 (1.1)**	22.2 (2.2)**	12.8 (1.2)**	11.1 (2.4)**	4.2 (1.2)**	5.0 (2.6)**	−3.8 (1.5)*	−5.9 (2.9)*	1.8 (1.3)	0.4 (2.6)
BMI z-score	0.4 (0.5)	0.4 (0.5)	0.4 (0.5)	0.5 (0.5)	1.0 (0.6)	1.0 (0.6)	1.4 (0.7)*	1.4 (0.7)*	0.7 (0.6)	0.7 (0.6)
PACER laps	0.5 (0.0)**	0.5 (0.0)**	0.3 (0.0)**	0.3 (0.0)**	0.6 (0.1)**	0.6 (0.1)**	0.3 (0.1)**	0.3 (0.1)**	0.3 (0.1)*	0.3 (0.1)*
Sex PACER* laps		−0.04 (0.1)		0.08 (0.1)		0.01 (0.1)		0.09 (0.1)		0.06 (0.1)
Model fit										
−2 the Log Likelihood Ratio test statistic	56,131.4[a]	56,131.2	57,081.4[a]	57,080.8	58,065.0[a]	58,065.0	46,709.4[a]	46,708.8	46,175.6[a]	46,175.2
AIC	56,153.4	56,155.2	57,103.4	57,104.8	58,087.0	58,089.0	46,731.4	46,732.8	46,197.6	46,199.2
BIC	56,173.8	56,177.4	57,123.8	57,127.0	58,107.4	58,111.2	46,751.8	46,755.0	46,217.9	46,221.4

Reference categories: fifth grade, white, full pay lunch, male.
*$P < 0.05$.
**$P < 0.01$.
[a]Statistically significant better model fit compared with the previous model.

between any of the subject area test scores and aerobic fitness. Although numerous studies have explored differences by sex in the relationship between aerobic fitness and academic achievement, with most finding that the relationship is stronger for females versus males, few have attempted to explain the reason for these differences (7,10,15,34). One suggested theory is that female youth may benefit more from the self-esteem enhancing benefits of improved aerobic fitness and participation in PA compared with male youth, especially given that female youth often start at lower fitness levels and engage less regularly in PA (10,39).

Interestingly, no research to date supports that increased classroom instruction time, at the expense of PE or recess and free play, has had a positive effect on standardized testing scores (5,15,23,38). Rather, most research indicates that increased time spent in PA, which if undertaken regularly, increases youth fitness levels and in turn improves brain health and cognition, leading to potential improvements in academic achievement (5–9,31). Furthermore, some research suggests that the greatest improvements in cognitive function and academic achievement are achieved when youth engage in moderate-to-vigorous versus light PA (23).

These findings support the need for policy and practice change efforts directed at the revision of school curricula to increase the amount of time, frequency, and intensity in which youth engage in PA through both daily PE and recess or free play (14). Incorporation of PA into academic curricula may increase learning in the classroom by increasing attention to task, while also providing healthful breaks from sedentary classroom behavior (24). These changes have potential to not only support academic achievement throughout childhood and adolescence, but also support overall physical and mental health throughout the adult life course. School-based PA and PE can improve cardiovascular fitness among youth, thereby reducing the risk of chronic disease risk factors, including elevated blood cholesterol, fasting blood glucose, and blood pressure, without sacrificing current and future educational attainment. Overall findings from this and previous studies suggest that school health advocates and policy makers should consider a holistic approach to educational attainment that incorporates not on learning, but total mind and body health as well (2,5,15).

In a 2004 study by Stewart et al. (34), researchers found that with limited training and resources, teachers will able to gain the confidence and skills to incorporate PA into their academic curricula. Inclusion of PA supporting classroom enhancements may expend excess energy, allowing youth to focus on classroom learning objectives, while simultaneously improving classroom behavior.

Limitations

One major limitation of the present study is the cross-sectional nature of the data, which limits the researchers' ability to definitively establish causality of the association between aerobic fitness and academic achievement; therefore, we cannot conclusively determine if the findings are related to some other spurious relationship. To support inferences of causality, future studies should consider using longitudinal measures of the main relationship of interest. In addition, although we used multilevel modeling to adjust for the nesting of students within schools, there were no other level 2 school indicators available in the present study. Future studies should consider the inclusion of important school level factors, such as school PE policy or differences in teacher training in FitnessGram or level of education (i.e., bachelors vs masters) by school. A further limitation of the study is that although previous research has demonstrated that participation in regular PA and increased levels of aerobic fitness are highly correlated, the present study did not have a direct measure of youth PA participation. Future studies should consider examining both youth PA participation and aerobic fitness measures within the same sample, thus allowing researchers to gain a better understanding of the relative importance of aerobic fitness levels versus participation in regular bouts of PA or engagement in PA before learning or task completion.

A major strength of this study is that it was one of the few to include multiple demographic characteristics such as sex, grade level, race/ethnicity, and a socioeconomic indicator as potential confounders in the relationship between aerobic fitness and academic achievement; however, the use of school lunch status as a proxy for youth socioeconomic status is limited in its utility. Eligibility for free/reduced lunch status is determined by household income; however, receipt of the benefit is dependent on parent/guardian completion of a self-report application. Therefore, there is potential that the socioeconomic status of individual youth is either over- or underestimated. Another potential limitation is that youth physical fitness, height, and weight measures were collected by PE teachers. Teachers receive annual training from the district as part of continuing education; however, no method is available to check accuracy of measurement technique. Future studies should consider incorporating fidelity checks conducted by trained researcher to ensure that PE teachers are using proper PACER, height, and weight measurement techniques.

CONCLUSION

Overall, these results indicate that even after controlling for important covariates including youth BMI, sex, grade level, race/ethnicity, and school lunch status, there is a significant and positive relationship between youth aerobic fitness and academic achievement across all subject area tests, with academic achievement increasing as levels of aerobic fitness increase. These findings are supported by previous research highlighting the important role that aerobic fitness among elementary school youth plays in healthy brain development during this rapid period of growth and acquisition of new cognitive skills. Thus improving youth fitness levels at an early age may impact lifelong academic achievement and educational attainment. The results from this study provide valuable evidence to advocate for the inclusion policies that provide youth daily PA and PE opportunities at the national, state, and local levels, and that the inclusion of these policies may have academic achievement enhancing rather than detracting effects.

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