Children's Aerobic Fitness and Academic Achievement: A Longitudinal Examination of Students During Their Fifth and Seventh Grade Years

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Objectives. We assessed children's potential differences in academic achievement based on aerobic fitness over a 2-year period.

Methods. The longitudinal study sample included 3 cohorts of students (n = 1725; 50.1% male) enrolled in a West Virginia public school system. Students received baseline fitness and academic assessments as fifth graders and at a 2-year follow-up assessment. We used FitnessGram to assess fitness in aerobic capacity and WESTEST, a criterion-based assessment, for academic performance.

Results. Students who stayed in the healthy fitness zone (HFZ) had significantly higher WESTEST scores than did students who stayed in the needs improvement zone (NIZ). Students who moved into or out of the HFZ occasionally had significantly higher WESTEST scores than did students who stayed in the NIZ, but they were rarely significantly lower than those of students who stayed in the HFZ.

Conclusions. Students' aerobic capacity is associated with greater academic achievement as defined by standardized test scores. This advantage appears to be maintained over time, especially if the student stays in the HFZ. (*Am J Public Health.* 2012;102:2303–2307. doi:10.2105/AJPH.2011.300515)

Multiple studies have examined the variety of benefits that physical activity and physical fitness offer youths. The health benefits of physical activity for children of any age (e.g., physical, physiological, emotional) are well documented.[1–11] A growing body of research has built an argument for positive associations between physical activity, physical fitness, and academic achievement.

In 2003, a meta-analysis by Sibley and Etnier[12] established that more physically active students perform better on a variety of tasks than students who are not as physically active. The investigators particularly noted that this level of performance was also found among physically active students who had experienced fewer hours of academic instruction time. A 2005 literature review by Taras[13] documented evidence of short-term cognitive benefits of physical activity.

More recently, studies in California,[14] Massachusetts,[15] and West Virginia[16] have demonstrated a significant positive association between the number of FitnessGram tests passed and academic achievement test performance. These assessments measure 3 health-related fitness areas: (1) aerobic capacity, (2) body composition, and (3) muscular strength, endurance, and flexibility; they are scored by criterion-referenced standards.[17] Other studies have found that academic achievement is most associated with aerobic fitness, generally the FitnessGram mile run or the Progressive Aerobic Cardiovascular Endurance Run (PACER), a back-and-forth run across a 20-meter space at a pace defined on a beep-only or music audiotape.[18–20] Additional research has provided further evidence that time away from the desk for physical education does not appear to affect academic achievement.[21,22] However, further work is needed to understand the extent to which physical activity affects student performance as measured by academic achievement.

Longitudinal fitness effects on student academics are limited. In one study, Aberg et al. used compulsory screening results from all Swedish men born from 1950 to 1976. They found that aerobic fitness levels from ages 15 to 18 predicted cognitive performance at age 18.[23] Examining similar outcomes among young children and in reference to their physical and academic performance could have significant clinical and policy implications. Accordingly, we explored the effects of aerobic fitness over a 2-year period on student academic achievement test scores. Sufficient evidence exists to predict differences in academic achievement between children in the healthy fitness zone (HFZ) and children in the needs improvement zone (NIZ) for aerobic fitness. However, greater evidence is needed to decipher the impact of children's fitness on their academic achievement over time. We therefore used a longitudinal examination to assess potential differences in academic achievement among children on the basis of their aerobic fitness FitnessGram category in the 2-year period.

METHODS

The study sample consisted of 3 cohorts of students (n = 1725) enrolled in the 19 elementary school (fifth-grade) and 6 middle school (seventh-grade) sites of a West Virginia public school system set within a relatively rural, primarily White area of West Virginia. During the 2009–2010 school year, 51% of the students met the financial requirements to receive their meals at a reduced rate or for free. Students were in fifth grade during the 2005–2006, 2006–2007, and 2007–2008 school years and in seventh grade during the 2007–2008, 2008–2009, and 2009–2010 school years. Students received baseline fitness and academic assessments as fifth graders. Follow-up assessments were conducted 2 years later. About half (50.1%) of the sample were male. Students participated through passive

school-based consent. Fewer than 2% of students opted out of the study by parent or guardian request each year.

