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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. 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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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. The National Education Association (NEA) commissioned a study of the issue that concluded as follows:

> "For fat students, the school experience is one of ongoing prejudice, unnoticed discrimination, and almost constant harassment. From nursery school through college, fat students experience ostracism, discouragement, and sometimes violence. Often ridiculed by their peers and discouraged by even well-meaning education employees, fat students develop low self-esteem and have limited horizons. They are deprived of places on honor rolls, sports teams, and cheerleading squads and are denied letters of recommendation." (National Education Association, 1994)

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.

The purpose of this paper is to provide evidence of the association between overweight and obesity, and children's educational achievement, as measured by scores on achievement tests and grade attainment. 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 covers 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.

Previous Literature

There are relatively few studies of the effects of obesity on educational achievement.[1] Tara 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 to 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 Sigfusdotir et al. (2006) note in their recent paper, well-designed empirical studies of the relationship between obesity and academic achievement are scarce.

[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., Edwards and Grossman 1979; Shakotko et al. 1981; Blau and Grossberg 1992; and Korenman, Miller and Sjaastad 1994; Rosenzweig and Wolpin 1994; Kaestner and Corman 1995). However, all but Shakotko et al. (1981) and Edwards and Grossman (1979) focused on underweight as a measure of health.

Studies of adolescents often find negative associations between obesity and educational achievement.[2] For example, Falkner et al. (2001) studied this issue using a sample of 10th, 11th, and 12th grade students in Connecticut. Results from multivariate regression analyses indicated that obese girls were 1.51 times more likely to be held back a grade than normal weight girls. A similar association was not found for boys. Sabia (2007) studied a geographically broader sample of adolescents aged 14 to 17 drawn from the National Longitudinal Survey of Adolescent Health, and he used a variety of statistical methods (e.g., fixed effects and instrumental variables) to account for potential confounding from omitted variables. In general, he found that obesity was negatively correlated with grade point average (GPA), although the most robust and consistent evidence of this association was limited to white, female adolescents. For this group, the GPA of obese girls was approximately 10 percent lower than that of normal weight girls. Finally, Sigfusdotir et al. (2006) found that among Icelandic youth aged 14 to 15, a high Body Mass Index (1 or 2 standard deviations above mean) was associated with lower grades after adjusting for personal and family characteristics. While not an exhaustive review, these studies are the largest and most sophisticated and their findings suggest that obesity is associated with lower educational achievement of adolescents.[3]

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.[4] Edwards and Grossman (1979) used data on children aged 6 to 11 from the Cycle II of the National Health Examination Survey, conducted between 1963 and 1965. They found that overweight kids had lower scores on the Wechsler Intelligence Scale for Children (WISC) and the Wide Range Achievement Test

[2] Shakotko, Edwards, and Grossman (1981) investigated the effect of being overweight in childhood (ages 6-11) on scores from the Wechsler Intelligence Scale for Children (WISC) and the Wide Range Achievement Test (WRAT) in adolescence (ages 12-17) using children who were examined in two consecutive National Health Examination Surveys (II and III). Estimates were obtained in the context of a Granger-causality model. Coefficients of overweight were positive, but not significant.

[3] Canning and Mayer (1967) compared obese and non-obese high school student in suburban Boston and found no difference in test (SAT) scores or educational aspirations. Gortmaker et al. (1993) studied adolescents and young adults from the 1979 cohort of the National Longitudinal Survey of Youth and found that girls between the ages of 16 and 23 who were overweight had 0.3 years less education than normal weight girls eight years later.

[4] Geier et al. (2007) investigated the relationship between weight and school absences. Among a sample of elementary school student in Philadelphia, obese students missed more school than non-obese students.

(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. The sample used in this study consisted of approximately 7,000 children from 1,000 Kindergarten classes in the US who were part of the Early Childhood Longitudinal Study (ECLS). Datar and Sturm (2006) used multivariate regression methods to obtain estimates of the association between changes in overweight status and achievement and included controls for baseline achievement, child, family and school characteristics. Results indicated that girls who became overweight had lower math and reading scores than girls who were never overweight. The largest effect was for reading; becoming overweight decreased reading scores by 12 to 14 percent of a standard deviation. 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, the children of the National Longitudinal Survey of Youth (1979 cohort), and studied children of similar ages (6 to 13). They used a variety of statistical methods (e.g., fixed effects and instrumental variables) to control for unmeasured factors and 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. Most estimates are relatively small in magnitude (approximately 10 percent of a standard deviation).[5]

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

[5] Averett and Stifel (2007) also reported instrumental variables estimates, but these are imprecisely estimated and implausibly large.

