Research Article

Children's Physical Fitness and Academic Performance

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ABSTRACT

Background: *Childhood obesity is a major public health threat. Increased fitness may have a positive influence on cognitive performance in both adults and children.* ***Purpose:*** *To examine which aspects of children's fitness assessment are associated with their performance on four different academic areas.* ***Methods:*** *FITNESSGRAM measures aerobic capacity, abdominal strength, upper body strength/endurance, flexibility, and trunk lift. Gender and a socio-economic status proxy were compared with mean group performance scores across four subscales: mathematics, reading/language arts, science, and social studies of a statewide standardized academic performance test on a sample of 968 5th grade students (50.7% male; mean age = 10.6 years).* ***Results:*** *Achievement test scores were significantly better for children who were in the Healthy Fitness Zone (HFZ) for aerobic capacity and abdominal strength tests when compared to children who were unable to achieve the healthy zone. Children in the HFZ for upper body strength performed significantly better in math. Children in the HFZ for flexibility performed significantly better in math and science. No differences were found in academic performance when children in the HFZ for trunk lift were compared to children not in the healthy zone. When all FITNESSGRAM measures were used in a full factorial ANOVA with Body Mass Index (BMI), gender and meal program (a proxy variable for socioeconomic status) as covariates, aerobic capacity was found to be the only fitness variable consistently appearing as important. It was always significant as a main effect variable while no other main effect fitness variable achieved significance for any WESTEST subject. Two-way, three-way, and four-way interactions always included aerobic fitness and no other fitness measure was universal in these interactions.* ***Discussion:*** *Whereas, aerobic fitness appears universally important in academic success, additional mechanisms may be at work due to the several interactions that achieved significance. The interactions may be an indication of the importance of overall fitness in addition to aerobic fitness. These findings support the development and implementation of childhood cardiovascular risk surveillance programs that not only evaluate children's overweight risks but also their fitness.* ***Translation to Health Education Practice:*** *Increased focus on ways to improve children's fitness levels may create the need to reevaluate current policy recommendations for children's physical education.*

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BACKGROUND

Childhood obesity is considered to be one of the major public health threats of the 21st century.[1] Since 1980, the percentage of children who are overweight has more than doubled, while rates among adolescents have more than tripled.[2] In 2004, 18.8% of 6- to 11-year-old children were overweight and 17.4% of 12- to 19-year-old adolescents were overweight.[2]

Childhood overweight has been shown to significantly affect a child's physical, social, and emotional development. A variety of physical health concerns known to be correlated with children's weight include high blood pressure, high cholesterol, and type II diabetes.[3] Studies have also shown that overweight children are more likely to be socially withdrawn, depressed, and anxious when compared to children of lower weight categories.[4-7] Less studied is the relationship between childhood overweight and cognitive functioning.[8-13]

Previous studies have established a relationship between childhood obesity and students' academic performance. A study by Ding, Lehrer, Rosenquist, and Audrain-McGovern revealed that obesity was associated with an average GPA that was 0.43 less than non-obese adolescents.[13] Further

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evidence was provided by Datar, Sturm, and Maganabossa who found significant differences in test scores by overweight status at the beginning of kindergarten and at the end of grade one.[9] These authors, however, argued that the differences in student academic performance scores could be explained by other individual characteristics such as parental education and home environment.

In related research, the restorative effects of physical activity on cognitive functioning have been described over the past two decades.[15-20] For instance, Blomquist and Danner demonstrated that the group of adults (18-48 years old) who improved 15% or more in physical fitness improved significantly more on name recall than the group whose fitness remained stable.[15] Colcombe and colleagues demonstrated that physical exercise may slow aging effects and help people maintain cognitive abilities well into older age, resulting in decreased incidence of Alzheimer's and dementia.[16] Likewise, Etnier and Berry showed significant improvements in cognitive function at three months with distance walked in older patients with Chronic Obstructive Pulmonary Disease (COPD).[17] Another study found that fitness at age 11 was significantly associated with successful cognitive aging at age 79.[18] Furthermore, some researchers have hypothesized that the relationship between aerobic fitness and cognitive processes is more complex. They differ by age and type of cognitive processes, with tasks requiring strong attentional capacities being more affected.[19]