Instruments

FitnessGram, a health-related fitness assessment, is used in West Virginia schools to assess health-related fitness levels in grades 4 through 8 and in 1 high school year. Assessment areas include aerobic capacity, upper body strength and endurance, body composition, abdominal strength and endurance, flexibility, and trunk extensor strength and flexibility. Aerobic capacity is measured by either the mile run or the PACER. The score for the mile run is the time it takes the child to run or walk 1 mile. With the PACER assessment, 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, which gets faster each minute. A student who gets to the other side before the pacing beep must wait until the beep to run back. A student is stopped if they do not reach the line the second time before the beep.

Choice of the PACER versus the mile run was each individual physical education teacher's decision, based on available resources and teacher preference. It was possible that students could have different tests in the different grades (for example, the PACER in the fifth grade and the mile run in the seventh). The validity or reliability of each assessment and the rationale behind the determination of the standards is explained in the FitnessGram/ActivityGram Reference Guide.[24] Trainers from Physical Best (a health-related fitness education program) trained physical education teachers in FitnessGram administration in October 2005 and conducted follow-up discussion and review sessions in February and May 2006. To standardize assessment procedures, we provided Physical Best and FitnessGram books and PACER compact discs.

We measured student aerobic capacity on the basis of each student's performance on either the PACER or mile run of the FitnessGram. Students performed in the HFZ if they met or exceeded the fitness target or in the NIZ if they failed to meet the fitness target. These designations were originally based on the number of circuits or miles completed by the student but were available for analyses only in categorical form.

WESTEST (West Virginia Educational Standards Test) is the West Virginia criterion-based reference for academic performance in grades 3 through 8 and 10. It is used to identify areas in need of additional instruction in 4 test areas—mathematics, science, social studies, and reading and language arts. Student results in each area are classified as (1) novice, (2) partial mastery, (3) mastery, (4) above mastery, and (5) distinguished. An acceptable range of mastery in a given subject is a score of 3 or higher (raw scores are not available). The criterion for the subscale scores across the 2-year assessment changed slightly. To correct for criterion differences, we standardized the mean scores for each of the 4 test areas.

Procedure

Fifth-grade students take physical education over the course of the school year, with a minimum of three 30-minute classes per week required; fifth-grade aerobic capacity assessment is completed in the spring of the academic year. Seventh-grade students are required to take 1 semester (2 terms) of physical education; seventh-grade FitnessGram assessments are completed in January, March, or May (second, third, or fourth term) depending on student physical education schedules.

WESTEST was conducted in compliance with state guidelines in the spring of each academic year. FitnessGram results, entered into a Web-based application, were later merged with WESTEST scores and other student information maintained in the West Virginia Education Information System (a computer-based data collection system) into a de-identified database for this study. Prior to statistical analysis, all descriptors, such as school identification number, student identification number, and student birth date, were removed.

Data Analysis

Using analysis of variance, we compared the standardized WESTEST scores in fifth and seventh grades of (1) children who stayed in the HFZ over the 2 years (880 students), (2) children who were in the HFZ in the fifth grade but fell into the NIZ in the seventh (280 students), (3) children who were in the NIZ in the fifth grade and moved into the HFZ in the seventh (221 students), and (4) children who stayed in the NIZ in both grades (344 students). We conducted all analyses using SPSS 18.0 (SPSS Inc, Chicago, IL).

RESULTS

We included all students who had complete information from both assessment periods (fifth and seventh grade) in these analyses. Of the total available (n = 2844) in the 3 cohorts, 681 did not have matching records between the fifth and seventh grades for a variety of reasons (moving into or out of a school or district, home schooling, prolonged absence), leaving 2163 available. Of the remainder, some students were missing aerobic fitness data for the fifth grade (n = 272) or seventh grade (n = 90), and others were missing 1 or more WESTEST scores for the fifth grade (n = 46) or seventh grade (n = 87). Fifth- and seventh-grade data were often missing for the same student. In all, 438 students were eliminated from the cohorts because of missing data, leaving 1725 records in the database.

