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Towering Intellects? Sizing Up the Relationship Between Height and Academic Success

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Abstract

Do tall students do better in school? While a robust literature documents higher earnings among taller people, we know little about the potential academic origins of the height earnings gradient. In this paper, we use unique student-level longitudinal data from New York City (NYC) to examine the link between height and academic outcomes, shedding light on underlying mechanisms. The centerpiece of our empirical work is a regression linking academic outcomes to height, measured as a z-score normalized to same grade/sex peers within schools. We estimate a meaningful height gradient for both boys and girls in ELA and math achievement in all grades 3-8. Controlling for observed student characteristics, a one standard deviation (sd.) increase in height for grade is associated with a 3.5% (4.6%) sd. increase in math (ELA) score for boys and 4.1% (4.8%) sd. for girls. The height gradient is not explained by contemporaneous health, while time-invariant student characteristics correlated with height and achievement explain roughly half of the relationship for boys (3/4 for girls). We also find evidence that ordinal height rank relative to peers may have a small effect on achievement conditional on cardinal height. This paper contributes to a long-standing literature on the effect of age-within-grade on achievement. Our estimates suggest that failing to account for relative height may upwardly bias the relationship between relative age and achievement by up to 25%.

JEL No.: I14, I21, I24

Keywords: Height, Education, Childhood Health

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1. Introduction

A long-standing literature documents a relationship between physical characteristics and labor market outcomes. Tall people earn more that short ones (roughly 2% for each additional inch of height)[1], average-weight people earn more than obese ones (see, for instance: Cawley, 2004, Larose et al., 2016, Chu & Ohinmaa, 2016, Böckerman et al., 2019), and beautiful people earn more than plain ones (Hamermesh & Biddle, 1994; Hamermesh and Parker, 2005). Further, there is evidence that these adult labor market relationships may have academic antecedents. Case and Paxson (2009) document that, on average, taller men and women attain more education, a relationship which explains roughly half of the height earnings premium. Gorry (2017) finds that tall boys earn higher grades and attain more schooling at large schools but not small ones and posits that height may offer an advantage in capturing scarce resources. In the case of obesity, a broader literature documents that obese students perform substantially lower on math and ELA tests compared to non-obese peers (for example: Kaestner & Grossman, 2009; Averett & Stifel, 2010; Zavodny, 2013; Black et al., 2015)

Existing research on the relationship between height and academic achievement has been hindered by data limitations. Many existing datasets have limited measures of height or academic performance throughout childhood. We contribute to the literature using unique student-level longitudinal data from New York City public schools containing annual measures of height and test scores to examine the link between height and academic success.

Our primary analysis focuses on a sample of roughly 2.28 million observations from over 528,000 students between academic years (AY) 2010 and 2017. Our results shed light on the trajectory of the academic height gradient, when it emerges, and how to changes over time. We probe

[1] The association is so persistent that Mankiw and Weinzierl (2010) show that the standard utilitarian framework for optimal taxation implies that a tall person earning $50,000 should pay $4,500 more in tax than a short person.

potential mechanisms by estimating a variety of specifications and considering alternative measures of height, including height for grade/sex z-scores normalized within-school and height for age/sex z-scores normalized using CDC growth tables. Panel data offer a significant advantage to our study, facilitating the estimation of models with student fixed effects. By identifying the height gradient using variation in the differential growth of students over time, we isolate the effects of contemporaneous height from the underlying time-invariant (dis)advantage associated with height.

We have four primary findings. First, we document the existence of a statistically significant relationship between height and math and ELA achievement, which emerges by grade 3 (the first year in which students take standardized tests) and persists through grade 8 (the last year of testing). Controlling for observed student characteristics, a one standard deviation (sd.) increase in height for grade is associated with a .035 (.046) sd. increase in math (ELA) score for boys and .041 (.048) sd. for girls. [2] The height gradient is not explained by an association between height and measures of contemporaneous health including obesity and absenteeism. Second, time-invariant student characteristics explain much of the relationship between height and achievement, particularly for girls and particularly among the shortest students. Still, a significant height gradient persists after accounting for unobserved, time-invariant student characteristics. A one sd. increase in height is associated with a .017 (.025) sd. increase in math (ELA) for boys and a .015 (.013) sd. increase for girls. Third, ordinal height rank relative to same-sex classmates may impact achievement independent of cardinal height. The effect of ordinal height is small conditional on height for age; moving from the being the shortest student within grade to the tallest is associated with an increase in achievement of up to .054 (.085) sd. in ELA for boys (girls). Fourth, the height gradient may contribute to the well-documented effect of age-within-

[2] Averaged across grades, one sd. in height for grade is roughly 7.3 (7.7) cm for boys (girls).

grade on achievement. While part of the raw relationship between height and achievement arises because taller students tend to be older, a meaningful height gradient persists after controlling for age. Failing to account for relative height may upwardly bias the estimated relationship between relative age and achievement by roughly 25%.

As in other literature examining the relationship between physical characteristics and labor market or academic outcomes, we are limited in our ability to pinpoint the specific mechanisms which underly the academic height gradient. It is difficult to disentangle differences in academic success that may arise from preferences or discrimination related to height from those attributable to differences in productivity between short and tall students. While we control for time-invariant student differences via fixed-effects, we cannot rule out time-varying differences related to both height and achievement. Additionally, while we propose several mechanisms that may contribute to the academic height gradient and provide evidence on their plausibility, we are unable to provide direct evidence for all potential mechanisms.

This paper proceeds as follows. Section 2.1 reviews the literature documenting a height gradient in the labor market and in academic achievement. Section 2.2 reviews related literature on the effect of age-within-grade and ordinal rank on achievement. Section 3 describes a variety of channels through which height may be related to academic success, including time-invariant cognitive ability, social and human capital building opportunities and contemporaneous health, and discusses the empirical implications of each. In section 4, we describe our administrative data on NYC public school students and explore alternative measures of height. Section 5 describes our estimation strategy, beginning with a parsimonious model linking height for grade z-score to achievement before moving on to more detailed and flexible specifications. Section 6 contains our main results, documenting the existence of an academic height gradient that is robust to alternative specifications. We provide empirical evidence on potential mechanisms in Section 7. Section 8 explores heterogeneity in the height gradient by race and quarter of birth and presents evidence of the robustness of our results. Finally, Section 9 investigates whether any of the effect of age-within-grade on achievement may be attributable to differences in height while Section 10 concludes.

2. Background

2.1 Height, the Labor Market and Academic Outcomes

The relationship between stature and the labor market is well known in the social sciences and has been documented for both sexes in countries around the world. Various authors estimated height premia that were roughly the same in magnitude. In one example, Case and Paxson (2008) estimated an increase in weekly earnings of between 4-12% for each additional 10 cm of height for men and women in the United States and United Kingdom.[3] Han and Kim (2017) found that an additional 10 cm of height was associated with an increase in earnings of 6-7% for men and women in Korea. Likewise, an additional 10 cm of height was associated with an increase in earnings of 6% among Swedish men (Lundborg et al., 2014).

While several alternative explanations have been suggested, a frequently cited theory attributes the relationship between height and earnings to a positive association between stature and cognitive ability (Case & Paxson, 2008). Though the mechanism behind this association is not well understood, it is thought to arise through insulin-like growth factors which contribute to both physical and neural growth. In support of this theory, Case and Paxson (2008) showed that controlling for childhood tests of cognitive ability reduced the magnitude of the estimated height premium by roughly 50% for men and 60% for women, and the latter was no longer statistically significant. Lundborg et al. (2014)

[3] Around 1-2% for each inch of height

demonstrated that cognitive skills explained roughly one third of the height premium they estimated for Swedish men, while Schick and Steckel (2015) found that controlling for childhood test scores reduced the male height premium by 40% and rendered the female height premium statistically insignificant. Additionally, Baker and Cornelson (2019) found evidence of a non-linear relationship between height and cognitive ability among men; accounting for this non-linearity further increased the explanatory power of cognitive ability as a driver of the height earnings premium.

Complementarily, tall individuals may be more likely to be included in activities which build human capital, leading to an association between height and non-cognitive skills. Persico, Postlewaite and Silverman (2004) argued that the preponderance of the height earnings premium can be explained by the fact that tall adults were more likely to have been tall adolescents; they found no evidence of an adult height earnings premium after conditioning on height at age 16. They demonstrated that short individuals were less likely to have participated in athletics and other clubs during high school, explaining about half the height earnings premium. Evaluating the relative importance of cognitive and non-cognitive skills, Schick and Steckel (2015) found that the two contributed roughly equally to the height earnings premium. Baker and Cornelson (2019) found the same result for women but found that cognitive skills were more cogent for men.

Other authors have explored different dimensions of the height premium, shedding further light on its intricacies. Lindqvist (2011) showed that a 10 cm increase in height was associated with a 2.2 percentage point increase in the probability of being observed in a managerial role among Swedish men, a fact which explains roughly 15% of the unconditional height earnings premium. Han and Kim (2017) used quantile regression to explore heterogeneity in the height-wage premium in Korea and find the largest premium for men and women in the upper quantiles of the conditional wage distribution. Additionally, Böckerman and Vainiomäki (2013) used a twin-pair differencing strategy to control for genetic and early childhood factors and found a statistically significant height-wage premium for women, but not men.

A smaller number of studies explore the relationship between childhood height and academic outcomes. Case and Paxson (2008) used a variety of datasets and showed that a positive relationship between height and cognitive test scores was present as early as age 5 for children in the USA and UK, with each one sd. increase in height for age associated with an increase in test scores of between .028 and .132 sd. depending on the dataset used. Gorry (2017) used AddHealth and showed that each additional inch of height in high school was associated with an increase in GPA of roughly .2 sd. and with an increase in of rough .06 years of schooling attained for boys who attend schools at or above the 75th percentile in enrollment size. After controlling for extensive family background characteristics, she found no statistically significant relationship between height and academic outcomes for girls or for boys who attend smaller schools. She posited that height may confer a greater advantage at large schools where there is more competition for scarce human-capital building opportunities and showed that the relationship between height and sports participation followed a pattern similar to the relationship between height and academic outcomes. While tall students were more likely to participate in sports at schools of all sizes, the magnitude of the relationship was increasing in school size (Gorry, 2017).[4]

Though Case and Paxson (2008) and Gorry (2017) each provided evidence of an academic height gradient in childhood, their results suggested opposing mechanisms, indicating the need for further research. The datasets used by Case and Paxson (2009) contained only periodic observations of height

[4] Studies focusing on countries outside the US include Cinnirella et. al (2017) who show that, conditional on academic performance height at age 11-12 is associated with an increase in the probability of being assigned to the most rigorous secondary school track in Germany, and von Hinke Kessler Scholder et. al (2013) who instrument for height with genetic variance and show that while an association between height and achievement at age 14 exists for boys and girls, the relationship is causal for girls only.

during childhood, while the AddHealth data used by Gorry (2017) contained a single observation of height in high school. We build on these papers using a unique dataset which contains annual observations of both height and achievement. Additionally, our dataset consists of the universe of NYC public school students, allowing us to investigate the possible salience of student height *relative* to same sex peers.