Although most of the work in this area has been conducted among older samples, a large study in California demonstrated significant differences in academic performance when the number of FITNESSGRAM tests for which the child was in the Healthy Fitness Zone (HFZ) was considered.[20] Specifically, the more tests for which the child was in the HFZ, the better the child's scores on California Standards Tests. The authors also found socioeconomic status (SES) to be a factor in academic success. They found that the relationship between fitness and academic achievement was especially strong for females and for higher SES students. Finally, they cautioned that causality that increased fitness caused a higher level of academic achievement could not be inferred. Cottrell et al. have shown that a collective model consisting of student gender, socioeconomic status (SES), and fitness explains a considerable amount of the variation in 5th graders' academic performance on the West Virginia Educational Standards Test (WESTEST).[14] While this data set had Body Mass Index (BMI) data, this variable was not found to be significantly associated with any academic score when used in the above multivariate model, providing evidence that fitness may be a better predictor of academic achievement than BMI.

To improve the understanding of relationships between physical fitness and cognitive functioning among child samples, several remaining questions must be addressed. First, what are the specific areas of fitness accounting for differences in academic test scores? Multiple areas of fitness are assessed using standardized procedures, but not all types of fitness may be related to academic performance. Identifying particular areas of fitness would allow programs to target certain types of physical activity that might maintain or improve cognitive performance on school assessments. Second, do different fitness areas relate to different types of cognitive assessment? For instance, certain types of fitness may be more germane to mathematic ability than others related to science or social studies applications.

PURPOSE

This study examines potential associations of some of the factors examined previously:[14] SES, gender, student BMI, and the various fitness tests featured in the FITNESSGRAM, with children's academic performance on four standardized subscales: mathematics, reading/language arts, science, and social studies. Specifically, FITNESSGRAM tests were explored individually to assess their effect on student academic performance after other variables (BMI, socio-economics, gender) are considered.

Target Audience

Participants were 5th grade students enrolled in Wood County, a relatively rural, primarily Caucasian school district in West Virginia. A total of 968 students (50.7% male) ranging from age 9 to 13 (mean age 10.6 years) participated in this study through passive school-based consent process associated with the BMI screening. Fitness test score data from three schools were reported in the aggregate only, causing individual students to have missing FITNESSGRAM data. Subjects who had missing data for either WESTEST or FITNESSGRAM were eliminated from the data set, leaving 741 students in the analysis.

MATERIALS AND RESOURCES

Children's Standardized Academic Test Scores

The West Virginia Educational Standards Test (WESTEST) is completed annually by West Virginia children in grades 3-8 and 10 during a selected week in May. It is a criterion-based reference for academic performance, and is used to identify areas in need of additional instruction. WESTEST scores four areas of academic performance: reading/language arts, mathematics, science, and social studies. A student is given one of five possible classifications in each area: novice (scored as a "1"), partial mastery ("2"), mastery ("3"), above mastery ("4"), and distinguished mastery ("5"). An acceptable range of mastery in a given subject is considered to be a score greater than or equal to 3.

Children's Standardized Fitness Test Scores

All students from kindergarten to the first year of high school are enrolled in physical education. FITNESSGRAM[24] is administered to all students in West Virginia grades 4-8 plus one high school year, except those students excused for reasons such as illness, injury, or long term absence. FITNESSGRAM utilizes criterion-referenced standards associated with good health in children to assess their fitness in six areas: aerobic capacity, abdominal strength and endurance, body composition, upper body strength and endurance, flexibility, and trunk extensor strength and flexibility. It is designed to complement Physical Best, a comprehensive physical education program that promotes lifelong physical fitness and activity. Validity/reliability of each assessment and the rationale behind the determination of the standards is explained in the FITNESSGRAM/ACTIVITYGRAM Reference Guide.[25]

Physical Best trainers provided in-service training to physical education (PE) teachers in FITNESSGRAM administration in October, 2005, and conducted follow-up discussion and review sessions in February and May, 2006. Physical Best and FITNESSGRAM books and pacer CDs were provided. During the 2005-2006 school year, FITNESSGRAM was administered in PE class by school-assigned PE educators at the 19 elementary school sites during the winter and spring months. In those assessment areas with more than one option (such as choosing between the one mile run and the pacer test for aerobic fitness), testing choice was driven by available resources and teacher preference. Counting repetitions and correcting form/technique were accomplished through a combination of PE teacher observation and partner participation.

