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ORIGINAL ARTICLE

Childhood overweight and elementary school outcomes

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Objective: To examine the link between childhood overweight status and elementary school outcomes.

Design: Prospective study design: multivariate regression models examining the association between changes in overweight status and school outcomes between kindergarten entry and end of third grade, after controlling for various child, family and school characteristics.

Subjects: Nationally representative sample of US children who entered kindergarten in 1998, with longitudinal data on body mass index (BMI) and school outcomes at kindergarten entry and end of third grade.

Measurements: Wide range of elementary school outcomes collected in each wave including academic achievement (math and reading standardized test scores); teacher reported internalizing and externalizing behavior problems (BP), social skills (self-control, interpersonal skills) and approaches to learning; school absences; and grade repetition. Measurements of height and weight in each wave were used to compute BMI and indicators of overweight status based on CDC growth charts. A rich set of control variables capturing child, family, and school characteristics.

Results: Moving from not-overweight to overweight between kindergarten entry and end of third grade was significantly associated ($P<0.05$) with reductions in test scores, and teacher ratings of social-behavioral outcomes and approaches to learning among girls. However, this link was mostly absent among boys, with two exceptions – boys who became overweight had significantly *fewer* externalizing BPs ($P<0.05$), but more absences from school compared to boys who remained normal weight. Being always-overweight was associated with more internalizing BP among girls but *fewer* externalizing BPs among boys.

Conclusion: Change in overweight status during the first 4 years in school is a significant risk factor for adverse school outcomes among girls but not boys. Girls who become overweight during the early school years and those who start school being overweight and remain that way may need to be monitored carefully.

Introduction

The dramatic rise in childhood overweight in recent years has sparked numerous research studies that have examined the consequences of overweight at young ages on health and socioeconomic outcomes in adulthood.[1–4] A number of studies have also examined health consequences in childhood and adolescence, in particular, psychological outcomes such as self-esteem and depression.[5–9]

Less is known, however, about how childhood overweight might affect children's school outcomes. As children spend a

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significant amount of time in school daily it is possible that the effects of being overweight are felt in various aspects of school-life, including academic achievement, social skills, and attendance. There are multiple pathways through which this effect might transfer. First, being overweight may lower self-esteem and body image and make it harder for children to concentrate or be attentive in class, thereby preventing them from learning in school. This psychosocial aspect has been emphasized in the literature. In addition, health problems associated with being overweight may increase sick days, leading to missed classes or tardiness, and subsequently affect school performance.

Examining whether childhood overweight is related to school performance has been difficult previously owing to the lack of suitable data. Few representative data sets exist that have measures for both obesity and a wide range of school outcomes, particularly academic achievement.

Moreover, longitudinal data that contain these measures are even rarer, leading researchers to rely primarily on cross-sectional data. However, cross-sectional associations may be confounded by unobserved differences between overweight and not-overweight children which are also related to their school outcomes.

Only a very recent survey, the Early Childhood Longitudinal Study (ECLS-K), collected data on overweight and school outcomes for a nationally representative sample of children entering kindergarten which are being followed over time. Initial analyses of these data were limited because they only covered the first 2 years in school.[10–11] It showed that cross-sectionally, overweight status at kindergarten entry was associated with significantly lower test scores and more behavior problems at kindergarten entry (baseline), but not with either test score gains or onset of new behavior problem in the first 2 years of school. These analyses were limited for a number of reasons. First, these results were based on cross-sectional variation in overweight status and may be confounded by unobserved differences between overweight and not-overweight children. Second, the relatively short duration (2 years) over which children were observed in the study makes the detection of substantively important changes in overweight status unlikely owing to limited statistical power. Finally, children in kindergarten and first grade may be too young to develop any significant behavioral effects of overweight that may emerge as children get older. The availability of more waves of the ECLS-K data allows us to address each of the above limitations of prior work.

With the release of the latest wave of ECLS-K data, we can now analyze the association between overweight and school outcomes over 4 years, from the beginning of kindergarten through the end of third grade. We examine the relationship between childhood overweight and a wider range of school outcomes such as children's test scores, behavior problems, social skills, approaches to learning, school attendance and grade repetition. The availability of multiple waves also permits methodological improvements. In particular, we can relate *changes* in overweight status over time to *changes* in school outcomes, which eliminates the influence of unobserved confounders that are fixed over time and bias cross-sectional estimates.

Methods

Sample

We analyze data from the Early Childhood Longitudinal Study – Kindergarten Class (ECLS-K). The ECLS-K is a longitudinal study of a nationally representative cohort of kindergartners in the 1998–1999 school year, spanning about 1000 kindergarten programs in the US. The study was sponsored by the National Center for Education Statistics and is designed to collect detailed information on young children's cognitive, health and developmental outcomes in the early school years along with rich contextual data regarding their family, teachers and school. Starting with baseline data in fall of kindergarten, this sample will be followed-up through grade 5, with data collection on the full sample in the spring of kindergarten and grades 1, 3 and 5. At this point, data from kindergarten, first and third grades are available. Our sample includes around 7000 first-time kindergarteners with information on height, weight, and school outcomes in kindergarten and third grade. The exact sample size varies across different outcomes owing to differential missing data on the outcomes.

Measures

The key variables in this study are child overweight status and school outcomes, including academic achievement, teacher-reported social and behavioral outcomes, teacher-reported approaches to learning, school attendance, and grade repetition. The ECLS-K collected information on each of these variables in each wave of the study. These measures are described below.

Overweight status. The ECLS-K study measured children's height and weight at each data collection point. The height and weight measurements were recorded by the assessor using the Shorr Board (accuracy = 0.01 cm) and a Seca digital bathroom scale (model 840; accuracy = 0.1 kg), respectively. All children were measured twice in order to minimize measurement error. If the two height values from the instrument were less than 5.1 cm apart, the average of the two height values was computed and used as the composite measure of height. Otherwise, the value that was closest to the average (for kindergarten measures) or median (for third grade measures) height for that grade was used as the composite. For the weight composite, if the two weight values from the instrument were less than 2.27 kg apart, the average of the two values was computed. Otherwise, the value that was closest to the average (for kindergarten measures) or median (for first and third grade measures) weight for that grade was used as the composite. The two measurements for height at the end of third grade were less than 1 cm apart for 96.5% of our sample. The two weight measurements were less than 0.2 kg apart for 97.5% of our sample.

