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Effects of weight on children's educational achievement

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ABSTRACT

In this paper, we investigate the association between weight and children's educational achievement, as measured by scores on Peabody Individual Achievement Tests in math and reading, and grade attainment. Data for the study came from the 1979 cohort of the National Longitudinal Survey of Youth (NLSY), which contains a large, national sample of children between the ages of 5 and 12 between 1986 and 2004. We obtained estimates of the association between weight and achievement using several regression model specifications that controlled for a variety of observed characteristics of the child and his or her mother, and time-invariant characteristics of the child. Our results suggest that, in general, children who are overweight or obese have achievement test scores that are about the same as children with average weight.

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1. Introduction

Growing rates of childhood obesity and the potential long-term health consequences of obesity have focused public attention on identifying the causes of and solutions to obesity. While the health consequences of obesity are potentially serious, obesity may also adversely affect other dimensions of child well-being that have long-term and equally important consequences. Specifically, obesity may reduce educational achievement. There is a large literature on the stigma and discrimination that overweight and obese students face and these societal influences may adversely affect student performance. Discriminatory behavior towards overweight and obese children may also bring on depression and cause children to adopt coping mechanisms (e.g., substance use) that could further harm educational achievement. Moreover, obesity may directly reduce cognitive achievement because of physiological consequences of obesity such as sleep apnea and asthma.

Despite plausible mechanisms linking obesity (weight) to educational achievement there has been relatively little research that has investigated the effect of obesity on children's educational achievement. From a public policy point of view this is unfortunate because there are several potential justifications for government action. First, if size (weight) discrimination is the cause of reduced educational achievement, then the government should arguably take action to eliminate or offset the effects of such discrimination so that children and parents undertake the appropriate amount of investments in education. Second, several government policies related to food prices (e.g., farm subsidies), the built environment (e.g., transportation and zoning), and physical activity (e.g., school programs) may be partly responsible for the growth in obesity. If obesity deters human capital investment, current and future government polices that potentially affect obesity need to consider this consequence. Finally, given the firmly documented positive relationship between education and health, enhancing the educational achievement of overweight and obese children may decrease the future social costs of obesity-related health problems.

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The purpose of this paper is to provide evidence of the association between weight status and children's educational achievement. We focus on children between the ages of 5 and 12, and data come from the National Longitudinal Survey of Youth (1979 children cohort), which cover the period from 1986 to 2004. We conduct a number of cross-sectional and longitudinal analyses that compare the achievement test scores of overweight and obese children to the achievement scores of normal weight children. We find little evidence that overweight and obese children's educational achievement has been adversely affected by their weight.

2. Previous literature

There are relatively few studies of the effects of obesity on educational achievement.[1] Taras and Potts-Datema (2005) reviewed nine recent studies and reported that all nine showed at least one negative association between obesity and school performance, but that this was not a uniform finding of this research. Moreover, these studies varied significantly in size and quality ranging from a study of 65 obese children ages 8–13 in Brazil, to 60,000 Finnish adolescents, to 12,537 persons aged 23 who were born in England and Scotland the week of March 3–9, 1958. As Sigfusdotirr, Kristjansson, and Allegrante (2006) noted in their recent paper, well-designed empirical studies of the relationship between obesity and academic achievement are scarce.

Studies of adolescents often find negative associations between obesity and educational achievement (see for example, Canning & Mayer, 1967; Crosnoe & Muller, 2004; Falkner et al., 2001; Gortmaker, Must, Perrin, Sobol, & Dietz, 1993; Sabia, 2007; Sigfusdotirr et al., 2006). Studies of the effect of obesity on children's educational achievement are particularly scarce. We know of only three studies that used a large, geographically broad-based sample. Edwards and Grossman (1979) used data on children aged 6–11 from the Cycle II of the National Health Examination Survey. They found that overweight kids had lower scores on the Wechsler Intelligence Scale for Children (WISC) and the Wide Range Achievement Test (WRAT) than children of normal weight. However, these effects were not statistically significant. Datar and Sturm (2006) analyzed the association between becoming overweight (>95 percentile of BMI), and changes in math and reading tests scores and grade repetition between kindergarten and third grade using data from the Early Childhood Longitudinal Study (ECLS). Results indicated that girls who became overweight had lower math and reading scores than girls who were never overweight. For boys, becoming overweight had no statistically significant effect on achievement. Averett and Stifel (2007) is the closest study to ours, as they used the same data and studied children of similar ages (6–13). They found that being overweight is associated with lower reading scores, but not lower math scores. They also examined underweight and found that being underweight is associated with lower math scores, but not lower reading scores.

While the findings from previous studies suggest that obesity has an adverse effect on children's educational achievement, there are several reasons why more study is warranted. First, given that there are only three previous studies, additional studies of the effect of obesity on educational achievement of young children are needed. Second, there is a need for more research that addresses the probable confounding from omitted variables. Children's weight is likely to be correlated with several hard-to-measure determinants of educational achievement. Therefore, cross-sectional analyses that adjust for a limited number of covariates are unlikely to provide an accurate estimate of the effect of obesity on children's educational achievement. Consider the results from Falkner et al. (2001). Unadjusted odds ratio indicated that obese girls were 114 percent more likely to be held back a grade than normal weight girls, but after adjusting for grade, race and parental socioeconomic status, this obesity disadvantage decreased to 51 percent—approximately a halving of the effect size. Third, existing research in this area has not incorporated important theoretical developments that have been made more generally in the literature on education production functions (Todd & Wolpin, 2003, 2007).

To summarize, there are several potential pathways through which weight and obesity may adversely affect children's educational achievement. However, there has been little study of the issue, particularly for young children. The paucity of research in this area is significant given the importance of education to lifetime well-being. Here we begin to address this shortfall by providing an analysis of the effect of weight on children's educational achievement using a large, national sample of children aged 5–12. We obtain age- and gender-specific estimates of the association between weight status (e.g., overweight) and educational achievement. Other contributions of this research are the attention paid to model specification and justification, and the use of methods to control for unobserved factors that may confound the association between obesity and children's educational achievement.

