# Is There a Relationship Between Physical Fitness and Academic Achievement? Positive Results From Public School Children in the Northeastern United States

VIRGINIA R. CHOMITZ, PhD[a]
MEGHAN M. SLINING, MS, MPH[b]
ROBERT J. MCGOWAN, EdD[c]
SUZANNE E. MITCHELL, MD, MS[d]
GLEN F. DAWSON, MA[e]
KAREN A. HACKER, MD, MPH[f]

## ABSTRACT

**OBJECTIVES:** To determine relationships between physical fitness and academic achievement in diverse, urban public school children.

**METHODS:** This cross-sectional study used public school data from 2004 to 2005. Academic achievement was assessed as a passing score on Massachusetts Comprehensive Assessment System (MCAS) achievement tests in Mathematics (fourth, sixth, and eighth grade, n = 1103) and in English (fourth and seventh grade, n = 744). Fitness achievement was assessed as the number of physical fitness tests passed during physical education (PE). Multivariate logistic regression analyses were conducted to assess the probability of passing the MCAS tests, controlling for students' weight status (BMI *z* score), ethnicity, gender, grade, and socioeconomic status (school lunch enrollment).

**RESULTS:** The odds of passing both the MCAS Mathematics test and the MCAS English test increased as the number of fitness tests passed increased ($p < .0001$ and $p < .05$, respectively).

**CONCLUSIONS:** Results show statistically significant relationships between fitness and academic achievement, though the direction of causation is not known. While more research is required, promoting fitness by increasing opportunities for physical activity during PE, recess, and out of school time may support academic achievement.

**Keywords:** physical fitness and sport; policy; academic achievement.

**Citation:** Chomitz VR, Slining MM, McGowan RJ, Mitchell SE, Dawson GF, Hacker KA. 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: 30-37.

Accepted on February 4, 2008

[a]Senior Scientist, Institute for Community Health, Lecturer on Medicine, Harvard Medical School, and Adjunct Assistant Professor, Friedman School of Nutrition Science and Policy, Tufts University, (vchomitz@challiance.org), 163 Gore St, Cambridge, MA 02141.

[b]PhD Candidate (slining@email.unc.edu), Department of Nutrition, University of North Carolina at Chapel Hill, 123 W. Franklin St, University Square CB #8120, Chapel Hill, NC 27516-3997.

[c]Coordinator of Health, (rmcgowan@cpsd.us), Physical Education and Athletics, Cambridge Public Schools, 159 Thorndike St, Cambridge, MA 02141.

[d]Academic Faculty Fellow, (suzanne.mitchell@bmc.org), Department of Family Medicine, Boston University School of Medicine, Dowling 5, 1 BMC place, Boston, MA 02118.

[e]Biostatistician, (glendawson99@yahoo.com), 27 Reynolds Ave, Natick, MA 01760.

[f]Executive Director, Institute for Community Health and Assistant Professor of Medicine, Harvard Medical School, (khacker@challiance.org), 163 Gore St, Cambridge, MA 02141.

Address correspondence to: Virginia R. Chomitz, Senior Scientist, Institute for Community Health, Lecturer on Medicine, Harvard Medical School, and Adjunct Assistant Professor, Friedman School of Nutrition Science and Policy, Tufts University, (vchomitz@challiance.org), 163 Gore St, Cambridge, MA 02141.

This study was supported in part through the US Department of Education Carol M White Physical Education Program grant Q215F041121 to the Cambridge Public School Department.

Increased public attention to the rise in childhood obesity has resulted in a sharper focus on the role of food and physical activity in the academic environment. *Healthy People 2010* goals advocate increasing the proportion of schools requiring daily physical education (PE) for all students and increasing the proportion of adolescents who participate in daily school-based PE to 50%.[1] However, simultaneous pressures to meet academic achievement testing thresholds legislated by the federal ''No Child Left Behind Act of 2001'' has required some school administrators to shift resources away from PE toward time on academics. Some 14% of school districts report decreasing PE time to accommodate more Math and English.[2] In 1991, 41.6% of high school students participated in daily PE compared with 28.4% in 2003.[3] The consequences of this trend away from school-based PE on students' physical activity or fitness are not fully understood nor are the consequences to academic achievement. Physical fitness and physical activity have been shown to have positive effects on cognition and concentration.[4] To date, while some published evidence positively links physical activity, fitness, or PE to academic performance in the classroom, few studies have utilized standardized fitness and academic achievement scores to examine these relationships.[5,6]

A potential relationship of physical fitness to cognitive function may be explained by both physiological and psychological mechanisms. Results from animal studies show that physical activity stimulates neural development including a greater density of neuronal synapses[7] and higher capillary volume.[8] Physical activity is also consistently related to higher levels of self-esteem and lower levels of anxiety and stress—each of which has been associated with enhanced academic performance.[9-11] In reviews of physical activity and academic performance, researchers concluded that student attention was likely to be greater in an active rather than in a sedentary student. This may facilitate favorable interactions between the learning environment and the cognitive development.[12,5,6]