A composite BMI was calculated using the composite height and weight values and was multiplied by the appropriate factor to convert into $kg\,m^{-2}$. We use the body mass index (BMI), measured as weight in kg divided by the square of height in m^2, to classify children into overweight and not-overweight categories in each wave. Children who had a BMI greater than or equal to the 95th percentile for their age and gender were classified as overweight.[12]

Academic achievement. Children surveyed in the ECLS-K were given individually administered math and reading

assessments at each data collection point. In each subject area, assessments consisted of a two-stage assessment. In the first stage, children received a 12–20 item routing test. Performance on the routing items guided the selection of one of the several alternative second-stage tests. The second-stage test contained items of appropriate difficulty for the level of ability indicated by the routing test. As all children did not take exactly the same test, item response theory (IRT) scale scores were computed for all children. IRT scores represent estimates of the number of items students would have answered correctly if they had taken all of the 92 questions in the first- and second-stage reading forms and the 64 questions in all of the mathematics forms. These scores are comparable across students within a wave and also across waves enabling comparison of children's performance over time. The reliability of test scores was very high – 0.93 for reading and 0.92 for math. NCES (1999)[13] provides more detailed information about the tests administered. We use raw IRT scale scores in reading and mathematics at kindergarten entry and spring of third grade to measure children's academic achievement.

Teacher-reported behavior problems. The ECLS-K includes two behavior problem scales based on the teacher-reported social rating scale (SRS). The SRS scale is adapted from the social skills rating system (SSRS) Instrument developed by Gresham and Elliot,[14] which is a well-established and useful tool in assessing and targeting social skills deficits and competing problem behaviors. The teacher SRS is a self-administered questionnaire consisting of two scales – externalizing and internalizing behavior problems. The externalizing scale includes information on acting out behaviors of children and is based on five items that rate the frequency with which a child argues, fights, gets angry, acts impulsively and disturbs ongoing activities. The internalizing behavior problem scale consists of four items that ask about the apparent presence of anxiety, loneliness, low self-esteem, and sadness in the child. Teachers used a response scale to report how often the child demonstrated the behavior described – 1 (never), 2 (occasionally or sometimes), 3 (regularly but not all the time), and 4 (most of the time). The scores on both scales are the mean rating on the items included in the scale. Both scales have very high reliability; the split half reliabilities for the teacher SRS scales in fall of kindergarten are 0.90 for externalizing problems and 0.80 for internalizing problems. We use scores on the internalizing and externalizing scales at kindergarten entry and spring of third grade in our analysis. Higher scores on each of the behavior problem scales represents worse outcomes.

Teacher-reported social skills and approaches to learning. The teacher SRS also consisted of three other scales that measured children's positive behaviors such as approaches to learning (ATL), self-control, and interpersonal skills. The ATL scale measured behaviors that affect the ease with which children can benefit from the learning environment. It included six items that rate the child's attentiveness, task persistence, eagerness to learn, learning independence, flexibility, and organization. The self-control scale included four items that capture the child's ability to control behavior by respecting the property rights of others, controlling temper, accepting peer ideas for group activities, and responding appropriately to pressure from peers. Finally, the interpersonal skills scale included five items that rate the child's skills in forming and maintaining friendships, getting along with people who are different, comforting or helping other children, expressing feelings, ideas and opinions in positive ways, and showing sensitivity to the feelings of others. The reliability of these three scales is also high – split-half reliability of 0.89, 0.79, and 0.89 for ATL, self-control and interpersonal skills, respectively. We use scores on the three scales at kindergarten entry and spring of third grade in our analysis. Higher scores on each of the three scales represents better outcomes.

School attendance. In the spring of kindergarten and third grade, information was collected from each child's teacher regarding the number of excused and unexcused absences from school during the academic year. We use the total number of days absent from school in third grade as our dependent variable.

Grade repetition. We construct an indicator variable capturing whether the child was retained in any grade between kindergarten and third grade.

Other explanatory variables. The ECLS-K data contains rich information about children's families, teachers, schools, as well as home environment that allows the inclusion of a detailed set of control variables in our models. These variables include gender, age in months in spring of third grade, race-ethnicity, birth weight, annual family income, mother's education, whether the child belongs to single parent household, maternal depression scores, parent–child interaction, hours of television watching in the waves collected, parent-reported physical activity in the waves collected, amount of physical education instruction received in school in kindergarten, first and third grades, and school characteristics such as enrollment, percent minority, and urbanicity. These variables have been shown to be important correlates of children's school outcomes and BMI.[10,11,15–18] Table 1 reports descriptive statistics for all control variables in our analyses.

Statistical analysis

We estimate multivariate linear and logistic regression models for continuous and dichotomous outcomes, respectively. The dependent variable in each model is the child's school outcome in spring of third grade (final wave), which depends on the child's outcomes at kindergarten entry (baseline), and changes in overweight status between kindergarten entry and third grade. In addition,

Table 1 Descriptive statistics

Variable	Mean	Std. dev.
Female	0.51	
Child's race		
White	0.66	
Black	0.10	
Hispanic	0.14	
Other	0.10	
Child's age in months in spring of third grade (G3)	110.86	4.13
Score on maternal depression scale	0.93	0.96
Mother's education		
Less than high school	0.09	
High school diploma/equivalent/vocational college	0.36	
Some college	0.27	
Bachelor's degree or higher	0.27	
Family income		
<$15 000	0.11	
$15 000–$25 000	0.11	
$25 000–$35 000	0.12	
$35 000–$50 000	0.16	
$50 000–$75 000	0.25	
⩾$75 000	0.25	
Child lives in central city	0.35	
Child lives in the urban fringe or large town	0.39	
Child lives in a small town or rural area	0.26	
Percent minority in child's school less than 10%	0.43	
Less than 150 students enrolled in school	0.06	
Whether child changed schools between K and G3	0.16	
Number of siblings when child entered K	1.44	1.11
Number of activities that parent and child engage in together	8.31	1.13
Birth weight (pounds)	7.42	1.27
Whether child lived in single parent family in K	0.17	
Hours per day child watched TV (K)	1.97	1.05
Hours per day child watched TV (G1)	2.15	1.04
Days per week child did vigorous exercise (K)	3.92	2.20
Days per week child did vigorous exercise (G3)	3.99	1.84
Hours per week child had physical education class (K)	0.94	0.79
Hours per week child had physical education class (G1)	1.08	0.73
Hours per week child had physical education class (G3)	1.14	0.78

outcomes in third grade also depend on child, family, and school characteristics that were described in the previous section.