3. Causal pathways

To motivate our empirical analysis, we rely on standard economic theories of the household and child quality (Becker, 1965; Becker & Lewis, 1973; Grossman, 1972). In these models, consumption goods that produce utility (well-being, satisfaction) for family members are produced by the household using time and market purchased goods. Money to buy goods is earned by household members in the labor market. One of the most important goods produced by the household is child quality, in this case, educational achievement. However, child health is another aspect of child quality that is particularly relevant to our study because weight and obesity are related to child health.

A core aspect of these household models is the production function for household consumption goods, which is the relationship between inputs—the quantities of market goods and time used to produce household

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[1] There is a somewhat larger, although still relatively small, literature on the effects of child health on educational achievement and some of these papers use weight as an indicator of child health (e.g., Blau & Grossberg, 1992; Edwards & Grossman, 1979; Kaestner & Corman, 1995; Korenman, Miller, & Sjaastad, 1995; Levine & Schanzenbach, 2009; Rosenzweig & Wolpin, 1994; Shakoto, Edwards, & Grossman, 1981).

consumption—and outputs—the quantity of consumption. An admittedly simple production function for child educational achievement may be specified as follows (Todd & Wolpin, 2007):

$$E_{it} = \alpha_i + \gamma_t + \sum_{k=0}^{t}(\tau_k OWN_{ik} + \beta_k HEALTH_{ik} + \delta_k PAR_{ik}) + \sum_{k=0}^{t}(\lambda_k TEACH_{ik} + \pi_k PEER_{ik} + Z_{ik}\Gamma_k) + u_{it} \quad (1)$$

Eq. (1) indicates that the educational achievement (E) of child i at age t depends on a child-specific endowment (α_t), developmental age at time t (γ_t), the time the child spends in educational activities (OWN) at each age from birth to age t, child health ($HEALTH$) at each age from birth to age t, time spent by family members (e.g., mother) producing education (PAR) from birth to age t, the quantity and quality of school and teacher inputs ($TEACH$) from birth to age t, the quantity and quality of peer inputs ($PEER$) from birth to age t, and other market goods (Z) from birth to age t that are used to produce educational achievement.

Eq. (1) assumes that determinants of educational achievement have different effects depending on age, for example, the parental time input (PAR) will have a different effect at age 6 than at age 10. However, Eq. (1) assumes that effects do not depend on time since investments were made, which is equivalent to assuming that there is no depreciation of education capital (or for a slight variation of this model that the depreciation rate is the same for all inputs). This specification was chosen to facilitate estimation, which we discuss in more detail below including ways to test the restrictions embodied in Eq. (1).

Our interest is to obtain estimates of the effect of weight on educational achievement. There are several reasons why weight (overweight) would affect educational achievement. Probably the most prominently cited potential cause is because of size (weight) discrimination. Overweight and obese children face a variety of discrimination from peers and teachers that may adversely affect educational achievement (Eisenberg, Neumark-Sztainer, & Story, 2003; Jalongo, 1999; Jsanssen, Craig, Boyce, & Pickett, 2004; National Education Association, 1994; Neumark-Sztainer, Story, & Faibisch, 1998; Puhl & Brownell, 2003; Ritts, Patterson, & Tubbs, 1992; Solovay, 2000; Schwartz & Puhl, 2003). In terms of Eq. (1), size discrimination (weight) would affect the quantity and quality of school and teacher inputs and the quantity and quality of peer inputs. Weight may even affect the quantity and quality of parental inputs if households allocate resources in response to size discrimination (Crandall, 1995; Puhl & Latner, 2007).

Discrimination against overweight and obese children may also lead to depression (health in Eq. (1)) that can adversely affect educational achievement (Goodman & Whitaker, 2007; Hoebel, Rada, Mark, & Pothos, 1999; Smith, Marcus, Lewis, Fitzgibbon, & Schreiner, 1998; Wurtman, 1993). Childhood obesity is also associated with other aspects of health such as asthma, sleep apnea and sleeping disorders, which may adversely affect cognitive functioning and school attendance, and thus educational achievement (Beuther, Weiss, & Sutherland, 2006; Dietz, 1998; Geier et al., 2007; Gilliland et al., 2003; Gozal, 1998; Must & Strauss, 1999; Redline et al., 1999; Von Mutius, Schwartz, Neas, Dockery, & Weiss, 2001).

Size (weight) discrimination could also affect the child's time use. Ostracism may lead a child to have fewer social relationships and engage in fewer social activities. This may result in greater time spent in educational activities and higher educational achievement (all else equal). A child's weight may also affect their physical fitness and prevent children from engaging in recreational activities, which again may provide more time for educational activities.

In sum, past study from a variety of disciplines (e.g., psychology and medicine) suggests that overweight and obese children may have lower educational achievement than normal weight children, although the alternative, that obesity is associated with higher achievement, is possible. One way to incorporate these causal pathways in the conceptual model is to replace the proximate causes of educational achievement (e.g., child health) with determinants of those causes, most notably child weight. Making these substitutions results in the following:

$$E_{it} = \tilde{\alpha}_i + \tilde{\gamma}_t + \sum_{k=0}^{t}(\rho_k WEIGHT_{ik} + Z_{ik}\tilde{\Gamma}_k) + \tilde{u}_{it} \quad (2)$$

Eq. (2) is a quasi-reduced form model because we have substituted for the determinants of educational achievement, but weight ($WEIGHT$) remains endogenous. We have used the symbol $\sim$ to indicate a reduced form parameter. The coefficient on weight will measure the effect of weight that operates through changes in the quantity or quality of educational inputs (e.g., child's use of time, child health, and school resources). We will focus on the quasi-reduced form.