2.2 Ordinal Rank, Age Within Grade and Academic Outcomes

Our paper is related to two additional strands of literature which show that a student's ordinal achievement position and age relative to her classmates each impact academic achievement. Ordinal rank effects are thought to arise because it is human nature to make social comparisons, and because ordinal rankings are a simple heuristic via which individuals can compare themselves to those around them (Murphy & Weinhardt, 2020). Studies of academic rank typically isolate academic rank effects by exploiting the fact that two students with the same test scores may have very different ranks depending on the distribution of achievement among their classmates. Murphy and Weinhardt (2020) show that among UK students, a one sd. increase class rank on end of primary school (age 11) exams improves age-14 and age-16 exam scores by roughly .08 sd. Using administrative data on Texas public school students, Denning et al. (2020) show that third grade academic rank impacts a range of long run outcomes including AP course-taking, high school graduation and earnings up to 19 years later.

Studies of the impact of age-within-grade typically employ a regression discontinuity design exploiting exogenous variation in age generated by kindergarten entrance age cutoffs; compared to children born just after the school entry cutoff date, those born just before it are almost one year younger when starting school. Students who are young for grade begin their schooling at a disadvantage, scoring roughly .53 (.83) sd. lower in reading (math) in the autumn of kindergarten when compared with their oldest peers (Elder & Lubotsky, 2009). Though the disparity diminishes as students progress through school, young for grade children do not catch up. By grade 3 they score .25 sd. lower in math and reading, falling to roughly .15 sd. by grade 8 (Dhuey et al., 2019). Compared to the oldest students within grade, students born just before the cutoff are roughly twice as likely to be diagnosed with ADHD and treated with prescription stimulants (Elder, 2010), and are less likely to ultimately take the SAT/ACT and enroll in a four-year college/university (Bedard & Dhuey, 2006).

It should be noted that much of the research concerning the effects of age on academic outcomes is unable to distinguish between the effect of absolute and relative (to classmates) age on achievement. Cascio and Schanzenbach (2016) exploit random variation in relative age-within-class generated by the Tennessee STAR Experiment together with variation in expected kindergarten entrance age based on birthdate to separately identify the effects of relative and absolute age. They find that the reduced-form benefit of age documented in prior literature is driven by an absolute age effect which reflects some combination of age at kindergarten entry and age at test.

3. Mechanisms and Implications for Empirical Work

We consider two broad categories of mechanisms through which height may be related to academic achievement. First, stature may be correlated with other determinants of productivity including contemporaneous health, age-within-grade, or cognitive ability. Among adults, research documents a negative correlation between height and certain chronic health conditions including asthma and acute cardiac disease (Perelman, 2014). If a similar correlation exists among students in our sample, tall students may perform better because they are healthier, and thus more productive learners. We test this empirically by estimating models which control for another measure of contemporaneous good health, obesity, and by investigating whether height predicts absenteeism. Our primary measure of height is normalized to same-sex peers within the same grade, and tall students may perform better simply because they are old for their grade. We test this empirically by estimating models with and without controls for quarter of birth.

In the statistical model presented by Case and Paxson (2008), stature and cognitive ability are each determined by an unobserved individual *endowment*. The unobserved endowment reflects the combined effects of genetic factors, environmental conditions and gene-environment interactions and is fixed during very early childhood (before age three). Our panel data allow us to control for these fixed factors via student fixed effects; we interpret the reduction in the magnitude of the height coefficient with student fixed effects as the percentage of the height gradient which can be explained by the unobserved endowment.

The second broad type of mechanisms we consider is the causal benefit of height that may arise through social factors. For instance, tall students are more likely to participate in sports during high school, which may contribute to the development of human capital (Gorry, 2017; Persico et al., 2004), and short students are disproportionately bullied (Voss & Mulligan, 2000). Though we are unable to investigate these particular mechanisms directly, the possible relevance of social factors has several implications for our empirical work. First, the height gradient may be non-linear, if, say, the shortest students are especially disadvantaged. We thus estimate models with a categorical measure of height in addition to models with a continuous height measure. Second, height relative to classmates may be especially salient and ordinal height rank may affect achievement conditional on cardinal height. Our primary analysis uses a height z-score which is normalized to same-sex peers by grade/school/year, but we also estimate models which contain both a cardinal height measure normalized to same-age children nationwide and an ordinal height which ranks students relative to same-sex classmates.

4. Data and Measures

We draw on rich, longitudinal data on the universe of NYC public elementary and middle school students in Academic Years (AY) 2009-2017. Importantly for our analysis, NYC public schools began collecting annual measures of student height, weight, and physical fitness in 2006 as part of the Fitnessgram initiative. When combined with math and ELA test scores in grades 3-8, our annual measures of height facilitate a more nuanced analysis of the trajectory of the academic height gradient when compared with studies limited by sparse measures of childhood height. Key student sociodemographic data include age, sex, race/ethnicity, month of birth, participation in special education, primary language spoken at home, poverty status (measured by free/reduced-price lunch eligibility) and attendance.

In our primary analysis, we restrict the sample to students who have at least three years of complete test score and height data in grades 3-8, yielding a sample of roughly 2.4 million observations of 528,061 students at 1,166 schools. Table 1 shows the means of several key variables for students in out analytic sample. Students in our sample are predominately minority, and around 75% are poor (as measured by free or reduced-price lunch eligibility). Additionally, over 40% speak a language other than English at home and 9-15% participate in special education. The average third grade math and ELA scores in analytic sample suggests that our sample of more stable students who are observed at least three times between grades 3-8 are positively selected from the universe of NYC students. Students in our sample scored between 6% and 20% sd. above the city average on third grade tests.

To estimate the relationship between height and achievement, we must decide how to measure height. First, following the literature, we estimate separate models for boys and girls. Estimates of the adult height earnings premium typically use absolute height measured in centimeters or inches. However, because an additional centimeter of height represents a larger difference among younger children than older ones, the convention in research involving the height of children is to use a height-for-age z-score based on growth charts from the Centers for Disease Control (CDC). We use this nationally normalized measure of height (*CDCheight*) as a robustness check and in our analysis of ordinal versus cardinal height, but our primary analysis focuses on a height-for-grade z-score (*Zheight*) which is normalized to same-sex/grade peers within the same school. While we generally impose a particular linear relationship between height and achievement, we also consider more a flexible specification which models height as a series of dummy indicators for *Zheight* less than -2, -2 to -1.5, -1.5 to -.1, -1 to -.5, -.5 to .5, .5 to 1, 1 to 1.5, 1.5 to 2 and greater than 2, with -.5 to .5 left as the reference group.

To explore the relative importance of ordinal versus cardinal height, we estimate models which contain two height measures. To measure cardinal height, we use *CDCheight,* to measure ordinal height, we calculate local percentile rank relative to same grade/school/year/sex peers as follows:

$$R_{istgf} = \frac{n_{istgf} - 1}{N_{stgf} - 1}, \; R_{istgf} \in \{0,1\}$$

Where N_{stgf} is the cohort size of sex *f*, in grade *g*, school s and year *t* and n_{istgf} is the ordinal height rank position of student *i* within their grade/school/year/sex. As noted above, these alternative measures of height provide suggestive evidence regarding the mechanisms behind the academic height premium. Table 1 shows the mean value of each of these height measures among students in our analytic sample during grade 3. With an average *Zheight* of -.01 for both boys and girls, students in our sample have roughly same average height as third graders city wide. However, the average *CDCheights* of boys and girls in our sample are .425 and .384, respectively, indicating that children in NYC are somewhat taller than same-age children nationally. Turning to our ordinal measure of height, the average percentile rank of students in our sample in grade 3 was .486 for both boys and girls.

Table 2 shows the mean value of sociodemographic variables among students in our sample separately by *Zheight* category.[5] Tall students are different from short ones in several observed ways. Tall students are less likely to be poor and less likely to speak a language other than English at home. Turning to disability status, the tallest and shortest students are each more likely to be classified with a disability when compared with students near the middle of the height distribution. Tall students are more likely to be black or white, and less likely to be Hispanic compared to short ones. Meanwhile, the tallest and shortest students are each more likely to be Asian when compared with average height students. The results in Table 2 highlight that observed and unobserved differences between tall and short students may each give rise to an academic height gradient, and we explore the relative importance of each in the analysis that follows.

5. Estimation Strategy

We begin by estimating a parsimonious model which relates math and ELA scores in grades 3-8 to contemporaneous height:

$$y_{it} = \beta z_{it} + \boldsymbol{X}_{it}\gamma + \mu_t + \varphi_g + \varepsilon_{it} \qquad (1)$$

where z_{it} is continuous height-for-grade z-score, φ_g and μ_t are grade and year fixed effects, respectively and $\boldsymbol{X}_{it}$ is a vector of student characteristics. We first include only an indicator which equals one if the student is overage for grade before adding further controls including race/ethnicity, poverty status, disability status, whether the student speaks a language other than English at home, and quarter of birth.

[5] We exclude students who are overage for grade from Table 2 as students who are held back are relatively tall within grade, confounding the relationships between demographic characteristics and height

In (1), the estimated height gradient picks up any causal benefits of height *per se* plus the effects of any omitted underlying student or family characteristics associated with both height and achievement.[6]

After documenting the relationship between height and achievement, we investigate several of the mechanisms discussed above. We test whether part of the academic height gradient is attributable to contemporaneous health both by adding an indicator variable for obesity status to (1) and by re-estimating (1) with attendance as the outcome variable. Next, we explore the how much of the height gradient is explained by time-invariant versus time-varying factors by adding student fixed effects as follows:

$$y_{it} = \beta z_{it} + \boldsymbol{X}_{it}\gamma + \varphi_g + \mu_t + \phi_i + \varepsilon_{it} \qquad (2)$$

Student fixed effects (ϕ_i) wipe out the effects of time-invariant student (dis)advantage. The remaining height gradient represents causal benefits of contemporaneous height if all confounding factors associated with height and achievement are time-invariant. As in (1), we estimate (2) for both a continuous height measure and discrete height categories.