Our key explanatory variable captures changes in a child's overweight status between fall of kindergarten and spring of third grade. We construct a categorical variable that equals 0 if the child was not overweight at baseline and in the final wave, equals 1 if the child was not overweight at baseline but was overweight in the final wave, and equals 2 if the child was overweight at baseline as well as in the final wave. There were very few cases ($N = 139$) that went from being overweight at baseline to not-overweight in the final wave. We drop these cases from our analyses owing to insufficient statistical power.

Including a baseline measure of the third grade outcome as an explanatory variable controls for the influence of background factors before school entry. This specification also allows us to interpret all coefficients in terms of their impact on *changes* in the outcome. This is because estimating a model where third grade outcome is regressed on baseline outcome and other covariates is akin to estimating a model where change in the outcome between baseline and third grade is regressed on baseline outcome and other covariates.

Examining changes in school outcomes as a function of changes in overweight status eliminates all unobserved child-specific confounding factors that remain constant over time and are related to overweight status and school outcomes. For example, families where parents are actively involved in their child's overall development may not only inculcate healthy eating and exercise habits in their children but may also invest in activities that enhance their cognitive and social skills (e.g. tutoring, discipline). Failure to control for these unobserved family characteristics may overstate the relationship between overweight status and school outcomes.

As the ECLS-K has a clustered sampling design, we estimate school-level random effects models. These models correct for the hierarchical structure (children are clustered in schools) by allowing for varying intercepts across schools. All models are estimated using STATA version 8 (StataCorp, College Station, TX, USA).

Results

In our analysis sample, about 83% of the children were not overweight at baseline and in the final wave, 8% were not overweight at baseline but were overweight in the final wave, and 9% were overweight at both times. From here on we refer to these three categories of children as 'never overweight', 'became overweight', and 'always overweight', respectively. These estimates suggest that overweight prevalence in our sample increased from 9% at kindergarten entry to 17% at the end of third grade. These figures differ from the US growth charts because the growth charts are based on historical data and the 95th percentile is the BMI at a certain age that in the past was only exceeded by 5% of the population. However, that is no longer true; the national estimates for 1999–2000 based on the National Health and Nutrition Examination Survey (NHANES) data show that 15.3% of 6–11-year olds exceed the (traditional) 95th percentile BMI threshold.[19] Our data replicate these results, but we show an additional result that much of the excess weight is gained in elementary school; whereas 9% exceed the threshold in kindergarten, 17% exceed it by the end of third grade.

Table 2 shows the means and standard deviations of children's body mass index (BMI) and school outcomes at baseline and in the final wave by change in overweight

Table 2 Descriptive statistics of body mass index (BMI) and school outcomes by change in overweight status between fall of kindergarten (FK) and spring of third grade (S3)

Variable	Not-overweight in FK and S3			Not-overweight in FK, overweight in S3			Overweight in FK and S3		
	Mean	Std. dev.	N	Mean	Std. dev.	N	Mean	Std. dev.	N
Change in BMI between FK and S3	1.56	1.56	5874	6.30**	1.48	564	5.08**	2.10	652
Reading IRT score (FK)	28.51	10.51	5663	26.51**	8.51	541	26.44**	8.52	609
Reading IRT score (S3)	110.84	19.08	5854	106.38**	19.52	560	107.56**	19.49	652
Math IRT score (FK)	22.90	9.10	5874	21.19**	8.15	562	21.20**	8.10	652
Math IRT score (S3)	87.13	17.06	5873	83.55**	17.52	564	84.54**	17.12	652
Teacher rating of externalizing behavior problems (FK)	1.55	0.59	5782	1.58	0.60	552	1.63**	0.64	632
Teacher rating of externalizing behavior problems (S3)	1.65	0.58	5794	1.69	0.60	559	1.67	0.57	643
Teacher ratings of internalizing behavior problems (FK)	1.50	0.50	5732	1.55*	0.54	545	1.53	0.52	627
Teacher ratings of internalizing behavior problems (S3)	1.60	0.51	5752	1.64	0.55	549	1.67**	0.57	642
Teacher ratings of self-control (FK)	3.15	0.59	5639	3.11	0.60	541	3.09*	0.59	620
Teacher ratings of self-control (S3)	3.25	0.60	5753	3.16**	0.64	553	3.19*	0.59	637
Teacher ratings of interpersonal skills (FK)	3.04	0.61	5598	2.99	0.60	530	2.96**	0.61	611
Teacher ratings of Interpersonal skills (S3)	3.14	0.63	5733	3.05**	0.68	552	3.10	0.64	634
Teacher ratings of approaches to learning (FK)	3.07	0.65	5838	2.98**	0.66	558	2.95**	0.65	648
Teacher ratings of approaches to learning (S3)	3.11	0.66	5805	2.98**	0.69	559	3.05*	0.67	643
Number of school absences in Kindergarten	7.96	10.67	4668	8.97	7.94	452	9.52**	12.87	530
Number of school absence in third grade	6.17	7.48	5452	6.51	5.56	519	6.82*	6.76	606
Whether repeated any grade	7.08%	25.65%	5874	9.57%*	29.45%	564	5.52%	22.86%	652

**denotes significantly different from the 'never overweight' group at 1% based on a two-tailed t-test, *significant at 5%.

status during this period. Children who became overweight had slightly higher BMI at baseline compared to children who were never overweight, even though both these groups of children were not overweight at baseline. The changes in BMI over time are also very different across the three groups of children. Children who were never overweight gained on average 1.56 units, compared to 6.3 units and 5.08 units gained by children who became overweight and those who were always overweight, respectively. These numbers highlight the importance of examining changes in overweight status over time instead of simply looking at baseline overweight status. Using baseline overweight status to predict changes in school outcomes would categorize children who were never overweight and those who became overweight in the same group, even though these descriptive statistics show significant differences.