Performance on individual components was categorized into one of two groups. Children were either scored (1=Healthy Fitness Zone) where students met or exceeded the fitness target, or (0=Needs Improvement) where the student failed to meet the fitness target. For this study, body composition, which is part of FITNESSGRAM, was not scored in the above categories. CDC-defined BMI percentiles calculated in a separate health screening conducted from January through March, 2006[14] were used instead and analyzed as a continuous variable rather than the 1 or 0 option. Therefore, only five fitness variables were examined in this study. The following tests used are described in Table 1: (1) aerobic capacity (one mile run/pacer); (2) Abdominal strength and endurance (curl-up); (3) upper body strength and endurance (push-up, modified pull-up, pull-up, or flexed arm hang); (4) flexibility (back-saver sit and reach or shoulder stretch); and (5) trunk extensor strength and endurance (trunk lift).

Data

Fitness scores and BMI screening information were entered into a web-based application designed by the West Virginia Department of Education Office of Technology and Information Systems (OTIS). Information including child age, gender, WESTEST scores, and meal program status is routinely collected and managed in the West Virginia Education Information System (WVEIS). OTIS merged this information with the web-based application information in an Excel database. Meal program status (whether the child received a free lunch, a reduced cost lunch, or paid for their lunch) served as a proxy for SES. Other information about the participants' backgrounds and demographics (except for child age and gender) was not available. All descriptors were removed such as school ID number, student ID number, and student birth date prior to statistical analysis. These procedures were implemented at the county level and approved by the County Superintendent of Schools and West Virginia University Internal Review Board.

Assessment Technique

One-way analysis of variance (ANOVA) was used to compare means for children who were in the Healthy Fitness Zone for each individual fitness test with those in the Needs Improvement zone (NIz). An ANOVA model was used to examine the effects of the fitness tests (e.g., aerobic capacity) on students' academic proficiency (e.g., reading) after controlling for meal program (SES proxy), BMI and gender.

RESULTS

Student Fitness and Academic Performance

The mean scores on the WESTEST subscales of reading/language arts, mathematics, science, and social studies for the present sample were 3.212, 3.337, 3.350, and 3.292, respectively. The majority of children performed within the Healthy Fitness Zone for each FITNESSGRAM component with 67.2% in the HFZ for aerobic capacity, 85.8% for abdominal strength, 72.5% for upper body strength, 86.0% for flexibility, and 91.1% for trunk lift.

Varying Effects of Fitness Areas on Academic Measures

All children who were in the HFZ for aerobic capacity and abdominal strength scored significantly higher on every academic achievement test than those children who were in the Needs Improvement zone (Table 2). Mathematic scores were significantly higher among children who were in the HFZ for the upper body strength test and flexibility test. Science scores were also significantly higher for students in the HFZ for flexibility. There was no effect noted in the academic performance areas based on children's performances on the trunk lift test.

BMI, Soci-economic Status, Gender, and Fitness

No association between BMI and meal program (SES) was found in this data set, meaning similar BMI distributions were found for all children regardless of their economic background. To see which fitness variable(s) was (were) most associated with academic success after BMI, gender, and SES variables are controlled, a full factorial analysis of variance was used for each academic achievement test using BMI, gender, and SES as covariates. Significant associations are presented in Table 3. Being in the HFZ for the aerobic capacity test was significantly associated with success in all WESTEST components. No other main effect fitness variables improved the model accounting for the variances in student academic achievement. Multiple interactions were noted for all academic achievement areas except math. Where found, aerobic capacity performance was a consistent variable in each of these variable interactions (Table 3).