4. Empirical model

The main problem associated with obtaining estimates of an empirical analog to Eq. (2) is that weight ($WEIGHT$) may be correlated with the error, which includes unmeasured exogenous determinants of the inputs in the production function (Eq. (1)). Further, the data requirements necessary to obtain unbiased estimates of Eq. (2) are daunting, as the entire history of the exogenous determinants of production function inputs enter the model.

One way to reduce the data demands of Eq. (2) is to examine changes in educational achievement between two ages. Such a model is given by

$$E_{it} - E_{i(t-1)} = (\gamma_t - \gamma_{t-1}) + \rho_t WEIGHT_{it} + Z_{it}\Gamma_t + (u_{it} - u_{i(t-1)}) \quad (3)$$

As is made clear by Eq. (3), the difference in educational achievement between ages $t-1$ and t depends on the difference in developmental age ($\gamma_t - \gamma_{t-1}$) and resources used between these ages. Notably, endowed intelligence (α_i) is eliminated from the model. However, one consequence of this approach is that estimates of the effects of educational inputs are specific to age t (Todd & Wolpin, 2003, 2007).

Three aspects of Eq. (3) merit discussion. The first point relates to the fact that the left hand side of Eq. (3) is the change in educational achievement, but the right hand side variables are the levels of inputs between ages $t-1$ and t, or the change in stock of what may be referred to as educational capital. For example, it is the weight of the child between ages $t-1$ and t that enters and not the change in weight between ages $t-1$ and t. The change in achievement (e.g., test scores) between ages $t-1$ and t depends on the child's weight at (during) age t. This is reasonable. It is not the change in weight that matters, but the weight itself that brings forth discrimination that adversely affects achievement. Analogously, it is not the change in parental time inputs that matter, but the actual amount of time spent during the period producing child education. This point has not been well understood by previous researchers and as a result, their models have been mis-specified (Todd & Wolpin, 2003). Second, because most educational inputs are not measured, proxy variables (i.e., reduced form determinants) are often used. For example, mother's educational achievement is used as a measure of the quality of parental time input. This "quality" input enters the production function each period and therefore is included in Eq. (3) even if it is time-invariant. Similarly, a time-invariant demographic characteristic such as race, which may be a proxy for unmeasured inputs, also enters the model because of the age-specific effects of inputs. Third, estimates are age-specific. Consider the case in which the period $t-1$ to t represents two years, as in our data. In this case, the coefficient on weight (e.g., obesity), which is best measured as obesity between time $t-1$ and t, measures the effect of obesity on educational achievement at age t.[2]

While Eq. (3) reduces the data demands necessary to estimate the model considerably, it remains unlikely that all relevant variables will be measured and estimates of the effect of weight (obesity) may still be biased. Given the common set of underlying factors that affect resource allocation decisions, the quantities of measured inputs (weight) are likely to be correlated with the error, which includes time-varying, unmeasured exogenous (e.g., preferences) determinants of educational inputs. One solution is instrumental variables and the structure of Eq. (3) suggests many potential instruments. Specifically, inputs in periods prior to period t may be used as instruments because only time t inputs are included in Eq. (3) (Todd & Wolpin, 2003). The assumption underlying this approach is that the future does not cause the past and therefore, for example, weight in previous periods will be uncorrelated with the error $(u_{it}-u_{i(t-1)})$ in Eq. (3). Therefore, lagged weight (e.g., $t-2$) can be used as an instrument for weight in period t. In our case, past weight is likely to be a particularly good instrument in that it is likely to be strongly correlated with current weight given the documented persistence of weight (McTigue, Garrett, & Popkin, 2002; Power, Lake, & Cole, 1997; Serdula et al., 1993; Whitaker, Pepe, Wright, Seidel, & Dietz, 1998).

The fact that past period inputs, or their determinants, do not enter Eq. (3) provides the basis of a specification test. If included, past period inputs should have no statistically significant effect on achievement. In our case, we implemented this test by including in Eq. (3) several lagged variables: mother's hours and weeks worked, number of children in family, and family income. For male children, we could not reject the null hypothesis (at 0.05 or 0.10 level) that the coefficients on these lagged variables were jointly equal to zero in seven of nine cases (corresponding to Table 2). For females, we could not reject the null in eight of nine cases (corresponding to Table 3). While not uniform, the preponderance of evidence suggests that the specification of Eq. (3), which omits lagged variables, is reasonable. These specification tests also provide support for the instrumental variables approach, which uses lagged weight as instruments.

5. Data

The data for the analysis are drawn from the children of the National Longitudinal Survey of Youth (NLSY)—1979 Cohort. We focused on children between the ages of 5 and 12 who were born to female respondents of the NLSY who themselves were born from 1957 to 1964 and who were living in the United States in 1978. Children and mothers were interviewed every two years between 1986 and 2004, which is the last year of data used in the analysis. The NLSY child survey collected detailed information about children and their mothers.

Children's cognitive achievement was measured by the Peabody Individual Achievement Test (PIAT) for math, reading recognition and reading comprehension. The validity and reliability of these assessments are well documented (Center for Human Resources, 2006). Notably, all children aged 5 and over take the same PIAT test, but begin the test at different points appropriate for their age. A basal and ceiling are established for each child and scores are calculated as the ceiling minus the number of incorrect answers between the basal and ceiling. This provides a consistent metric to assess changes in test scores over time.

The weight and height of children was recorded at each interview and for approximately two-thirds of the children these measurements were made using a scale and tape. The remaining children's weight and height was reported by the mother. We use weight and height to calculate body mass index (BMI). Specifically, we measure weight as the average of weights at times $t-2$ (the most recent lag) and t, as children are surveyed every two years in the NLSY. As noted above, it is the weight during the period between time $t-2$ and t that is the appropriate measure, and given available data the average weight is a good approximation of this variable. We categorize children according to where their BMI falls in the distribution of children's weight in the First National Health and Nutrition Examination Survey (NHANES I). We use the following percentile categories for the first measure: 0–5, 6–15, 16–84, 85–94, and 95–100. As can be seen in Table 1, the weight distribution of the children of the NLSY is shifted to the right vis-à-vis the

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[2] Estimates (not presented) demonstrate the importance of the specification of Eq. (3). For example estimates of time-invariant variables such as race and mother's education remain statistically significant in the first-difference model and estimates of the effects of variables differ significantly by age.

