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RESEARCH ARTICLE

Associations of Physical Fitness and Academic Performance Among Schoolchildren*

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ABSTRACT

BACKGROUND: Public schools provide opportunities for physical activity and fitness surveillance, but are evaluated and funded based on students' academic performance, not their physical fitness. Empirical research evaluating the connections between fitness and academic performance is needed to justify curriculum allocations to physical activity programs.

METHODS: Analyses were based on a convenience sample of 254,743 individually matched standardized academic (TAKS™) and fitness (FITNESSGRAM®) test records of students, grades 3-11, collected by 13 Texas school districts. We categorized fitness results in quintiles by age and gender and used mixed effects regression models to compare the academic performance of the top and bottom fitness groups for each test.

RESULTS: All fitness variables except body mass index (BMI) showed significant, positive associations with academic performance after adjustment for socio-demographic covariates, with standardized mean difference effect sizes ranging from .07 to .34. Cardiovascular fitness showed the largest interquintile difference in TAKS score (32-75 points), followed by curl-ups. Additional adjustment for BMI and curl-ups showed dose-response associations between cardiovascular fitness and academic scores ($p < .001$ for both genders and outcomes). Analysis of BMI demonstrated limited, nonlinear association with academic performance after socio-demographic and fitness adjustments.

CONCLUSIONS: Fitness was strongly and significantly related to academic performance. Cardiovascular fitness showed a dose-response association with academic performance independent of other socio-demographic and fitness variables. The association appears to peak in late middle to early high school. We recommend that policymakers consider physical education (PE) mandates in middle high school, school administrators consider increasing PE time, and PE practitioners emphasize cardiovascular fitness.

Keywords: FITNESSGRAM; physical fitness; academic performance; exercise; child and adolescent health; physical education and training; school health services; health policy.

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Child and adolescent health promotion interventions frequently rely on schools as a key delivery setting. Although physical education (PE) has been a curricular component in schools for many years, attention has recently increased on the important role that schools play for physical activity and physical fitness surveillance due to concern about childhood obesity.[1,2] Yet schools' incentives are oriented to the results of standardized academic testing, due in part to the requirements of the No Child Left Behind Act.[3] This Act may have exacerbated a long-term narrowing of school curricula favoring core academics to the detriment of PE. The National Association for Sport and Physical Education found that the portion of students attending PE daily dropped from 42% to 28% between 1991 and 2003.[4] Though educators sometimes claim that taking time for PE detracts from academic performance, scientific evidence refutes that notion.[5] To explore ways in which these goals may in fact overlap, this study examined the associations of physical fitness and standardized academic test performance in a large sample of schoolchildren in Texas.

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Although several studies have investigated the association between physical fitness and academic achievement in school children, results have been plagued by a variety of methodological limitations.[5-11] Differences in study design, small or otherwise limited samples, lack of control of important confounding variables, and in some cases, the absence of an individual-level link between fitness and academic achievement records have all hampered a clear understanding of this important question. The purpose of this study was to quantify the cross-sectional association between standardized mathematics and reading academic achievement scores and measures of physical fitness using more rigorous statistical methods and a larger sample of 254,743 elementary, middle, and high school children and adolescents.

METHODS

Measures and Covariates

All of the study data, including covariates, were secondary data previously collected by Texas school districts for mandatory reporting to the Texas Education Agency (TEA). Physical fitness was measured by 6 independent fitness tests using FITNESSGRAM® (The Cooper Institute, Dallas, TX). The FITNESSGRAM test battery was originally developed in 1977 as a fitness report card and consists of 6 parts[12]:

1. aerobic capacity, as measured by the mile run or PACER test;
2. body composition, as measured by skin folds or body mass index (BMI);
3. abdominal strength and endurance, as measured by curl-ups;
4. trunk extensor strength and flexibility, as measured by trunk lift;
5. upper body strength and endurance, as measured by push-ups; and
6. flexibility, as measured by shoulder stretch or the sit-and-reach test.

FITNESSGRAM is a criterion-based rather than norm-based assessment of fitness. The result of each test is not compared using percentile ranks to other results from the same cohort; it is compared to a range of acceptable values, based on established health standards for the age and gender of the individual. If the student meets the minimum standard, she is said to ''meet the Healthy Fitness Zone'' (HFZ) for that test regardless of how well or poorly her peers have performed.