Finally, we investigate whether ordinal height rank within grade is salient for achievement conditional on cardinal height by first estimating a version of (1) which includes ordinal height rank as the only measure of height and then adding our measure of cardinal height, *CDCheight*. We also test whether part of the well documented relationship between age within grade and achievement may be attributable to previously unobserved differences in height-for-grade by exploring how the addition of *Zheight* impacts the magnitudes of the coefficients on quarter of birth in a regression predicting achievement.

[6] To investigate whether the height gradient is larger for low or high achievement students, we also estimate a quantile regression model specified as follows:

$$q_\tau(y_{it}) = \beta_\tau z_{it} + \boldsymbol{X}_{it}\gamma_\tau + \mu_t + \varphi_g + \varepsilon_{it}$$

where all variables are as described in (1) and τ represents the τth quantile of math or ELA test scores. These estimates can be found in Appendix Table B5.

6. Do tall students perform better in grades 3-8?

Figure 1 demonstrates a statistically significant relationship between height and math and ELA test scores in each grade from 3-8, for boys and girls.[7,8] For boys, the raw height gradient is roughly constant across grades; a one sd. increase in height is associated with an increase in ELA (math) achievement of roughly .06 (.04) sd. in each grade. For girls, the raw height gradient is larger in elementary grades than middle grades but is always positive and statistically significant. A one sd. increase in height is associated with an increase in ELA achievement of between .031 sd. (grade 8) and .062 sd. (grade 6). In math a one sd. increase in height is associated with an increase in math achievement of between .013 (grade 8) and .048 sd. (grade 3). Because we estimate similar height gradients in math and ELA for boys and girls, going forward we only present estimates for boys in ELA, highlighting any important distinctions between the four height gradients.

Table 2 demonstrates that the average academic height gradient in grades 3-8 is stable and robust to including a variety of controls. Shown in Column 1, we estimate an average "raw" height gradient of .058 sd. for each one sd. increase in height for boys in ELA. The addition of controls for student demographics in column 2 and quarter of birth in column 3 reduce the magnitude of the height gradient to .052 sd. and .046 sd., respectively. The academic height gradient for boys in math is smaller than in ELA, .035 sd. for each one sd increase in height after controlling for student characteristics and quarter for birth.[9] For girls, we estimate height gradients of .048 and .041 sd. in ELA and math,

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[7] The coefficients in Figure 1 can be thought of as the "raw" height gradient (estimated with minimal controls). Because students have been redshirted or retained are often tall for grade, we include a dummy indicating whether a student is overage for grade. For example, a first grader who turns seven before December 31 (the kindergarten entrance age in NYC) is considered overage. In addition, we control for year and grade fixed effects,

[8] One alternative to normalizing height within school/ grade would be to estimate the height gradient using absolute height and include school fixed effects. The results of these regressions for each grade can be found in Appendix Figure B1.

[9] Estimates of the boys' height gradient in math are contained in Appendix Table A3a

respectively.[10] The categorical height measures also highlight that while the average height gradient is small in magnitude, it is sufficiently large to generate meaningful differences in achievement between the tallest and the shortest students within grade. In our baseline model, the shortest boys perform .245. sd. worse in ELA than the tallest, falling to .203 sd. after controlling for demographics and quarter of birth. In all cases, achievement is monotonically increasing in height; we find no evidence that students can be "too tall." Though the height gradient is roughly linear, the shortest students in grade perform especially poorly.

7. Exploring Mechanisms

We explore several mechanisms which may contribute to our estimated height gradient, including contemporaneous health, time-invariant differences in ability, and ordinal height rank compared to classmates. A height gradient in academic performance may arise if height is associated with good health and healthy students are more productive learners. We explore this in two ways. First, we estimate a model which controls for student obesity status. If tall students perform better because they are healthier, controlling for an additional measure of good health (obesity) should reduce the magnitude of the estimated height gradient. Second, if taller students are healthier, they should be less frequently absent, so we estimate models in which the outcome is a measure of attendance.

We find little evidence that tall students perform better in school primarily because they enjoy better contemporaneous health. Column 4 of Table 2 shows that controlling for obesity increases the magnitude of the estimated height gradient by roughly 25%. The results in Table 2 suggest that, because obesity is positively associated with height, omitting obesity may attenuate the estimated height gradient. Table 3 shows the results of regressions in which the dependent variable is the absence rate

[10] Estimates of the girls' height gradient in ELA and math are contained in Appendix Tables A3b and A3c

(measured between 0-100%) or an indicator for chronic absenteeism. As shown in Column 1, increased stature is associated with an increase in the absence rate on average, but the relationship is not statistically significant at conventional levels. Our categorical height measure reveals that the relationship between height and absenteeism is non-monotonic. Compared to students the middle of the height distribution, the tallest and shortest students are each absent more frequently.

While these estimates are statistically significant, they are not economically meaningful and do not explain the monotonically increasing relationship between height and achievement. Our estimates indicate that the tallest students miss roughly 0.7 additional days of school annually when compared with average height students, while the shortest students miss about .4 more days of school than average height peers. We estimate a similar non-monotonic relationship between stature and chronic absenteeism in Column 3. There is no statistically significant relationship between chronic absenteeism and height on average, but the tallest and shortest students are 2.3 and 1 percentage points more likely to be chronically absent, respectively, compared to students in the middle of the height distribution. For girls we find no statistically significant relationship between height and either measure of absenteeism.[11]

We explore how much of the height gradient is explained by time-invariant differences between tall and short students by introducing student fixed effects in Column 5 of Table 2. Compared to the baseline estimates contained in Column 1, the inclusion of student fixed effects reduces the height gradient by roughly ½. A one sd. increase in height is now associated with an increase in ELA achievement of .025 sd. and an increase in math achievement of .017 sd. For girls, student fixed effects dampen the height gradient by about ¾. A one sd. increase in height is now associated with an increase in ELA (math) achievement of .013 (.015) sd. Turning to the categorical height measure, the inclusion of student fixed

[11] Estimates for girls' absenteeism shown in Appendix Table A4

effects reduces the negative coefficient for the shortest boys in ELA by roughly 64% while only reducing the positive coefficient for the tallest students by about 43%. A similar pattern emerges for boys in math and for girls in ELA and math.

The fixed effect estimates shed light on the extent to which cognitive ability, early childhood advantage and other time invariant factors correlated with both height and achievement (i.e., the *endowment*) explain the height gradient. The large reduction in the magnitudes of all height gradients indicates that underlying, unobserved differences account for much of the height gradient, especially for the shortest students and especially for girls.[12] Still, meaningful disparities persist between the tallest and the shortest students. Boys in the tallest height category perform .11 sd. better in ELA than peers in the shortest category. To the extent that the fixed effects estimates represent the causal effect of height on achievement, our results suggest that the benefits of height *per se* are larger for boys than girls.[13]

The addition of student fixed effects in our estimates for absenteeism in Table 4 alters the coefficients such that absenteeism is monotonically decreasing in height, but the relationship is not economically meaningful. The results in column 2 indicate that boys in the tallest height category are absent about .36 fewer days compared to the shortest students within grade. After including student fixed effects, we estimate a similar, but larger relationship for girls. The tallest girls in grade miss roughly 1.4 fewer days of school compared to the shortest.

[12] This finding is consistent with those of Case and Paxon (2008) and Schick and Steckel (2015) who each show that cognitive ability explains more of the adult height wage premium for women than for men, and with Gorry (2017) show finds no evidence of a height gradient in high school GPA or educational attainment for girls after controlling for family background.
[13] We also estimate a value-added (VA) specification and a dynamic panel specification which combines the VA and student fixed effects models and is characterized by two sources of persistence over time: autocorrelation due to the lagged dependent variable among the regressors and heterogeneity among individuals (Baltagi, 2013). We estimate these models using the Arellano and Bond GMM procedure. The results can be found in Appendix Table B2 and Appendix Table B3, respectively

Thus far, we have estimated the height gradient using a measure of height which is calculated relative to peers within the same grade/school/year. However, these estimates do little to shed on whether it is merely being *tall* or being *taller* than classmates that is most salient. The former is most consistent with hypothesis that height is related to achievement because it is correlated with underlying characteristics which effect achievement (e.g. contemporaneous health or the individual endowment) while the latter is consistent with benefits of height that operate through social channels (e.g. access to human capital building opportunities). A related question is whether ordinal height rank may affect achievement independently of cardinal height in the manner that academic rank has been shown to.

Following the literature on academic rank effects, we investigate this using idiosyncratic variation in the height distribution across grades and schools. This variation arises because grade cohorts within schools are relatively small and vary in height, meaning two ten-year-old girls of the same height may have different ordinal ranks depending on which school they attend (Murphy & Weinhardt, 2020). First, we estimate the height gradient using our measure of ordinal height rank $R_{istgf} \in \{0,1\}$ and then add our cardinal measure of height, *CDCheight*, to explore the effect on ordinal height rank coefficient. *CDCheight* is calculated relative to all same-sex/age children nationwide and thus measures whether a student is tall say, for a 10-year-old girl, regardless of what grade she is in and the height distribution of her classmates.[14] Because we identify rank effects via differences in height across schools, we must first demonstrate that there is enough variation in the height distributions across grade/school/years. Figure 2 shows the 25th, 50th and 75th percentiles of the distribution of *CDCheight* across grade/school/years and indicates substantial variation. For instance, a student of average height for the age/sex (*CDCheight*

[14] All estimates of the effect of ordinal height rank also contain school fixed effects.

= 0) could be at the 25th, 50th or 75th percentile in the grade/school/year height distribution depending on which school they attend (Huang et al., 2021).

Columns 1 and 3 of Table 5 show the relationships between ordinal height rank and ELA and math achievement, respectively for boys. Because rank is measured from zero to one, the coefficients can be interpreted as the effect of moving from being the shortest boy within grade to being the tallest. When it is the only measure of height included, a one unit increase in ordinal rank is associated with an increase in ELA achievement of .131 sd. and increase in math achievement of .084 sd. Controlling for *CDCheight* in Column 2 reduces the magnitude of the coefficient on ordinal rank by roughly 60% in ELA, but it is still statistically significant. Our estimates indicate that for a boy of a given height, attending a school where he is the tallest boy in his grade rather the shortest is associated with an increase in achievement of up to .054 sd. After controlling for *CDCheight*, we find no significant relationship between ordinal height rank and math achievement for boys. Table 6 shows that the effect of ordinal height rank on achievement may be larger for girls than boys. After controlling for *CDCheight*, a one unit increase in ordinal rank is associated with an increase in ELA (math) achievement of .085 (.047) sd. for girls. Taken together, our results indicate that height rank relative to classmates may impact achievement independently of cardinal height, particularly in ELA, and particularly for girls. However, the magnitude of the effect is only meaningful for large difference in height rank.[15]

8. Heterogeneity and Robustness

We find that the height gradient is similar in magnitude across racial/ethnic groups. Though we find statistically significant differences between groups, they are generally not economically meaningful.