Table 1A
Achievement scores of male children by NHANES I weight status.

	Weight status (NHANES I standard)				
	0–5%	5–15%	15–85%	85–95%	95–100%
Ages 7–8					
PIAT-Math	29.0[a]	31.4	31.1	31.8	29.7[a]
PIAT-Reading Recognition	31.9	32.2	32.8	33.8	32.1
PIAT-Reading Comprehension	29.1[a]	29.9	30.7	30.9	30.0
Number of observations (Column %)	184 (7)	149 (6)	1418 (56)	393 (15)	407 (16)
Age 9–10					
PIAT-Math	40.5[a]	42.7	43.5	44.7[a]	43.3
PIAT-Reading Recognition	42.5[a]	43.7	44.4	45.7	44.9
PIAT-Reading Comprehension	39.3	38.9[a]	40.8	41.8	41.2
Number of observations (Column %)	199 (8)	174 (7)	1430 (54)	417 (16)	410 (16)
Ages 11–12					
PIAT-Math	48.0[a]	50.1	50.7	51.7	50.1
PIAT-Reading Recognition	50.5[a]	52.8	53.2	53.9	53.0
PIAT-Reading Comprehension	45.4[a]	47.7	48.1	48.8	48.2
Number of observations (Column %)	141 (6)	132 (5)	1308 (54)	442 (18)	398 (16)

Note: Number of observations refers to the number of valid scores on PIAT-Math.

[a] Estimate is statistically different (0.05 level) from estimate for children in 15–85 percentiles.

Table 1B
Achievement scores of female children by NHANES I weight status.

	Weight status (NHANES I standard)				
	0–5%	5–15%	15–85%	85–95%	95–100%
Ages 7–8					
PIAT-Math	29.4[a]	31.8	31.4	31.1	30.6
PIAT-Reading Recognition	33.6	35.6	35.0	35.5	33.6[a]
PIAT-Reading Comprehension	31.5	33.4	32.6	32.8	31.6[a]
Number of observations (Column %)	198 (8)	192 (8)	1236 (49)	397 (16)	477 (19)
Age 9–10					
PIAT-Math	41.0[a]	42.5	43.7	43.9	42.6[a]
PIAT-Reading Recognition	44.9[a]	47.1	47.3	47.0	45.0[a]
PIAT-Reading Comprehension	41.0[a]	42.0	42.9	43.1	41.2[a]
Number of observations (Column %)	210 (8)	209 (8)	1304 (49)	474 (18)	451 (17)
Ages 11–12					
PIAT-Math	48.5[a]	47.8[a]	50.7	50.0	49.3[a]
PIAT-Reading Recognition	53.4[a]	54.9	56.0	55.7	54.3[a]
PIAT-Reading Comprehension	48.2	48.7	49.2	48.8	46.7[a]
Number of observations (Column %)	119 (5)	112 (5)	1378 (57)	465 (19)	344 (14)

Note: (1) Number of observations refers to the number of valid scores on PIAT-Math.

[a] Estimate is statistically different (0.05 level) from estimate for children in 15–85 percentiles.

weight distribution of children in the NHANES I and this fact reflects the widely reported growth in obesity of children.

The NLSY also provides detailed data about the mothers and children. We make use of the following information about the child: race, age, gender, grade in school, birth order, and birth weight. For mothers, we used information on: age at birth, age, BMI, educational attainment, AFQT test score, marital status, number of children born, nativity, hours of work and weeks worked per year, and mother's family background (family structure at age 14, magazines and books in household).

As is common in the literature, we use variables that proxy for missing inputs such as mother's education, AFQT test score, and marital status, which are likely to be correlated with the quantity and quality of maternal time spent producing child educational achievement. Similarly, child characteristics (e.g., age and birth order) proxy for inputs related to the child.

The sample sizes by age and gender of child are provided in Table 1. In general, the sample sizes are sufficiently large, approximately 2200 per two-year age group, to obtain precise estimates and to detect reliably effect sizes of 10 percent (or mean) or less. The smallest sample sizes are for children in the low-weight categories. For these children, we do not have sufficient statistical power to detect small effects.

6. Descriptive analysis

Table 1 presents (unweighted) sample mean test scores for children by weight status. Figures are presented separately by age and gender. Figures in Table 1 suggest that children in the top and bottom of the weight distribution

Table 2
Estimates of the effect of BMI (NHANES I Classification) on achievement scores of male children.