Yet, the question remains as to whether the level of physical fitness can be directly linked to students' academic performance on standardized achievement tests. Intervention trial results have been mixed. Some have shown a significant positive relationship between PE time and class grades,[13] while others have noted no differences in academic performance.[14,15] Cross-sectional analyses have demonstrated positive associations between physical fitness and academic performance.[16,17] For example, investigators in Illinois found that students' total fitness, as measured by passing all 5 components of the *Fitnessgram*, positively correlated with academic achievement, measured by the standardized Illinois State Achievement Test, particularly Mathematics and Science.[18]

Few studies have used standardized fitness measures and standardized test scores in large urban populations or examined the relationship of academic achievement and fitness among elementary and middle school students. To help fill this research gap, we examined the relationship between standardized measures for both fitness and academic achievement, adjusting for important demographic variables known to influence academic achievement using a large cohort of diverse urban students in fourth through eighth grade. Our study aimed to determine the relationship between physical fitness as measured in 5 domains, and standardized achievement as measured on the Massachusetts Comprehensive Assessment System (MCAS) Math and English components in fourth-, sixth-, seventh-, and eighth-grade public school children.

## METHODS

### Setting Subjects/Data Collection

The setting for the study was the Cambridge Public School Department (CPSD), a racially and economically diverse urban public school district. In 2004-2005, there were 3990 students enrolled in 12 CPSD elementary grades (kindergarten through eighth grade). Sixty-four percent of the students were non-white, and 43% qualified for the National School Lunch program (NSLP). Since 2000, the Physical Education Department at CPSD annually measures students' height, weight, and physical fitness during PE class with students from kindergarten to eighth-grade. PE teachers annually receive training in anthropometry, physical fitness, and data entry measurement protocols prior to data collection. Body mass index (BMI) and fitness data from the CPSD showed that 37.6% of the kindergarten to eighth-grade students were overweight or at risk of overweight as categorized by the CDC BMI-for-age growth charts, and 31.9% of the students passed all the fitness tests (unpublished data, VR Chomitz, PhD, July 2005).

For the purposes of this study, school record data that included standardized test scores, fitness, and BMI information for students who were enrolled in grades 4-8 during the 2004-2005 academic year were used. The study protocol was reviewed and approved by CPSD, the Institutional Review Board of the Cambridge Health Alliance, and the Institutional Review Board of Tufts University Health Sciences/Tufts-New England Medical Center in August 2005.

### Measures

***Academic Achievement.*** Academic achievement was measured using the MCAS, which annually tests all public school students across Massachusetts, including students with disabilities and students with limited

English proficiency. MCAS tests were administered in May 2005 by teachers in classrooms. As mandated by the Education Reform Law of 1993 and the federal No Child Left Behind Law from 2001, all students educated with public funds are required to participate in the MCAS tests administered in their grades. The CPSD Development and Assessment Office (DAO) performs management, analysis, and maintenance of student data and MCAS databases. MCAS is a criterion-referenced test that provides scores to parents and educators according to performance levels (advanced, proficient, needs improvement, and warning). Students in grades 4, 7, and 10 take English language arts MCAS tests, and students in grades 4, 6, 8, and 10 take Mathematics MCAS tests.[19]

We used both raw MCAS scores and dichotomous (''passing'' or ''not passing'') English MCAS achievement and Mathematics MCAS achievement variables since educators and policy makers generally use performance rather than raw MCAS scores to interpret achievement results. Congruent with CPSD standards (personal communication with Marianne McDonald, CPSD, August 2005), ''Advanced,'' ''Proficient,'' and ''Needs Improvement'' performance levels were considered ''Passing,'' while ''Warning'' was considered ''Not Passing.''

***Fitness Achievement.*** For this analysis, a Fitness Achievement variable was constructed as the number of fitness tests passed by an individual student (from 0 to 5 tests passed) and was used in statistical models as a continuous explanatory variable. In March and April 2005, students completed fitness tests in 5 domains adapted from the Amateur Athletic Union (AAU)[20] and Fitnessgram (Cooper Institute, Dallas, TX)[21] guidelines: an endurance cardiovascular test, an abdominal strength test, a flexibility test, an upper body strength test, and an agility test. Proficiency status (Participant, Attainment, Outstanding) was assigned for each test according to AAU and Cooper Institute guidelines as described in detail elsewhere.[22] A student received a ''Participant'' score if he or she participated but did not attain the criteria for passing the test, ''Attainment'' indicates a student met the criteria for passing, and ''Outstanding'' indicates a student exceeded the criteria for passing. For each fitness test, students were considered ''passing'' if they achieved ''Attainment'' or ''Outstanding.'' The number of passing scores was summed to create the analytic variable.