[15] Estimates of the relationship between ordinal height and achievement with student fixed effects are available in Appendix Table A5 for boys and A6 for girls.

Table 7 shows that the raw height gradient in ELA achievement is largest for Asian boys at .055 sd., and smallest for black boys at .043 sd. With the addition of student fixed effects, the height gradient is largest for Asian boys, at .029 sd., and smallest for white boys, at .018 sd.[16]

As shown in Table 8, we find more evidence of systematic differences in the raw height gradient by quarter of birth. The raw height gradient shown in the odd columns is largest among boys born in the first quarter (who are the oldest within grade). Each one sd. increase in height is associated with an increase of ELA achievement of .063 sd. For boys born in the fourth quarter (who are the youngest within grade) the raw height gradient is only .038 sd. for each one sd increase in height.[17] The addition of student fixed effects in the even columns alters this pattern. The height gradient is now largest for students born in the fourth quarter, at .028 sd., and smallest for those born in second quarter, at .021 sd. Thus, while students who are both taller and older than their peers perform especially strongly, any causal benefits of height *per se* are roughly equivalent across birth quarters.

As noted above, our primary analytic sample consists of students with at least three years of complete height and test score data, who are positively selected from the universe of NYC students. To test the sensitivity of our estimated height gradient to an alternative sample, we re-estimate each of the 5 regression specifications found in Table 3 on a sample of students with at least two complete height and test score observations (the minimum number required for the fixed effect estimator). The addition of students with only two observations increases the sample size by roughly 100,000 students (200,000 observations). As shown in Table 9, the estimated height gradients using the full student sample are slightly larger in magnitude than those in Table 3, ranging from .048 - .060 sd. in models without student

[16] Estimates of the height gradient for by race/ethnicity boys in math are available in Appendix Table A7a. Estimates of the girls height gradients in ELA and math are available in Appendix Tables A7b and A7c, respectively.
[17] Estimates of the height gradient for by birth quarter for boys in math are available in Appendix Table A8a. Estimates of the girls height gradients in ELA and math are available in Appendix Tables A8b and A8c, respectively.

fixed effects. The inclusion of student fixed effects in Column 5 yields a height gradient of .025 sd., identical to the one we estimate using our more restricted sample.

9. Relative age, height, and achievement

In Section 5, we showed that, because height for grade is correlated with age for grade, failing to account for relative age upwardly biases the estimated height gradient. Nevertheless, differences in age only explain up to 16% of the "raw" gradient. Here, we investigate a related question: to what extent can part of the well-documented relationship between age-within-grade and achievement be explained by differences in relative height? We first estimate the relationship between quarter of birth and achievement without controls for height. Given that NYC requires students to turn five before December 31 to enter kindergarten, the omitted references group of children born in the fourth quarter are the youngest within grade.

Table 10 shows that, compared to students born in the fourth quarter, boys born in the first quarter (who are an average of nine months older) perform .1 sd. better in ELA. This estimate is somewhat smaller in magnitude than that of Dhuey et al. (2019), who find that students who are roughly one year older perform around .2 sd. better in grades 3-8.[18] Controlling for *Zheight* reduces the magnitude of the coefficients on quarter of birth by roughly 25%, suggesting that as much of one quarter of the effect of age-within-grade on achievement may be attributable to previously unobserved differences in height.[19]

[18] One possible explanation for this disparity between our estimates and those of Dhuey et al. (2019) is that most of the students in our sample are poor. Elder and Lubostky (2009) provide evidence that the effects of age within grade are larger for high SES students.

10. Discussion

Consistent evidence shows height is associated with improved labor market outcomes, attributed to a relationship between stature and cognitive ability, non-cognitive skills, or both. However, the relationship between height and success during schooling (an important factor in eventual labor market success) has remained relatively unexplored. Drawing on a unique longitudinal dataset tracking the height and test scores of NYC public school students, we show that a meaningful height gradient in academic performance emerges by grade 3 for boys and girls in both ELA and math and persists through grade 8. The height gradient is not explained by contemporaneous good health, but unobserved time invariant differences related to both height and achievement explain roughly half of the relationship for boys and ¾ of the relationship for girls. Though the height gradient controlling for student fixed effects is small in magnitude, it is sufficient to generate economically significant differences in performance between the shortest and the tallest students. For instance, the shortest boys score roughly .1 sd. lower in ELA compared to the tallest boys within grade.

Though our main analysis uses a measure of height which is normalized relative to same-sex classmates, the estimated height gradient likely represents the combined benefits of being *tall* and of being *taller*. We parse this and investigate potential rank effects by estimating models which contain both a cardinal measure of height for age and an ordinal measure of height rank relative to same-sex classmates. We find evidence that height rank may impact achievement independently of cardinal height, but the magnitudes of effects are small; moving from being the shortest to the tallest student within grade may increase achievement by up to .09 sd. Finally, we show that up to 25% of the well-established relationship between age-within-grade and achievement may be attributable to previously unobserved differences in relative height.

Our findings can be contextualized by the relationship between test scores and eventual earnings. Chetty et al. (2014) demonstrate that a one sd. increase in math or ELA test scores in grades 3-8 is associated with a 12% increase in adult earnings conditional on observed student characteristics. Back of the envelope math suggest our average estimated academic height gradient would lead to roughly a .6% increase in earnings for each one sd. increase in height, much smaller than the height earnings premium typically documented among adults. Thus, while academic success during childhood may contribute to the relationship between height and earnings, it is not the only mechanism.

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Tables and Figures

Table 1. Sample means

	Boys (1)	Girls (2)
Black	.236	.252
Hispanic	.398	.405
White	.170	.160
Asian	.184	.172
SWD	.157	.094
FRPL	.742	.754
No English at home	.437	.428
Math z-score grade 3	.154	.101
Reading z-score grade 3	.62	.204
Height grade 3 (cm)	133.17	132.40
Zheight grade 3	-.01	-.01
CDCheight grade 3	.425	.384
Percentile Rank grade 3	.486	.486
BMI grade 3	18.65	18.36
N (obs)	259,871	268,190
N (students)	1,055,535	1,084,850

Notes: FRPL and SWD denote students eligible for free or reduced-price lunch, respectively. Math and ELA Z-scores are standardized for each grade, citywide, with a mean of zero and a standard deviation of one.

Table 2. Student characteristics by height category

	Poor	Non-English	SWD	Black	Hispanic	White	Asian	N
	(1)	(2)	(3)	(5)	(6)	(7)	(8)	
Zheight				**Boys**				
[2, ∞)	.685	.409	.141	.241	.291	.242	.217	15,149
[1.5, 2)	.697	.409	.133	.252	.315	.219	.204	32,294
[1, 1.5)	.703	.418	.128	.249	.333	.207	.201	70,165
[.5, 1)	.714	.430	.126	.235	.354	.198	.203	124,862
[-.5, .5)	.726	.441	.127	.222	.385	.185	.198	364,130
[-1, -.5)	.735	.446	.126	.206	.409	.177	.198	159,828
[-1.5, -1)	.732	.447	.130	.198	.420	.173	.198	99,621
[-2, -1.5)	.732	.452	.130	.185	.431	.174	.200	45,750
(-∞, -2)	.723	.459	.148	.181	.424	.176	.210	17,467
					Girls			
[2, ∞)	.706	.339	.071	.338	.286	.210	.153	17,844
[1.5, 2)	.723	.357	.073	.334	.309	.192	.155	35,773
[1, 1.5)	.729	.385	.070	.302	.337	.184	.167	82,838
[.5, 1)	.737	.402	.068	.284	.360	.175	.172	140,276
[-.5, .5)	.738	.432	.066	.241	.391	.172	.186	389,421
[-1, -.5)	.743	.452	.071	.210	.421	.168	.192	162,641
[-1.5, -1)	.744	.458	.073	.191	.438	.165	.197	102,905
[-2, -1.5)	.748	.466	.078	.178	.449	.165	.198	46,822
(-∞, -2)	.744	.460	.081	.177	.435	.169	.209	20,439

Notes: Sample means separated by Zheight category. Zheight is standardized to same-sex peers by grade/school/year with a mean of zero and a standard deviation of one. Students overage for grade are excluded.

Table 3. Regression results, Boys ELA

	(1)	(2)	(3)	(4)	(5)	
			A. Continuous height measure			
Zheight	.057 (.001)	.052 (.001)	.046 (.001)	.054 (.001)	.025 (.001)	
			B. Discrete height measure			N (obs)
[2, ∞)	.102 (.006)	.091 (.005)	.077 (.005)	.096 (.007)	.058 (.006)	25,148
[1.5, 2)	.085 (.004)	.074 (.004)	.063 (.004)	.078 (.005)	.044 (.004)	46,117
[1, 1.5)	.066 (.003)	.057 (.003)	.049 (.003)	.059 (.004)	.029 (.003)	92,335
[.5, 1)	.043 (.003)	.035 (.002)	.030 (.002)	.037 (.003)	.018 (.002)	152,255
[-.5, .5)	-	-	-	-	-	405,690
[-1, -.5)	-.049 (.002)	-.046 (.002)	-.041 (.002)	-.047 (.003)	-.012 (.002)	168,119
[-1.5, -1)	-.080 (.003)	-.075 (.003)	-.067 (.003)	-.076 (.004)	-.021 (.003)	102,270
[-2, -1.5)	-.112 (.004)	.102 (.006)	-.099 (.004)	-.110 (.006)	-.031 (.004)	46,136
(-∞, -2)	-.143 (.007)	.085 (.004)	-.126 (.006)	-.137 (.006)	-.052 (.006)	17,465
Demographics	N	Y	Y	Y	Y	
QOB	N	N	Y	Y	N	
Obesity	N	N	N	Y	Y	
Student FE	N	N	N	N	Y	
N-schools	1,164	1,164	1,164	1,164	1,164	
N-students	259,871	259,871	259,871	259,871	259,900	
N-observations	1,055,53 5	1,055,53 5	1,055,53 5	1,055,53 5	1,055,62 6	

Notes: Each column of Panels A and B represents a separate regression. ELA Z-score is standardized for each grade, citywide, with a mean of zero and standard deviation of one. Zheight is normalized to same-sex peers by grade/school/year with a mean of zero and a standard deviation of one. Demographic controls include race/ethnicity, poverty status, disability status and an indicator identifying students with home language other than English. All regressions include an indicator identifying students overage for grade and grade and year fixed effects.