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. While still statistically significant, the large reported decrease in estimates when just a few covariates are included suggest a significant amount of selection (omitted variables) and make it difficult to draw any conclusions from the Falkner et al. (2001) study. Results reported by Sabia (2007) also indicate a significant amount of selection and potential bias from omitted variables.[6]

Only three studies have addressed the omitted variable problem directly: Datar and Sturm (2006), Sabia (2007) and Averett and Steifel (2007). All three used longitudinal data to control for unmeasured, time-invariant child and family characteristics, and Sabia (2007) and Averett and Stifel (2007) also used an instrumental variables approach. The limited amount of research that accounts for the influence of unobserved factors suggests the need for additional research and specifically, research that addresses this issue.

A third reason more research is needed is the theoretical models of the effect of obesity on children's educational achievement are complex and mapping such models into an appropriate empirical specification is difficult (Todd and Wolpin 2003, 2007). Several issues arise. To begin, how should weight and obesity be measured? To answer this question requires specification of the causal pathways through which weight and obesity affect achievement. Consider discrimination. Does size (weight) discrimination exhibit a dose-response relationship, or is it more apparent above a specific relative or absolute weight? Similarly, do the physiological consequences of obesity that may adversely affect achievement begin at a specific threshold? Is that threshold the 95th percentile (i.e., standard definition of obesity) of the contemporaneous or historical weight distribution? The ambiguity as to how to measure

[6] Sabia used adolescent reports of parental obesity as an instrument for weight. The theoretical validity of this instrument is suspect, as genetic factors and family resources are likely to be correlated with parental weight and these factors will affect adolescent achievement.

weight is illustrated by differences between studies of the effect of obesity on health, which mostly use measures of obesity based on an historical (1970s) weight distribution, and studies of the effect of obesity on educational achievement, which use measures of obesity (overweight) based on the contemporaneous weight distribution.

Yet another empirical issue is how to account for the likelihood that current educational achievement is a function of a lifetime of influences (Todd and Wolpin 2003, 2007). How do researchers control for these past influences? How does current weight and obesity fit into such a model? Past research has not paid much attention to these issues and has proceeded in an ad hoc basis. For example, Datar and Sturm (2006) use a model that makes third grade achievement scores dependent on baseline (Kindergarten) achievement, changes in obesity, and characteristics measured primarily at the time of third grade, although for some covariates both baseline and third grade values are included. There is no justification given for this specification. Perhaps because of the absence of a well conceived specification, some results are counter intuitive and raise questions as to the validity of other findings. For example, child age in third grade is negatively associated with math scores and positively associated with reading scores. Similarly, birth weight is positively associated with test scores for girls and negatively associated with test scores of boys. While there are many potential specifications consistent with models of cognitive achievement, more research is needed that acknowledges these issues and which provides a more defensible model specification and research design.

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 to 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.

Causal Pathways

To motivate our empirical analysis of the relationship between weight and children's educational achievement, we rely on standard economic theories of the household and child quality (Becker 1965; Becker and 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 particular 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 consumption—and outputs—the quantity of consumption. For example, an admittedly ad-hoc production function for child educational achievement may be specified as follows:

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

Equation (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.

Equation (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, equation (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. This specification was chosen to facilitate estimation, which we discuss in more detail below including ways to test the restrictions embodied in equation (1).

All goods produced by the household have a production function analogous to equation (1) and household resources are allocated to the production of different household goods so as to maximize household well being within some framework of bargaining among household members. In general, the determinants of the quantity of resources allocated to the production of any particular household good, and therefore the quantity of any good produced, are the following (in all periods from birth to age t):

- prices of market inputs (e.g., *TEACH, PEER,* and *Z*);
- wages (price of time) of household members;
- health and educational endowments of each family member;
- productivity of family members in the production of household goods;
- preferences of family members;
- and endowed wealth. [7]

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 (Ritts et al. 1992; NEA 1994; Neumark-Sztainer et al. 1998; Jalongo 1999; Solovay 200; Puhl and Brownell 2003; Schwartz and Puhl 2003; Eisenberg et al. 2003; Janssen et al. 2004). In terms of equation (1), size discrimination (weight) would affect the quantity and quality of school and teacher

[7] The determinants of the bargaining power of various household members may be added to the list.

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 and Latner 2007).

Discrimination against overweight and obese children may also lead to depression (health in equation 1) that can adversely affect educational achievement (Wurtman 1993; Smith et al. 1998; Hoebel et al. 1999; Goodman and Whitaker 2002). However, the causal relationship between obesity and depression is unresolved and some have argued that depression causes obesity, for example, because of affective disorders such as binge eating. Others argue that there is a common genetic component linking depression and obesity (Mustillo et al. 2003; Bjontorp and Rosmond 2000; Rosmond et al. 2001). 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 (Gozal 1998; Dietz 1998; Must and Strauss 1999; Redline et al. 1999; Mutius et al. 2001; Gilliland et al. 2003; Beuther et al. 2006; Geier et al. 2007). In the case of sleeping disorders, the direction of causality is uncertain, as some have argued that inadequate sleep is a cause of obesity (Sekine et al. 2002).

