Evidence that Aerobic Fitness Is More Salient than Weight Status in Predicting Standardized Math and Reading Outcomes in Fourth- through Eighth-Grade Students

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Objective To determine whether aerobic fitness is more salient than weight status in predicting performance on standardized math and reading tests in fourth- to eighth-grade students.

Study design A cross-sectional study of data abstracted from 11 743 students in 47 public schools. Aerobic fitness was defined by entering the healthy fitness zone of Fitnessgram's Progressive Aerobic Cardiovascular Endurance Run, which has been shown to correlate highly with maximum oxygen consumption. Mixed-effects logistic regression analyses were conducted to model the student-level effect of aerobic fitness status on passing the Nebraska State Accountability (NeSA) math and reading tests after adjusting for body mass index (BMI) percentile, free/reduced lunch status, sex, race, grade level, and school type.

Results After adjustment, aerobically fit students had greater odds of passing the NeSA math and reading tests compared with aerobically unfit students regardless of whether the students received free/reduced lunch; however, the effect of being aerobically fit on the standardized test scores was significantly greater for students not receiving free/reduced lunch. Weight status, as measured by BMI percentile, was not a significant predictor of passing the NeSA math or reading test after including free/reduced lunch status in the model.

Conclusions Aerobic fitness was a significant predictor of academic performance; weight status was not. Although decreasing BMI for an overweight or obese child undoubtedly improves overall health, results indicated all students benefit academically from being aerobically fit regardless of weight or free/reduced lunch status. Therefore, to improve academic performance, school systems should focus on the aerobic fitness of every student. *(J Pediatr 2013;163:344-8)*.

The long-term health consequences of obesity are well documented. Insufficient aerobic fitness has also been shown to be an independent risk factor for both long-term health problems and mortality.[1-3] Thus, monitoring aerobic fitness in addition to adiposity in children and adolescents is critically important. Despite the positive effects of improved aerobic fitness, school systems require empirical evidence showing an association between aerobic fitness and academic outcomes before prioritizing time and resources to this endeavor.

Several studies have shown significant associations between the Fitnessgram components and the standardized academic tests used for school accountability and funding.[4-7] Chomitz et al[4] indicated increased odds of passing math and reading tests with increases in the number of Fitnessgram components where the student entered the healthy fitness zone (HFZ); mixed associations were indicated between body mass index (BMI) and academics. Additional studies have shown aerobic fitness to predict academic outcomes similar to the multicomponent Fitnessgram.

The purpose of this study was 2-fold. First, we determined the unique student-level association between aerobic fitness and passing standardized math and reading tests. Second, we determined the student-level effect of BMI on passing standardized math and reading tests.

Methods

Math and reading test scores and Progressive Aerobic Cardiovascular Endurance Run (PACER), BMI, and demographic data, excluding unique individual identifiers, were abstracted from the school district's internal systems for all students enrolled in 37 elementary and 10 middle schools within a large Nebraska city. Abstracted data were collected between September 2010 and March 2011.

The primary outcome variables were the scaled scores from the Nebraska State Accountability (NeSA) tests for math and reading administered annually to all

BMI	Body mass index
HFZ	Healthy fitness zone
NeSA	Nebraska State Accountability
PACER	Progressive Aerobic Cardiovascular Endurance Run

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third- through eighth-grade students as well as students in grade 11. The reading test is administered on computer and the math test is administered via paper-and-pencil. The NeSA tests were developed as a result of state legislation requiring statewide testing in math, reading, writing, and science.[8] NeSA scores are used for federal accountability reporting as required by the No Child Left Behind Act of 2001.[9] Raw test scores are converted to scaled scores ranging from 0 to 200. For state assessment purposes, scaled scores are categorized as below the standards (0-84), meets the standards (85-134), or exceeds the standards (135-200).[10] The tests have not been vertically scaled across grades; thus, identical scaled scores do not imply the same level of math or reading ability across grade levels, precluding the use of continuous scaled scores as outcomes. Therefore, students' scaled scores were modeled as dichotomous using the defined state-level cutoff between below the standards and meets the standards (ie, not pass: <85; pass: ≥85).