***Weight Status.*** For this analysis, weight status was assessed by BMI $z$ scores based on height and weight measurements collected with a standard protocol[23] by CPSD PE teachers in March and April 2005. Height was measured to the nearest 0.25 inch with a wall-mounted stadiometer (Seca 216 Accu-Hite, Snoqualmie, WA). Weight was measured to the nearest 0.1 pound with an electronic scale (Seca 216 Bellisima-digital) in light indoor clothing without shoes. BMI $z$ scores were calculated based on CDC protocol and utilized in the regression models. The range of BMI $z$ scores included in this analysis was BMI $z \geq -4$ and BMI $z \leq 5$. In addition, for descriptive purposes, BMI-for-age percentiles for boys and girls were constructed using the Centers for Disease Control and Prevention/National Center for Health Statistics growth charts and categorized as: overweight (≥95th percentile), at risk of overweight (between ≥85th and <95th percentile), healthy weight (between ≥5th and < 85th percentile), and underweight (<5th percentile).[24]

***Sociodemographic Measure.*** Gender (male/female), race/ethnicity (Black, Hispanic, Asian, White), and socioeconomic status (SES) (eligible/not eligible) for the NSLP were extracted from the school administration record system. NSLP eligibility (≤185% of federal household income level) was used as an indirect measure of family SES. SES was coded as a binary variable, lower SES (eligible for NSLP), or higher SES (ineligible for NSLP).[25]

### Data Analysis

To assess the association between the fitness status and the MCAS test, we used bivariate and multivariate regression analysis. A series of bivariate analyses were conducted to identify explanatory variables, and diagnostic analyses were run to assess any confounding effects among the variables. Individual students were the unit of analysis. All analyses were performed using the SAS statistical analysis system.[26]

Frequencies of health and demographic characteristics of the overall sample were obtained and stratified by the binary academic achievement outcome variables to identify potential explanatory variables for logistic regression modeling. Chi-square tests were used to assess statistical significance. Analysis of variance was used to test for differences between health and demographic group means by fitness achievement, the primary explanatory variable (analysis not shown). The raw Mathematics and English MCAS scores, as well as the proportion of students passing the Mathematics and English MCAS test scores, were controlled by gender, ethnicity, lunch status, and weight status through regression analysis. The adjusted scores were plotted according to the number of fitness tests passed to assess the shape and strength of the relationships.

Multivariate logistic regression models were constructed to evaluate the strength of the association between fitness achievement and the odds of a passing score on the Math and English MCAS tests after controlling for gender, SES, weight status, grade, and ethnicity. Variable selection for the logistic regression models was guided by the bivariate analyses and by use of the selection = score option in SAS proc logistic. The selection = score option is analogous to the

R-Square selection method. For both the Math and the English MCAS logistic regression models, the optimum model with highest chi-square score included the 8 variables of our original hypothesis (fitness achievement, gender, SES, weight status, grade, black race, Hispanic ethnicity, and Asian race). Odds ratios were calculated from the regression coefficients by exponentiation and are presented with 95% confidence intervals.

Interactions between fitness achievement and each covariate were tested using interaction terms. The criterion for statistical significance of covariates was $p < .05$. To adjust for multiple comparisons when testing interaction effects, $p < .0005$ was used as a criterion for statistical significance (.05/10 comparisons).

## RESULTS

A total of 2127 children were enrolled in grades 4, 6, 7, and 8 for the 2004-2005 academic year. Student records excluded from analysis included: 7.4% (157 students) who did not complete all 5 fitness tests; 1.2% (26 students) who had biologically implausible BMI $z$ scores, that is, BMI $z$ below −4 or above +5;[27] 1.0% (12 students) with implausible MCAS scores ≤0 or above 54 for Math and ≤0 or above 72 for English;[28] 1% (11 students) who were Native Americans and due to small cell size counts were excluded to protect confidentiality of subjects; and finally, 3.8% (80 students) who had special needs code indicating a significant degree of impairment. The final analytic sample included 1841 fourth-, sixth-, seventh-, and eighth-grade students, 87% of the original data set.

Sample characteristics are provided in Table 1. Sixty-five percent of the sample students were nonwhite, and 45% were of low income. Almost 40% (39.3%) of the students were overweight or at risk of overweight. Students passed, on average, 3.6 fitness tests. Overall, 72% and 89% of students passed the Mathematics and English tests, respectively.