Test reliability ranges from .64 to .99, excluding work performed on children in kindergarten through second grade, as they are not part of the population for this study (reliability was almost universally lower for younger subjects, especially those under the age of 10).[12] As for validity, the FITNESSGRAM aerobic tests estimate VO_2max (mL $\times$ kg^{-1} $\times$ minute^{-1}), generally a good measure of cardiovascular capacity, with 10-15% error in children age 10 and over.[12] Among the muscle strength and flexibility tests, several studies confirm the validity of the curl-up as a measure of abdominal strength by virtue of electromyographic and anatomical analysis; push-ups were found to be a valid measure of upper body strength and the sit-and-reach test a valid measure of hamstring flexibility (but not of lower back flexibility).[12] Little evidence exists to support trunk lift as a valid measure of trunk extensor strength, and no published evidence exists to support either the reliability or the validity of the shoulder stretch test as a measure of flexibility.

FITNESSGRAM's criterion-based system reports a binary ''meets'' or ''does not meet'' result on each test based on the HFZ for the individual's gender and age. Thus, most prior work using this fitness measure has reported the sum of binary results for the 6 tests, yielding a composite result of 0-6, resulting in substantial loss of information. We departed from conventional practice in 2 ways: (1) we examined each test score individually to obtain information on individual fitness components and (2) instead of reducing continuous data to binary, we categorized results by quintile, allowing detection of linear dose-response or nonlinear associations.

Academic performance was measured using the Texas Assessment of Knowledge and Skills (TAKS™, NCS Pearson, Bloomington, MN), which is administered to Texas public school students according to grade level (Table 1).[13] As described by the TEA, TAKS testing began in 2003 after a 3 year development and trial process led by TEA which solicited input from educators, community members, and other experts, with the goal of assessing a student's understanding of the elements of the Texas Essential Knowledge and Skills (TEKS) curriculum. The Student Success Initiative (SSI) uses reading and mathematics TAKS scores to determine eligibility for advancement beyond third

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Duncan Van Dusen had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. No funding was received for this project, and the authors declare no conflicts of interest.

Table 1. **TAKS Test Administration by Grade Level[13]**

	Grade Level								
TAKS Subject	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Reading/English Language Arts	X	X	X	X	X	X	X	X	X
Mathematics	X	X	X	X	X	X	X	X	X
Writing		X			X				
Social Studies						X		X	X
Science			X			X		X	X

(reading only), fifth, and eighth grades.[13] We used TAKS reading and mathematics scale scores as outcome measures because these 2 tests are administered in all grades and are the basis for student advancement. They are thus a primary basis for measuring school performance and figure in curricular decisions and educator evaluation.

TAKS reliability ranges from .81 to .93; TAKS validity has been ascertained through comparisons to the TEKS curriculum which it is designed to test, national programs such as ACT and SAT I, and grades in subject coursework.[14] Additional variables collected by the TEA used in the analysis included gender, age, grade, ethnicity, economic disadvantage (measured by school lunch status), school number, and special educational status.[15]

Data Sampling

We solicited data from 99 Texas school districts using personal contacts and publicly available information. Thirteen districts submitted usable data, leading to a final convenience sample of 254,743 student records, each consisting of at least 1 fitness score and 1 TAKS score from the 2007-2008 school year, and basic socio-demographic identifiers (Table 2). Because of the information technology demands of combining academic performance, demographic, and fitness assessment data residing in different systems, we had disproportionate participation by larger (urban and suburban) districts with greater information technology resources, yielding a sample with a higher proportion of non-White students than the population. The higher fitness testing rate of elementary children[16] was also reflected in the sample. However, our sample covered students in 8 of the 20 geographic regions in the state and included a similar gender breakdown and proportion of economically disadvantaged students to that found in the entire Texas school population.[17]