Reading and math test scores at baseline are significantly higher among never overweight children compared to the other two groups. Interestingly, test scores of children who became overweight were very similar to those who were always overweight. Teacher-reported externalizing behavior problems were significantly more among the always-overweight children compared to the other two groups. However, there were no statistically significant differences across the three groups at the end of 4 years. Internalizing behavior problems were slightly higher among children who became overweight compared to those never-overweight. In the final wave, however, the always-overweight group had significantly more internalizing behavior problems compared to the never-overweight group. Children who were always overweight had significantly more school absences in kindergarten and third grade compared to the other two

groups. Finally, grade repetition was significantly higher among children who became overweight compared to the other two groups.

Table 3 shows the multivariate regression estimates of the relationship between change in overweight status and children's school outcomes for girls and boys (full results are reported in Tables A1 and A2 in the Appendix). We find that girls who became overweight between kindergarten entry and end of third grade were significantly more likely to score lower on math and reading tests, score higher on teacher-reported externalizing behavior problems, and score lower on teacher ratings of self-control, interpersonal skills and approaches to learning compared to girls who were never overweight. Interestingly, girls who were always overweight were not significantly different on most outcomes compared to girls who were never overweight, with the exception of internalizing behavior problems. Change in overweight status was not associated with either school attendance or grade repetition among girls.

In contrast to girls, the relationship between change in overweight status and school outcomes was weaker among boys. There were no significant differences in test scores, internalizing behavior problems, and ratings of self-control, interpersonal skills and approaches to learning between the three groups of boys. However, boys who became overweight had significantly more absences in third grade compared to boys who were never overweight.

Although most of our results suggest that becoming overweight is associated with worse school outcomes, we found the opposite result in one case. Boys who became overweight and those who were always overweight scored

Table 3 Multivariate regression estimates of the relationship between changes in overweight status and changes in school outcomes

	Dependent variable (third grade outcome)								
	Math test score	Reading test score	Externalizing behavior problems	Internalizing behavior problems	Self-control	Interpersonal skills	Approaches to learning	No. of days absent from school	Whether child repeated any grade[a]
Girls									
Became overweight[b]	−1.623**	−2.541***	0.062**	0.028	−0.085**	−0.081**	−0.086**	−0.438	1.41
	(0.753)	(0.924)	(0.029)	(0.031)	(0.034)	(0.037)	(0.036)	(0.501)	(0.397)
Always overweight[b]	−0.157	0.287	−0.009	0.119***	−0.046	−0.037	−0.018	−0.086	0.505*
	(0.712)	(0.890)	(0.028)	(0.029)	(0.032)	(0.035)	(0.034)	(0.475)	(0.188)
Boys									
Became overweight[b]	−0.037	−0.264	−0.069**	0.013	0.034	−0.007	−0.035	0.950**	0.947
	(0.757)	(0.968)	(0.033)	(0.033)	(0.035)	(0.036)	(0.036)	(0.447)	(0.246)
Always overweight[b]	−0.271	−1.059	−0.069**	0.004	−0.001	0.016	0.012	−0.113	0.781
	(0.713)	(0.915)	(0.031)	(0.031)	(0.033)	(0.034)	(0.035)	(0.424)	(0.211)

Notes: Figures in the table represent estimates of the relationship between change in overweight status between K and G3 and school outcomes in G3 from multivariate, school level random-effects regression models that control for baseline school outcomes, and child-, family- and school characteristics. Figures in brackets are standard errors. *Significant at 10%, **significant at 5%, ***significant at 1%. [a]A random-effects logit model was estimated for grade repetition. Coefficients in this column are odds ratios. [b]Omitted category is 'never overweight'.

significantly *lower* on teacher ratings of externalizing behavior problems ($P<0.05$) compared to boys who were never overweight.

Discussion

Childhood overweight has been linked to a variety of adverse health outcomes in adulthood,[20] however, less is known about its relationship with children's school outcomes. Whereas adverse health consequences of childhood overweight imply significant health care costs, poor school outcomes might threaten psychosocial development in childhood and even permanently alter educational trajectories.[21,22]

One recent study examined whether childhood overweight and obesity was associated with health-related quality of life (QOL) among elementary school children.[23] The QOL measures in that study included child and parent reports about physical, emotional, social and school functioning of children. Questions about school functioning included problems at school such as difficulty paying attention or missing school because of hospital or doctor visits. The authors found that there were significant decreases in physical and social functioning for obese children compared with children who were not overweight, but no significant decreases in emotional and school functioning scores. This study, however, was not able to investigate the temporal relationship between overweight and health-related QOL owing to its cross-sectional design. Moreover, parent reports of children's functioning may be problematic since they partly reflect the parents' own psychological health.

In our study, we examined whether changes in overweight status were associated with worse school outcomes during the first 4 years in school. To our knowledge, this is the first prospective study that examines the link between *change* in overweight status and a wide range of school outcomes using longitudinal data on a national sample of US elementary school children. Our outcome measures were obtained through a combination of direct assessments of the child (test scores), teacher reports (social-behavioral skills, approaches to learning) and school records (grade repetition, days absent). Moreover, our analyses controlled for baseline differences in school outcomes, along with a host of individual, family and school characteristics.

Our results show that moving from not-overweight to overweight between kindergarten entry and end of third grade had a positive and statistically significant association with adverse third grade outcomes such as academic achievement and social-behavioral outcomes among girls. However, this link was mostly absent among boys (except for absences), and was even opposite in one case – boys who either became overweight or were always overweight had *fewer* teacher-reported externalizing behavior problems compared to boys who maintained BMI in the normal range. Even though becoming overweight was associated with greater absences in third grade among boys, this did not translate into any significant adverse academic or social-behavioral outcomes. In contrast, change in overweight status was not associated with absences among girls, but was nevertheless significantly associated with adverse outcomes.

Change in overweight status was not associated with grade repetition in either girls or boys.

Our finding that change in overweight status is a bigger risk factor for girls compared to boys is consistent with prior cross-sectional evidence. Prior studies examining the link between overweight status and academic and social-behavioral outcomes at a point in time have found the link to be present among girls but not among boys.[8,10,11,24,25] These studies also did a prospective analysis that examined whether overweight status at a point in time was associated with subsequent *changes* in child outcomes, but they did not find a significant link in either boys or girls. However, findings from our study show that using overweight status at a point in time to predict subsequent changes in child outcomes may be problematic as baseline overweight status does not separate children who become overweight subsequently from those who remain not-overweight. In fact, in our data children who become overweight appear to have similar outcomes at baseline as those who were always overweight.

