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No relationship between academic achievement and body mass index among fourth-grade, predominantly African-American children

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Abstract

School-based initiatives to combat childhood obesity may use academic performance to measure success. This cross-sectional study investigated the relationship between academic achievement and body mass index (BMI) percentile, socioeconomic status (SES), and race by linking existing datasets that are not routinely linked. Data from a school-based project (with National Institutes of Health funding) concerning dietary recall accuracy were linked with data from the state's Department of Education through the state's Office of Research and Statistics. Data were available on 1,504 fourth-grade, predominantly African-American children from 18 schools total in one district in South Carolina during the 2004–2005, 2005–2006, and 2006–2007 school years. School staff administered standardized tests in English, math, social studies, and science. Researchers measured children's weight and height. Children were categorized as low-SES, medium-SES, or high-SES based on eligibility for free, reduced-price, or full-price school meals, respectively. Results from marginal regression analyses for each sex for the four academic subjects, separately and combined, showed that test scores were not related to BMI percentile, but were positively related to SES (P -values <0.0001), and were related to race, with lower scores for African-American children than children of other races (P -values <0.0039). Cost-efficient opportunities exist to create longitudinal data sets to investigate relationships between academic performance and obesity across kindergarten through 12th-grade children. State agencies can house BMI data in state-based central repositories where staff can use globally unique identifiers and link data across agencies. Results from such studies could potentially change the way school administrators view nutrition and physical education.

Keywords

Academic achievement; Body Mass Index; Children

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INTRODUCTION

Over the last several decades, the prevalence of childhood obesity has increased in the United States (US)¹ and around the world.² Childhood obesity is associated with increased risk of health problems and social discrimination.³

The relationship between childhood obesity and academic achievement is of interest.⁴ Outside the US, of 10 studies^{5–14} published between 1994 and 2012, five found an inverse relationship between obesity and academic achievement,^{6,7,10–12} one found no significant relationship,¹⁴ and four found results which varied depending on sex and/or age/grade.^{5,8,9,13} Race/ethnicity was included in only a few of these studies^{5,13,14} and socioeconomic status (SES) was analyzed in most,^{5,7–14} so race/ethnicity and SES may not explain the disparate findings across these 10 studies. Within the US, of 18 studies^{15–32} published between 1994 and 2012, seven found an inverse relationship,^{16,18,22–24,28,32} three found no significant relationship,^{27,29,31} and eight found results which varied depending on sex, age/grade, timing of obesity development, academic subject, source of academic achievement information, or whether analyses were repeated with other variables such as SES and race/ethnicity included.^{15,17,19–21,25,26,30} Most of these 18 studies analyzed race/ethnicity^{16–21,24–28,30–32} and SES,^{15–19,21–26,28–32} so they may not explain the vastly different conclusions reached.

Initiatives to combat childhood obesity may use academic performance as a measure of success.³³ Additional research is needed to investigate the relationship between childhood obesity and academic achievement.¹⁴ Largely absent from the literature on this relationship are investigations of specific minority groups in the US with two exceptions—a 2006 study²⁰ with primarily Latino children and a 1994 study¹⁵ with a small sample of only African-American children.

This study linked existing datasets that are not routinely linked to investigate the relationship between academic achievement and body mass index (BMI) percentile, SES, and race among fourth-grade children. It was hypothesized that academic achievement would be negatively related to BMI percentile and positively related to SES in this almost exclusively African-American sample.

METHODS

Sample and design

Cross-sectional data from a school-based project (funded by the National Institutes of Health) concerning fourth-grade children's dietary recall accuracy³⁴ were linked with data from the South Carolina Department of Education through the state's Office of Research and Statistics. The Department of Education granted the Office of Research and Statistics permission to link data sets, conduct analyses, and provide aggregate results to researchers. This Office is a central repository where agencies entrust their health and human service data; it uses globally unique identifiers, instead of personal identifiers, which enable its staff to link data across multiple agencies while protecting confidentiality.

For the school-based project, the University of South Carolina Institutional Review Board for research involving human subjects approved data collection. Parents provided written consent; children provided written assent. All children were in fourth grade and approximately age 10 years. Data were collected in 18 schools total in a district in Columbia, South Carolina, with 17 schools during the 2004–2005 school year, 17 schools during the 2005–2006 school year, and eight schools during the 2006–2007 school year. Of the 2,391 fourth-grade children invited to participate, 1,780 (74%) agreed.