Research Questions

Our research focused on the following questions: (1) what is the magnitude and direction of the association between each individual FITNESSGRAM fitness test score and reading and math TAKS scale scores? (2) what differences exist in the associations by gender, grade, and TAKS subject? (3) is there a dose-response relationship whereby additional increments of performance (by quintile for age and gender) on a fitness test correlate with increments of performance on a TAKS test? and (4) what differences exist in the associations for the lowest and highest BMI levels compared to moderate BMI? We devised the final question based on research suggesting the possibility that excessive leanness in children is detrimental to health.[12]

Table 2. **Comparison of Sample to Total Population[16,17]**

Variable	**Sample**	**Total Population***
Number of students† (grades 3-11)	254,743	2,728,536
Number of ESC geographic regions	8	20
Portion of students in large districts (>50,000)	81.4%	27.6%
Portion of students economically disadvantaged	63.2%	55.3%
Gender distribution (male/female)	48.7%/51.3%	50%/50%
Ethnicity distribution (White/Hispanic/all other)	19.0%/53.3%/27.8%	34.8%/47.2%/18%
School-level distribution‡ (elementary/middle/high)	43.9%/30.8%/25.2%	28.2%/31.5%/40.3%

*Total population figures are approximate.
†State law mandates fitness testing beginning in third grade. Grade 12 and special education students are excluded as described under "*Data Analysis.*"
‡School-level distribution of 39.3%/34.0%/26.7% in tested population of 2,450,051.

Data Analysis

Our data preparation process consisted of (1) discarding records from 12th graders because those who passed the exit-level TAKS in 11th grade are exempt from academic testing,[18] possibly leading to a biased sample; (2) discarding records from special education students because they are characterized by lower TAKS scores but similar average physical fitness which could also skew the analysis; (3) discarding outlying BMI measures (defined as scores that were more than 5 z-scores from the mean based on 2000 CDC growth charts),[19] to reduce measurement error including instances where height and weight data were switched; (4) creating quintiles (tertiles for trunklift due to large number of identical scores) of FITNESSGRAM test results for each gender-age combination to allow a more granular analysis than the binary HFZs permit. Although the only measure of BMI available in these data (kg/m^2) is a less reliable measure of body composition than DEXA scans or skin-fold tests, creating gender-age quintiles allowed us to normalize differences in growth patterns by gender and age. We performed analysis with mixed effects regression methods available in SAS 9.2 (PROC MIXED) using a school-level random effect to control for peer grouping with each fitness component as an independent variable, each TAKS scale score as a dependent variable, and stratifying by grade and gender. Secondary analysis showed ethnicity and economic disadvantage to be significant covariates and interaction terms, so we added covariate adjustment and interaction terms for these variables (and for grade level in the combined grade analyses) with each fitness variable. To isolate the impact of each fitness variable, we added adjustments for BMI and curl-ups in the cardiovascular-specific analyses and adjustments for cardiovascular and curl-ups in the BMI-specific analyses. We did not adjust for push-ups due to its high correlation with curl-ups or flexibility metrics due to their low overall association with academic achievement. Additional adjustments would have also reduced the sample size. The analyses focused on estimation of the differences in TAKS scale score between the top and bottom fitness group for each variable after the statistical adjustments described. We also calculated Cohen's standardized mean difference of the interquintile values using the Effect Size Calculator 3.1.[20,21]

RESULTS

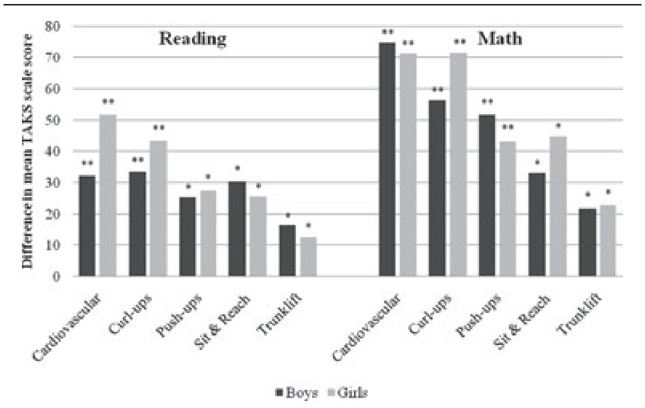
TAKS scores for students in the top group for each fitness variable were compared to those in the bottom group for that variable, using stratification by gender and controls for ethnicity, grade level, and economic disadvantage (Figure 1). Results after statistical controls showed the same significance and direction of association as unadjusted results, but with attenuated effect sizes due to the confounding nature of the covariates. We considered BMI separately to test for a nonlinear relationship with academic achievement. Cardiovascular fitness was found to have the strongest direct associations with academic achievement, with a standardized mean difference effect size of .17 (95% CI: .15-.19) for boys-reading, .34 (.32-.35) for boys-math, .27 (.25-.29) for girls-reading, and .33 (.31-.35) for girls-math. The next largest associations (as measured by effect size and mean difference in TAKS score) were with curl-ups, followed by push-ups, sit and reach, and trunklift which registered the lowest effect size of .07 (95% CI: .05-.08). No nonsignificant or inverse associations were found between any fitness variable and academic achievement in the overall analysis.