Table 4. Regression results, Boys absenteeism

	Absence Rate		Chronic Absenteeism	
	(1)	(2)	(3)	(4)
	A. Continuous Height Measure			
Zheight	.017 (.009)	-.031 (.012)	.001 (.001)	-.001 (.001)
	B. Discrete Height Measure			
[2, ∞)	.444 (.058)	-.121 (.051)	.023 (.003)	-.002 (.004)
[1.5, 2)	.126 (.038)	-.085 (.034)	.007 (.002)	.001 (.002)
[1, 1.5)	.078 (.026)	-.034 (.023)	.004 (.002)	.001 (.002)
[.5, 1)	.027 (.020)	-.017 (.016)	.002 (.001)	.003 (.001)
[-.5, .5)	-	-	-	-
[-1, -.5)	.012 (.018)	-.001 (.015)	.001 (003)	.000 (.001)
[-1.5, -1)	.062 (.024)	.034 (.022)	.005 (.002)	.003 (.002)
[-2, -1.5)	.144 (.033)	.024 (.030)	.009 (.002)	.003 (.002)
(-∞, -2)	.232 (.054)	.076 (.044)	.010 (.003)	.002 (.004)
Student FE	N	Y	N	Y
N-schools	1,164	1,164	1,164	1,164
N-students	259,900	259,900	259,900	259,900
N-observations	1,055,397	1,055,397	1,055,397	1,055,397

Notes: Each column of Panels A and B represents a separate regression. Zheight is normalized to same-sex peers by grade/school/year with a mean of zero and a standard deviation of one. Absence rate is measured from zero to 100. Chronic Absenteeism is an indicator equal to one for students who are absent at least 10% of days. All columns control for poverty status and disability status and include an indicator identifying students overage for grade, an indicator identifying students with home language other than English, and grade and year fixed effects. Columns 1 and 3 control for race/ethnicity and quarter of birth.

Table 5. Regression results, boys

	ELA		Math	
	(1)	(2)	(3)	(4)
Percentile Rank	.131 (.003)	.054 (.006)	.084 (.003)	.007 (.006)
CDC Height	-	.022 (.002)	-	.021 (.002)
N-schools	1,159	1,159	1,159	1,159
N-students	259,108	259,108	259,108	259,108
N-observations	1,042,739	1,042,739	1,042,739	1,042,739

Notes: Each column represents a separate regression. Percentile rank is calculated relative to same sex peers by grade/school/year and is measured from zero to one. CDC Height is standardized by age and sex using CDC growth charts with mean zero and standard deviation one. ELA and math Z-scores are standardized for each grade, citywide, with a mean of zero and standard deviation of one All regressions control for race/ethnicity quarter of birth, disability status, and poverty status and include an indicator identifying students overage for grade, an indicator identifying students with home language other than English and grade, year and school fixed effects.

Table 6. Regression results, girls

	ELA		Math	
	(1)	(2)	(3)	(4)
Percentile Rank	.138 (.002)	.085 (.006)	.101 (.002)	.047 (.006)
CDC Height	-	.015 (.002)	-	.015 (.002)
N-schools	1,160	1,160	1,160	1,160
N-students	267,511	267,511	267,511	267,511
N-observations	1,072,923	1,072,923	1,072,923	1,072,923

Notes: Each column represents a separate regression. Percentile rank is calculated relative to same sex peers by grade/school/year and is measured from zero to one. CDC Height is standardized by age and sex using CDC growth charts with mean zero and standard deviation one. ELA and math Z-scores are standardized for each grade, citywide, with a mean of zero and standard deviation of one. All regressions control for disability status and poverty status and include an indicator identifying students overage for grade, an indicator identifying students with home language other than English and grade, year and school fixed effects.

Table 7. Heterogeneity by race/ethnicity, boys ELA

	Asian		Hispanic		Black		White	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Zheight	.055 (.003)	.029 (.004)	.052 (.002)	.020 (.002)	.043 (.003)	.024 (.003)	.052 (.004)	.018 (.004)
Student FE	N	Y	N	Y	N	Y	N	Y
N-schools	1,093	1,093	1,161	1,161	1,151	1,151	1,070	1,070
N-students	49,656	49,656	104,310	104,310	64,527	64,527	45,629	45,629
N-observations	194,967	194,967	420,479	420,479	248,985	248,985	179,788	179,788

Notes: Each column represents a separate regression. Zheight is normalized to same-sex peers by grade/school/year with a mean of zero and a standard deviation of one. ELA and math Z-scores are standardized for each grade, citywide, with a mean of zero and standard deviation of one. Odd columns control for quarter of birth. All columns control for disability status and poverty status and include an indicator identifying students overage for grade, an indicator identifying students with home language other than English and grade, year and school fixed effects.

Table 8. Heterogeneity by birth quarter, boys ELA

	Q1		Q2		Q3		Q4	
	(1)	(2)	(3)	(3)	(5)	(6)	(7)	(8)
Zheight	.063 (.003)	.024 (.003)	.055 (.003)	.021 (.003)	.050 (.003)	.027 (.003)	.038 (.003)	.028 (.003)
Student FE	N	Y	N	Y	N	Y	N	Y
N-schools	1,162	1,162	1,164	1,164	1,162	1,162	1,162	1,162
N-students	63.690	63.690	63,678	63,678	67,368	67,368	65,382	65,382
N-observations	258,611	258,611	258,182	258,182	273,687	273,687	265,055	265,055

Notes: Each column represents a separate regression. Zheight is normalized to same-sex peers by grade/school/year with a mean of zero and a standard deviation of one. ELA and math Z-scores are standardized for each grade, citywide, with a mean of zero and standard deviation of one. Odd columns control for race/ethnicity. All columns control for disability status and poverty status and include an indicator identifying students overage for grade, an indicator identifying students with home language other than English and grade, year and school fixed effects.

Table 9. Regression results, full student sample

	(1)	(2)	(3)	(4)	(5)
Zheight	.060 (.001)	.054 (.001)	.048 (.001)	.056 (.001)	.025 (.001)
Demographic controls	N	Y	Y	Y	Y
QOB	N	N	Y	Y	N
Obesity	N	N	N	Y	N
Student FE	N	N	N	N	Y
N-schools	1,181	1,181	1,181	1,181	1,181
N-students	370,346	370,346	370,346	370,346	370,346
N-observations	1,224,643	1,224,643	1,224,643	1,224,643	1,224,643

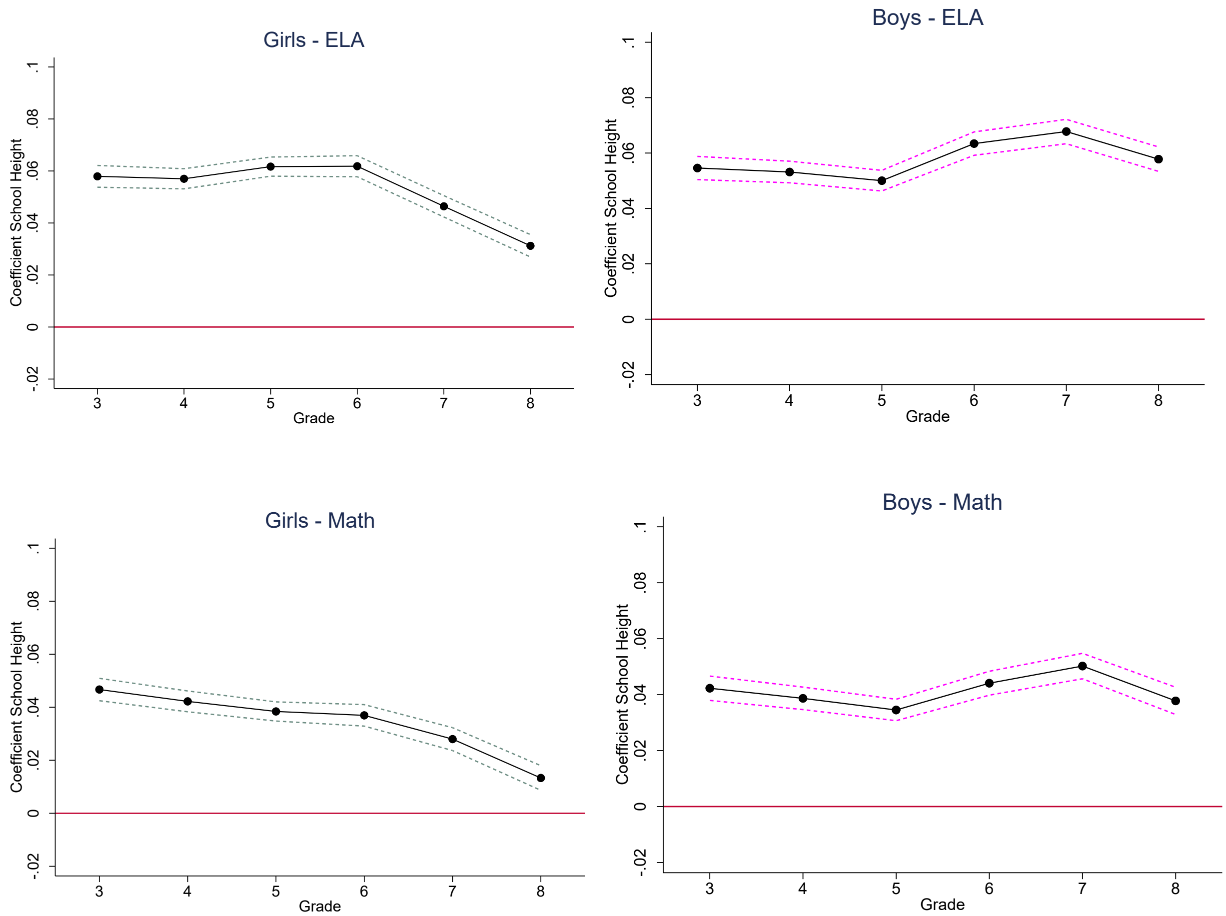
Notes: Sample is all students with at least two complete observations. Each column represents a separate regression. ELA Z-score is standardized for each grade, citywide, with a mean of zero and standard deviation of one. Zheight is normalized to same-sex peers by grade/school/year with a mean of zero and a standard deviation of one. Demographic controls include race/ethnicity, poverty status, disability status and an indicator identifying students with home language other than English. All regressions include an indicator identifying students overage for grade and grade and year fixed effects.