One other study[26] used an approach similar to ours and examined the development of psychiatric disorders among four groups of 9–16-year old children who were divided based on their obesity trajectories – obese in childhood only, obese in adolescence only, never obese and chronically obese. The study found significantly more psychiatric disorders only among chronically obese children. In comparison, the results from our study show that while children in our sample who were chronically overweight were not significantly different in terms of test scores from children who were never overweight, chronically overweight girls had significantly more teacher-reported internalizing behavior problems. These findings suggest that girls who start kindergarten being overweight and remain that way in the early grades may need to be monitored carefully.

The literature on societal attitudes towards overweight by gender, and child and adolescent gender differences in body image might suggest some likely explanations for the gender differences we detect in our study. Studies have found that women in general are significantly more dissatisfied with their bodies than men are,[27–29] due to which being female may be a risk factor for body image distress in western culture.[28] Similar gender differences in body dissatisfaction and weight concern have also been seen among young children, with girls preferring to be leaner whereas boys prefer to be heavier.[30–34] These patterns might also explain our finding that becoming overweight was associated with more externalizing behavior problems among girls but fewer such problems among boys.

Even though we find a significant association between increase in BMI and worse school outcomes among girls, it is important to note that the magnitude of this association is smaller relative to that of family characteristics. For example, the largest associations we detected were for self-control ratings and reading scores – the difference in reading scores and self-control teacher ratings between girls who became overweight in third grade and those who remained not-overweight was 12–14% of a standard deviation. In comparison, background factors such as mother's education and family income had 2–3 times larger associations with changes in child outcomes. However, to the extent that learning in school is cumulative, lower achievement in early grades may translate into bigger achievement gaps between overweight and not-overweight children in the later years.

Our study results should be interpreted in light of its limitations. First, even though we use longitudinal data and examine the association between *changes* in overweight status and *changes* in school outcomes our approach does not allow us to ascertain causality. Our results merely indicate that becoming overweight during the first four years in school was accompanied by worsening school outcomes among girls, however, they do not establish whether changes in overweight lead to worsening school performance or *vice versa*. Moreover, while our approach eliminates the influence of unobserved confounders that vary across children but that remain constant over time within the same child, we are unable to control for the influence of other unobserved factors that may have changed contemporaneously with overweight status and school performance. Second, outcome measures such as social skills and internalizing and externalizing behavior problems are teacher reported. Although teachers' assessments are usually the only ones available in large-scale surveys, they may be biased, depending upon the quality and psychological state of the teacher, and his/her ability to make such assessments. Moreover, teachers are not trained psychologists and do not have the expertise to make clinical judgments about children's psychological state and behavior.

The good news is that some recent school-based strategies have been shown to be effective in reducing overweight, particularly among girls.[35,15] Our study suggests that these school-based programs may have broader effects on school outcomes more generally by reducing overweight in the early years.

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Appendix

Tables A1 and A2 present the full multivariate regression results for girls and boys, respectively.

Table A1 Full multivariate regression results – girls

	Dependent variable (third grade outcome)[a]								
	Math score	Reading score	Externalizing behavior problems	Internalizing behavior problems	Self-control	Interpersonal skills	Approaches to learning	Days absent from school	Repeated any grade[b]
Change in overweight status between kindergarten and third grade (Omitted: never-overweight)									
Became overweight	−1.623**	−2.541***	0.062**	0.028	−0.085**	−0.081**	−0.086**	−0.438	1.41
	(0.753)	(0.924)	(0.029)	(0.031)	(0.034)	(0.037)	(0.036)	(0.501)	(0.397)

Table A1 (Continued)