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:

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

Equation (2) is a quasi-reduced form model because we have substituted for the determinants of educational achievement, but weight (*WEIGHT*) remains endogenous.[8] We have used the symbol ~ 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.

Theoretically, families will take the educational consequences of obesity into consideration when allocating resources to the production of various goods, and so one may wonder whether this is an issue for public concern. Presumably, the family will make the best choices given their constraints (e.g., wealth) and thus the weight (health) and educational achievement of the children from this family are optimal—what the family prefers. In this case, while it may be of interest to understand how families allocate resources to produce child outcomes, a specific focus on obesity and educational achievement may not be particularly important.

However, as mentioned earlier, obesity may be a problem from a social point of view because of government policies that affect (distort) prices, which in turn affect household resource allocation. For example, farm subsidies may lower the price of high-caloric foods and transportation policy may raise the price of physical activity (e.g., walking). These will tend to increase obesity, all else equal, and potentially reduce educational achievement. Families will take this into account, but they will have made decisions in part because of government policy that may or may not be warranted. Moreover, given that there is evidence that child obesity persists into adulthood and is strongly associated with some significant health problems, reduced educational achievement of obese children may exacerbate the social cost of health-related obesity problems that stem from imperfections in the health insurance market. Therefore, analyses of the effect of obesity on children's educational achievement are particularly relevant for public policy.

[8] We discuss the source of endogeneity below.

Empirical Implications

The quasi-reduced form production function represented by equation (2) is the basis of our empirical model. The main problem associated with obtaining estimates of an empirical analog to equation (2) is that weight (*WEIGHT*) may be correlated with the error, which includes unmeasured exogenous determinants of the inputs in the production function (equation 1). Further, the data requirements necessary to obtain unbiased estimates of equation (2) are daunting, as the entire lifetime history of the exogenous determinants of production function inputs enter the model.

One approach to address this problem is to use instrumental variables, which theoretically uses variation in child weight that is uncorrelated with unmeasured determinants of child educational achievement. For example, Sabia (2007) and Averett and Stifel (2007) used parental obesity (weight) as an instrument for child obesity (weight). However, parental obesity is likely to be correlated with family resources and educational inputs in all periods from birth to age t, for example, because of size (weight) discrimination in labor markets (see Cawley 2004). Therefore, parental obesity is likely to be correlated with unmeasured educational inputs and is not likely to be a valid instrument. In general, it will be very difficult to identify a valid instrument in the context of equation (2).

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

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

As is made clear by equation (3), the difference in educational achievement between ages t-1 and t depends on the difference in developmental age (γ_t - γ_{t-1}) and resources used between these ages. Notably, endowed intelligence (α_i) is eliminated from the model.[9] However, one consequence of this approach is that estimates of the effects of educational inputs are specific to age t (Todd and Wolpin 2003, 2007).

[9] This is not necessarily the case, as the endowment could have different age-specific effects. If so, there would be a age subscript on the endowment in equation (1) and differencing would not eliminate the endowment effect.

Three aspects of equation (3) merit discussion. The first point relates to the fact that the left hand side of equation (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. Similarly, it is the parental time input between ages t-1 and t that enters and not the change in the parental time input ages t-1 and t. This specification results from the assumption of equation (1) that the effects of educational inputs are cumulative. Consider child weight and the hypothesis that there is size (weight) discrimination. 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 and Wolpin 2003). For example, Averett and Stifel (2007) and Sabia (2007) used fixed effects methods that regress differences in educational achievement (e.g., test scores) on differences in children's weight, which is incorrect given the specification of equation (1).[10] Similar problems are present in Datar and Sturm (2006).

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 equation (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.

[10] There may be a measurement error problem given the nature of most available data. In our case, weight is measured at time t-2 and t and may not be constant during the period. Possible solutions include using the average of time t-2 and t weights, which is our approach. Using the difference in weight between periods, however, is not justified.

The age-specific estimates of equation (3) merit further discussion. 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 the growth in educational achievement between time t-1 and t. Obesity (and other inputs) may have a different effect at each age. Indeed, it would be surprising if that was not the case as cognitive development slows over time (see Table 1). Changes in achievement test scores between ages 7/8 and 9/10 are larger than changes in achievement test scores between ages 9/10 and 11/12. While this may reflect a decrease in the amount of educational inputs with age, it more likely reflects a declining marginal productivity (effects) of inputs, which is consistent with an age specific effect specified in equation (1). However, there may be other causes of age-specificity of effects. For example, discrimination associated with obesity may be more important at older than young ages.

While equation (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 equation (3) suggests many potential instruments. Specifically, inputs in periods prior to t-1 may be used as instruments because only time t inputs are included in equation (3) (Todd and Wolpin 2003). The assumption underlying this approach is that the future does not cause the past and therefore, for example, weight in period t-2 will be uncorrelated with the error $(u_{it} - u_{i(t-1)})$ in equation (3). Therefore, weight in period 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 (Serdula et al. 1993; Lake et al. 1997; McTigue et al. 2002; Whitaker et al. 1998).[11]

The fact that past period inputs, or their determinants, do not enter equation (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 lagged family income in some versions of equation (3). In all cases, lagged income was not significantly related to achievement, which provides evidence to support the specification of equation (3). We chose income to implement the test because it is likely to be correlated with the level of inputs used in that period.