For each of the 5 fitness variables, overall associations were stronger for math TAKS scores than for reading TAKS scores, particularly in the cardiovascular, curl-ups, and push-ups tests. The stronger fitness-reading association in girls than boys was also found for cardiovascular, curl-ups, and push-ups tests, but the genders were reversed in sit & reach and trunklift tests. Gender differences in fitness-math associations were also mixed.

Cardiovascular fitness performance did not vary substantially across grades. For example, average 1 mile run/walk times ranged from 696 seconds (eighth grade) to 754 seconds (third grade) in boys and from 733 seconds (seventh grade) to 828 seconds (11th grade) in girls, with similar standard deviations.

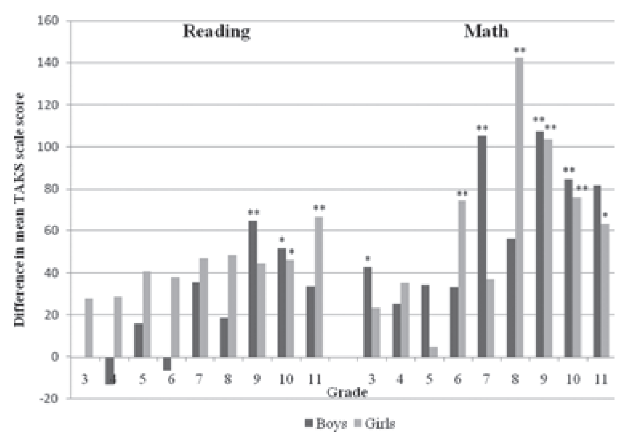
However, there were significant differences by grade in the association between cardiovascular fitness and academic performance. Interquintile differences for both genders and both outcome measures peaked in adolescence (7th-10th grade), after adjusting for ethnicity, economic disadvantage, BMI, and curl-ups to isolate the impact of cardiovascular fitness from other fitness variables (Figure 2). For boys, the difference in both reading and math TAKS score

Figure 1. **Interquintile Difference in Mean TAKS Scale Score by Fitness Measure**



Note: Difference between first and fifth quintile value (first and third tertile value for trunklift) for mean TAKS scale score, adjusted for ethnicity, grade level, and economic disadvantage status (N = 66,338-106,330; large range due to varying numbers of students taking each test); *p < .05; **p < .0001.

Figure 2. **Interquintile Difference in Mean TAKS Scale Score by Grade for Cardiovascular Fitness**



Note: Difference between first and fifth cardiovascular fitness quintile value for mean TAKS scale score, adjusted for BMI, curl-ups, ethnicity, and economic disadvantage status (N = 71,529-78,231); *p < .05; **p < .01.

was highest among ninth graders with a peak math difference of 108 TAKS points (effect size: .44[.38-.50]). For girls, the difference was highest for both scores among eighth graders with a peak math difference of 142 TAKS points (effect size: .75[.69-.82]). The point estimate for the association was positive for all grade-test-gender combinations except fourth- and sixth-grade reading for boys. Point estimates, statistical significance, and effect sizes of the associations between cardiovascular fitness and academic performance all increased beginning in middle school around the onset of adolescence in sixth to seventh grade. In boys, associations dipped below significance level in 11th grade whereas girls' associations were still significant.