	Math score	Reading score	Externalizing behavior problems	Internalizing behavior problems	Self-control	Interpersonal skills	Approaches to learning	Days absent from school	Repeated any grade[b]
				Dependent variable (third grade outcome)[a]					
Always overweight	−0.157	0.287	−0.009	0.119***	−0.046	−0.037	−0.018	−0.086	0.505*
	(0.712)	(0.890)	(0.028)	(0.029)	(0.032)	(0.035)	(0.034)	(0.475)	(0.188)
Baseline outcome (FK)	1.173***	0.730***	0.389***	0.182***	0.289***	0.254***	0.355***	0.297***	
	(0.028)	(0.027)	(0.015)	(0.016)	(0.016)	(0.017)	(0.016)	(0.016)	
Child's race (omitted: white)									
Black	−6.544***	−7.542***	0.177***	−0.078**	−0.182***	−0.139***	−0.115***	−0.665	2.527***
	(0.850)	(1.033)	(0.033)	(0.035)	(0.039)	(0.042)	(0.040)	(0.594)	(0.802)
Hispanic	0.784	0.009	−0.002	−0.04	0.053	0.067*	0.033	−0.674	0.837
	(0.716)	(0.898)	(0.028)	(0.029)	(0.033)	(0.035)	(0.034)	(0.497)	(0.279)
Other race	−1.064	−3.712***	−0.03	−0.046	0.027	−0.022	0.061*	−0.622	1.549
	(0.740)	(0.894)	(0.028)	(0.029)	(0.033)	(0.036)	(0.034)	(0.498)	(0.470)
Age in months in spring G3	−0.149***	0.108*	−0.002	−0.003	0.001	0.002	0.005**	−0.006	0.821***
	(0.052)	(0.063)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.034)	(0.021)
Maternal depression score	−0.211	−0.553**	0.028***	0.027***	−0.024**	−0.015	−0.024**	0.168	0.954
	(0.211)	(0.261)	(0.008)	(0.009)	(0.009)	(0.010)	(0.010)	(0.138)	(0.082)
Mother's education (omitted: less than high school)									
High school or equivalent	2.573***	3.072***	0.01	−0.042	−0.02	−0.01	−0.007	−0.565	0.418***
	(0.775)	(1.027)	(0.030)	(0.032)	(0.035)	(0.039)	(0.036)	(0.528)	(0.106)
Some college	4.577***	4.986***	−0.003	−0.034	−0.025	0.008	0.034	−0.956*	0.415***
	(0.838)	(1.089)	(0.033)	(0.034)	(0.038)	(0.041)	(0.039)	(0.570)	(0.121)
Bachelors or higher	5.905***	7.425***	−0.057	−0.077**	0.04	0.086*	0.130***	−0.797	0.217***
	(0.906)	(1.167)	(0.035)	(0.037)	(0.041)	(0.045)	(0.042)	(0.611)	(0.082)
Family income (omitted: < $15 000)									
$15,000–$25,000	1.294	1.02	0.036	−0.058*	0.045	0.013	0.063	0.27	0.550**
	(0.842)	(1.084)	(0.033)	(0.034)	(0.038)	(0.042)	(0.039)	(0.571)	(0.158)
$25,000–$35,000	2.094**	3.024***	−0.023	−0.079**	0.109***	0.077*	0.112***	0.618	0.67
	(0.875)	(1.117)	(0.034)	(0.036)	(0.040)	(0.043)	(0.041)	(0.589)	(0.202)
$35,000–$50,000	2.622***	3.746***	−0.026	−0.079**	0.119***	0.063	0.134***	1.045*	0.374***
	(0.866)	(1.096)	(0.034)	(0.035)	(0.039)	(0.043)	(0.041)	(0.581)	(0.125)
$50,000–$75,000	2.577***	3.798***	−0.037	−0.147***	0.124***	0.085**	0.149***	−0.142	0.270***
	(0.862)	(1.089)	(0.034)	(0.035)	(0.039)	(0.042)	(0.040)	(0.581)	(0.095)
⩾$75,000	2.385***	4.497***	−0.021	−0.132***	0.161***	0.105**	0.194***	0.271	0.343***
	(0.924)	(1.159)	(0.036)	(0.037)	(0.041)	(0.045)	(0.043)	(0.626)	(0.130)
Urbanicity (omitted: central city)									
Urban fringe/large town	−0.741	−1.17	0.021	0.017	0.02	−0.014	−0.018	−0.851	0.842
	(0.596)	(0.725)	(0.024)	(0.024)	(0.029)	(0.031)	(0.029)	(0.518)	(0.208)
Small town/rural area	−0.34	−1.002	0.045	0.049*	0.007	−0.043	−0.033	0.007	1.031
	(0.710)	(0.854)	(0.028)	(0.028)	(0.035)	(0.036)	(0.034)	(0.608)	(0.284)
% Minority in school (omitted: less than 10%)									
10 to less than 25	−0.631	−0.302	0.028	0.033	−0.042	−0.015	−0.025	−0.283	0.586
	(0.720)	(0.857)	(0.028)	(0.028)	(0.035)	(0.037)	(0.035)	(0.629)	(0.192)
25 to less than 50	1.066	−1.395	−0.017	−0.006	0.029	0.024	0.007	−0.632	0.560*
	(0.800)	(0.960)	(0.032)	(0.032)	(0.039)	(0.041)	(0.039)	(0.661)	(0.191)
50 to less than 75	1.175	−0.601	0.009	−0.04	0.04	0.025	0.058	−0.958	0.711
	(0.999)	(1.214)	(0.039)	(0.040)	(0.048)	(0.051)	(0.048)	(0.837)	(0.272)
75 or more	−1.043	−4.255***	0.026	−0.039	0.012	0.014	0.059	−1.439*	0.448**
	(0.906)	(1.117)	(0.036)	(0.036)	(0.043)	(0.046)	(0.044)	(0.754)	(0.158)
School enrollment (omitted: 0–149 students)									
150–299 students	0.78	0.281	−0.009	−0.024	0.077	−0.044	−0.016	0.736	0.525
	(1.124)	(1.346)	(0.044)	(0.045)	(0.054)	(0.057)	(0.055)	(0.941)	(0.227)

Table A1 (Continued)

	Dependent variable (third grade outcome)[a]								
	Math score	Reading score	Externalizing behavior problems	Internalizing behavior problems	Self-control	Interpersonal skills	Approaches to learning	Days absent from school	Repeated any grade[b]
300–499 students	2.151*	0.426	−0.033	0.017	0.092*	−0.003	−0.031	−0.029	0.513
	(1.105)	(1.324)	(0.044)	(0.044)	(0.053)	(0.056)	(0.054)	(0.915)	(0.218)
500–749 students	3.227***	0.344	−0.036	0.042	0.066	−0.054	−0.059	0.689	0.572
	(1.112)	(1.333)	(0.044)	(0.044)	(0.054)	(0.056)	(0.054)	(0.923)	(0.243)
750 and above	3.137***	0.189	−0.068	−0.039	0.063	−0.049	−0.037	0.907	0.574
	(1.212)	(1.467)	(0.048)	(0.048)	(0.059)	(0.062)	(0.059)	(1.038)	(0.270)
Child changed school between kindergarten and third grade	−1.075*	−0.884	−0.024	−0.014	0.048*	0.018	0.007	0.763*	2.432***
	(0.609)	(0.747)	(0.024)	(0.025)	(0.029)	(0.031)	(0.029)	(0.460)	(0.564)
No. of siblings in the household	−0.004	−0.844***	−0.005	0.002	0.003	0.007	0.003	−0.181	1.197***
	(0.181)	(0.227)	(0.007)	(0.007)	(0.008)	(0.009)	(0.008)	(0.120)	(0.079)
No. of activities parent and child engage in together	0.127	0.704***	0	−0.012	0.013	0.021**	0.016*	0.057	0.929
	(0.179)	(0.226)	(0.007)	(0.007)	(0.008)	(0.009)	(0.008)	(0.119)	(0.065)
Birth weight in pounds	0.510***	0.615***	−0.008	−0.028***	0.006	0.012	0.022***	0.041	0.905
	(0.162)	(0.198)	(0.006)	(0.007)	(0.007)	(0.008)	(0.008)	(0.109)	(0.064)
Whether child lived in single parent family	−0.791	−1.419*	0.060***	0.064***	−0.066**	−0.075***	−0.044	1.124***	1.13
	(0.585)	(0.725)	(0.023)	(0.024)	(0.026)	(0.029)	(0.028)	(0.390)	(0.257)
Hours per day child watched TV (K)	0.441**	0.724***	−0.01	−0.017*	0.015	0.008	0.008	−0.423***	0.946
	(0.221)	(0.275)	(0.009)	(0.009)	(0.010)	(0.011)	(0.010)	(0.151)	(0.081)
Hours per day child watched TV (G1)	−0.833***	−0.849***	0.005	0.016*	0.001	−0.001	−0.001	0.319**	1.223**
	(0.219)	(0.272)	(0.009)	(0.009)	(0.010)	(0.011)	(0.010)	(0.147)	(0.101)
Days per week child did vigorous exercise (K)	0.07	−0.035	0.006	0	−0.005	−0.005	−0.008*	−0.041	0.944
	(0.092)	(0.113)	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.062)	(0.037)
Days per week child did vigorous exercise (G3)	−0.165	−0.234*	0.005	0.003	0	0	−0.002	0.067	1.046
	(0.114)	(0.140)	(0.004)	(0.005)	(0.005)	(0.006)	(0.005)	(0.076)	(0.052)
Hours per week child had physical education class (K)	0.361	0.139	0.003	−0.003	0.001	0.003	−0.009	−0.351	0.929
	(0.322)	(0.401)	(0.013)	(0.013)	(0.015)	(0.016)	(0.016)	(0.252)	(0.120)
Hours per week child had physical education class (G1)	−0.102	−0.358	0.016	0.003	0.002	−0.023	0	0.771***	1.23
	(0.378)	(0.468)	(0.015)	(0.015)	(0.018)	(0.019)	(0.018)	(0.281)	(0.180)
Hours per week child had physical education class (G3)	0.2	0.148	−0.009	0	0.007	0.013	0.002	−0.470*	1.091
	(0.361)	(0.448)	(0.014)	(0.015)	(0.017)	(0.018)	(0.017)	(0.275)	(0.155)
Observations	3607	3450	3539	3497	3422	3415	3588	2725	3650
Number of schools	839	818	831	829	817	818	837	644	843