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 7 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 assessed in several ways. We focus on the Peabody Individual Achievement Test (PIATs) for math, reading recognition and reading comprehension. The validity and reliability of these assessments are well documented (Center for Human Resources 2006). The PIAT math test measures a child's attainment in mathematics as taught in mainstream education. The PIAT reading recognition test measures word recognition and pronunciation ability. The PIAT reading comprehension test measures a child's ability to derive meaning from sentences that are read silently, and is given to children with a specified minimum score (19) on the PIAT reading recognition test. Notably, all children age five and over take the same PIAT test, but begin the test at different points

[11] Note that while we used lagged weight as an instrument, we do so in the context of a first difference model. Sabia (2007) and Averett and Stifel (2007) used lagged weight without taking differences.

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 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).[12] We use the following percentile categories for the first measure: 0-5, 6-15, 16-84, 85-94, 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 weight distribution of children in the NHANES I and this fact reflects the widely reported growth in obesity of children. Approximately 30 percent of the NLSY children are considered overweight on the basis of the NHANES I standard, and between 15 to 20 percent of the NLSY children are in the top two NHANES I categories. As discussed earlier, it is unclear how weight may affect educational achievement. For example, discrimination may be based on relative weight and therefore use of the NAHNES I standard may be inappropriate. To address this issue, we also classified children based on the contemporaneous weight distribution. Specifically we used the following percentile categories: 0-10, 11-30, 31-50, 51-70, 71-90, 91-100. Results using these alternative categories were similar to those reported below and are not presented, but are available form the authors.

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, birth weight. For

[12] Published data on the weight distribution of children age 5 from the NHANES I was not available so we use the cutoffs for children age 6.

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).

It is clear by the description of the data that we are missing information on most inputs that are likely to enter the child educational production function. As is common in the literature, we use variables that proxy for these 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 ten 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. Descriptive information about the sample is provided in Tables 1 and 2.

Results

Descriptive Analysis

Table 1 presents (unweighted) 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 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 nine 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 (two to five percent) lower than girls nine and over who are normal (15 to 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 to 5 percentiles) tail of the weight distribution have achievement test scores that are approximately four to six percent 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 to 12 that we observe a significant difference in test scores between obese girls and normal weight girls.

Table 2 presents (unweighted) sample means of child and mother characteristics by weight for females.[13] The purpose of this table is to investigate whether there are significant differences in child and mother characteristics by weight that may confound the relationship between weight and test scores observed in Table 1. Figures in Table 2 show some systematic differences. 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 to 5 percentiles) of the weight distribution and children in the middle of the weight distribution. The most consistent difference found in Table 2 relates to mother's BMI, which is positively and significantly correlated with child's BMI. In sum, figures in Table 2 provide 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.

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 equations (1) and (2). We refer to estimates from models based on equation (1) as cross-sectional

[13] An analogous table for males provides similar evidence of some selection on observed characteristics.

estimates. We obtain estimates for two specifications of this model: 1) a basic specification that includes only child characteristics; and 2) 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 equation (2) 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 3 presents the 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). 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 3 provide little evidence that weight is significantly related to male children's achievement test scores. If anything, very-low weight male children may have slightly lower (2-3 percent) math and reading comprehension scores than normal weight male children.

In column (3) we present the first-difference (FD) estimates. These are our preferred estimates. 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 to 0.7. Therefore, we could not reject effects that are plus or minus 1.2 to 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 4 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 to 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 4 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 to 40 percent (relative to the mean). With this caveat in mind, we note that none of the FDIV estimates in Table 4 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 theses associations are large.

We now turn to estimates for the female sample, which are presented in Table 5. Table 5 has same structure as Table 3. 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 five 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 6. While imprecisely estimated, these estimates are consistent with the FD estimates and do not suggest a systematic relationship between weight and achievement test scores. In sum, estimates in Tables 5 and 6 provide little evidence of an association between weight and female children's achievement test scores.

Throughout the paper, we have emphasized the importance of model specification. In particular, that the effects of covariates are age-specific, that covariates should be measured in levels and not changes, and that time-invariant covariates enter the model because of the age-specific nature of the effects. To illustrate the importance of these issues, we present estimates of the effect of mother's education and child's race on achievement test scores. We measure mother's education as whether a mother has a Bachelors or Professional degree (relative to less than a high school degree) and we measure child's race by whether the child is non-Hispanic, black (relative to non-Hispanic white). Estimates are presented in Table 7. For females, the magnitude of the associations between being black and math test scores declines (less negative) with age of child and increases with age of child in the case of reading comprehension test scores. A similar pattern of age-specific effects is found for the associations between mother's education and math and reading comprehension test scores for female children. Among male children, the age-pattern of effects is less clear, but estimates of the effects of child's race and mother's education differ by age. In short, estimates in Table 7 clearly show the age-specific nature of the associations between child and mother characteristics and test scores, and underscore the importance of model specification that we have emphasized.