Table 10. Relationship between birth quarter and ELA achievement, boys

	(1)	(2)
Born Q1	.100 (.004)	.075 (.004)
Born Q2	.068 (.004)	.048 (.004)
Born Q3	.023 (.004)	.014 (.004)
Zheight	-	.046 (.001)
N-schools	1,164	1,164
N-students	259,871	259,871
N-observations	1,055,535	1,055,535

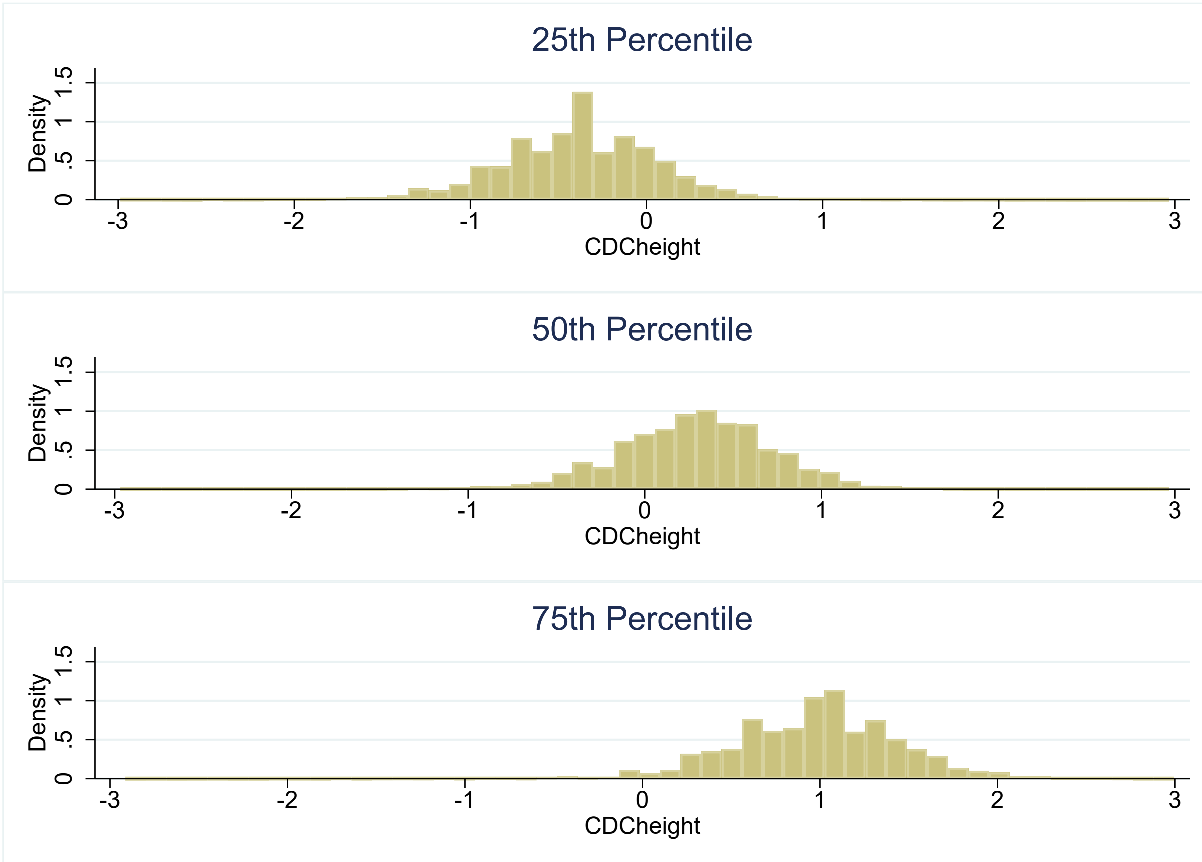
Notes: Each column represents a separate regression. All regressions control for race/ethnicity, disability status and poverty status and include an indicator identifying students overage for grade, an indicator identifying students with home language other than English and grade and year fixed effects.

Figure 1. Height gradient by grade (School/grade/year normed z-score for height) - Grades 3-8



Notes: Each coefficient comes from a separate regression of test scores on school/grade/year normed z-score for height. All regressions control for overage for grade and year fixed effects.

Figure 2. Distribution of *CDCheight* by grade/school/year



Appendix A. Supplemental Regression Estimates

Table A3a. Regression results, Boys Math

	(1)	(2)	(3)	(4)	(5)	
	C. Continuous height measure					
Zheight	.041 (.001)	.038 (.001)	.035 (.001)	.045 (.001)	.017 (.001)	
	D. Discrete Height measure					N (obs)
[2, ∞)	.074 (.006)	.067 (.005)	.058 (.005)	.096 (.007)	.051 (.006)	25,148
[1.5, 2)	.052 (.004)	.046 (.004)	.040 (.004)	.078 (.005)	.027 (.004)	46,117
[1, 1.5)	.044 (.003)	.039 (.003)	.034 (.003)	.059 (.004)	.022 (.003)	92,335
[.5, 1)	.031 (.003)	.024 (.002)	.022 (.002)	.037 (.003)	.012 (.002)	152,255
[-.5, .5)	-	-	-	-	-	405,690
[-1, -.5)	-.036 (.003)	-.034 (002)	-.031 (002)	-.047 (.003)	-.006 (002)	168,119
[-1.5, -1)	-.061 (.003)	-.058 (.003)	-.053 (.003)	-.076 (.004)	-.015 (.003)	102,270
[-2, -1.5)	-.083 (.004)	-.085 (.004)	-.078 (.004)	-.110 (.006)	-.020 (.004)	46,136
(-∞, -2)	-.099 (.007)	-.104 (.006)	-.096 (.006)	-.137 (.006)	-.022 (.006)	17,465
Demographic	N	Y	Y	Y	Y	
QOB	N	N	Y	Y	N	
Obesity	N	N	N	Y	Y	
Student FE	N	N	N	N	Y	
N-schools	1,164	1,164	1,164	1,164	1,164	
N-students	259,871	259,871	259,871	259,871	259,871	
N-observations	1,055,53 5	1,055,53 5	1,055,53 5	1,055,53 5	1,055,53 5	

Notes: Each column of Panels A and B represents a separate regression. Math Z-score is standardized for each grade, citywide, with a mean of zero and standard deviation of one. Zheight is normalized to same-sex peers by grade/school/year with a mean of zero and a standard deviation of one. Demographic controls include race/ethnicity, poverty status, disability status and an indicator identifying students with home language other than English. All regressions include an indicator identifying students overage for grade and grade and year fixed effects.

Table A3b. Regression results, Girls ELA

	(1)	(2)	(3)	(4)	(5)	
	A. Continuous height measure					
Zheight	.055 (.001)	.056 (.001)	.048 (.001)	.057 (.001)	.013 (.001)	
	B. Discrete Height measure					N (obs)
[2, ∞)	.107 (.006)	.110 (.005)	.093 (.005)	.116 (.007)	.029 (.006)	24,234
[1.5, 2)	.075 (.004)	.083 (.004)	.071 (.004)	.089 (.005)	.018 (.004)	47,317
[1, 1.5)	.051 (.003)	.058 (.003)	.048 (.003)	.061 (.004)	.011 (.003)	98,314
[.5, 1)	.037 (.002)	.043 (.002)	.037 (.002)	.045 (.003)	.009 (.002)	158,971
[-.5, .5)	-	-	-	-	-	417,534
[-1, -.5)	-.050 (.002)	-.048 (.002)	-.042 (.002)	-.049 (.003)	-.007 (.002)	167,518
[-1.5, -1)	-.077 (.003)	-.075 (.003)	-.064 (.003)	-.075 (.004)	-.012 (.003)	103,715
[-2, -1.5)	-.111 (.004)	-.105 (.004)	-.091 (.004)	-.103 (.005)	-.016 (.004)	46,722
(-∞, -2)	-.147 (.006)	-.148 (.006)	-.131 (.006)	-.141 (.008)	-.033 (.006)	20,525
Demographics	N	Y	Y	Y	Y	
QOB	N	N	Y	Y	N	
Obesity	N	N	N	Y	Y	
Student FE	N	N	N	N	Y	
N-schools	1,166	1,166	1,166	1,166	1,166	
N-students	268,190	268,190	268,190	268,190	268,190	
N-observations	1,084,85 0	1,084,85 0	1,084,85 0	1,084,85 0	1,084,85 0	

Notes: Each column of Panels A and B represents a separate regression. ELA Z-score is standardized for each grade, citywide, with a mean of zero and standard deviation of one. Zheight is normalized to same-sex peers by grade/school/year with a mean of zero and a standard deviation of one. Demographic controls include race/ethnicity, poverty status, disability status and an indicator identifying students with home language other than English. All regressions include an indicator identifying students overage for grade and grade and year fixed effects.

Table A3c. Regression results, girls math

	(1)	(2)	(3)	(4)	(5)	
			A. Continuous height measure			
Zheight	.036 (.001)	.046 (.001)	.041 (.001)	.050 (.001	.015 (.001)	
			B. Discrete Height measure			N (obs)
[2, ∞)	.068 (.006)	.096 (.005)	.084 (.005)	.108 (.007)	.045 (.006)	24,234
[1.5, 2)	.031 (.004)	.061 (.004)	.052 (.004)	.071 (.005)	.027 (.004)	47,317
[1, 1.5)	.029 (.003)	.049 (.003)	.043 (.003)	.056 (.004)	.016 (.003)	98,314
[.5, 1)	.018 (.003)	.033 (.002)	.029 (.002)	.037 (.003)	.010 (.002)	158,971
[-.5, .5)	-	-	-	-	-	417,534
[-1, -.5)	-.039 (.003)	-.043 (.002)	-.038 (.002)	-.045 (.003)	-.009 (.002)	167,518
[-1.5, -1)	-.056 (.003)	-.062 (.003)	-.055 (.004)	-.065 (.004)	-.014 (.003)	103,715
[-2, -1.5)	-.085 (.004)	-.089 (.004)	-.079 (.004)	-.092 (.005)	-.015 (.004)	46,722
(-∞, -2)	-.111 (.006)	-.124 (.006)	-.112 (.006)	-.123 (.006)	-.022 (.006)	20,525
Demographics	N	Y	Y	Y	Y	
QOB	N	N	Y	Y	N	
Obesity	N	N	N	Y	Y	
Student FE	N	N	N	N	Y	
N-schools	1,166	1,166	1,166	1,166	1,166	
N-students	268,190	268,190	268,190	268,190	268,190	
N-observations	1,084,85 0	1,084,85 0	1,084,85 0	1,084,85 0	1,084,85 0	

Notes: Each column of Panels A and B represents a separate regression. Math Z-score is standardized for each grade, citywide, with a mean of zero and standard deviation of one. Zheight is normalized to same-sex peers by grade/school/year with a mean of zero and a standard deviation of one. Demographic controls include race/ethnicity, poverty status, disability status and an indicator identifying students with home language other than English. All regressions include an indicator identifying students overage for grade and grade and year fixed effects.