We focused on Fitnessgram's PACER as the measure of aerobic fitness, with the primary independent variable being aerobic fitness status (ie, fit vs unfit).[11] The PACER was chosen as the stand-alone measure of aerobic fitness based on results from Varness et al[12] that showed a strong correlation between the PACER and maximum oxygen consumption ($r_s = 0.83$) measured by maximal oxygen consumption treadmill testing, the gold standard for measuring aerobic fitness. The PACER consists of a multistage progressive 15- or 20-m shuttle run requiring students to run laps between 2 markers in time with prerecorded audible beeps. The time between beeps decreases each minute, requiring a progressive increase in pace, and students run laps until they are unable to finish before the beep on 2 separate occasions. The PACER determines aerobic fitness status based on the number of laps completed, with the minimum number of laps required to enter the HFZ varying based on age and sex.[13] Historically, the HFZ for 9- and 10-year-old girls has been either 7 or 15 laps. The schools' physical education staff had been critical of the 7-lap threshold, judging it to be excessively low and not an accurate reflection of aerobic fitness. Our data showed that 98.3% and 88.6% of fourth- and fifth-grade girls, respectively, entered the HFZ using the 7-lap threshold, whereas 71.5% and 77.1% entered the HFZ using the 15-lap threshold. Given that the latter results were consistent with HFZ rates from other age and sex combinations, we chose to use the 15-lap threshold. The number of PACER laps completed for each student was entered into the Fitnessgram software (http://www.fitnessgram.net/home/) by their physical education teacher. The majority of schools used the 20-m version; schools with insufficient gym space used the 15-m version. A conversion procedure in the Fitnessgram software ensures that entering the HFZ requires identical effort across versions.[14]

Remaining covariates were selected based on previous literature and theory. BMI, BMI z score, and weight status based on BMI percentile (ie, underweight to obese) have shown conflicting associations with academic outcomes. Trained health technicians and treatment nurses collected and entered height and weight data into Sapphire Suite (K12 Systems, Inc, Allentown, Pennsylvania), a computer program used to compute BMI percentile based on Centers for Disease Control and Prevention BMI-for-age growth charts. For analysis, BMI percentile was treated as a continuous variable to prevent loss of information due to classification.

Free/reduced lunch status was used as a proxy for student socioeconomic status. Families apply for the federally funded free/reduced lunch program with qualification determined by the US Department of Agriculture and the Nebraska Department of Education's Nutrition Services. Approval is based on several factors, including household income, number of persons living in the household, whether the family receives food stamps, and enrollment in the Temporary Assistance to Needy Families or Food Distribution Program on Indian Reservations programs.

Student ethnicity is collected via student or parent self-report and is allowed to change annually. Approximately 70.1% of the students identified as white, with the second highest proportion being Hispanic (11.6%). Proportions of remaining ethnicities ranged from 6.7% (black or African American) to 0.1% (Native Hawaiian). Before analysis, the decision was made to dichotomize ethnicity into white versus nonwhite.

Finally, students' sex, grade level, and school type (ie, elementary or middle) were included as covariates. For the school system in the current study, elementary schools included kindergarten through fifth-grade students and middle schools included sixth- through eighth-grade students.

Statistical Analyses

Descriptive and demographic data are presented as mean and SD for continuous variables and as frequency and percent for categorical variables. An independent-samples *t* test was used to test for differences in BMI percentile, whereas the χ^2 test was used to test for differences in all remaining categorical variables.

For the primary analyses, mixed-effects logistic regression models were estimated to evaluate the effect of aerobic fitness status on passing the NeSA math and reading tests after adjusting for BMI percentile, free/reduced lunch status, sex, ethnicity, grade level, and school type. The mixed-effects analysis was used to account for dependence resulting from students being nested within schools.[15] Predictors were added sequentially to the model, including aerobic fitness status, to evaluate the unique effect of aerobic fitness after inclusion of the covariates, in which the fixed effects can be interpreted as conditional on schools, with all random effects fixed at zero (ie, unit-specific models).[16] At the student level, continuous predictors were centered near their grand mean; binary predictors remained uncentered. School-level means for all predictors, except school type, were included to represent contextual effects (ie, the incremental effects of school characteristics after controlling for student characteristics),[17] all of which were retained regardless of statistical significance for proper interpretation of student-level effects. Finally, the necessity for random slopes was evaluated separately for each student-level predictor; a random grade slope was observed for NeSA math and a random ethnicity slope was observed for NeSA reading.