DISCUSSION

This study provides evidence of an association between physical fitness and academic achievement. Children who were in the Healthy Fitness Zone for the FITNESSGRAM tests of aerobic capacity and abdominal strength were significantly more likely to master the WESTEST components of reading/language arts, math, science and social studies than children who were in the Needs Improvement zone. Upper body strength and flexibility assessments were also found to be associated with particular academic achievement areas (i.e., upper body strength associated with children's mathematics performances and flexibility associated with mathematics and science performances). No associations were found between children's trunk lift performance and their WESTEST results. These findings provide further support to previous work suggesting that a fitter child is more likely to succeed in the academic environment.[20]

Among the various fitness measures, aerobic capacity was the only main effect variable that was associated with children's academic performances when all fitness variables were used in concert in a full factorial ANOVA. It was also the only variable, other than the SES proxy variable (meal program), that was significantly associated with every WESTEST component. Children's aerobic capacity reflects a relationship that has been studied in both animal models and human samples.[15-19, 21, 22] In summary, these findings reveal a positive association between aerobic capacity and improved cognitive functioning. Additional longitudinal findings like those described by Barnes, et al. demonstrate that aerobic capacity improvements directly affect older adults' performances on tasks assessing attention, verbal memory, and verbal fluency.[26] Several mechanisms have been proposed to support this relationship including issues related to improvements in endothelium-dependent vasodilation, increased oxygen supply to the brain, and decreased protein levels.[21, 22] To date, however, there has been limited work on this issue in terms of children's functioning. While the present findings support a connection between aerobic capacity and cognitive functioning, the mechanism for this relationship still remains unidentified among child samples.

There were several two-way, three-way, and four-way interactions that achieved significance. These interactions may point towards the importance of a "total body fitness" link with academic performance. Again, aerobic fitness was the only variable that was present in all interactions. Therefore, future work may continue to focus on this fitness variable as a central point to an overall total body fitness relationship. Flexibility was present in all but one interaction. Previous studies that focused on older adult samples have demonstrated a connection between improved muscle strength, mass, and increased energy. These performance measures and outcomes have also been associated with improved performance on mini-mental examinations and other cognitive tasks.[23] Similar mechanisms could be present with children and support the findings presented here. The fact that interactions were important in science, reading/language arts, and social science test scores, but were not found for mathematics is very interesting and may indicate different brain functions being involved for these academic subjects. Alternatively, certain forms of academic application may be more susceptible to changes in one's energy level and muscle composition at an earlier time point. Additional work is needed prior to making conclusive statements about the significant association between these types of tasks and children's academic performance measures.

In the few studies that have focused on student fitness and academic performance,[14, 20] FITNESSGRAM tests were examined together via a composite measure of fitness. The assumption was made that the effects of being in the HFZ in any sub-measure of fitness were additive in their relation to academic performance. The results of this study show that while children who achieved the HFZ for most of the FITNESSGRAM tests did significantly better on academic tests, one of the FITNESSGRAM tests (trunk lift) was not associated with academic performance. Furthermore, many of the remaining tests did not explain the variation in academic scores any better than one or two of the tests (specifically aerobic capacity). Thus, the different FITNESSGRAM tests do not appear to be additive in their relation to academic performance for this sample and the particular FITNESSGRAM component that was in the HFZ matters.

It is particularly noteworthy that BMI was not associated with academic achievement in the model. Even after looking at the different fitness tests separately and controlling for SES and gender, aerobic fitness and fitness interactions were a better predictor of academic success than BMI, which never achieved significance. This is more evidence that BMI is a symptom, not a disease, and that the focus needs to be on diet and activity as root causes.

There are several limitations of this study. The FITNESSGRAM tests were administered by different PE teachers across the school system. Despite training and review, there were most likely differences in how the assessments were conducted. FITNESSGRAM tests are scored as either in the HFZ or in the NIz; actual times (e.g., time for the mile run) or the number of repetitions (e.g., number of curl-ups completed) were not available. WESTEST results were categorical and actual scores on these tests were also not available. Tests like FITNESSGRAM and WESTEST are one-time events, and if a child was ill, or otherwise impaired, results would not be a reflection of their true ability to perform. All told, 23% of the students in the sample population missed at least one FITNESSGRAM test or WESTEST subject; or belonged to one of the three schools that did not provide individual fitness results, which could contribute to sampling error/bias. Finally, students in the study were predominantly Caucasian and representative of an average West Virginia school district, but results may not translate well to other areas of the country with more ethnic diversity.