Students who stayed in the HFZ in the fifth and seventh grades had significantly higher WESTEST scores than students who stayed in the NIZ in both grades. The students who moved into the HFZ or fell out of it between the fifth and seventh grades had similar WESTEST scores in both fifth and seventh grades. Compared with students who stayed in the NIZ, students who moved into or out of the HFZ had WESTEST scores closer to those of students who stayed in the HFZ. There was only one occasion, for fifth-grade reading, when scores were significantly lower for children in the NIZ who later moved into the HFZ than for students who stayed in the HFZ. On the other hand, there were multiple times when students who moved into or out of the HFZ scored significantly higher on WESTEST than students who stayed in the NIZ (Table 1). Figure 1 illustrates the often sizable difference between the scores of the children who stayed in the NIZ and the scores of children in the other 3 categories. For each of the 4 categories (HFZ to HFZ, HFZ to NIZ, NIZ to HFZ, and NIZ to NIZ), there were no significant differences

TABLE 1—Association Between Average Standardized Student Academic Achievement Scores and Student Fitness in Fifth and Seventh Grades: Wood County, West Virginia, 2005–2010

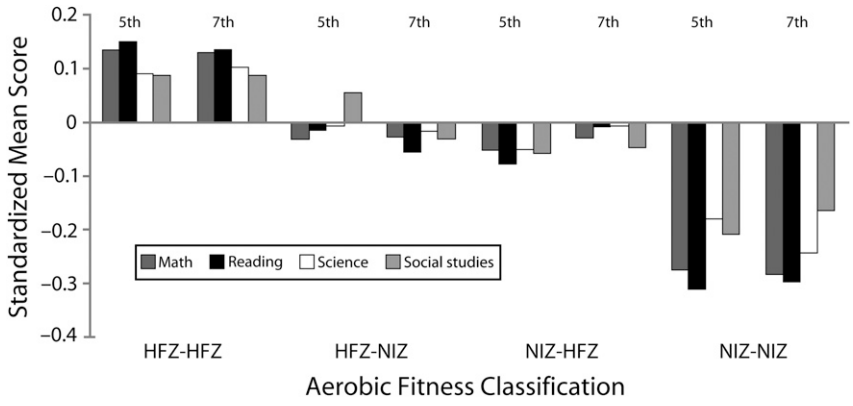
Fitness Zone Cohort	Math Score, Mean	Reading Score, Mean	Science Score, Mean	Social Studies Score, Mean
HFZ–HFZ (n = 880)				
5th grade	0.133[a]	0.148[a,b]	0.088[a]	0.084[a]
7th grade	0.127[m]	0.133[m]	0.101[m]	0.087[m]
HFZ–NIZ (n = 280)				
5th grade	−0.033	−0.014[c]	−0.005	0.055[b]
7th grade	−0.029	−0.056	−0.018	−0.030
NIZ–HFZ (n = 221)				
5th grade	−0.053	−0.078[b]	−0.052	−0.058
7th grade	−0.030[n]	−0.006[n]	−0.004	−0.048
NIZ–NIZ (n = 344)				
5th grade	−0.276[a]	−0.311[a,c]	−0.181[a]	−0.209[a,b]
7th grade	−0.284[m,n]	−0.298[m,n]	−0.244[m]	−0.164[m]

Note. HFZ = healthy fitness zone; NIZ = needs improvement zone. Students were assigned cohorts based on whether they stayed in the same or changed fitness zone. For standardized test scores, overall mean = 0, standard deviation = 1. For superscripts "a" and "m," $P < .001$; for superscripts "b," "c," and "n," $P < .01$. Superscripts "a," "b," and "c" always refer to fifth grade and "m" and "n" always to seventh grade. Comparisons are always within the same category. For example, HFZ–HFZ fifth-grade math is significantly different from NIZ–NIZ fifth-grade math at the .001 level, as designated by the "a" superscript. Likewise, NIZ–NIZ reading in seventh grade is significantly different at the .001 level from HFZ–HFZ reading as designated by the "m" superscript and significantly different at the .01 level from NIZ–HFZ reading as designated by the "n" superscript.

in WESTEST scores for fifth versus seventh grades.