Academic achievement

Across South Carolina's public schools, from 1999–2008, the Palmetto Achievement Challenge Tests (PACT) were implemented annually with third- through eighth-grade children in adherence to the Education Accountability Act of 1998.³⁵ The PACT were state-level assessments that aligned with state standards for four academic subjects—English, math, social studies, and science.³⁵ School staff administered PACT each May. The district provided PACT scores for each child in the study. Researchers created a single PACT combined score for each child by summing the child's four PACT academic subject scores.

BMI percentile

Trained research staff used established procedures^{36,37} to measure weight and height after breakfast but before lunch in the early spring (i.e., midpoint) of children's fourth-grade school year. Weight was measured on digital scales (LifeSource Precision Health Scale UC-321, A&D Medical, Milpitas, CA) and recorded to the nearest 0.10 pound. Height was measured on portable stadiometers (PE-AIM-102 Portable adult/infant measuring unit with knitting needle technology, Perspective Enterprises, Inc, Portage, MI) and recorded to the nearest 0.125 inch. Weight and height were measured twice per child. Inter-rater reliability was assessed daily for research-staff pairs on a random sample of at least 10% of children; for all pairs, intraclass correlations exceeded 0.99 for weight and height each school year. Researchers used children's weight and height to calculate BMI (kg/m^2). Each child's BMI percentile was determined using the Centers for Disease Control and Prevention's age/sex BMI charts.³⁸ For descriptive purposes, children were categorized as underweight (<5th percentile), healthy weight (5th to <85th percentiles), overweight (85th to <95th percentiles), obese (95th to <99th percentiles), and severely obese (99th percentile).³⁹

SES

Eligibility for free/reduced-price school meals was used as a proxy for SES. Children from families with incomes 130%, and between 130% and 185%, of the poverty level were eligible for free meals and reduced-price meals, respectively, and children from all other families paid full price.⁴⁰ This study used three SES-marker categories—low-SES (eligible for free meals), medium-SES (eligible for reduced-price meals), and high-SES (paid full price). The Office of Research and Statistics used children's names, sex, race, and date of birth (all provided by the school district based on parental reports) to link the school-based project's data to SES data (provided by the Department of Education).

Data analyses

For the four academic subjects, separately and combined, first-order marginal regression models were fit using PACT score as the dependent variable. In each model, covariates included BMI percentile, SES (low, medium, high), race (African American, other) and school year (2004–2005, 2005–2006, 2006–2007). Separate models were fit for girls and boys due to sex differences in academic achievement⁴¹ and BMI percentile.³⁸ To assess potentially informative interactions, higher-order models included the BMI-percentile-by-race and BMI-percentile-by-SES interactions. The GENMOD procedure in SAS (version 9.2, Copyright 2002–2008, SAS Institute Inc, Cary, NC) was used to fit all regression models with generalized estimating equations, acknowledging that children are naturally clustered within school. An independence working correlation structure was assumed to calculate corrected standard errors for all covariate effects in all models. For each model fit, an effect was judged significant, when treated individually, if its corresponding *p*-value (*P*) was <0.05. Using a Bonferroni correction, a *p*-value of $P=0.05/6 \approx 0.0083$ was needed to classify an effect as significant after adjusting for multiple comparisons. Each model had six

(non-intercept) first-order effects—one for BMI percentile, two for SES, one for race, and two for school year.

RESULTS AND DISCUSSION

Of the 1,504 fourth-grade children (808 girls; 696 boys) for whom complete data were available, 90% were African-American, 77.6% low-SES, 5.9% medium-SES, and 16.5% high-SES. Of these, 2.5% were underweight, 48.6% healthy weight, 19.3% overweight, 20.4% obese, and 9.2% severely obese. Table 1 provides descriptive information by sex for PACT scores by BMI percentile quartile, SES, race, and school year. Table 2 provides results by sex according to BMI percentile, race, SES, and school year.

BMI percentile

For girls, among the four academic subjects, separately and combined, PACT scores were not significantly related to BMI percentile. For boys, PACT scores were inversely related to BMI percentile for science only ($P=0.0237$), but this became insignificant after adjusting for multiple comparisons. Overall, these findings are consistent with four studies that did not find a significant relationship between academic achievement and childhood obesity,^{14,27,29,31} but these findings conflict with the inverse relationship found in numerous studies globally^{6,7,10–12} and within the US.^{16,18,22–24,28,32} By sex, these findings conflict with results for girls and are consistent with results for boys in one study globally⁵ and three within the US.^{19,26,30} The disparate BMI percentile findings may be (1) due to different methods used to assess obesity, including those where weight and height were measured,^{5,8,9,14,15,17,19–25,27–32} self-reported by children,^{10–12,16,18} or reported by parents,^{13,26,27} (2) due to different methods used to assess academic achievement, which included standardized test scores,^{13,17,19,21–25,27–32} IQ tests,⁷ and grades that were self-reported by children,^{5,11,12,16,18,20} reported by parents,²⁶ or obtained from schools,^{6,8–10,14,15,20,24} or (3) because of differences in race characteristics of study samples.