TRANSLATION TO HEALTH EDUCATION PRACTICE

The role of schools is to prepare students for higher education, the world of work, and, ultimately, their role as responsible, productive citizens. The present findings may have significant implications for school policy and public health in terms of the possibilities for physical activity interventions. One of the main reasons listed for reducing an emphasis on physical activity and physical

Table 1. FITNESSGRAM Updated Third Edition

FITNESSGRAM Test	Description and Healthy Zone Thresholds
Aerobic Capacity	
Pacer	The student is expected to run back and forth across a 20-meter space at a pace defined on a beep-only or music audiotape and which gets faster each minute. If student gets to the other side before the pacing beep, he or she must wait until the beep to run back. The student is stopped when he/she does not reach the line the 2nd time before the beep. 10 yr. girls – 7 circuits; 10 yr. boys – 23 circuits 11 yr. girls – 15 circuits; 11 yr. boys – 23 circuits
One mile run	The student is expected to run one mile as fast as he/she is able. Walking is permitted if the student cannot run the entire distance. 10 yr. girls – 12:30; 10 yr. boys – 11:30 11 yr. girls – 12:00; 11 yr. boys – 11:00
Abdominal Strength & Endurance	
Curl-up	The student is expected to complete as many defined-form curl-ups as he/she is able at a gauged cadence of about 1 curl-up every 3 seconds. The student stops after completing 75 curl-ups, when he/she can no longer continue, or when a 2nd form correction is made. Either boy or girl: 10 yrs. – 12; 11 yrs. – 15
Upper Body Strength & Endurance	
90-degree push-up	The student is expected to complete as many defined-form 90-degree push-ups as he/she is able at a pace of 1 push-up every 3 seconds. The student is stopped when a second form correction is made. 10-yr. girls – 7; 10 yr. boys – 7 11-yr. girls – 7; 11 yr. boys – 8
Modified pull-ups	The student is expected to complete as many defined-form modified pull-ups as he/she is able and with rhythmical, continuous movement. The student is stopped when a second form correction is made. 10-yr. girls – 4; 10 yr. boys – 5 11-yr. girls – 4; 11 yr. boys – 6
Pull-ups	The student is expected to complete as many defined-form complete pull-ups as he/she is able. Either boy or girl: 10 or 11 yrs. – 1
Flexed arm hang	The student is expected to hang with the chin above the bar as long as he/she is able. The student is stopped when student's chin touches the bar, his/her head tilts back to keep the chin above bar, or the chin falls below the bar. Either boy or girl: 10 yrs. – 4 seconds; 11 yrs. – 6 seconds
Flexibility	
Back-saver sit & reach	The student is expected to reach along a measuring scale of the test apparatus in a defined-form position with both the right and left sides of the body. 10 yr. girls – 9″; Boys – 8″ 11 yr. girls – 10″; Boys – 8″
Shoulder stretch	The student is expected to touch the fingertips together behind the back by reaching over the shoulder and under the elbow. 10 /11 yr. boys & girls - touch fingers.
Trunk extensor strength & flexibility	
Trunk lift	The student is expected to lift the upper body off the floor from a prone, defined-form position and hold that position for measurement. 10 /11 yr. boys & girls – 9″