Table 2 presents the proportion of students who passed the Mathematics and English MCAS tests by demographic, health, and fitness variables and their associated level of statistical significance. Student characteristics significantly associated with passing the Mathematics test included ethnicity, higher SES, and higher fitness achievement. Similarly, student characteristics significantly associated with passing the English test included being female versus male, ethnicity, higher SES, and higher fitness achievement. A student's weight status (underweight, "healthy weight," "at risk of overweight," and "overweight") was inversely associated with passing the Math MCAS test ($p = .05$) though not significantly associated with English achievement.

To assess relationships between explanatory variables, we compared the group means of health and demographic variables by fitness achievement. Statistically significant differences between groups were observed for gender ($p < .05$), ethnicity ($p < .05$), SES ($p < .001$), and weight status ($p < .001$). Interactions between fitness achievement and each covariate were tested using interaction terms. No significant interactions were found for either the Math or the English MCAS models.

Figures 1 and 2 plot, respectively, the proportion of students who passed the Mathematics and English MCAS tests by the number of fitness tests passed, controlling for demographic and health variables. Figure 1 demonstrates the strong, almost linear relationship between Mathematics MCAS tests and passing fitness tests ($p < .0001$). The logistic regression analysis (Table 3) estimated that the odds of passing the Math MCAS increased by 38% for each 1-unit increase in the number of fitness tests passed, holding gender, ethnicity, weight status, grade, and SES constant. Figure 2 demonstrates a statistically significant

Table 1. **Sample Characteristics for Cambridge Public School Fourth, Sixth, Seventh, and Eighth Graders (2004-2005 School Year)**

| Characteristics | Percentage or Mean (±SD) | Number |
|---|---|---|
| Age | | |
| Mean age | 11.73 (±1.58) | 1478 |
| Sex | | |
| Male | 52.96 | 975 |
| Female | 47.04 | 866 |
| Ethnicity | | |
| White | 34.82 | 641 |
| Black | 40.25 | 741 |
| Hispanic | 15.43 | 284 |
| Asian | 9.51 | 175 |
| SES (eligibility for NSLP) | | |
| Low SES | 44.97 | 827 |
| Higher SES | 55.03 | 1012 |
| Grade | | |
| Fourth | 24.97 | 369 |
| Sixth | 24.02 | 355 |
| Seventh | 25.37 | 375 |
| Eighth | 25.64 | 379 |
| Weight status* | | |
| Underweight | 1.41 | 26 |
| Healthy weight | 59.32 | 1092 |
| At risk of overweight | 18.31 | 337 |
| Overweight | 20.97 | 386 |
| Math MCAS | | |
| Raw score | 31.58 (±12.09) | 1103 |
| Passed Math MCAS | 71.53 | 789 |
| English MCAS | | |
| Raw score | 48.53 (±11.12) | 744 |
| Passed English MCAS | 89.25 | 664 |
| Number of fitness tests passed | | |
| Mean number of tests passed | 3.59 (±1.33) | 1478 |
| BMI *Z* score mean (±SD) | 0.70 (±1.01) | 1478 |

*Underweight is defined as ≤5 BMI percentile for age and gender; normal weight is defined as <85 BMI percentile for age and gender; at-risk weight is defined as ≥85 < 95 BMI percentile for age and gender; and overweight is defined as ≥95 BMI percentile for age and gender.

Table 2. **MCAS Passing Scores by Demographic and Health Characteristics of Cambridge Public School Fourth, Sixth, Seventh, and Eighth Graders (2004-2005 School Year)**

| | Math Passing Score | | English Passing Score | |
|---|---|---|---|---|
| | N | % Passed | N | % Passed |
| Overall | 789 | 72 | 664 | 89 |
| Female | 383 | 73 | 324 | 91 |
| Male | 414 | 70 | 345 | 86 |
| | p = .36† | | p = .0498 | |
| Underweight* | 13 | 76 | 8 | 89 |
| Healthy weight | 488 | 74 | 393 | 90 |
| At-risk weight | 150 | 70 | 120 | 89 |
| Overweight | 146 | 64 | 148 | 86 |
| | p = .0496 | | p = .6853 | |
| Ethnicity | | | | |
| White | 322 | 85 | 267 | 93 |
| Black | 271 | 58 | 235 | 82 |
| Latino | 105 | 66 | 98 | 88 |
| Asian | 91 | 90 | 65 | 98 |
| | p < .001 | | p < .001 | |
| SES (eligibility for NSLP) | | | | |
| Low SES | 327 | 64 | 272 | 83 |
| Higher SES | 469 | 78 | 395 | 93 |
| | p < .001 | | p < .001 | |
| Fitness achievement: number of fitness tests passed | | | | |
| 0 | 20 | 35 | 11 | 73 |
| 1 | 73 | 51 | 48 | 88 |
| 2 | 154 | 66 | 81 | 84 |
| 3 | 195 | 73 | 142 | 93 |
| 4 | 309 | 71 | 218 | 86 |
| 5 | 352 | 80 | 244 | 93 |
| | p < .0001 | | p = .015 | |

*Underweight is defined as ≤5 BMI percentile for age and gender; normal weight is defined as <85 BMI percentile for age and gender; at-risk weight is defined as ≥85 < 95 BMI percentile for age and gender; and overweight is defined as ≥95 BMI percentile for age and gender.
†p values determined by chi-square analysis.