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. So we obtained estimates of the effect of weight on grade attainment. Models used for this analysis are the same as those used previously. Table 8 presents the estimates of the effect of weight status on grade attainment. Estimates in Table 8 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 five percent decrease in the probability of advancing a grade per year of age for girls ages 9 to 10 and a five percent higher probability of advancing a grade per year of age for girls 11 to 12.

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. Indeed, it is widely believed that overweight and obese children face significant peer and teacher discrimination that could adversely affect educational outcomes (NEA 1994). In addition, contemporaneous health consequences of obesity such as elevated risk of asthma, sleeping disorders and depression may adversely affect 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 (Datar and Sturm 2006; Averett and Stifel 2007). 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. Data for the study came from the children of the NLSY, which represents a large, national sample of children between the ages of 5 and 12. We obtained estimates of the association between weight and achievement using several regression model specifications that controlled for a variety of observed factors and time-invariant characteristics of children.

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). 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. We demonstrated that covariates have age-specific effects (see Table 7), so combining children of different ages and restricting effects to be the same across ages, as in Averett and Stifel (2007), is inappropriate. Also, dropping time-invariant covariates is not justified (again see Table 7). Further, Averett and Stifel (12007) control for time-invariant factors using a conventional fixed-effects analysis that is inconsistent with the human capital production function that specifies that growth in achievement depends on the level of inputs used during the interval for which growth is measured. Similarly, the model used by Datar and Sturm (2006) is not consistent with the human capital production function described here, and more importantly does not seem to have been derived from a clearly specified behavioral model.

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. 1991; 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. Sabia (2007) used conventional fixed effects methods that are not consistent with the standard human capital production function. In addition, the instrumental variables procedure that Sabia (2007) used is unlikely to be valid.

Our results also challenge the conclusions of the National Education Association that cited discriminatory practices as a 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 affects achievement. They are also inconsistent with explanations that link obesity to educational achievement through health (Geier et al. 2007).

It closing, we note that there are only a handful of studies of the issue. Further study is clearly warranted given the potential importance of the issue and the inconsistency of 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 efficacious. 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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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*	31.4	31.1	31.8	29.7*
PIAT-Reading Recognition	31.9	32.2	32.8	33.8	32.1
PIAT-Reading Comprehension	29.1*	29.9	30.7	30.9	30.0
Num. of Obs. (Column %)	184 (7)	149 (6)	1418 (56)	393 (15)	407 (16)
Age 9-10					
PIAT-Math	40.5*	42.7	43.5	44.7*	43.3
PIAT-Reading Recognition	42.5*	43.7	44.4	45.7	44.9
PIAT-Reading Comprehension	39.3	38.9*	40.8	41.8	41.2
Num. of Obs. (Column %)	199 (8)	174 (7)	1430 (54)	417 (16)	410 (16)
Ages 11-12					
PIAT-Math	48.0*	50.1	50.7	51.7	50.1
PIAT-Reading Recognition	50.5*	52.8	53.2	53.9	53.0
PIAT-Reading Comprehension	45.4*	47.7	48.1	48.8	48.2
Num. of Obs. (Column %)	141 (6)	132 (5)	1308 (54)	442 (18)	398 (16)

Notes: 1. * indicates that estimate is statistically different (0.05 level) from estimate for children in 15-85 percentiles. 2. Number of observations refers to the number of valid scores on PIAT-Math.

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*	31.8	31.4	31.1	30.6
PIAT-Reading Recognition	33.6	35.6	35.0	35.5	33.6*
PIAT-Reading Comprehension	31.5	33.4	32.6	32.8	31.6*
Num. of Obs. (Column %)	198 (8)	192 (8)	1236 (49)	397 (16)	477 (19)
Age 9-10					
PIAT-Math	41.0*	42.5	43.7	43.9	42.6*
PIAT-Reading Recognition	44.9*	47.1	47.3	47.0	45.0*
PIAT-Reading Comprehension	41.0*	42.0	42.9	43.1	41.2*
Num. of Obs. (Column %)	210 (8)	209 (8)	1304 (49)	474 (18)	451 (17)
Ages 11-12					
PIAT-Math	48.5*	47.8*	50.7	50.0	49.3*
PIAT-Reading Recognition	53.4*	54.9	56.0	55.7	54.3*
PIAT-Reading Comprehension	48.2	48.7	49.2	48.8	46.7*
Num. of Obs. (Column %)	119 (5)	112 (5)	1378 (57)	465 (19)	344 (14)

Notes: 1. * indicates that estimate is statistically different (0.05 level) from estimate for children in 15-85 percentiles. 2. Number of observations refers to the number of valid scores on PIAT-Math.