	PIAT-Math			PIAT-Reading Recognition			PIAT-Reading Comprehension		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Ages 7–8									
BMI 0–5%	−1.34* (0.71)	−0.95 (0.68)	0.03 (0.78)	−0.04 (0.75)	−0.21 (0.73)	−0.16 (0.78)	−0.69 (0.72)	−0.79 (0.71)	−1.15 (0.84)
BMI 5–15%	0.44 (0.76)	0.32 (0.73)	−0.57 (0.91)	−0.29 (0.81)	−0.66 (0.78)	−0.63 (0.92)	−0.28 (0.78)	−0.51 (0.76)	−0.22 (1.00)
BMI 85–95%	0.02 (0.51)	−0.08 (0.50)	0.54 (0.71)	0.15 (0.54)	0.07 (0.54)	0.08 (0.72)	−0.51 (0.52)	−0.61 (0.52)	−0.83 (0.78)
BMI 95–100%	−0.83* (0.50)	−0.03 (0.50)	0.37 (0.66)	−0.43 (0.54)	0.27 (0.53)	−0.28 (0.66)	−0.28 (0.51)	0.39 (0.52)	0.13 (0.72)
Ext. Covariate Set	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
First differences	No	No	Yes	No	No	Yes	No	No	Yes
Mean Dep. Var.	30.9	30.9	15.5	32.8	32.8	16.0	30.6	30.6	14.0
Number of observations	2490	2380	2303	2483	2372	2262	2390	2281	2093
Ages 9–10									
BMI 0–5%	−1.94** (0.73)	−1.62** (0.72)	−0.41 (0.74)	−1.18 (0.90)	−0.47 (0.88)	1.12 (0.69)	−0.72 (0.78)	−0.19 (0.76)	0.32 (0.80)
BMI 5–15%	−0.33 (0.77)	−0.07 (0.76)	1.20 (0.86)	−0.24 (0.95)	0.19 (0.93)	0.95 (0.80)	−1.28 (0.83)	−0.84 (0.80)	−1.76* (0.93)
BMI 85–95%	0.76 (0.53)	0.97* (0.53)	0.69 (0.75)	0.58 (0.66)	0.73 (0.65)	0.71 (0.71)	0.62 (0.57)	0.88 (0.56)	0.15 (0.82)
BMI 95–100%	−0.88* (0.54)	0.22 (0.55)	−0.30 (0.69)	−0.56 (0.67)	0.71 (0.68)	0.46 (0.65)	−0.12 (0.58)	1.10* (0.58)	0.64 (0.76)
Ext. Covariate Set	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
First differences	No	No	Yes	No	No	Yes	No	No	Yes
Mean Dep. Var.	43.4	43.4	13.6	44.5	44.6	12.7	40.8	40.9	11.0
Number of observations	2578	2452	2371	2572	2445	2352	2542	2419	2215
Ages 11–12									
BMI 0–5%	−0.50 (0.85)	−0.20 (0.84)	0.64 (0.78)	−0.62 (1.17)	−0.86 (1.16)	0.57 (0.75)	−0.92 (0.99)	−0.92 (0.98)	0.47 (0.84)
BMI 5–15%	−0.25 (0.87)	−0.50 (0.85)	1.48 (0.97)	0.88 (1.20)	0.32 (1.16)	0.77 (0.93)	0.51 (1.01)	0.19 (0.97)	−0.32 (1.04)
BMI 85–95%	0.44 (0.53)	0.82 (0.52)	−0.38 (0.69)	−0.43 (0.73)	−0.25 (0.71)	0.02 (0.66)	0.04 (0.61)	0.41 (0.60)	−0.76 (0.74)
BMI 95–100%	−0.84 (0.54)	−0.15 (0.55)	0.40 (0.66)	−0.63 (0.75)	0.16 (0.76)	0.60 (0.63)	0.06 (0.63)	0.85 (0.63)	0.08 (0.71)
Ext. Covariate Set	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
First differences	No	No	Yes	No	No	Yes	No	No	Yes
Mean Dep. Var.	50.7	50.8	7.6	53.2	53.3	9.1	48.1	48.2	7.4
Number of observations	2369	2252	2165	2361	2249	2160	2350	2237	2115

Notes: (1) All models include dummy variables for age in months, race/ethnicity, grade in school, year, region, and birth order. Extended covariate set also includes dummy variables for the following mother's characteristics: age at birth, number of children born, BMI (quintiles), marital status, education, AFQT score (quadratic), family structure and environment at age 14, weeks worked in last year (quadratic), hours worked in last year (quadratic), and an interaction between weeks and hours worked in last year. (2) Standard errors in parentheses.

* $0.05 < p$-value < 0.10.

** p-Value < 0.05.

have lower achievement test scores than children in the middle of the weight distribution. There is little evidence that tests scores of overweight (85–95 percentiles) children differ from normal weight children, and only among girls is there consistent evidence that obese children have lower test scores than normal weight children. Differences in test scores are not large. For example, female children ages 9 and over who are considered obese using the NHANES I standard (>95 percentile) have math and reading tests scores that are approximately one to two points (2–5 percent of mean, or 10–20 percent of a standard deviation) lower than girls 9 and over who are normal (15–85 percentiles) weight. Among males, with once exception, there are no statistically significant differences in test scores between those in the upper tails of the weight distribution and those in the middle of the distribution. Boys and girls between who are in the lowest (0–5 percentiles) tail of the weight distribution have achievement test scores that are approximately 4–6 percent (10 percent of a standard deviation) lower than similar children in the middle of the weight distribution. Overall, figures in Table 1 suggest that there may be some relatively small effects of weight on children's educational achievement. There is more consistent evidence of a low-weight effect than a high-weight effect. It is only among girls ages 9–12 that we observe a significant difference in test scores between obese girls and normal weight girls.

A similar table (not presented) showing differences in child and mother characteristics by weight reveals that children in the upper tail of the weight distribution are more likely to be Black and their mothers tend to be less educated, less likely to be married and have lower AFQT test scores than children in the middle of the weight distribution. There are few systematic differences between children in the lower tail (0–5 percentiles) of the weight distribution and children in the middle of the weight distribution. This finding provides some evidence that children in the upper tails of the weight distribution may differ in measured and unmeasured ways and that these differences may confound the relationship between weight and educational achievement.

7. Multivariate analysis

To account for differences in child and mother characteristics that may affect children's education achievement and be correlated with weight, we estimated several multivariate regression models based on Eq. (2). We refer to estimates from this model as cross-sectional estimates. We obtain estimates for two specifications of this model: a basic specification that includes only child characteristics and a specification that adds a large set of maternal characteristics. While the cross-sectional model is not our preferred model, estimates from it help establish whether there are any significant correlations between weight and educational achievement, and whether these correlations are sensitive to selection on observed covariates. Estimates from models based on Eq. (3) are referred to as first-difference (FD) estimates. These are our preferred estimates, as they control for the effect of time-invariant, unmeasured factors and are more consistent with a theoretical model of educational achievement.