SES

For girls and boys, for the four academic subjects, separately and combined, PACT scores were related to SES (all P -values <0.0001), even after adjusting for multiple comparisons. The PACT scores were lowest for low-SES children and highest for high-SES children. These findings are consistent with studies which found that lower-SES children had poorer academic performance.^{7,9,23,25,29,41,42}

Race

For girls, for three academic subjects (English, math, science) and for the four academic subjects combined, PACT scores were related to race (all P -values <0.0001), even after adjusting for multiple comparisons; for social studies, the result ($P=0.0129$) became insignificant after adjusting for multiple comparisons. For boys, for the four academic subjects, separately and combined, PACT scores were related to race (all P -values <0.0039), even after adjusting for multiple comparisons. For girls and boys, PACT scores were lower for African-American children than children of other races. These findings are consistent with other data reporting that African-American children comprised the lowest-performing racial/ethnic subgroup,⁴³ and that large gaps in scores exist between Asian and White children (who performed best) when compared to African-American, Native-American, and Latino children.⁴¹

School year

For girls and boys, PACT scores were largely consistent across the three school years. The PACT scores were related to school year for social studies (girls $P=0.0129$; boys $P=0.0234$) and science (girls $P<0.0001$; boys $P=0.0215$); however, after adjusting for multiple comparisons, three of these findings became insignificant. This suggests that the year-to-year effect was weak at best.

Higher-order models

Although higher-order regression models were fit including the BMI-percentile-by-race interaction, it was insignificant in all models; this finding is consistent with a study¹⁷ reporting no significant differences by race/ethnicity in the effect of overweight on test scores. Analogously, fitting higher-order models with a BMI-percentile-by-SES interaction term yielded the same insignificant conclusion.

Limitations

There are several limitations worth noting. First, the school-based project was not designed to investigate this study's hypotheses. Also, eligibility for free/reduced-price school meals was used as a surrogate for SES. The cross-sectional design does not allow for causal inferences. The sample included only fourth-grade children from one district. Physical fitness data were not collected, although data have suggested a positive relationship between academic achievement and physical fitness,⁴⁴ and that overall physical fitness was a better predictor of academic achievement than BMI.⁴⁵ No data were collected concerning the stigma of childhood obesity, interpersonal skills, and internalizing behaviors. Previously, data were reported showing that obese children's stigmatization increased between 1961 and 2001;⁴⁶ such stigma may influence negative outcomes related to obesity.⁴⁷ In kindergarten through fifth-grade children, interpersonal skills have been found to mediate the association between weight status and math performance for girls, and internalizing behaviors to mediate the association for both sexes.³²

Strengths

The study also had several strengths. Weight and height were measured rather than relying on parents' or children's reports.⁴⁸ Inter-rater reliability was assessed daily for research-staff pairs who conducted weight and height measurements.⁴⁸ Achievement test scores were assessed objectively by the district and were based on standardized tests. The participation rate (74%) was high. The large sample provided adequate power.⁴⁹

Additional comments

The literature documents several inter-relationships of children's nutrition, BMI, academic performance, and poverty. More comprehensive wellness policy goals and stronger nutrition education goals in school districts have been related to stronger academic performance in children.⁵⁰ Iron deficiency anemia has been linked to academic disadvantages.⁵¹ Eating breakfast,^{29,50–52} regularly eating three meals a day,⁵³ drinking more milk,²⁹ and drinking less sugar-sweetened beverages^{29,54} have been related to improved academic performance. Frequent high-calorie food intake³¹ and food insecurity have been related to decreased academic performance.^{55,56} Increased overweight and obesity prevalence have been linked to increased consumption of sugar-sweetened beverages.⁵⁷ Childhood obesity has been found to disproportionately affect low-income and minority children.^{57,58}

Limited BMI data exist at state and local levels, and gaps in BMI data on children ages five to 14 years are readily apparent.⁵⁹ School-based BMI-measurement has attracted attention across the US as an approach to address childhood obesity.⁶⁰ A 2012 study⁶¹ found very

high reliability for weight and height measurements by multiple volunteer health professionals compared to a trained researcher for Ohio's school-based BMI surveillance program; those measurement methods can be adopted by other states to produce high-quality BMI data.⁶¹ In 2010, 20 states required, and nine states recommended, school-based measurement of BMI or body composition.⁶² Unfortunately, it appears most states do not link BMI data for individual children to other child-level data collected by these states, perhaps due to legal, financial, and technical challenges.⁵⁹