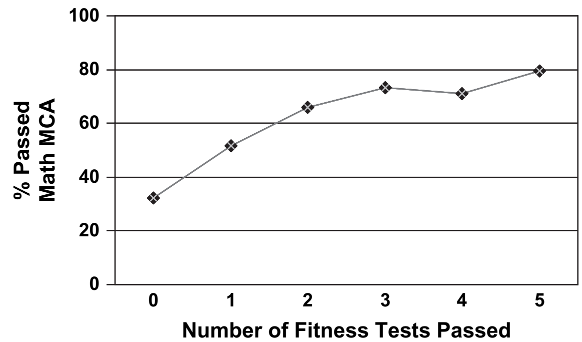
but substantially weaker relationship between the English MCAS test and passing successive fitness tests ($p < .05$). Logistic regression models (Table 3) estimated that the odds of passing the English MCAS test increased by 24% for each 1-unit increase in the number of fitness tests passed, holding gender, ethnicity, weight status, grade, and SES constant. Similar relationships were seen using the raw MCAS scores and the number of fitness tests passed (Math MCAS model $r^2 = .24$, $p < .0001$ and English MCAS model $r^2 = .20$, $p = .0004$). The results are not shown.

## Discussion

Our findings contribute to a growing body of evidence indicating a significant relationship between students' academic achievement and physical fitness. Based on cross-sectional data gathered from a racially diverse urban school district, our results demonstrated a significant positive relationship between fitness and Math and English academic achievement, using either the raw MCAS scores or the categorical pass/fail variables. After controlling for the effects of gender, weight status, grade, ethnicity, and SES, students' odds of passing the MCAS Mathematics test and the MCAS English test increased by the successive number of fitness tests passed.

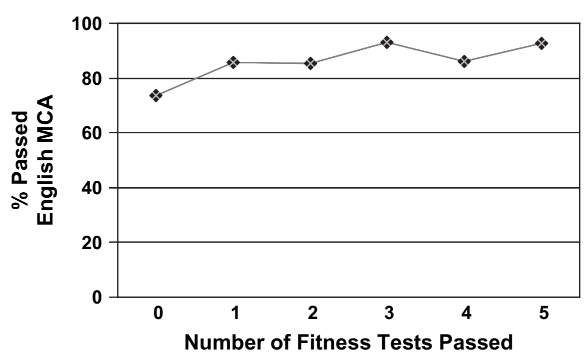
In this study, students' fitness was more strongly associated with Math achievement than English achievement scores. While we do not yet know why Math scores may be more highly associated with fitness level than English scores, similar findings were

Figure 1. **2005 Cambridge Public School Percentage of Students Who Passed Math MCAS by Number of Fitness Tests Passed, Controlling for Gender, Ethnicity, and Lunch Status (Combined Fourth, Sixth, and Eighth Grade)**




Possible MCAS Math raw scores range from a minimum of 0 to a maximum of 54. There were a total of 5 fitness tests. Number of students by fitness tests passed is as follows: 0 tests passed: 20 students; 1 test passed: 73 students; 2 tests passed: 154 students; 3 tests passed: 195 students; 4 tests passed: 309 students; 5 tests passed: 352 students. Data source: Cambridge Public School Department, 2005; Analysis and Presentation: Institute for Community Health, April 2006.

Figure 2. **2005 Cambridge Public School Percentage of Students Who Passed English MCAS by Number of Fitness Tests Passed, Controlling for Gender, Ethnicity, and Lunch Status (Combined Fourth, Sixth, and Eighth Grade)**




Possible MCAS English raw scores range from a minimum of 0 to a maximum of 72. There were a total of 5 fitness tests. Number of students by fitness tests passed is as follows: 0 tests passed: 11 students; 1 test passed: 48 students; 2 tests passed: 81 students; 3 tests passed: 142 students; 4 tests passed: 218 students; 5 tests passed: 244 students. Data source: Cambridge Public School Department, 2005; Analysis and Presentation: Institute for Community Health, April 2006.