Table 2 presents estimates for male children. Estimates in column (1) indicate that there is a consistent negative association between being in the lowest weight category and achievement test scores, although most estimates are not statistically significant. Estimates in column (1) are also small in magnitude (<5 percent of mean, or 10 percent of a standard deviation). Similarly, there is some evidence that being in the highest weight category is negatively associated with achievement test scores, particularly for math. In this case, there is only one statistically significant estimate and estimates are small (<3 percent mean). Adding maternal characteristics to the basic cross-sectional model further erodes the evidence of adverse effects of low- or high-weight on test scores. Estimates of the association between the extreme weight categories and test scores in column (2) are usually less negative than those in column (1), particularly for the obese (95–100 percentiles) category, and virtually all but one are not statistically significant. In sum, cross-sectional estimates in Table 2 provide little evidence that weight is significantly related to male children's achievement test scores. If anything, very-low

Table 3

Instrumental variables estimates of the effect of BMI (NHANES I Classification) on achievement scores of male children.

	PIAT-Math		PIAT-Reading Recognition		PIAT-Reading Comprehension	
	(1)	(2)	(1)	(2)	(1)	(2)
Ages 9–10						
BMI 0–15%	−0.32 (0.62)	−3.30 (2.41)	0.52 (0.57)	3.53 (2.23)	−0.84 (0.68)	−1.11 (2.61)
BMI 95–100%	−0.50 (0.73)	−1.84 (2.02)	0.20 (0.68)	2.97 (1.88)	0.65 (0.80)	1.07 (2.20)
Instrumental variables	No	Yes	No	Yes	No	Yes
Mean Dep. Var.	13.5	13.5	12.6	12.6	11.1	11.0
Number of observations	2033	2033	2012	2352	1919	2215
Ages 11–12						
BMI 0–15%	1.25 (0.65)	2.55 (1.77)	0.79 (0.63)	−0.00 (1.72)	0.48 (0.69)	2.08 (1.90)
BMI 95–100%	0.49 (0.69)	−1.51 (1.45)	0.84 (0.67)	1.31 (1.41)	−0.05 (0.74)	0.19 (1.54)
Instrumental variables	No	Yes	No	Yes	No	Yes
Mean Dep. Var.	7.5	7.5	9.0	9.0	7.7	7.4
Number of observations	1897	1897	1890	1890	1858	1858

Notes: (1) All models use extended covariate set (see notes to Table 3). (2) Instruments for BMI categories are BMI categories lagged four years. (3) Standard errors in parentheses.

*$0.05 < p$-value < 0.10.

**p-Value < 0.05.

Table 4

Estimates of the effect of BMI (NHANES I Classification) on achievement scores of female children.

	PIAT-Math			PIAT-Reading Recognition			PIAT-Reading Comprehension		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Ages 7–8									
BMI 0–5%	−1.41** (0.67)	−1.06 (0.66)	−0.58 (0.80)	−0.81 (0.69)	0.01 (0.69)	0.23 (0.80)	−0.62 (0.67)	0.06 (0.66)	0.29 (0.81)
BMI 5–15%	−0.16 (0.67)	0.05 (0.66)	−0.50 (0.84)	0.14 (0.69)	0.10 (0.69)	−0.05 (0.85)	0.38 (0.66)	0.57 (0.65)	−0.15 (0.86)
BMI 85–95%	−0.73 (0.50)	−0.51 (0.50)	−0.08 (0.71)	−0.06 (0.52)	0.18 (0.52)	0.38 (0.71)	−0.23 (0.50)	0.04 (0.49)	1.51** (0.72)
BMI 95–100%	−0.82* (0.48)	−0.09 (0.48)	−0.13 (0.63)	−1.71** (0.49)	−1.01** (0.50)	−0.77 (0.64)	−0.96** (0.47)	−0.44 (0.48)	−0.45 (0.64)
Ext. Covariate Set	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
First differences	No	No	Yes	No	No	Yes	No	No	Yes
Mean Dep. Var.	31.1	31.2	15.2	34.8	34.9	16.9	32.4	32.5	14.8
Number of observations	2440	2303	2240	2440	2302	2195	2376	2245	2052
Ages 9–10									
BMI 0–5%	−1.42** (0.64)	−0.94* (0.62)	0.20 (0.69)	−0.93 (0.79)	−0.18 (0.77)	0.10 (0.63)	−0.54 (0.70)	0.15 (0.67)	−0.05 (0.73)
BMI 5–15%	−0.35 (0.63)	−0.09 (0.62)	−0.42 (0.80)	0.86 (0.78)	0.81 (0.77)	0.69 (0.73)	0.03 (0.69)	−0.07 (0.68)	−0.27 (0.85)
BMI 85–95%	−0.50 (0.46)	0.02 (0.45)	−0.73 (0.70)	−1.01* (0.56)	−0.45 (0.55)	0.52 (0.64)	−0.33 (0.50)	0.18 (0.49)	−0.39 (0.74)
BMI 95–100%	−0.67 (0.47)	0.41 (0.48)	0.48 (0.65)	−1.45** (0.58)	−0.02 (0.59)	0.56 (0.59)	−1.14** (0.52)	0.12 (0.52)	0.40 (0.69)
Ext. Covariate Set	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
First differences	No	No	Yes	No	No	Yes	No	No	Yes
Mean Dep. Var.	43.3	43.3	13.1	46.7	46.8	12.7	42.4	42.4	10.7
Number of observations	2599	2447	2373	2599	2449	2369	2582	2432	2286
Ages 11–12									
BMI 0–5%	−1.73** (0.86)	−1.74** (0.84)	−0.18 (0.74)	−1.76 (1.12)	−1.58 (1.10)	−0.46 (0.78)	−0.53 (0.94)	−0.37 (0.92)	1.12 (0.88)
BMI 5–15%	−2.08** (0.88)	−2.30** (0.88)	−0.03 (0.91)	0.29 (1.16)	0.80 (1.16)	−0.53 (0.96)	0.29 (0.97)	0.03 (0.97)	−1.50 (1.08)
BMI 85–95%	−0.30 (0.48)	−0.04 (0.47)	1.05 (0.64)	−0.23 (0.63)	0.19 (0.62)	2.11** (0.67)	−0.07 (0.53)	0.14 (0.52)	−0.01 (0.76)
BMI 95–100%	−0.79 (0.55)	−0.07 (0.55)	−0.39 (0.65)	−1.17 (0.71)	−0.22 (0.72)	−0.14 (0.68)	−1.46** (0.60)	−0.64 (0.60)	−1.83** (0.76)
Ext. Covariate Set	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
First differences	No	No	Yes	No	No	Yes	No	No	Yes
Mean Dep. Var.	50.1	50.1	7.2	55.6	55.6	9.1	48.7	48.8	6.4
Number of observations	2375	2251	2178	2368	2246	2182	2352	2229	2146