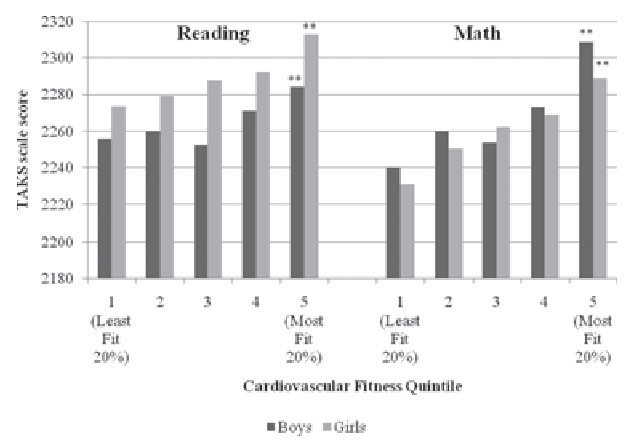
Comparison of the TAKS scores for each quintile of cardiovascular fitness revealed a strong positive linear association with academic performance (Figure 3). All 4 test-gender combinations had a p value <.001.

To test for nonlinear associations between BMI and academic performance, we compared each of the top and bottom BMI quintiles to the middle 3 quintiles, adjusting for grade level, ethnicity, economic disadvantage, cardiovascular fitness, and curl-ups (Figure 4). Low-BMI boys showed significantly lower TAKS scores than the moderate (but not high) BMI group. No significant associations were present in girls or between the high BMI group and either the low or moderate BMI group.

DISCUSSION

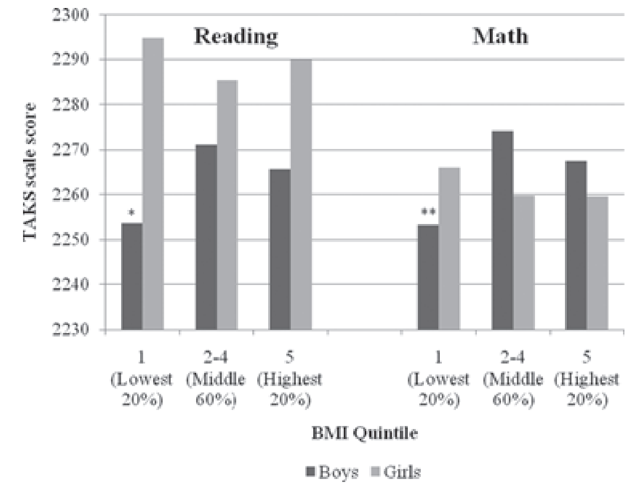
The findings of this study add evidence and detail to the proposition that an association exists between physical fitness and academic performance

Figure 3. **TAKS Scale Score by Cardiovascular Fitness Quintile**



Note: TAKS scale score by cardiovascular fitness quintile, adjusted for BMI, curl-ups, ethnicity, grade level, and economic disadvantage status (N = 71,529-78,231); **p for trend <.001.

Figure 4. **TAKS Scale Score by BMI Group**



Note: TAKS scale score by BMI quintile group, adjusted for cardiovascular fitness, curl-ups, ethnicity, grade level, and economic disadvantage status (N = 71,529-78,231); *p < .05 relative to quintiles 2-4; **p < .01 relative to quintiles 2-4.

in schoolchildren. It was notable that all 5 fitness tests (excluding BMI) had a positive, linear association with academic test scores and no variable had a nonsignificant association by gender or academic test outcome. The relative strengths of the associations among fitness variables show that cardiovascular fitness had the highest interquintile difference and Cohen's effect size, followed by the strength tests and flexibility. This ordering suggests a particular importance for cardiovascular capacity in cognition, and a secondary role for core strength (measured by curl-ups). Our results confirm prior work finding an overall association, strongest for cardiovascular and strength tests. Prior work indicating stronger fitness-academic achievement associations in girls than boys was partially confirmed, particularly the larger girls-reading associations than those found in boys. The overall effect size we found was higher than had been previously reported, though comparison is difficult as prior work combined fitness variables, used a more restricted grade range, and did not report a standardized mean difference.