This study used South Carolina's standards-based tests; several US studies have used other state's tests.^{22,23,25,28,30} Each US state has its own academic standards, so children in each state learn to different levels.⁶³ However, this is changing with the Common Core State Standards Initiative—a state-led effort which has established grade-specific (kindergarten through 12) end-of-year expectations for student knowledge.⁶³ To date, 45 US states have formally adopted the final standards (released in June 2010),⁶³ although most do not expect to fully implement them until the 2014–2015 school year or later.⁶⁴ Full implementation of the standards by all US states will facilitate the ability to compare results concerning the relationship between academic achievement and childhood obesity across states.

This study took advantage of a unique opportunity to link existing datasets that are not routinely linked. Considering the numerous US states that conduct school-based BMI measurement,⁶² and the Common Core State Standards Initiative,⁶³ cost-efficient opportunities exist in the US to create longitudinal cohort data sets to investigate relationships between academic performance and obesity, along with other variables (e.g., physical education) across kindergarten through 12th-grade children. State agencies can house data in state-based central repositories such as South Carolina's Office of Research and Statistics. Staff at those offices can use globally unique identifiers to protect confidentiality, link data across agencies and research projects, and analyze data. Results from such longitudinal studies would fill existing research gaps⁶⁵ and potentially help school administrators view nutrition and physical education as facilitators, rather than competitors, to academic achievement.

CONCLUSIONS

This study including fourth-grade, predominantly African-American children did not find significant relationships between academic achievement and BMI percentile, but it did find relationships between academic achievement and SES, and between academic achievement and race. Due to the increased prevalence of obesity in minority children,⁶⁶ additional research is needed to investigate the relationship between academic achievement and childhood obesity in predominantly minority populations in the US.

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Table 1

Descriptive information for fourth-grade children.

Palmetto Achievement Challenge Test scores ^a					
	n	Combined score for all four academic subjects	English	Math	Social studies
Girls					
BMI percentile quartile ^b					
First (range 0–56 th percentiles)	199	1600 (47)	403 (12)	406 (14)	397 (12)
Second (range 57 th –84 th percentiles)	176	1596 (47)	403 (12)	403 (15)	397 (12)
Third (range 85 th –96 th percentiles)	218	1605 (46)	404 (13)	407 (13)	398 (12)
Fourth (range 97 th –100 th percentiles)	215	1600 (46)	403 (13)	405 (15)	397 (12)
SES ^c					
Low	630	1593 (43)	402 (11)	403 (14)	395 (12)
Medium	49	1616 (38)	408 (11)	409 (12)	402 (11)
High	129	1632 (52)	411 (14)	414 (15)	404 (13)
Race					
African American	728	1596 (44)	403 (12)	404 (14)	396 (12)
All other races	80	1639 (51)	412 (14)	416 (14)	404 (14)
School year					
2004–2005	305	1605 (46)	403 (11)	406 (14)	400 (12)
2005–2006	337	1600 (47)	405 (13)	405 (15)	396 (12)
2006–2007	166	1594 (44)	402 (12)	404 (14)	395 (11)
Boys					
BMI percentile quartile					
First (range 0–56 th percentiles)	177	1597 (48)	400 (12)	405 (15)	397 (14)
Second (range 57 th –84 th percentiles)	200	1594 (47)	400 (12)	405 (14)	396 (12)
Third (range 85 th –96 th percentiles)	158	1590 (46)	399 (12)	402 (15)	396 (11)
Fourth (range 97 th –100 th percentiles)	161	1596 (51)	400 (13)	405 (15)	398 (14)
SES					
Low	630	1593 (43)	402 (11)	403 (14)	395 (12)
Medium	49	1616 (38)	408 (11)	409 (12)	402 (11)
High	129	1632 (52)	411 (14)	414 (15)	404 (13)
African American	728	1596 (44)	403 (12)	404 (14)	396 (12)
All other races	80	1639 (51)	412 (14)	416 (14)	404 (14)
2004–2005	305	1605 (46)	403 (11)	406 (14)	400 (12)
2005–2006	337	1600 (47)	405 (13)	405 (15)	396 (12)
2006–2007	166	1594 (44)	402 (12)	404 (14)	395 (11)