Notes: (1) All models include dummy variables for age in months, race/ethnicity, grade in school, year, region, and birth order. Extended covariate set also includes dummy variables for the following mother's characteristics: age at birth, number of children born, BMI (quintiles), marital status, education, AFQT score (quadratic), family structure and environment at age 14, weeks worked in last year (quadratic), hours worked in last year (quadratic), and an interaction between weeks and hours worked in last year. (2) Standard errors in parentheses.

* $0.05 < p\text{-value} < 0.10$.

** $p\text{-Value} < 0.05$.

Table 5

Instrumental variables estimates of the effect of BMI (NHANES I Classification) on achievement scores of female children.

	PIAT-Math		PIAT-Reading Recognition		PIAT-Reading Comprehension	
	(1)	(2)	(1)	(2)	(1)	(2)
Ages 9–10						
BMI 0–15%	−0.06 (0.56)	−1.50 (1.71)	0.20 (0.51)	1.05 (1.54)	−0.21 (0.60)	0.80 (1.81)
BMI 95–100%	0.78 (0.68)	−2.38 (1.82)	0.82 (0.62)	0.92 (1.65)	0.66 (0.73)	0.82 (1.94)
Instrumental variables	No	Yes	No	Yes	No	Yes
Mean Dep. Var.	12.7	12.7	12.5	12.5	10.8	10.8
Number of observations	2060	2060	2054	2054	1997	1997
Ages 11–12						
BMI 0–15%	−0.41 (0.62)	0.38 (1.41)	−1.12 (0.65)	−1.33 (1.47)	0.31 (0.73)	2.53 (1.66)
BMI 95–100%	−0.29 (0.67)	0.33 (1.28)	−0.89 (0.70)	0.17 (1.34)	−2.05** (0.79)	−1.43 (1.51)
Instrumental Variables	No	Yes	No	Yes	No	Yes
mean Dep. Var.	7.2	7.2	9.1	9.1	6.5	6.5
Number of observations	1924	1924	1922	1922	1897	1897

Notes: (1) All models use extended covariate set (see notes to Table 5). (2) Instruments for BMI categories are BMI categories lagged four years. (3) Standard errors in parentheses.

* $0.05 < p$-value < 0.10.

** p-Value < 0.05.

weight male children may have slightly lower (2–3 percent of the mean or 5 percent of a standard deviation) math and reading comprehension scores than normal weight male children.[3]

In column (3) we present first-difference (FD) estimates. These are our preferred estimates.[4] Note here that the mean of the dependent variable is much smaller than the mean of the dependent variable in columns (1) and (2). This is because we are examining the educational achievement during a two-year period. In addition, achievement gains decline with age so that between ages 9/10 and 11/12, male children are gaining approximately seven points on these achievement tests. Estimates in column (3) provide no consistent evidence that being in either tail of the weight distribution is associated with lower test scores. Almost every estimate in column (3) is statistically insignificant and even the sign pattern of the estimates does not suggest adverse effects. However, the first-difference analysis has less statistical power than the cross-sectional analysis. Consider the standard errors associated with the estimates of the association between obesity and test scores. They are in the range of 0.6–0.7. Therefore, we could not reject effects that are plus or minus 1.2–1.4, which relative to the mean are between 9 and 16 percent. Nonetheless, most effect sizes are well below one (<10 percent of mean) and as noted, the pattern of results suggests little evidence of an association between weight status and achievement test scores of male children.

Table 3 presents instrumental variables estimates for male children. In this analysis, we have collapsed weight categories to reduce the number of endogenous variables. We use three categories based on the NHANES I weight distribution: low-weight (0–15 percentiles), normal weight (16–94 percentiles) and obese (95–100 percentiles). Normal weight is the reference category. Instruments for these two endogenous weight categories are the five weight categories used in previous analyses lagged four years, which in our data is period $t-2$ because children are surveyed every two years. The partial correlations between these instruments and the two endogenous weight categories are quite strong and tests of the joint significance of the excluded instruments are all significant at the 0.01 level with partial F-statistics of 100 or more. Due to the four-year lag of the instruments, we limit the sample to children between the ages of 9 and 12. Because we have changed our weight categories slightly, we present both first-difference (FD) estimates, which should be and are comparable to those in Table 3, and instrumental variables, first-difference (FDIV) estimates.

FDIV estimates in Table 3 are imprecisely estimated. The magnitude of the standard errors of the estimates implies that will not be able to detect reliably effect sizes of less than 30–40 percent (relative to the mean). With this caveat in mind, we note that none of the FDIV estimates in Table 3 are statistically significant. Moreover, the pattern of the estimates in terms of both signs and magnitudes does not suggest a systematic effect. Thus, while we cannot reject the possibility that low- or high-weight is significantly associated with achievement test scores, we can reject that these associations are large.