Table 2
Individual and Family Characteristics 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					
Black	0.28	0.27	0.26	0.30	0.42*
Hispanic	0.21	0.18	0.18	0.21	0.20
Age in Months	95.2	96.5	95.9	96.4	96.1
Mom Age	33.6	33.0	33.3	33.7	34.1*
Mom AFQT	35.7	37.3	39.4	37.1	30.6*
Mom LTHS	0.17	0.14	0.15	0.11*	0.14*
Mom BA	0.12*	0.16	0.18	0.15	0.12*
Mom Married	0.62	0.71	0.67	0.65	0.57*
Mom BMI	24.7*	24.6*	25.5	27.0*	29.3*
Ages 9-10					
Black	0.31	0.28	0.28	0.32	0.45*
Hispanic	0.25*	0.19	0.19	0.19	0.21
Age in Months	117.8*	118.5	119.6	120.3*	119.4
Mom Age	33.8	34.0	34.2	34.8*	34.5
Mom AFQT	34.6	35.7	37.6	35.4	27.8*
Mom LTHS	0.16	0.19	0.15	0.12	0.19*
Mom BA	0.13	0.11*	0.16	0.15	0.09*
Mom Married	0.63	0.63	0.65	0.62	0.56*
Mom BMI	25.2	24.8*	25.8	28.0*	30.6*
Ages 11-12					
Black	0.27	0.26	0.31	0.33	0.47*
Hispanic	0.18	0.20	0.18	0.21	0.21
Age in Months	142.4	140.9*	143.3	143.9	143.4
Mom Age	34.8	34.9	35.5	35.7	35.6
Mom AFQT	35.5	35.9	36.4	33.4*	26.3*
Mom LTHS	0.20	0.21	0.17	0.14	0.22*
Mom BA	0.08*	0.11	0.15	0.12	0.08*
Mom Married	0.56	0.69	0.62	0.59	0.53*
Mom BMI	25.1*	25.3	26.2	28.7*	31.0*

Notes:
1. * indicates that estimate is statistically different from estimate for children in 15-85 percentiles.

Table 3
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*	-0.95	0.03	-0.04	-0.21	-0.16	-0.69	-0.79	-1.15
	(0.71)	(0.68)	(0.78)	(0.75)	(0.73)	(0.78)	(0.72)	(0.71)	(0.84)
BMI 5-15%	0.44	0.32	-0.57	-0.29	-0.66	-0.63	-0.28	-0.51	-0.22
	(0.76)	(0.73)	(0.91)	(0.81)	(0.78)	(0.92)	(0.78)	(0.76)	(1.00)
BMI 85-95%	0.02	-0.08	0.54	0.15	0.07	0.08	-0.51	-0.61	-0.83
	(0.51)	(0.50)	(0.71)	(0.54)	(0.54)	(0.72)	(0.52)	(0.52)	(0.78)
BMI 95-100%	-0.83*	-0.03	0.37	-0.43	0.27	-0.28	-0.28	0.39	0.13
	(0.50)	(0.50)	(0.66)	(0.54)	(0.53)	(0.66)	(0.51)	(0.52)	(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 Obs.	2490	2380	2303	2483	2372	2262	2390	2281	2093
Ages 9-10									
BMI 0-5%	-1.94**	-1.62**	-0.41	-1.18	-0.47	1.12	-0.72	-0.19	0.32
	(0.73)	(0.72)	(0.74)	(0.90)	(0.88)	(0.69)	(0.78)	(0.76)	(0.80)
BMI 5-15%	-0.33	-0.07	1.20	-0.24	0.19	0.95	-1.28	-0.84	-1.76*
	(0.77)	(0.76)	(0.86)	(0.95)	(0.93)	(0.80)	(0.83)	(0.80)	(0.93)
BMI 85-95%	0.76	0.97*	0.69	0.58	0.73	0.71	0.62	0.88	0.15
	(0.53)	(0.53)	(0.75)	(0.66)	(0.65)	(0.71)	(0.57)	(0.56)	(0.82)
BMI 95-100%	-0.88*	0.22	-0.30	-0.56	0.71	0.46	-0.12	1.10*	0.64
	(0.54)	(0.55)	(0.69)	(0.67)	(0.68)	(0.65)	(0.58)	(0.58)	(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 Obs.	2578	2452	2371	2572	2445	2352	2542	2419	2215
Ages 11-12									
BMI 0-5%	-0.50	-0.20	0.64	-0.62	-0.86	0.57	-0.92	-0.92	0.47
	(0.85)	(0.84)	(0.78)	(1.17)	(1.16)	(0.75)	(0.99)	(0.98)	(0.84)
BMI 5-15%	-0.25	-0.50	1.48	0.88	0.32	0.77	0.51	0.19	-0.32
	(0.87)	(0.85)	(0.97)	(1.20)	(1.16)	(0.93)	(1.01)	(0.97)	(1.04)
BMI 85-95%	0.44	0.82	-0.38	-0.43	-0.25	0.02	0.04	0.41	-0.76
	(0.53)	(0.52)	(0.69)	(0.73)	(0.71)	(0.66)	(0.61)	(0.60)	(0.74)
BMI 95-100%	-0.84	-0.15	0.40	-0.63	0.16	0.60	0.06	0.85	0.08
	(0.54)	(0.55)	(0.66)	(0.75)	(0.76)	(0.63)	(0.63)	(0.63)	(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 Obs.	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.
3. ** indicates p-value<0.05, * indicates 0.5 < p-value < 0.10