Table A4. Regression results, girls absenteeism

	Absence Rate		Chronic Absenteeism	
	(1)	(2)	(3)	(4)
	A. Continuous Height Measure			
Zheight	.010 (.010)	-.234 (.011)	.001 (.001)	-.011 (.001)
	B. Discrete Height Measure			
[2, ∞)	.236 (.058)	-.447 (.005)	.008 (.003)	-.022 (.003)
[1.5, 2)	.146 (.037)	-.361 (.033)	.008 (.002)	-.013 (.002)
[1, 1.5)	.080 (.026)	-.272 (.003)	.002 (.002)	-.013 (.001)
[.5, 1)	.052 (.019)	-.149 (.015)	.003 (.001)	-.005 (.001)
[-.5, .5)	-	-	-	-
[-1, -.5)	.040 (.018)	.114 (.014)	.001 (.001)	.004 (.001)
[-1.5, -1)	072 (.023)	.249 (.021)	.003 (.001)	.013 (.002)
[-2, -1.5)	.085 (.032)	.318 (.029)	.004 (.002)	.016 (.002)
(-∞, -2)	.225 (.052)	.372 (.043)	.010 (.003)	.015 (.003)
Student FE				
N-schools	1,166	1,166	1,166	1,166
N-students	268,204	268,204	268,204	268,204
N-observations	1,119,229	1,119,229	1,119,229	1,119,229

Notes: Each column of Panels A and B represents a separate regression. Zheight is normalized to same-sex peers by grade/school/year with a mean of zero and a standard deviation of one. Absence rate is measured from zero to 100. Chronic Absenteeism is an indicator equal to one for students who are absent at least 10% of days. All columns control for poverty status and disability status and include an indicator identifying students overage for grade, an indicator identifying students with home language other than English, and grade and year fixed effects. Columns 1 and 3 control for race/ethnicity and quarter of birth.

Table A5. Regression results - percentile rank student fixed effects models, boys

	ELA		Math	
	(1)	(2)	(3)	(4)
Percentile Rank	.065 (.004)	.037 (.006)	.042 (.004)	.014 (.006)
CDC Height	-	.010 (.002)	-	.010 (.002)
N-schools	1,159	1,159	1,159	1,159
N-students	259,108	259,108	259,108	259,108
N-observations	1,042,739	1,042,739	1,042,739	1,042,739

Notes: Each column represents a separate regression. Percentile rank is calculated relative to same sex peers by grade/school/year and is measured from zero to one. CDC Height is standardized by age and sex using CDC growth charts with mean zero and standard deviation one. ELA and math Z-scores are standardized for each grade, citywide, with a mean of zero and standard deviation of one All regressions control disability status and poverty status and include an indicator identifying students overage for grade, an indicator identifying students with home language other than English and grade, year, school and student fixed effects.

Table A6. Regression results - percentile rank student fixed effects models, girls

	ELA		Math	
	(1)	(2)	(3)	(4)
Percentile Rank	.035 (.004)	.062 (.004)	.042 (.004)	.014 (.006)
CDC Height	-	-.010 (.002)	-	.010 (.002)
N-schools	1,160	1,160	1,160	1,160
N-students	267,547	267,547	267,547	267,547
N-observations	1,073,019	1,073,019	1,073,019	1,073,019

Notes: Each column represents a separate regression. Percentile rank is calculated relative to same sex peers by grade/school/year and is measured from zero to one. CDC Height is standardized by age and sex using CDC growth charts with mean zero and standard deviation one. ELA and math Z-scores are standardized for each grade, citywide, with a mean of zero and standard deviation of one All regressions control for race/ethnicity quarter of birth, disability status, and poverty status and include an indicator identifying students overage for grade, an indicator identifying students with home language other than English and grade, year and school fixed effects.

Table A7a. Heterogeneity by race/ethnicity, boys math

	Asian		Hispanic		Black		White	
	(1)	(2)	(3)	(3)	(5)	(6)	(7)	(8)
Zheight	.046 (.003)	.029 (.004)	.035 (.002)	.020 (.002)	.034 (.003)	.024 (.003)	.036 (.004)	.018 (.004)
Student FE	N	Y	N	Y	N	Y	N	Y
N-schools	1,093	1,093	1,161	1,161	1,151	1,151	1,070	1,070
N-students	49,656	49,656	104,310	104,310	64,527	64,527	45,629	45,629
N-observations	194,967	194,967	420,479	420,479	248,985	248,985	179,788	179,788

Notes: Each column represents a separate regression. Zheight is normalized to same-sex peers by grade/school/year with a mean of zero and a standard deviation of one. Math Z-scores are standardized for each grade, citywide, with a mean of zero and standard deviation of one. Odd columns control for quarter of birth. All columns control for disability status and poverty status and include an indicator identifying students overage for grade, an indicator identifying students with home language other than English and grade, year and school fixed effects.

Table A7b. Heterogeneity by race/ethnicity, girls ELA

	Asian		Hispanic		Black		White	
	(1)	(2)	(3)	(3)	(5)	(6)	(7)	(8)
Zheight	.067 (.004)	.004 (.004)	.057 (.002)	.002 (.002)	.050 (.002)	.018 (.002)	.060 (.004)	.002 (.004)
Student FE	N	Y	N	Y	N	Y	N	Y
N-schools	1,068	1,068	1,165	1,165	1,159	1,159	1,064	1,064
N-students	47,914	47,914	109,568	109,568	71,034	71,034	44,102	44,102
N-observations	186,825	186,825	439,661	439,661	274,192	274,192	17,097	17,097

Notes: Each column represents a separate regression. Zheight is normalized to same-sex peers by grade/school/year with a mean of zero and a standard deviation of one. ELA Z-scores are standardized for each grade, citywide, with a mean of zero and standard deviation of one. Odd columns control for quarter of birth. All columns control for disability status and poverty status and include an indicator identifying students overage for grade, an indicator identifying students with home language other than English and grade, year and school fixed effects.

Table A7c. Heterogeneity by race/ethnicity, girls math

	Asian		Hispanic		Black		White	
	(1)	(2)	(3)	(3)	(5)	(6)	(7)	(8)
Zheight	.065 (.004)	.005 (.003)	.041 (.002)	.018 (.002)	.046 (.003)	.022 (.003)	.046 (.004)	.00 (.003)
Student FE	N	Y	N	Y	N	Y	N	Y
N-schools	1,068	1,068	1,165	1,165	1,159	1,159	1,064	1,064
N-students	47,914	47,914	109,568	109,568	71,034	71,034	44,102	44,102
N-observations	186,825	186,825	439,661	439,661	274,192	274,192	173,097	173,097

Notes: Each column represents a separate regression. Zheight is normalized to same-sex peers by grade/school/year with a mean of zero and a standard deviation of one. Math Z-scores are standardized for each grade, citywide, with a mean of zero and standard deviation of one. Odd columns control for quarter of birth. All columns control for disability status and poverty status and include an indicator identifying students overage for grade, an indicator identifying students with home language other than English and grade, year and school fixed effects.

Table A8a. Heterogeneity by birth quarter, boys math

	Q1		Q2		Q3		Q4	
	(1)	(2)	(3)	(3)	(5)	(6)	(7)	(8)
Zheight	.051 (.003)	.014 (.003)	.041 (.003)	.018 (.003)	.038 (.003)	.015 (.003)	.026 (.003)	.021 (.003)
Student FE	N	Y	N	Y	N	Y	N	Y
N-schools	1,162	1,162	1,164	1,164	1,162	1,162	1,162	1,162
N-students	63,090	63,090	63,678	63,678	67,368	67,368	65,382	65,382
N-observations	258,611	258,611	258,182	258,182	273,387	273,387	265,055	265,055

Notes: Each column represents a separate regression. Zheight is normalized to same-sex peers by grade/school/year with a mean of zero and a standard deviation of one. Math Z-scores are standardized for each grade, citywide, with a mean of zero and standard deviation of one. Odd columns control for race/ethnicity. All columns control for disability status and poverty status and include an indicator identifying students overage for grade, an indicator identifying students with home language other than English and grade, year and school fixed effects.

Table A8b. Heterogeneity by birth quarter, girls ELA

	Q1		Q2		Q3		Q4	
	(1)	(2)	(3)	(3)	(5)	(6)	(7)	(8)
Zheight	.057 (.003)	.008 (.003)	.048 (.002)	.008 (.003)	.043 (.003)	.014 (.003)	.036 (.003)	.010 (.003)
Student FE	N	Y	N	Y	N	Y	N	Y
N-schools	1,164	1,164	1,165	1,165	1,162	1,162	1,161	1,161
N-students	65,593	65,593	64,719	64,719	69,689	69,689	68,442	68,442
N-observations	264,931	264,931	261,162	261,162	282,323	282,323	276,434	276,434

Notes: Each column represents a separate regression. Zheight is normalized to same-sex peers by grade/school/year with a mean of zero and a standard deviation of one. ELA Z-scores are standardized for each grade, citywide, with a mean of zero and standard deviation of one. Odd columns control for race/ethnicity. All columns control for disability status and poverty status and include an indicator identifying students overage for grade, an indicator identifying students with home language other than English and grade, year and school fixed effects.

Table A8c. Heterogeneity by birth quarter, girls math

	Q1		Q2		Q3		Q4	
	(1)	(2)	(3)	(3)	(5)	(6)	(7)	(8)
Height	.045 (.003)	.012 (.003)	.030 (.002)	.011 (.003)	.026 (.003)	.010 (.003)	.022 (.003)	.015 (.002)
Student FE	N	Y	N	Y	N	Y	N	Y
N-schools	1,164	1,164	1,165	1,165	1,162	1,162	1,161	1,161
N-students	65,593	65,593	64,719	64,719	69,689	69,689	68,442	68,442
N-observations	264,931	264,931	261,162	261,162	282,323	282,323	276,434	276,434

Notes: Each column represents a separate regression. Zheight is normalized to same-sex peers by grade/school/year with a mean of zero and a standard deviation of one. Math Z-scores are standardized for each grade, citywide, with a mean of zero and standard deviation of one. Odd columns control for race/ethnicity. All columns control for disability status and poverty status and include an indicator identifying students overage for grade, an indicator identifying students with home language other than English and grade, year and school fixed effects.