We now turn to estimates for the female sample, which are presented in Table 4. Table 4 has same structure as Table 2. Estimates in this table tell a lead to similar conclusions as in the case of male children. While cross-sectional estimates suggest that children in the highest and lowest weight may have lower test scores, first-difference estimates reject this conclusion. Estimates in column (3) are rarely statistically significant and almost always small—well below one and less than 5 percent of the mean. In two of three instances in which estimates are statistically significant, they are counterintuitive; overweight children have significantly higher tests scores than normal weight children.

FDIV estimates are presented in Table 5. While imprecisely estimated, these estimates are consistent with the

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[3] We re-estimated all models in Table 2 using a common sample of children with non-missing values. Results were virtually unchanged from those reported.

[4] We also estimated value-added models in which lagged achievement enters model on right hand side. Results form these models were very similar to those presented.

FD estimates and do not suggest a systematic relationship between weight and achievement test scores. In sum, estimates in Tables 4 and 5 provide little evidence of an association between weight and female children's achievement test scores.

To this point, we have found little evidence of an association between weight and children's achievement test scores. One explanation of this may be that we have controlled for grade in school. If weight is associated with grade repetition and grade in school affects achievement, we may have obscured the effect of weight by controlling for grade in school. To investigate this possibility, we obtained estimates of the effect of weight on grade attainment. Models used for this analysis are the same as those used previously. Estimates (not presented) provide no evidence that weight status is associated with grade attainment (grade retention). For male children, none of the FD estimates are statistically significant or large (>5 percent relative to the mean). For female children, this is also the case except for children in the lowest weight categories. For this group, low-weight is associated with a 5 percent decrease in the probability of advancing a grade per year of age for girls ages 9–10 and a 5 percent higher probability of advancing a grade per year of age for girls 11–12.

8. Conclusion

The rapid growth in child obesity in the last 30 years has caused alarm and focused public health policy on fighting the obesity epidemic. Much of the evidence to support public intervention centers on the health consequences of child obesity. However, obesity may affect other aspects of child well-being that will also have significant and long lasting consequences. One such outcome is educational achievement. Despite the importance of educational achievement to future well-being and the existence of plausible mechanisms through which weight could affect educational achievement, there is very little study of this issue. In fact, there are only two other studies that looked at the association between weight and educational achievement of children (Averett & Stifel, 2007; Datar & Sturm, 2006). Thus, the purpose of this paper was to investigate the association between weight and children's educational achievement, as measured by PIAT achievement test scores and grade attainment.

Our results suggest that, in general, children who are overweight or obese have achievement test scores that are about the same as children with average weight. These results differ from Datar and Sturm (2006) and Averett and Stifel (2007), but are consistent with results reported in Edwards and Grossman (1979). The differences between our results and those of Datar and Sturm (2006) and Averett and Stifel (2007) are somewhat surprising because all three analyses used data that showed similar differences in achievement between children in different weight categories. For example, all three papers showed that obese children have test scores that are approximately 10–20 percent of a standard deviation lower than normal weight children. Datar and Sturm (2006) found that becoming overweight was associated with lower educational achievement of female children as they move from kindergarten to the third grade. Averett and Stifel (2007) also reported that overweight children had lower test scores. A variety of factors may explain the differences, but we believe an important one is the failure to specify and estimate a theoretically consistent empirical model. Results not shown (see footnote 2) demonstrated that covariates have age-specific effects and that time-invariant variables belong in the first-difference model. However, both Datar and Sturm (2006) and Averett and Stifel (2007) used a specification that was inconsistent with these results.

These results also differ from most studies of adolescents who found that overweight and obese status was associated with worse school performance, particularly for girls (Falkner et al., 2001; Sabia, 2007; Sigfusdotirr et al., 2006). One potential explanation of this difference is that size discrimination becomes worse as children age and therefore the consequences of such bias may not manifest until older ages. While the different ages of the samples may be part of the explanation, part of the explanation for the different findings is likely due to model specification. Studies of the relationship between weight and educational achievement of adolescents used empirical specifications that were not consistent with common theoretical formulations of the education (human capital) production function (Todd & Wolpin, 2003, 2007).

Our results also challenge claims (e.g., National Education Association, 1994) of size discrimination that cause of poor educational outcomes of obese children. Simple correlations between weight status and test scores did reveal a significant deficit for obese children, particularly girls. However, after controlling for observed characteristics of the child and mother, there were no significant associations between weight status and achievement. This was true even if we used the contemporaneous weight distribution to classify children into weight categories, which may be appropriate if discrimination is based on relative weight. Therefore, our results, at least for young children, are inconsistent with discrimination by teachers and peers that adversely affect achievement. They are also inconsistent with explanations that link obesity to educational achievement through health (Geier et al., 2007). To explore this issue explicitly, we re-estimated the models of Tables 2 and 4, but included measures of depression and peer conflict. While these variables were often significantly and negatively related to test scores, the addition of these variables had minor effects on estimates of the association between weight and tests scores.

It closing, we note that there are only a handful of studies of the relationship between weight and educational achievement. Further study is clearly warranted given the potential importance of the issue and the inconsistency of extant empirical evidence. In addition, while we have tried to advance the literature, there are several limitations of our study that we acknowledge. First, our data contain very little information on inputs actually used to produce educational achievement. School inputs are missing completely, and family inputs are only crudely measured, for example, by the number of hours and weeks worked by the mother (proxy for time of mother). Second, while the first-difference approach is valuable, it does not address the problem of omitted time-varying factors and our solution to this problem, instrumental variables, was not as efficacious as we had hoped it would be. In addition, the first-difference approach can also exacerbate measurement error problems. Finally, the sample sizes were relatively small and in some analyses we lacked the statistical power to detect small effects. In the case of instrumental variables, we lacked the statistical power to detect relatively large effects.

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