DISCUSSION

The results of this study expand on existing knowledge about the association between student fitness—particularly aerobic capacity—and academic achievement by illustrating potential changes that could occur over time. Specifically, students who maintained a healthy fitness zone in terms of their aerobic capacity had the highest mean scores in academic achievement tests. Those who had the lowest mean scores were students who were not in the healthy zone for aerobic capacity in either grade (fifth or seventh). These results suggest that reaching and maintaining a healthy fitness level in this particular area could be fruitful in terms of one's performance on standardized tests.



Note. HFZ = healthy fitness zone; NIZ = needs improvement zone.

FIGURE 1—Standardized mean WESTEST subtests compared across all assessment periods: Wood County, West Virginia, 2005–2010.

It is interesting that children who gained fitness between the fifth and the seventh grades did not increase their academic mean scores to equal the academic mean scores of children who stayed in the HFZ. Likewise, students who fell out of the HFZ did not experience a drop in their academic achievement scores.

There are several factors that affect a child's ability to score in the HFZ for aerobic capacity. The child's level of fitness is obviously one of them. Also important to performance are considerations such as a child's health status, self-confidence, attitude, and appropriate clothing and shoes. The child's age is also a factor. For instance, a 10- or 11-year-old boy needs only to complete 23 circuits on the PACER test to score in the HFZ, but 32 circuits is required for a 12-year-old boy and 41 for a 13-year-old boy. If the child took the aerobic fitness test the week before he turned 13, he would be much more likely to pass than a child who turned 13 the week before the tests. Nevertheless, FitnessGram has been extensively tested for validity and reliability.[24]

Academic achievement is also influenced by many factors, especially a family's socioeconomic conditions[20] and, undoubtedly, genetics. Other factors are gender,[20,25] health, and sleep. One of the few factors that schools seem able to influence significantly is how much a child is able to move. Encouraging movement and fitness is likely to improve grades.[12,13,15–16,18–23]

Another possible way to look at the data presented here is that the children who "gained" or "lost" fitness during the 2 years between fifth and seventh grades were actually children whose fitness levels allowed them to score near the FitnessGram aerobic fitness target. Because FitnessGram is categorical (HFZ vs NIZ), it does not distinguish students who have moderate fitness; it is meant to distinguish between fit children and those who need improvement in their fitness. Children with moderate fitness may be those who come close to achieving the HFZ or barely make the HFZ, and their performance on any given day (or year) could fluctuate between the 2 categories.

Wittberg et al. identified aerobic fitness thresholds in a group of fifth-grade students

that confer the greatest benefit to academic achievement.[25] In the current study, students' aerobic capacity over time was associated with more effective academic achievement. Children who maintained aerobic fitness scored significantly higher in every WESTEST subject than did children who were in the NIZ both years. Children who changed aerobic fitness zones between the fifth and seventh grades scored higher in WESTEST than did those in the NIZ both years but lower than did those in the HFZ both years. Because the academic scores of children who changed fitness zones were closer to those of children who stayed in the HFZ than to those of children who stayed in the NIZ, it is possible that aerobic fitness levels near the FitnessGram aerobic fitness target will confer much of the benefit of consistently exceeding the FitnessGram aerobic fitness target. These findings have significant implications for the role of school-based physical activity and fitness programming in promoting each child's optimal academic achievement. Interventions designed to increase aerobic capacity should have an impact on increased cognitive performance.

A recent review by the Centers for Disease Control and Prevention presents collective evidence supporting the association between physical activity and cognitive performance across diverse research designs.[26] Limited studies indicate improvement in cognitive function associated with physical activity interventions. For example, Davis et al. randomized healthy but overweight children into 20 minutes of aerobic exercise a day, 40 minutes of aerobic exercise a day, or a control group that met for 15 weeks.[27] The high-exercise group showed improved planning scores on a cognitive performance assessment. A study by Hillman et al. documented improved cognitive performance in children with a single session of moderately intense aerobic exercise.[28]

Limitations

FitnessGram tests were administered by different physical education teachers, who, despite training and review, may have varied administration technique. Although FitnessGram standards were based on the best available research at the time, they have been revised because of issues such as classification discrepancies between the PACER and the mile run, and the high prevalence of passing PACER scores among young girls, which may indicate that the bar for this test is set too low.[29] Both FitnessGram and WESTEST results were reported categorically, and actual scores were not available. Furthermore, student health status the day of assessment as well as issues such as athletic ability, self-confidence, and attitude could affect results. There was also a substantial number of students who had missing data because they missed one of the many assessments or moved in or out of the school district. It should be noted that the results may not translate to more ethnically diverse areas because these students were primarily White and representative of an average West Virginia school district. Many factors, such as socioeconomic status, parental education, gender, sleep, health, and genetics, influence academic achievement, and none of these were examined in this study. Finally, there is some evidence that there may be gender differences associated with fitness testing, physical activity, and academic achievement.[25,30]