Appendix B. Additional Results

Figure B1. Height gradient by grade - height in cm with school fixed effects

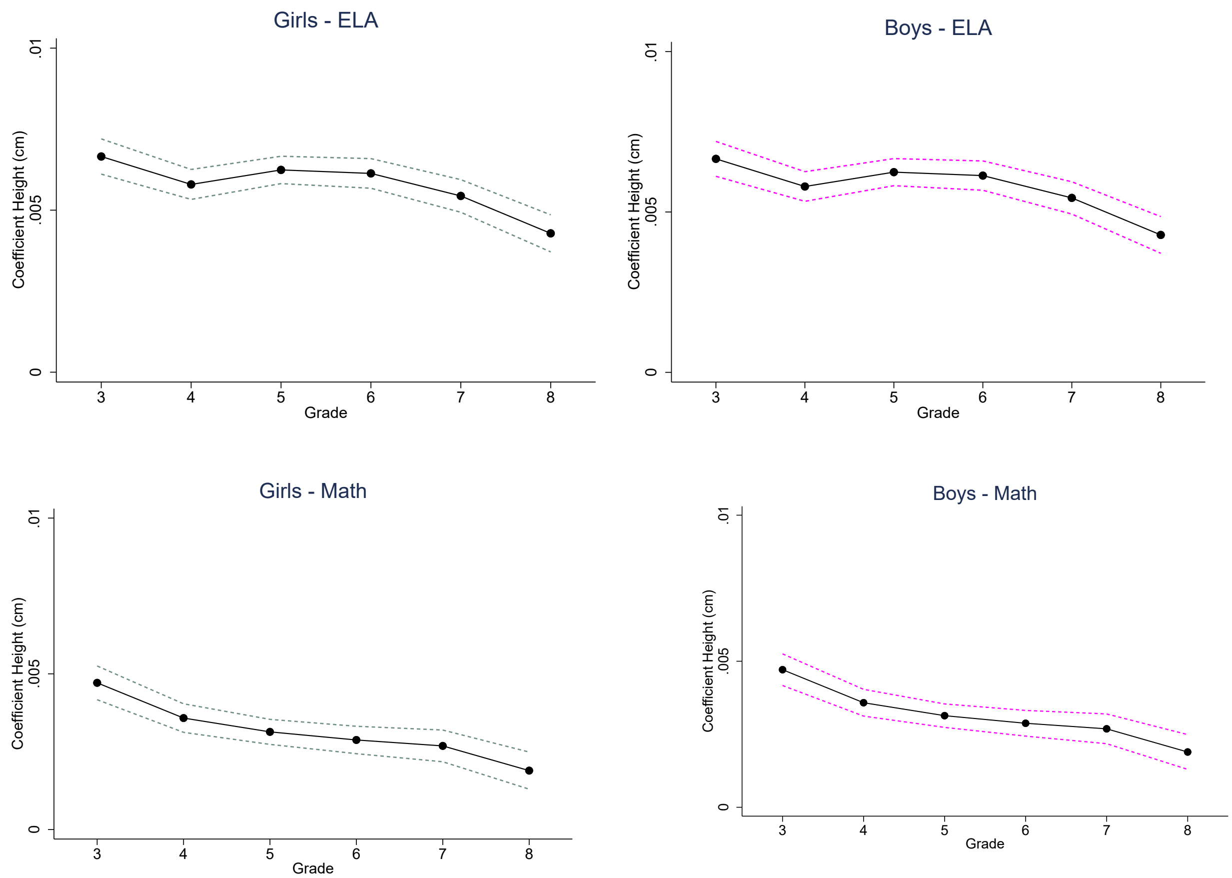


Table B1. Height gradient (School/grade/year normed z-score) - controlling for age in months

		Boys		Girls		
		ELA	Math	ELA	Math	
		(1)	(2)	(3)	(4)	
		A. Continuous height measure				
Zheight		.049	.038	.050	.043	
		(.001)	(.001)	(.001)	(.001)	
	N (obs)	B. Discrete height measures				N (obs)
[2, ∞)	25,148	.082	.065	.096	.088	25,728
		(.005)	(.005)	(.005)	(.005)	
[1.5, 2)	46,117	.067	.045	.074	.056	50,348
		(.004)	(.004)	(.004)	(.004)	
[1, 1.5)	92,335	.052	.038	.051	.045	104,636
		(.003)	(.003)	(.003)	(.003)	
[.5, 1)	152,255	.032	.024	.039	.031	168,867
		(.002)	(.002)	(.002)	(.002)	
[-.5, .5)	405,690	-	-	-	-	444,484
[-1, -.5)	168,119	-.044	-.034	-.044	-.040	178,801
		(.002)	(002)	(.002)	(.002)	
[-1.5, -1)	102,270	-.071	-.057	-.068	-.058	110,758
		(.003)	(.003)	(.003)	(.004)	
[-2, -1.5)	46,136	-.104	-.083	-.095	-.084	49,782
		(.004)	(.004)	(.004)	(.004)	
(-∞, -2)	17,465	-.132	-.103	-.136	-.118	21,689
		(.006)	(.006)	(.006)	(.006)	
Age		.044	.007	.091	.050	
		(.002)	(.002)	(.002)	(.002)	
N-schools		1,164	1,164	1,166	1,166	
N-students		259,871	259,871	268,190	268,190	
N-observations		1,055,535	1,055,535	1,084.850	1,084.850	

Notes: Each column of Panels A and B represents a separate regression. ELA and math Z-scores are standardized for each grade, citywide, with a mean of zero and standard deviation of one. Zheight is normalized to same-sex peers by grade/school/year with a mean of zero and a standard deviation of one. All regressions controls for race/ethnicity, poverty status, disability status and include an indicator identifying students with home language other than English, an indicator identifying students overage for grade, and grade and year fixed effects.

Table B2. Height gradient (School/grade/year normed z-score) - Value added model grades 4-8

		Boys		Girls		
		ELA	Math	ELA	Math	
		(1)	(2)	(3)	(4)	
		A. Continuous height measure				
Zheight		.017	.011	.019	.014	
		(.001)	(.001)	(.001)	(.001)	
	N (obs)	B. Discrete height measures				N (obs)
[2, ∞)	18,960	.033	.021	.068	.061	18,046
		(.004)	(.00)	(.006)	(.005)	
[1.5, 2)	35,227	.029	.015	.050	.038	36,433
		(.003)	(.003)	(.004)	(.003)	
[1, 1.5)	70,244	.017	.017	.032	.028	76,205
		(.002)	(.002)	(.003)	(.003)	
[.5, 1)	117,020	.011	.007	.024	.020	123,300
		(.002)	(.002)	(.002)	(.002)	
[-.5, .5)	310,584	-	-	-	-	320,478
[-1, -.5)	128,721	-.015	-.009	-.026	-.024	128,197
		(.002)	(.002)	(.002)	(.002)	
[-1.5, -1)	78,360	-.021	-.014	-.042	-.036	79,315
		(.002)	(.002)	(.003)	(.003)	
[-2, -1.5)	35,170	-.033	-.024	-.060	-.050	36,208
		(.0053	(.003)	(.004)	(.004)	
(-∞, -2)	13,402	-.051	-.028	-.084	-.071	16,329
		(.005)	(.004)	(.006)	(.005)	
Prior year score		.699	.736	.699	.732	
		(.001)	(.001)	(.001)	(.001)	
N-schools		1,160	1,160	1,161	1,161	
N-students		256,767	256,767	265,232	265,232	
N-observations		807,688	807,688	834,511	834,511	

Notes: Each column of Panels A and B represents a separate regression. ELA and math Z-scores are standardized for each grade, citywide, with a mean of zero and standard deviation of one. Zheight is normalized to same-sex peers by grade/school/year with a mean of zero and a standard deviation of one. All regressions controls for race/ethnicity, poverty status, disability status and include an indicator identifying students with home language other than English, an indicator identifying students overage for grade, and grade and year fixed effects.

Table B3. Height gradient (School/grade/year normed z-score) - Dynamic Panel Models

		Boys		Girls		
		ELA	Math	ELA	Math	
		(1)	(2)	(3)	(4)	
		A. Continuous height measure				
Zheight		.016	.011	.009	.009	
		(.002)	(.002)	(.002)	(.002)	
	N (obs)	B. Discrete height measures				N (obs)
[2, ∞)	18,201	.032	.025	.017	.024	17,230
		(.008)	(.007)	(.007)	(.007)	
[1.5, 2)	33,789	.031	.017	.012	.018	34,920
		(.008)	(.005)	(.005)	(.005)	
[1, 1.5)	67,350	.019	.015	.007	.011	72,855
		(.004)	(.004)	(.004)	(.003)	
[.5, 1)		.011	.005	.008	.009	
	112,244	(.003)	(.003)	(.003)	(.002)	117,939
[-.5, .5)	297,711	-	-	-	-	306,651
[-1, -.5)		-.010	-.004	-.007	-.007	
	123,505	(.003)	(.003)	(.003)	(.002)	122,622
[-1.5, -1)	75,129	-.012	-.006	-.006	-.008	75,923
		(.004)	(.004)	(.004)	(.003)	
[-2, -1.5)	33,771	-.021	-.015	-.009	-.006	34,624
		(.005)	(.005)	(.005)	(.004)	
(-∞, -2)	12,864	-.035	-.007	-.025	-.010	15,654
		(.008)	(.008)	(.007)	(.0070	
Prior year score		.120	.105	.136	.111	
		(.003)	(.003)	(.003)	(.003)	
N-schools		1,160	1,160	1,161	1,161	
N-students		255,317	255,317	263,768	263,768	
N-observations		774,564	774,564	798,418	798,418	

Notes: Each column of Panels A and B represents a separate regression. ELA and math Z-scores are standardized for each grade, citywide, with a mean of zero and standard deviation of one. Zheight is normalized to same-sex peers by grade/school/year with a mean of zero and a standard deviation of one. All regressions controls for race/ethnicity, poverty status, disability status and include an indicator identifying students with home language other than English, an indicator identifying students overage for grade, and grade and year fixed effects.

Table B4. Height gradient (School/grade/year normed z-score) - Quantile regression estimates

	ELA			Math		
	Q10	Q50	Q90	Q10	Q50	Q90
			A. Boys			
Zheight	.054	.045	.045	.045	.036	.032
	(.001)	(.001)	(.001)	(.001)	(.001)	(.002)
N-schools	1,164	1,164	1,164	1,164	1,164	1,164
N-students	259,871	259,871	259,871	259,871	259,871	259,871
N-observations	1,055,535	1,055,535	1,055,535	1,055,535	1,055,535	1,055,535
			B. Girls			
Zheight	.051	.046	.048	.047	.042	.039
	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)
N-schools	1,166	1,166	1,166	1,166	1,166	1,166
N-students	268,190	268,190	268,190	268,190	268,190	268,190
N-observations	1,084,850	1,084,850	1,084,850	1,084,850	1,084,850	1,084,850

Notes: Panels A and B represent separate regressions. ELA and math Z-scores are standardized for each grade, citywide, with a mean of zero and standard deviation of one. Zheight is normalized to same-sex peers by grade/school/year with a mean of zero and a standard deviation of one. All regressions controls for race/ethnicity, poverty status, disability status and include an indicator identifying students with home language other than English, an indicator identifying students overage for grade, and grade and year fixed effects.