*Significant at 10%, **significant at 5%, ***significant at 1%. [a]Constant was included in all models. [b]Coefficients in the grade repetition model are odds ratios from a random-effects logit model.

Table A2 Full multivariate regression results – boys

	Dependent variable (third grade outcome)[a]								
	Math score	Reading score	Externalizing behavior problems	Internalizing behavior problems	Self-control	Interpersonal skills	Approaches to learning	Days absent from school	Repeated any grade[b]
Change in overweight status between kindergarten and third grade (Omitted: never-overweight)									
Became overweight	−0.037	−0.264	−0.069**	0.013	0.034	−0.007	−0.035	0.950**	0.947
	(0.757)	(0.968)	(0.033)	(0.033)	(0.035)	(0.036)	(0.036)	(0.447)	(0.246)
Always overweight	−0.271	−1.059	−0.069**	0.004	−0.001	0.016	0.012	−0.113	0.781
	(0.713)	(0.915)	(0.031)	(0.031)	(0.033)	(0.034)	(0.035)	(0.424)	(0.211)
Baseline outcome (FK)	1.059***	0.707***	0.423***	0.226***	0.334***	0.295***	0.366***	0.231***	
	(0.026)	(0.028)	(0.015)	(0.018)	(0.017)	(0.017)	(0.017)	(0.016)	
Child's race (omitted: white)									
Black	−6.727***	−6.555***	0.107***	−0.028	−0.177***	−0.195***	−0.164***	−1.513**	2.015**
	(0.900)	(1.132)	(0.039)	(0.039)	(0.042)	(0.043)	(0.044)	(0.590)	(0.571)
Hispanic	−0.866	0.31	−0.036	−0.083**	0.05	0.01	0.052	−1.115**	0.597*
	(0.797)	(1.034)	(0.035)	(0.034)	(0.037)	(0.038)	(0.039)	(0.516)	(0.176)
Other race	−0.777	−0.596	−0.110***	−0.098***	0.127***	0.127***	0.179***	−0.893*	0.583
	(0.838)	(1.049)	(0.036)	(0.035)	(0.038)	(0.039)	(0.040)	(0.522)	(0.192)
Age in months in spring G3	−0.204***	0.128*	−0.001	−0.002	0.001	0.004*	0.002	0.03	0.774***
	(0.054)	(0.067)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.032)	(0.018)
Maternal depression score	−0.063	−0.237	0.021**	0.028***	−0.012	−0.014	−0.018*	0.349***	1.141*
	(0.221)	(0.282)	(0.010)	(0.010)	(0.010)	(0.011)	(0.011)	(0.135)	(0.081)
Mother's education (omitted: less than high school)									
High school or equivalent	3.037***	7.067***	−0.016	−0.064*	0.070*	0.093**	0.074*	−1.446***	0.415***
	(0.830)	(1.113)	(0.036)	(0.036)	(0.039)	(0.041)	(0.040)	(0.496)	(0.097)
Some college	4.851***	8.850***	−0.042	−0.082**	0.083**	0.114***	0.084*	−1.904***	0.231***
	(0.895)	(1.185)	(0.039)	(0.039)	(0.042)	(0.044)	(0.043)	(0.536)	(0.065)
Bachelors or higher	5.890***	11.425***	−0.103**	−0.109***	0.155***	0.189***	0.218***	−1.938***	0.223***
	(0.965)	(1.269)	(0.042)	(0.041)	(0.045)	(0.046)	(0.046)	(0.577)	(0.071)
Family income (omitted: < \$15,000)									
\$15,000–25,000	1.279	0.133	0.043	0.044	0.012	−0.005	−0.031	−0.293	0.761
	(0.926)	(1.235)	(0.041)	(0.041)	(0.044)	(0.045)	(0.045)	(0.571)	(0.205)
\$25,000–35,000	2.066**	1.999	−0.008	−0.037	0.025	0.002	−0.009	−0.164	0.529**
	(0.949)	(1.245)	(0.042)	(0.041)	(0.044)	(0.046)	(0.046)	(0.582)	(0.160)
\$35,000–50,000	1.788*	2.160*	0.007	−0.002	0.001	0.025	−0.013	−0.557	0.534**
	(0.934)	(1.218)	(0.041)	(0.040)	(0.044)	(0.045)	(0.045)	(0.581)	(0.160)
\$50,000–75,000	1.981**	1.76	−0.053	−0.027	0.071	0.045	0.056	−0.641	0.546**
	(0.927)	(1.210)	(0.041)	(0.040)	(0.043)	(0.045)	(0.045)	(0.580)	(0.166)
⩾\$75,000	2.341**	3.427***	−0.024	−0.045	0.046	0.038	0.048	−0.56	0.392***
	(0.979)	(1.268)	(0.043)	(0.042)	(0.045)	(0.047)	(0.047)	(0.611)	(0.134)
Urbanicity (omitted: central city)									
Urban fringe/large town	−0.671	−1.995**	0.014	0.03	−0.032	−0.059**	−0.022	0.132	1.036
	(0.635)	(0.802)	(0.027)	(0.026)	(0.030)	(0.029)	(0.030)	(0.765)	(0.245)
Small town/rural area	−1.097	−3.330***	0.039	0.023	−0.033	−0.062*	−0.074**	0.297	1.188
	(0.752)	(0.937)	(0.032)	(0.031)	(0.035)	(0.034)	(0.035)	(0.892)	(0.322)
% Minority in school (omitted: less than 10%)									
10 to less than 25	−1.064	−0.707	0.043	0.060*	−0.038	−0.036	−0.070*	0.911	0.658
	(0.764)	(0.945)	(0.032)	(0.031)	(0.035)	(0.035)	(0.036)	(0.921)	(0.200)
25 to less than 50	−0.823	−1.847*	−0.014	0.073**	0.001	0.004	−0.028	0.388	0.607
	(0.843)	(1.047)	(0.036)	(0.035)	(0.039)	(0.039)	(0.040)	(0.945)	(0.199)
50 to less than 75	−1.801*	−4.886***	0.079*	0.096**	−0.08	−0.033	−0.045	2.267*	1.358
	(1.078)	(1.366)	(0.046)	(0.045)	(0.050)	(0.050)	(0.051)	(1.201)	(0.493)
75 or more	−3.756***	−8.240***	0.074*	0.036	−0.053	0.02	−0.047	−0.654	0.509*
	(0.990)	(1.266)	(0.042)	(0.041)	(0.046)	(0.046)	(0.047)	(1.036)	(0.177)