Table 3. **Logistic Regression Models Predicting Math and English MCAS Passing Scores From Number of Fitness Tests Passed. Cambridge Public School Fourth, Sixth, Seventh, and Eighth Graders (2004-2005 School Year)†**

| | Math MCAS OR (95% CI) | English MCAS OR (95% CI) |
|---|---|---|
| Fitness achievement | 1.379 (1.234-1.541)*** | 1.236 (1.003-1.522)* |
| Female | 1.321 (0.994-1.756) | 1.778 (1.066-2.966)* |
| Black | 0.243 (0.168-0.352)*** | 0.338 (0.175-0.652)** |
| Asian | 1.805 (0.847-3.847) | 4.032 (0.516-31.57) |
| Hispanic | 0.321 (0.202-0.509)*** | 0.454 (0.199-1.037) |
| Weight status BMIZ | 1.098 (0.949-1.271) | 1.146 (0.864-1.520) |
| Grade | 0.910 (0.835-0.993)* | 1.696 (1.395-2.063)*** |
| SES | 0.760 (0.562-1.026) | 0.572 (0.331-0.989)* |
| Observations | 1102 | 742 |
| Likelihood ratio ($\chi^2$) | 153.60*** | 76.54*** |
| Homer and Lemeshow | 13.051, p = .1113 | 5.660, p = .6853 |
| Percent concordant | 72.5 | 78.0 |
| Percent discordant | 27.2 | 21.6 |

*p< .05; **p < .01; ***p < .001.
†All regressions included a constant.

reported by Castelli et al in their study of the relationship between students' scores on the Illinois Standards Achievement Test and fitness levels in elementary students.[18] In the Trois Rivières, Quebec, Canada, study, investigators found that 1 hour per day of additional PE was significantly related to improvements in standardized Math test scores for grades 2, 3, 5, and 6, but there were no differences in other subject areas.[13] It is important to use caution in drawing causal conclusions about the association between Math scores and achievement from available literature.

While the research literature cannot yet fully explain why fit students may perform better on standardized tests, there are potential mechanisms that may help explain this relationship. First, a relationship between fitness and academic achievement may reflect the achievement orientation of motivated students. That is, motivated students may strive for achievement in both academics and physical fitness or athletics.[29-31] Second, a student's physical fitness may reflect better overall health—better nutrition, physical activity, and/or weight status—and good health may contribute positively to academic achievement. Links between components of a students' health status such as weight status and food sufficiency and academic performance have been documented.[32-34] We demonstrated a relationship between fitness and weight status in previous studies with students from the same school district.[35] In our current study, weight status was inversely (though not significantly) associated with Math MCAS scores. Third, physical activity and fitness may enhance students' concentration and classroom behavior in school, which may contribute positively to academic achievement. Review papers report some evidence that physical activity helps students concentrate and focus, at least in the short term.[5,6] Fourth, physical activity may improve mental health and self-esteem. Vail noted that ''regular exercise can also alleviate stress, anxiety, and depression—problems that can affect school performance—and can even boost self-esteem.''[36] Finally, exercise and fitness may affect brain function and improve cognitive functioning. Studies on elderly adults show that exercise can help elders with cognitive functioning,[37-40] and Hillman et al. found an association between neurocognitive functioning and aerobic fitness in preadolescents.[41] Separately, or in combination, these mechanisms may help explain the relationship between fitness and academic achievement. Taras notes that the effects of physical activity on school performance may be very subtle and more pronounced among specific subpopulations or may only result from high-intensity activities.[5] Clearly, more research is warranted to understand the complex physical and psychosocial relationships reflected by the association of fitness and academic performance.

It is also important to recognize the influence of socioeconomic factors and the home background on how well students perform academically.[42,43] Studies have shown that family factors such as SES, specifically parents' education and income, as well as environmental factors such as school facilities and school practices influence children's academic achievement.[44-48] However, while socioeconomic and demographic factors are known to be associated with academics, we found in our analysis that the relationship between fitness and achievement was statistically significant after controlling for the students' race/ethnicity and the indicator of SES that was available in our data set, that is, the students' eligibility for participating in the NSLP.

### Limitations

There are design issues that should be taken into account when interpreting the results of this study. The data utilized are cross sectional and therefore these results do not indicate causality. It cannot be concluded from these data that higher levels of physical fitness caused an increase or improvement in academic achievement or vice versa. Although the PE teachers received training every year in methods of consistent and valid fitness testing, the fitness data were collected for curricular rather than for research purposes, and the reliability of the data is unknown. We do not have reason to believe that a systematic bias has been introduced in the fitness data, but the magnitude of our effect may be compromised by inconsistent data quality. Finally, although we controlled for known confounders related both to physical fitness and to academic achievement that were available for analysis, we cannot exclude the possibility that unmeasured confounding factors could explain our results. Further research using a prospective, randomized design to assess the longitudinal effect of improved fitness on academic achievement in children is clearly warranted.