Table 4
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	
Ages 9-10	(1)	(2)	(1)	(2)	(1)	(2)
BMI 0-15%	-0.32	-3.30	0.52	3.53	-0.84	-1.11
	(0.62)	(2.41)	(0.57)	(2.23)	(0.68)	(2.61)
BMI 95-100%	-0.50	-1.84	0.20	2.97	0.65	1.07
	(0.73)	(2.02)	(0.68)	(1.88)	(0.80)	(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 Obs.	2033	2033	2012	2352	1919	2215
Ages 11-12						
BMI 0-15%	1.25	2.55	0.79	-0.00	0.48	2.08
	(0.65)	(1.77)	(0.63)	(1.72)	(0.69)	(1.90)
BMI 95-100%	0.49	-1.51	0.84	1.31	-0.05	0.19
	(0.69)	(1.45)	(0.67)	(1.41)	(0.74)	(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 Obs.	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.
4. ** indicates p-value<0.05, * indicates 0.5 < p-value < 0.10

Table 5
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**	-1.06	-0.58	-0.81	0.01	0.23	-0.62	0.06	0.29
	(0.67)	(0.66)	(0.80)	(0.69)	(0.69)	(0.80)	(0.67)	(0.66)	(0.81)
BMI 5-15%	-0.16	0.05	-0.50	0.14	0.10	-0.05	0.38	0.57	-0.15
	(0.67)	(0.66)	(0.84)	(0.69)	(0.69)	(0.85)	(0.66)	(0.65)	(0.86)
BMI 85-95%	-0.73	-0.51	-0.08	-0.06	0.18	0.38	-0.23	0.04	1.51**
	(0.50)	(0.50)	(0.71)	(0.52)	(0.52)	(0.71)	(0.50)	(0.49)	(0.72)
BMI 95-100%	-0.82*	-0.09	-0.13	-1.71**	-1.01**	-0.77	-0.96**	-0.44	-0.45
	(0.48)	(0.48)	(0.63)	(0.49)	(0.50)	(0.64)	(0.47)	(0.48)	(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 Obs.	2440	2303	2240	2440	2302	2195	2376	2245	2052
Ages 9-10									
BMI 0-5%	-1.42**	-0.94*	0.20	-0.93	-0.18	0.10	-0.54	0.15	-0.05
	(0.64)	(0.62)	(0.69)	(0.79)	(0.77)	(0.63)	(0.70)	(0.67)	(0.73)
BMI 5-15%	-0.35	-0.09	-0.42	0.86	0.81	0.69	0.03	-0.07	-0.27
	(0.63)	(0.62)	(0.80)	(0.78)	(0.77)	(0.73)	(0.69)	(0.68)	(0.85)
BMI 85-95%	-0.50	0.02	-0.73	-1.01*	-0.45	0.52	-0.33	0.18	-0.39
	(0.46)	(0.45)	(0.70)	(0.56)	(0.55)	(0.64)	(0.50)	(0.49)	(0.74)
BMI 95-100%	-0.67	0.41	0.48	-1.45**	-0.02	0.56	-1.14**	0.12	0.40
	(0.47)	(0.48)	(0.65)	(0.58)	(0.59)	(0.59)	(0.52)	(0.52)	(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 Obs.	2599	2447	2373	2599	2449	2369	2582	2432	2286
Ages 11-12									
BMI 0-5%	-1.73**	-1.74**	-0.18	-1.76	-1.58	-0.46	-0.53	-0.37	1.12
	(0.86)	(0.84)	(0.74)	(1.12)	(1.10)	(0.78)	(0.94)	(0.92)	(0.88)
BMI 5-15%	-2.08**	-2.30**	-0.03	0.29	0.80	-0.53	0.29	0.03	-1.50
	(0.88)	(0.88)	(0.91)	(1.16)	(1.16)	(0.96)	(0.97)	(0.97)	(1.08)
BMI 85-95%	-0.30	-0.04	1.05	-0.23	0.19	2.11**	-0.07	0.14	-0.01
	(0.48)	(0.47)	(0.64)	(0.63)	(0.62)	(0.67)	(0.53)	(0.52)	(0.76)
BMI 95-100%	-0.79	-0.07	-0.39	-1.17	-0.22	-0.14	-1.46**	-0.64	-1.83**
	(0.55)	(0.55)	(0.65)	(0.71)	(0.72)	(0.68)	(0.60)	(0.60)	(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 Obs.	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.
3. ** indicates p-value<0.05, * indicates 0.5 < p-value < 0.10