Our cardiovascular fitness analyses show substantial differences by grade, including mostly nonsignificant associations in elementary school and peak effect sizes in early adolescence. The pattern of weaker associations among elementary students may be partly explained by the lower test reliability below age 10 years (these students were included in the analyses because they were tested under state mandates). The similar standard deviations of 1 mile/walk times across grades refutes the possibility that lower fitness-academic performance associations in elementary school are because of a narrower range of fitness outcomes. Although the range of fitness changes little across grades, the difference in academic performance between the most fit and least fit does change substantially. The fact that prior work found significant cardiovascular associations in elementary students, although we did not, may be explained by our use of additional statistical adjustments.

Our cardiovascular fitness analyses also show a clear dose-response relationship across quintiles for both genders and both academic outcomes. This result demonstrates that each additional unit of cardiovascular fitness is associated with increased TAKS performance, independent of socio-demographics and other fitness variables.

We found few associations between BMI and academic performance after covariate adjustment, but found evidence in boys that low BMI is associated with lower academic performance relative to moderate BMI, but not to high BMI. The factors leading to this finding need further exploration in future research. The absence of statistical difference in academic performance between lowest and highest quintile BMI for either gender or academic outcome measure implies that there is no linear association between these variables after covariate adjustment. This finding departs from some prior work which identified an association between BMI and academic performance,[9] perhaps due to our adjustment for the confounding effect of other fitness variables. The limited association between BMI and academic performance, if confirmed, has profound implications for PE and health promotion in schools, suggesting that other forms of fitness may be more important to cognition than weight control per se.

There exists other work suggesting that cardiovascular health may be more related to academic performance than weight or BMI; a longitudinal study examining the association between weight and academic achievement found that differences in test outcomes between children of different weights did not persist after covariate controls for socioeconomic and behavioral variables.[22] Although poor cardiovascular fitness and body fat are both important risk factors for type 2 diabetes and cardiovascular disease in children, only cardiovascular fitness has also been associated with cognition.[23] Children with higher cardiovascular test scores have higher P3 event-related brain potential (ERP) amplitude and lower P3 latency, suggesting better attention span, working memory, reaction time and overall processing speed—and pointing to the biological plausibility of an association between cardiovascular fitness and academic performance.[24]

Evidence associating muscle strength and flexibility with cognition is limited. One study showed that lower limb strength and flexibility is associated with 2 of 4 cognitive skills tested in elderly women without identifying a physiological pathway.[25] A study on children with Down syndrome suggests that a long-term cognitive benefit may stem from developmental interventions on motor skills; again no biological mechanism is mentioned.[26] Literature connecting muscle strength and brain functioning thus suffers from gaps in understanding of biological mediation and general population applicability.

Five cross-sectional studies have noted differences in standardized academic test scores among children of varying fitness levels (in all cases, measured with FITNESSGRAM), though they have generally failed to adjust for the impact of confounders such as age and socioeconomic status (SES), or were conducted at the group level using an ecologic approach, thus limiting precision.[6-11] Three of these studies were carried out by municipal, public authorities. Examination of the associations of 1.3 million FITNESSGRAM tests of fifth, seventh, and ninth graders to those students' scores on the California Standards Tests of reading and mathematics found a positive, stochastically ordered correlation between fitness and academic performance at all 3 grade levels.[6] A stronger relationship was noted for females than for males, and for students not in the National School Lunch Program and therefore presumably of higher SES. A study of nearly identical design reached similar conclusions, noting statistically significant direct associations between fitness and academic performance, stronger in girls than boys and for math test outcomes than reading outcomes in both genders.[7] Fourth- to eighth-grade students in the top fitness tier have also been found to have higher academic performance than those in the bottom one, across all ethnic groups and BMI levels (no effect size reported).[8]

At least 2 academic, peer-reviewed studies have also found direct associations between standardized academic test performance and physical fitness in elementary school children.[9,10] One study found cardiovascular fitness to be the fitness variable most strongly correlated to academic achievement, followed by BMI (inverse correlation), and muscle strength.[9] Little difference was found between reading and math tests. Another study found significant, direct associations between cardiovascular fitness and math scores and strength and math scores in both sexes, and between cardiovascular fitness and both math and reading scores in girls only, adding evidence to the possibility of a particular effect of physical fitness on math performance and on general academic achievement in girls.[10] They found no associations with BMI and any academic outcome. No known studies of this type have failed to show some relationship between fitness and academic performance in children.