Conclusions

Much work remains to better understand the relationship between physical activity, physical fitness, and academic achievement. Interventions designed to increase aerobic capacity should be assessed in terms of their impact on increased cognitive performance. Additional work to better understand the dose of physical activity (frequency, length, strength) required to affect academic achievement is also needed. If effective, these interventions may create a paradigm shift in school-based support strategies for optimal academic achievement.

Furthermore, improving child fitness levels through regular physical activity may address 2 seemingly unrelated goals: (1) improving academic achievement and (2) reducing rates of childhood obesity and associated health risk factors. Fitness has been shown to be a better predictor of academic achievement than body mass index (BMI),[16,31] and fit individuals generally have healthier BMIs.[32,33] Therefore, intervening in 1 domain has a positive effect on many aspects of children's functioning. By promoting fun physical activity of a proper dose during the school day, children may not only optimize academic potential but learn and practice healthier lifestyle habits, reduce health risks associated with overweight (sedentary lifestyle), and develop a foundation of knowledge and practice that will benefit them through adulthood. ■

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Contributors

R. A. Wittberg developed the initial conceptual draft, contributed to the analyses, and was the primary writer of all drafts. K. L. Northrup contributed to the conceptual design, oversaw all data collection and database development issues, and contributed to the written drafts. L. A. Cottrell contributed to the conceptual design of the study, designed and conducted the statistical analyses, developed related tables and figures, and contributed to the written drafts.

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Human Participant Protection

Study procedures were implemented at the county level and approved by the county superintendent of schools and the West Virginia University internal review board.

References

1. Barlow SE. Expert committee recommendations regarding the prevention, assessment, and treatment of child and adolescent overweight ad obesity: summary report. *Pediatrics.* 2007;120(suppl 4):S164–S192.

2. Isganaitis E, Levitsky LL. Preventing childhood obesity: can we do it? *Curr Opin Endocrinol Diabetes Obes.* 2008;15(1):1–8.

3. Institute of Medicine. *Progress in Preventing Childhood Obesity: How Do We Measure Up?* Koplan J, Liverman CT, Kraak VI, Wisham SL, eds. Washington, DC: National Academies Press; 2007.

4. Koplan J, Liverman CT, Kraak VI, eds. *Preventing Childhood Obesity: Health in the Balance.* Washington, DC: National Academies Press; 2005.

5. Freedman DS, Khan LK, Serdula MK, et al. The relation of childhood BMI to adult adiposity: The Bogalusa Heart Study. *Pediatrics.* 2005;115(1):22–27.

6. Singh AS, Mulder C, Twisk JWR, VanMechelen W, Chinapaw MJM. Tracking of childhood overweight into adulthood: a systematic review of the literature. *Obes Rev.* 2008;9(5):474–488.

7. Salvadori M, Sontrop JM, Garg AX, et al. Elevated blood pressure in relation to overweight and obesity among children in a rural Canadian community. *Pediatrics.* 2008;122(4):e821–e827.

8. Dietz WH. Childhood weight affects adult morbidity and mortality. *J Nutr.* 1998;128(2 suppl):411S–414S.

9. Freedman DS, Mei Z, Srinivasan SA, Berenson GS, Dietz WH. Cardiovascular risk factors and excess adiposity among overweight children and adolescents: The Bogalusa Heart Study. *J Pediatr.* 2007;150(1):12–17.

10. Dietz WH. Health consequences of obesity in youth: childhood predictors of adult disease. *Pediatrics.* 1998; 101(3 pt 2):518–525.

11. Pate RR, Heath GW, Dowda M, Trost SG. Associations between physical activity and other health behaviors in a representative sample of US adolescents. *Am J Public Health.* 1996;86(11):1577–1581.