Table 6
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	
Ages 9-10	(1)	(2)	(1)	(2)	(1)	(2)
BMI 0-15%	-0.06	-1.50	0.20	1.05	-0.21	0.80
	(0.56)	(1.71)	(0.51)	(1.54)	(0.60)	(1.81)
BMI 95-100%	0.78	-2.38	0.82	0.92	0.66	0.82
	(0.68)	(1.82)	(0.62)	(1.65)	(0.73)	(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 Obs.	2060	2060	2054	2054	1997	1997
Ages 11-12						
BMI 0-15%	-0.41	0.38	-1.12	-1.33	0.31	2.53
	(0.62)	(1.41)	(0.65)	(1.47)	(0.73)	(1.66)
BMI 95-100%	-0.29	0.33	-0.89	0.17	-2.05**	-1.43
	(0.67)	(1.28)	(0.70)	(1.34)	(0.79)	(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 Obs.	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.
4. ** indicates p-value<0.05, * indicates 0.5 < p-value < 0.10

Table 7
Estimates of the Effect of Child's Race and Mothers Education on Achievement Scores by Age

	PIAT-Math			PIAT-Reading Recognition			PIAT-Reading Comprehension		
Females	Ages 7-8	Ages 9-10	Ages 11-12	Ages 7-8	Ages 9-10	Ages 11-12	Ages 7-8	Ages 9-10	Ages 11-12
Child is Black	-1.88**	-1.14**	-0.91*	-0.19	-0.66	-0.28	-0.26	-0.51	-1.43**
	(0.53)	(0.50)	(0.51)	(0.56)	(0.62)	(0.72)	(0.53)	(0.54)	(0.60)
Mothers Has BA	3.73**	1.21	1.61*	3.47**	2.40**	1.63	1.23	2.73**	2.75**
	(0.86)	(0.81)	(0.90)	(0.89)	(1.01)	(1.18)	(0.85)	(0.89)	(0.99)
Males									
Child is Black	-3.18**	-2.93**	-3.32**	0.08	-0.34	-1.97	-0.61	-0.85	-2.52**
	(0.56)	(0.59)	(0.61)	(0.59)	(0.73)	(0.84)	(0.58)	(0.62)	(0.70)
Mothers Has BA	3.33**	1.22	1.66*	0.10	1.32	1.59	0.80	2.56**	1.67
	(0.85)	(0.90)	(0.95)	(0.91)	(1.11)	(1.31)	(0.88)	(0.95)	(1.10)

Notes:
1. Models based on extended covariate set. See notes to Table 3.
2. Standard errors in parentheses.
3. ** indicates p-value<0.05, * indicates 0.5 < p-value < 0.10

Table 8
Estimates of the Effect of BMI (NHANES I Classification) on Grade in School

	Male Children		Female Children	
	(1)	(2)	(1)	(2)
Ages 9-10				
BMI 0-5%	0.03	0.00	-0.08*	-0.10**
	(0.05)	(0.05)	(0.04)	(0.05)
BMI 5-15%	-0.04	-0.09	-0.09**	0.05
	(0.05)	(0.06)	(0.04)	(0.05)
BMI 85-95%	0.03	-0.05	0.03	0.03
	(0.03)	(0.05)	(0.05)	(0.05)
BMI 95-100%	0.04	-0.02	0.05	0.01
	(0.04)	(0.05)	(0.03)	(0.04)
Ext. Covariate Set	Yes	Yes	Yes	Yes
First Differences	No	Yes	No	Yes
Mean Dep. Var.	3.7	1.94	3.9	1.98
Number of Obs.	2557	2421	2522	2424
Ages 11-12				
BMI 0-5%	-0.14**	-0.01	-0.01	0.09*
	(0.06)	(0.05)	(0.06)	(0.05)
BMI 5-15%	-0.12**	0.00	-0.00	-0.03
	(0.06)	(0.07)	(0.06)	(0.06)
BMI 85-95%	0.11**	0.03	-0.01	0.06
	(0.03)	(0.05)	(0.03)	(0.04)
BMI 95-100%	0.03	0.04	0.02	-0.02
	(0.04)	(0.05)	(0.04)	(0.04)
Ext. Covariate Set	Yes	Yes	Yes	Yes
First Differences	No	Yes	No	Yes
Mean Dep. Var.	5.7	2.0	5.8	1.98
Number of Obs.	2371	2327	2323	2282

Notes:
1. All models include extended covariate set (see notes to Table 3).
2. Standard errors in parentheses.
3. ** indicates p-value<0.05, * indicates 0.5 < p-value < 0.10