## CONCLUSIONS

Given the pressure that educators and policy makers are under to achieve academic standards for all students, understanding the relationship of academic success to physical activity, fitness, and curricular PE is important for allocating scarce resources and for implementing the right mix of policies and programs. Concurrent with national pressure to increase academic achievement, national organizations such as the Institute of Medicine are recommending an increase of daily physical activity for children to at least 1 hour a day to enhance health and weight outcomes.[49] Current research does not indicate that increased school time on PE and activity has a negative effect on academic performance; in fact, learning may be enhanced in physically active students. A convincing trend in evidence indicates a supportive role for physical fitness on school performance. Thus, in light of the potential positive effect of physical activity and fitness on academics and healthy weight found in this study, advocating for increased time on physical activity is probably warranted. This could potentially be achieved through increased PE time, increased active time during PE, encouraging active recess time, and maximizing before and after school activity time.

## REFERENCES


1. HHS/CDC Healthy People 2010. *Physical Activity in Children and Adolescents*, Vol. 2. Available at: http://www.healthypeople.gov/Document/HTML/Volume2/22Physical.htm#_Toc4903808031. Accessed December 19, 2007.
2. Rentner DS, Scott C, Kober N, et al. *From the Capital to the Classroom: Year 4 of No Child Left Behind*. Washington, DC: Center for Education Policy; 2006. Available at: http://www.cep-dc.org/nclb. Accessed January 19, 2007.
3. Lowry A, Brener N, Lee S, Epping J, Futton J, Eaton D. Participation in high school physical education—United States, 1991-2003. *MMWR Wkly*. 2004;53(36):844-847. Available at: http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5336a5.htm. Accessed January 19, 2007.
4. Etnier JL, Salazar W, Landers DM, Petruzzello SJ, Han M, Nowell P. The influence of physical fitness and exercise upon cognitive functioning: a meta-analysis. *J Sport Exerc Psychol*. 1997;19:249-277.
5. Taras H. Physical activity and student performance at school. *J Sch Health*. 2005;75(6):214-218.
6. Trost G. *Active Education: Physical Education, Physical Activity and Academic Performance*. Fall 2007 Research Brief. San Diego, Calif: RWJF, Active Living Research.
7. Studenski S, Carlson MC, Fillit H, Greenough WT, Kramer A, Rebok GW. From bedside to bench: does mental and physical activity promote cognitive vitality in late life? *Sci Aging Knowledge Environ*. 2006;10: e21.
8. Kramer AF, Colcombe S, Erickson K, et al. Effects of aerobic fitness training on human cortical function: a proposal. *J Mol Neurosci*. 2002;19(1-2):227-231.
9. Ekeland E, Heian F, Hagen KB, Abbott J, Nordheim L. Exercise to improve self-esteem in children and young people. *The Cochrane Database Syst Rev*. 2004;(1)CD003683. Review.
10. Shephard R. Physical activity and the healthy mind. *CMAJ*. 1983; 128:525-530.
11. Flook L, Repetti RL, Ullman JB. Classroom social experiences as predictors of academic performance. *Dev Psychol*. 2005;41(2):319-327.
12. Shephard R. Curricular physical activity and academic performance. *Pediatr Exerc Sci*. 1997;9:113-126.
13. Shepard, R. Habitual physical activity and academic performance. *Nutr Rev*. 1996;54(4):S32-S36.
14. Dwyer T, Coonan WE, Leitch DR, Hetzel BS, Baghurst RA. An investigation of the effects of daily physical activity on the health of primary school students in South Australia. *Int J Epidemiol*. 1983;12(3):308-313.
15. Sallis JF, McKenzie TL, Kolody B, Lewis M, Marshall S, Rosengard P. Effects of health-related physical education on academic achievement: project SPARK. *Res Q Exerc Sport*. 1999;70(2): 127-134.
16. Kim HY, Frongillo EA, Han SS, et al. Academic performance of Korean children is associated with dietary behaviors and physical status. *Asia Pac J Clin Nutr*. 2003;12(2):186-192.
17. California Department of Education. A study of the relationship between physical fitness and academic achievement in California using 2004 test results. 2004. Available at: http://www.cde.ca.gov/ta/tg/pf/17. Accessed September 20, 2006.
18. Castelli DM, Hillman CH, Buck SM, Erwin HE. Physical fitness and academic achievement in third- and fifth-grade students. *J Sport Exerc Psychol*. 2007;29:239-252.
19. Massachusetts Department of Education. *Massachusetts Comprehensive Assessment System*. Available at: http://www.doe.mass.edu/mcas/. Accessed September 26, 2008.
20. *President's Challenge Physical Fitness Testing*. Available at: http://www.presidentschallenge.org/educators/program_details/physical_fitness_test.aspx. Accessed September 20, 2006.
21. Fitness Testing. Cooper Institute. 2008. Available at: http://www.cooperinst.org/ftgmain.asp. Accessed September 20, 2006.
22. Kim J, Must A, Fitzmaurice GM, et al. Incidence and remission rates of overweight among children aged 5 to 13 years in a district-wide school surveillance system. *Am J Public Health.22*. 2005; 95(9):1588-1594.
23. Ikeda JP, Crawford P. *Guidelines for collecting heights and weights on children and adolescents in school settings*. Calif: Center of Weight and Health, University of California at Berkeley; 2000.
24. Centers for Disease Control and Prevention. *Children and Teen BMI Growth Charts*. Available at: http://www.cdc.gov/nchs/about/major/nhanes/growthcharts/. Accessed May 16, 2008.
25. National School Meal Program. *US Department of Agriculture. Food and Nutrition Service*. Available at: http://www.fns.usda.gov/cnd/governance/notices/iegs/IEGs04-05.pdf. Accessed on August 12, 2008.
26. SAS Institute. 2003. *Version 9.1*. Cary, NC.
27. Centers for Disease Control and Prevention. *BMI for Children and Teens*. Available at: http://www.cdc.gov/nccdphp/dnpa/bmi/bmi-for-age.htm. Accessed on July 10, 2006.
28. Massachusetts Department of Education. *Massachusetts Comprehensive Assessment System*. 2005. Available at: http://www.doe.mass.edu/mcas/2005/interpretive_guides/full.pdf. Accessed August 15, 2006.
29. Thogersen-Ntoumani C, Ntoumanis N. The role of self-determined motivation in the understanding of exercise-related behaviors, cognitions and physical self-evaluation. *J Sports Sci*. 2006;24(4):393-404.
30. Pajares F, Urdan F. *Academic Motivation of Adolescents*. Greenwich, Conn: Information Age Publishing; 2002.
31. Wigfield A, Eccles JS. *Development of Achievement Motivation*. San Diego, Calif: Academic Press; 2002;