Table A2 (Continued)

	Math score	Reading score	Externalizing behavior problems	Internalizing behavior problems	Self-control	Interpersonal skills	Approaches to learning	Days absent from school	Repeated any grade[b]
				Dependent variable (third grade outcome)[a]					
School enrollment (omitted: 0–149 students)									
150–299 students	1.473	1.593	−0.048	−0.078	0.110*	0.009	−0.016	0.033	0.430**
	(1.221)	(1.515)	(0.052)	(0.050)	(0.056)	(0.056)	(0.057)	(1.407)	(0.181)
300–499 students	2.526**	1.03	0.029	−0.031	0.035	−0.049	−0.074	2.015	0.591
	(1.175)	(1.459)	(0.050)	(0.049)	(0.054)	(0.054)	(0.055)	(1.347)	(0.236)
500–749 students	3.491***	2.079	−0.086*	−0.052	0.132**	0.037	−0.004	1.502	0.433**
	(1.190)	(1.479)	(0.050)	(0.049)	(0.055)	(0.055)	(0.056)	(1.378)	(0.178)
750 and above	3.813***	2.952*	−0.069	−0.094*	0.057	−0.028	−0.057	1.495	0.367**
	(1.295)	(1.620)	(0.055)	(0.054)	(0.060)	(0.060)	(0.061)	(1.522)	(0.169)
Child changed school between kindergarten and third grade	0.66	−0.673	0.026	0.059**	−0.053*	−0.058*	−0.044	0.816*	1.998***
	(0.628)	(0.798)	(0.027)	(0.027)	(0.030)	(0.030)	(0.030)	(0.481)	(0.425)
No. of siblings in the household	0.026	−0.694***	−0.013	−0.01	0.013	0.024***	0.012	−0.021	1.189***
	(0.195)	(0.251)	(0.008)	(0.008)	(0.009)	(0.009)	(0.009)	(0.117)	(0.074)
No. of activities parent and child engage in together	0.175	0.581**	−0.025***	−0.032***	0.021**	0.032***	0.026***	−0.036	0.919
	(0.198)	(0.264)	(0.009)	(0.009)	(0.009)	(0.010)	(0.010)	(0.124)	(0.058)
Birth weight in pounds	−0.035	−0.045	−0.005	0	0.005	0	0.007	0.244**	0.853***
	(0.166)	(0.210)	(0.007)	(0.007)	(0.008)	(0.008)	(0.008)	(0.096)	(0.051)
Whether child lived in single parent family	−0.072	−1.798**	0.073***	0.107***	−0.043	−0.066**	−0.064**	0.335	1.026
	(0.643)	(0.829)	(0.028)	(0.028)	(0.030)	(0.031)	(0.031)	(0.392)	(0.216)
Hours per day child watched TV (K)	−0.377*	−0.265	0.001	0.002	0.006	0.005	−0.015	−0.013	1.12
	(0.219)	(0.281)	(0.010)	(0.009)	(0.010)	(0.010)	(0.011)	(0.129)	(0.080)
Hours per day child watched TV (G1)	−0.015	−0.31	−0.002	0.003	−0.01	−0.009	−0.001	−0.065	1.108
	(0.226)	(0.291)	(0.010)	(0.010)	(0.011)	(0.011)	(0.011)	(0.133)	(0.079)
Days per week child did vigorous exercise (K)	−0.237**	−0.161	0.004	0.011**	0	0.001	0.001	0.144**	0.972
	(0.100)	(0.128)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.060)	(0.034)
Days per week child did vigorous exercise (G3)	0.099	−0.078	0.005	−0.003	−0.008	−0.009*	−0.003	−0.019	1.001
	(0.118)	(0.150)	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.070)	(0.041)
Hours per week child had physical education class (K)	−0.367	0.311	−0.001	−0.018	0.014	−0.004	0	0.183	1.022
	(0.352)	(0.446)	(0.015)	(0.015)	(0.016)	(0.015)	(0.017)	(0.280)	(0.129)
Hours per week child had physical education class (G1)	0.738*	0.934*	−0.002	−0.006	−0.011	0.002	0.034*	−0.194	0.944
	(0.398)	(0.512)	(0.017)	(0.017)	(0.019)	(0.017)	(0.019)	(0.285)	(0.134)
Hours per week child had physical education class (G3)	0.03	−0.777	−0.005	−0.022	0.015		−0.004	−0.117	1.084
	(0.370)	(0.474)	(0.016)	(0.016)	(0.017)		(0.018)	(0.293)	(0.142)
Observations	3480	3340	3411	3331	3307	3426	3449	2620	3522
Number of schools	833	809	827	819	809	831	826	632	836

*Significant at 10%, **significant at 5%, ***significant at 1%. [a]Constant was included in all models. [b]Coefficients in the grade repetition model are odds ratios from a random-effects logit model.