Table 2. ANOVA Results with Fitness Variable Effects on Academic Performance

Source	Dependent Variable	Df	Mean Square	F Ratio	Academ. means for fitness test NIz/HFZ^
Aerobic Capacity	Reading/language arts	1	10.62	14.13***	3.09/3.34
Test total = 741	Math	1	23.12	28.06***	3.14/3.51
# in HFZ = 498	Science	1	11.44	19.39***	3.25/3.47
% in HFZ = 67.2%	Social Studies	1	8.50	11.99**	3.20/3.40
Abdominal Strength	Reading/language arts	1	10.03	13.34***	2.97/3.31
Test total = 741	Math	1	20.34	24.57***	2.98/3.46
# in HFZ = 636	Science	1	4.87	6.58**	3.20/3.43
% in HFZ = 85.8%	Social Studies	1	8.70	11.12**	3.07/3.38
Upper Body	Reading/language arts	1	.293	0.38	3.23/3.27
Test total = 741	Math	1	4.67	5.51*	3.26/3.44
# in HFZ = 537	Science	1	1.06	1.42	3.34/3.42
% in HFZ = 72.5%	Social Studies	1	0.01	0.01	3.33/3.34
Flexibility	Reading/language arts	1	1.31	1.71	3.15/3.27
Test total = 741	Math	1	8.41	9.97**	3.13/3.43
# in HFZ = 637	Science	1	4.72	6.38**	3.20/3.43
% in HFZ = 86.0%	Social Studies	1	1.52	1.92	3.22/3.35
Trunk Lift	Reading/language arts	1	2.40	1.82	3.08/3.28
Test total = 741	Math	1	1.55	1.82	3.24/3.40
# in HFZ = 675	Science	1	0.03	0.04	3.38/3.40
% in HFZ = 91.1%	Social Studies	1	0.02	0.02	3.32/3.33

* - significant at 0.05 level; ** - significant at .01 level, *** - significant at 0.001 level
^ - NIz – Needs Improvement zone, HFZ – Healthy Zone Zone

education in schools is the intense pressure to increase curriculum instruction for the purpose of improving standardized test scores.[1] This study gives evidence that this strategy may be counter-productive.

The results of this study indicate that aerobic training has a significant association with academic performance and that general fitness training may also be involved. This raises the possibility that a child's chances for academic success could be improved by increasing fitness. Aerobic fitness has been shown to influence the cognitive function of older adults and it has been hypothesized that these gains may not be in a good dose-response relationship with aerobic capacity.[17] They suggest that the biggest gains in cognitive ability may happen early in an exercise program as opposed to increasing aerobic fitness leading to higher cognitive gains. This is encouraging because cognitive gains can happen fairly quickly after taking up an exercise program. If this is true with children, academic performance may not increase with increasing aerobic fitness. Instead, there may be a threshold similar to the "healthy zone/needs improvement" classification of the FITNESSGRAM that denotes the benefit. Policy modifications increasing the amount and type of physical activity during school days may be reconsidered given these and future findings.

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Table 3. Full Factorial ANOVA results showing the significant associations found between children's FITNESSGRAM scores and each WESTEST subject (BMI, gender and socio-economic status used as covariates)

Source	Independent variables	Mean Square	F Ratio	Partial Eta Squared
Reading/language arts	Meal Program (SES)	41.73	60.39***	0.078
	Aerobic Capacity	3.35	4.86*	0.007
	Aerobic CapacityXFlexibility	4.68	6.78**	0.009
Math	Gender	8.30	11.22***	0.016
	Meal Program (SES)	49.55	67.03***	0.086
	Aerobic Capacity	4.04	5.46*	0.008
Science	Gender	12.70	19.46***	0.027
	Meal Program (SES)	46.60	71.41***	0.092
	Aerobic Capacity	7.80	11.95***	0.017
Aerobic CapacityXAbdom.XUpper Body Strength		3.21	4.92*	0.007
Aerobic CapacityXUpper Body StrengthXFlexibility		3.13	4.80*	0.007
Aerobic CapacityXAbdom.XUpper BodyXFlexibiility		2.87	4.39*	0.006
Aerobic CapacityXUpper BodyXFlexibilityXTrunk		4.01	6.14*	0.009
Social Studies	Gender	7.55	10.87***	0.015
	Meal Program (SES)	54.32	78.24***	0.099
	Aerobic Capacity	2.62	3.77*	0.005
Aerobic CapacityXUpper BodyXFlexibilityXTrunk		4.77	6.87**	0.010

* - significant at 0.05 level; ** - significant at 0.01 level, *** - significant at 0.001 level

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