A major drawback of the research prior to 2005 is the use of subjective academic measures rather than standardized test scores, leading to potential outcome measurement bias and difficulties in comparing outcomes. The 3 municipal studies since 2005 are also handicapped by their limited methodological rigor. The New York study did not stratify or control for SES or grade level. The Austin and California studies did not stratify or control for race, and converted each of the continuous primary fitness measures on the 6 tests to binary results, discarding potentially valuable variability. Moreover, both studies used a sum of those binary results as a composite fitness measure, mixing together cardiovascular fitness, body composition, muscle strength, and flexibility, and obscuring the independent association of each variable with academic outcomes. If an overall measure was to be created based on health importance, presumably cardiovascular fitness and body composition would carry the strongest weights given the evidence for their association with chronic disease risk factors. On the contrary, the combination used in these studies weights cardiovascular fitness, body composition, and flexibility each as only 16.7% (as each is measured by 1 of 6 tests), and weights the 3 muscle strength measures a total of 50%. No epidemiological basis for an overall fitness measure with this weighting scheme exists.

The biggest limitations of the 2 recent academic studies were small sample sizes of demographically homogenous third- to fifth-grade students ($N = 134$ and 259) and an absence of statistical controls for other fitness variables, SES, and age.[9,10] Furthermore, neither study statistically accounted for the effect of peer grouping by introducing a random effect at the school level, the primary social unit.

A primary strength of this study is the much larger and broader sample size than that used in prior work. The large amounts of data allowed us to be the first to analyze the independent effects of each fitness variable, and their associations with academic achievement scores across all school levels. We found novel evidence of a particularly strong association of cardiovascular fitness and academic performance in late middle to early high school. We also tried to account for confounding factors by controlling for grade, ethnicity, economic disadvantage, school-level random effects, and the results of other fitness tests to isolate each fitness component to the greatest extent practicable. Further, segmenting the fitness data by age-gender quintiles allowed us to identify a dose-response relationship between cardiovascular fitness and TAKS scores and a nonlinear association between BMI and TAKS scores in specific subgroups. Finally, we were the first to calculate and report a standardized mean difference effect size, facilitating comparison of associations across fitness variables, grade levels, and outcomes.

Limitations

The main limitation of this study is its cross-sectional design which does not allow any inference of temporality or a possible causal relationship between fitness and academic performance. It also does not specifically address connections between physical activity levels and academics. Finally, the fact that it was undertaken with a convenience sample, even a large one, may limit its generalizability across the population. However, this study's sample was representative of the state population of schoolchildren with regard to age range, gender, school-level distribution, and economic status, which supports its generalizability to the state level.

IMPLICATIONS FOR SCHOOL HEALTH

The results of this work carry implications for research, school health and education policy, and physical and general education practice. For research, next steps should include investigation of changes in fitness levels and academic performance in individuals over time to develop evidence of a temporal relationship. Primary biological research should also be pursued to elucidate potential physiological mechanisms mediating a connection between cardiovascular fitness and strength and mental acuity. Research should also be conducted into the impact of puberty on such pathways given our finding of strongest associations at the time of peak pubescence.

For education and school health policymakers, this evidence should be considered when setting PE requirements for schoolchildren. In Texas, PE requirements are strongest for elementary students, whereas the association of fitness and academic performance identified in this paper is strongest for middle and high school students. Texas and other states conducting mandatory fitness testing should also consider which fitness variables have an evidence-based connection with health and academic performance to maximize school cooperation. Finally, states with standardized fitness and academic testing should require individually linked reporting of academic and fitness test results to facilitate child fitness surveillance and longitudinal study of the connection between these 2 aspects of child health and development.

For physical and general education practitioners, the potential impact of physical fitness on academic performance should be considered in curricular schedules and administrator incentives. Given our findings, if PE is intended to support academic achievement, it should emphasize cardiovascular fitness and strength over body composition. Finally, every effort should be made to sustain an effective PE curriculum during the key period of adolescence.

Human Subjects Approval Statement

This study design and protocol was approved by the institutional review board of the University of Texas Health Science Center at Houston and qualified for exempt status (#HSC-SPH-08-0513).

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