Palmetto Achievement Challenge Test scores ^a mean (standard deviation)						
	n	Combined score for all four academic subjects	English	Math	Social studies	Science
Low	537	1587 (44)	398 (12)	402 (14)	396 (12)	392 (13)
Medium	40	1609 (53)	404 (13)	410 (15)	399 (14)	397 (17)
High	119	1622 (51)	405 (12)	411 (15)	403 (14)	402 (17)
Race						
African American	633	1590 (45)	399 (12)	403 (14)	396 (12)	393 (14)
All other races	63	1636 (54)	406 (13)	417 (16)	406 (13)	407 (18)
School year						
2004–2005	271	1596 (49)	399 (13)	405 (15)	398 (12)	394 (15)
2005–2006	284	1592 (49)	400 (12)	404 (15)	395 (13)	393 (15)
2006–2007	141	1594 (45)	399 (11)	403 (12)	397 (14)	395 (14)

^aSchool staff administered the Palmetto Achievement Challenge Tests (PACT) according to state guidelines in May of each school year.³⁵ The PACT, a set of standardized exams, covered four academic subjects (English, math, social studies, science). This table shows PACT scores; for fourth-grade children, respective ranges of PACT scores corresponding to four overall performance levels (below basic, basic, proficient, advanced) were as follows: English (345–394, 395–409, 410–429, 430–445), math (351–398, 399–415, 416–426, 427–451), social studies (336–393, 394–412, 413–424, 425–464), and science (336–396, 397–411, 412–423, 424–464).³⁵

^bResearch staff measured weight and height in the spring of children's fourth-grade school year. For analyses, BMI percentile³⁸ was treated as a continuous variable. For ease of presentation in this table, BMI percentile quartiles were used to divide the girls into four groups of approximately equal numbers and to divide the boys into four groups of approximately equal numbers.

^cEligibility for free/reduced-price school meals was used as a proxy measure for SES according to three categories: low-SES (eligible for free school meals), medium-SES (eligible for reduced-price school meals), and high-SES (not eligible for free or reduced-price school meals).⁴⁰

Table 2

Results from regression analyses with fourth-grade children.

Academic subjects from the Palmetto Achievement Challenge Tests (PACT) ^a					
Girls (n = 808)	English	Math	Social studies	Science	All four academic subjects combined
Independent variable					
Body mass index (BMI) percentile ^b	0.007 (0.3053)	-0.012 (0.3965)	0.009 (0.4675)	0.015 (0.1682)	0.019 (0.5929)
Race	-6.504 (<0.0001)	-9.274 (<0.0001)	-5.166 (0.0129)	-10.682 (<0.0001)	-31.626 (<0.0001)
Chi-square (P value)					
Socioeconomic status ^c	78.30 (<0.0001)	81.18 (<0.0001)	76.08 (<0.0001)	32.28 (<0.0001)	72.91 (<0.0001)
School year ^d	1.49 (0.4740)	1.87 (0.3929)	15.07 (0.0129)	19.32 (<0.0001)	4.79 (0.0910)
Boys (n = 696)	English	Math	Social studies	Science	All four academic subjects combined
Independent variable					
BMI percentile	-0.014 (0.4311)	-0.031 (0.1100)	-0.012 (0.5530)	-0.047 (0.0237)	-0.104 (0.1323)
Race	-5.226 (0.0039)	-11.615 (<0.0001)	-7.838 (0.0002)	-12.656 (<0.0001)	-37.335 (<0.0001)
Chi-square (P value)					
Socioeconomic status	73.96 (<0.0001)	23.44 (<0.0001)	22.25 (<0.0001)	26.12 (<0.0001)	35.07 (<0.0001)
School year	0.40 (0.8176)	1.76 (0.415)	7.51 (0.0234)	7.68 (0.0215)	2.86 (0.2398)

^aSchool staff administered the Palmetto Achievement Challenge Tests (PACT) according to state guidelines in May of each school year. ³⁵ The PACT, a set of standardized exams, covered four academic subjects (English, math, social studies, science).

^bIn the spring of children's fourth-grade school year, research staff measured weight and height, and calculated body mass index (BMI) and BMI percentile.³⁸

^cEligibility for free/reduced-price school meals was used as a proxy measure for socioeconomic status (SES) according to three categories: low-SES (eligible for free school meals), medium-SES (eligible for reduced-price school meals), and high-SES (not eligible for free or reduced-price school meals).⁴⁰

^dData were collected on children in the fourth grade during the 2004–2005, 2005–2006, and 2006–2007 school years.