32. Taras H, Potts-Datema W. Obesity and student performance at school. *J Sch Health*. 2005;75(8):291-295.
33. Taras H. Nutrition and student performance at school. *J Sch Health*. 2005;75(6):199-213.
34. Center on Hunger, Poverty and Nutrition Policy. *Statement on the Link Between Nutrition and Cognitive Development in Children*. 1995. 2nd ed. Medford, Mass: Tufts University School of Nutrition; 1998.
35. Kim J, Must A, Fitzmaurice GM, et al. Relationship of physical fitness to prevalence and incidence of overweight among schoolchildren. *Obes Res*. 2005;13:1246-1254.
36. Vail K. Mind and body: New research ties physical activity and fitness to academic achievement. *American School Board Journal*. 2006:March;30-33.
37. Colcombe S, Kramer AF. Fitness effects on the cognitive function of older adults: a meta-analytic study. *Psychol Sci*. 2003;14(2): 125-130.
38. Barnes DE, Yaffe K, Satariano WA. A longitudinal study of cardiorespiratory fitness and cognitive function in healthy older adults. *J Am Geriatr Soc*. 2003;51:459-465.
39. Laurin D, Veureault R, Lindsay J, MacPherson K, Rockwood K. Physical activity and risk of cognitive impairment and dementia in elderly persons. *Arch Neurol*. 2001;58(3):498-504.
40. Yaffe K, Barnes D, Nevitt M, Lui LY, Covinsky K. A prospective study of physical activity and cognitive decline in elderly women: women who walk. *Arch Intern Med*. 2002;162(3): 361-362.
41. Hillman CH, Castelli DM, Buck SM. Aerobic fitness and neurocognitive function in healthy preadolescent children. *Med Sci Sports Exerc*. 2005;37(11):1967-1974.
42. Cooper P. Social, emotional and behavioral difficulties, social class and educational attainment: which are the chickens and which are the eggs? *Emotional and Behavior Difficulties*. 2005; 10(2):75-77.
43. NICHD Early Child Care Research Network. A duration and developmental timing of poverty and children's cognitive and social development from birth through third grade. *Child Dev*. 2005;76(4):785-810.
44. Davis-Kean P. The influence of parent education and family income on child achievement: the indirect role of parental expectations and the home environment. *J Fam Psychol*. 2005;19(2):294-304.
45. Toutkoushian R, Curtis T. Effects of socioeconomic factors on public high school outcomes and rankings. *J Educ Res*. 2005; 98(5):259-270.
46. Garrison W. Profiles of classroom practices in U.S. public schools. *School Effectiveness and School Improvement*. 2004;15(3-4):377-406.
47. Mason B, Mason DA, Mendex M, Nelson G, Orwig R. Effects of top-down and bottom-up elementary school standards reform in an underperforming California district. *Elem Sch J*. 2005;105(4): 353-376.
48. Schneider M. *Do School Facilities Affect Academic Outcomes?* Washington, DC: National Clearinghouse for Educational Facilities; 2002.
49. *Preventing Childhood Obesity: Health in the Balance*. Washington, DC: Institute of Medicine; 2004.