12. Sibley BA, Etnier JL. The relationship between physical activity and cognition in children: a meta-analysis. *Pediatr Exerc Sci.* 2003;15:243–256.

13. Taras H. Physical activity and student performance at school. *J Sch Health.* 2005;75(6):214–218.

14. California Dept of Education. A study of the relationship between physical fitness and academic achievement in California using 2004 test results. 2005. Available at: http://www.cde.ca.gov/ta/tg/pf/documents/2004pftresults.doc. Accessed May 26, 2009.

15. Chomitz VR, Slining MM, McGowan RJ, et al. Is there a relationship between physical fitness and academic achievement? Positive results from public school children in the northeastern United States. *J Sch Health.* 2009; 79(1):30–37.

16. Cottrell LA, Northrup K, Wittberg R. The extended relationship between child cardiovascular risks and academic performance measures. *Obesity (Silver Spring).* 2007;15(12):3170–3177.

17. Welk GJ, Meredith MD. *Fitnessgram/Activitygram Reference Guide.* Dallas, TX: Cooper Institute; 2008.

18. Welk J, Allen WJ, Morrow JR, et al. The association of health-related fitness with indicators of academic performance in Texas schools. *Res Q Exerc Sport.* 2010; 81(3 suppl):S16–S23.

19. Castelli DM, Hillman CH, Buck SM, Erwin HE. Physical fitness and academic achievement in third- and fifth-grade students. *J Sport Exerc Psychol.* 2007;29(2): 239–252.

20. Wittberg RA, Northrup KL, Cottrell LA. Children's physical fitness and academic achievement. *Am J Health Educ.* 2009;40(1):30–36.

21. Trudeau F, Shephard RJ. Physical education, school physical activity, school sports and academic performance. *Int J Behav Nutr Phys Act.* 2008;5:10. Available at: http://www.ijbnpa.org/content/pdf/1479-5868-5-10.pdf. Accessed December 2, 2010.

22. Carlson SA, Fulton JE, Lee SM, et al. Physical education and academic achievement in elementary school: data from the early childhood longitudinal study. *Am J Public Health.* 2008;98(4):721–727.

23. Aberg MAI, Pedersen NL, Toren KT, et al. Cardiovascular fitness is associated with cognition in young adulthood. *Proc Natl Acad Sci USA.* 2009;106(49): 20906–20911.

24. Welk GJ, Meredith MD. *Fitnessgram/Activitygram Reference Guide.* Dallas, TX: Cooper Institute; 2008.

25. Wittberg R, Cottrell LA, Davis CL, Northrup KL. Aerobic fitness thresholds associated with fifth grade academic achievement. *Am J Health Educ.* 2010;41(5): 284–291.

26. *The Association Between School Based Physical Activity, Including Physical Education, and Academic Performance.* Atlanta, GA: Centers for Disease Control and Prevention; 2010.

27. Davis CL, Tomporowski PD, Boyle CA, et al. Effects of aerobic exercise on overweight children's cognitive functioning: a randomized controlled trial. *Res Q Exerc Sport.* 2007;78(5):510–519.

28. Hillman CH, Pontifex LB, Raine DM, et al. The effect of acute treadmill walking on cognitive control and academic achievement in preadolescent children. *Neuroscience.* 2009;159(3):1044–1054.

29. FitnessGram: Healthy Fitness Zone Standards. 2011. Available at: http://www.fitnessgram.net/newstandards/#whynew. Accessed October 11, 2011.

30. Kwak L, Kremers PJ, Bergman P, et al. Associations between physical activity, fitness, and academic achievement. *J Pediatr.* 2009;155(6):914–918.

31. Roberts CK, Freed B, McCarthy WJ. Low aerobic fitness and obesity are associated with lower standardized test scores in children. *J Pediatr.* 2010;156(5):711–718.

32. Blair SN, Church TS. The fitness, obesity, and health equation. Is physical activity the common denominator? *JAMA.* 2004;292(10):1232–1234.

33. Wedderkopp N, Froberg K, Hansen HS, Anderson LB. Secular trends in physical fitness and obesity in Danish 9-year-old girls and boys: Odense School Child Study and Danish Substudy of the European Youth Heart Study. *Scand J Med Sci Sports.* 2004;14(3):150–155.