Late but Right on Time? School Start Times and Middle Grades Students' Engagement and Achievement Outcomes in North Carolina

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Purpose: We assess whether school start times predict the engagement and achievement outcomes of middle grades students. Our focus on middle grades is important because biological changes in sleep often begin when adolescents are in middle school and because middle school is a time when more students struggle academically. **Research Methods/Approach:** We use 6 years (2011–12 through 2016–17) of statewide administrative data from North Carolina to assess how school start times predict the school attendance, disciplinary records, and test scores of middle grades (6–8) students. We estimate a range of models—school fixed effect, student fixed effect, propensity score—and include a rich set of covariates to isolate the impact of start times. **Findings:** Our school engagement results are somewhat inconsistent but suggest that later start times predict a reduction in absences and suspensions. Later start times consistently predict higher test scores in mathematics and reading. Subgroup analyses return mixed results regarding which students benefit more from later middle school start times. **Implications:** Our results emphasize the broader connections between health and academic outcomes and indicate that policy makers should delay start times for middle grades students. States can instigate start time changes by incentivizing districts to delay or requiring that districts delay start times. Districts can independently delay their start times. In doing so, it is important that district officials take time to build support for the policy change and think comprehensively about the start times of all—elementary, middle, and high—district schools.

Sufficient, high-quality sleep is vital to the health and physical development of adolescents—both younger adolescents, aged 10–14, and older adolescents, aged 15–19. In particular, chronic sleep loss in younger and older adolescents is

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significantly related to a range of physical and mental health outcomes, including obesity, hypertension, drug and stimulant use, anxiety, and depression (Alfano et al. 2009; Fredriksen et al. 2004; Hasler et al. 2004; Ludden and Wolfson 2010; Mednick et al. 2010). Beyond physical and mental health, insufficient sleep impairs adolescents' cognitive ability by limiting memory formation (Fogel and Smith 2011) and reducing alertness and attention (Lufi et al. 2011). With insufficient sleep, younger and older adolescents are less healthy and less ready to learn.

Given this evidence, adolescent sleep should be a priority for state and local education officials. Instead, school start times are often at odds with the importance of sleep, especially for middle school (grades 6–8) and high school (grades 9–12) students. Many adolescents in these grade levels are undergoing biological changes in their sleep-wake cycles that make it difficult for them to fall asleep before 11:00 p.m. and wake before 8:00 a.m. (Carskadon et al. 2001). Despite these biological changes, recent national data show that the average middle school start time in the United States is 8:04 a.m. and that the average high school start time is 7:59 a.m. The data show that 42% of middle schools and 46% of high schools start before 8:00 a.m. (US Department of Education 2016). These school start times are not compatible with the sleep needs—approximately 8.5–9.5 hours of sleep per night (National Sleep Foundation 2006)—and sleep cycles of middle and high school students.

In response to the evidence regarding adolescent sleep and health, in 2014, the American Academy of Pediatrics (AAP) issued a policy statement recommending that middle and high schools start no earlier than 8:30 a.m. (Owens et al. 2014). Although the sleep and health research supporting this recommendation are robust, the education research linking start times to student engagement and academic outcomes is still developing. This is especially true at the middle school level, where relatively few studies have assessed whether start times predict student engagement and achievement outcomes. Middle school start times need greater research attention because biological changes in sleep often begin with younger adolescents in middle school (Campbell et al. 2012).

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Likewise, prior work shows that students struggle academically and behaviorally in middle school and that middle school is a foundation for a successful transition to high school (Cook et al. 2008; Rockoff and Lockwood 2010; Schwartz et al. 2011).

With the present study, we address the need for rigorous start times research at the middle school level. In particular, we analyze 6 years of administrative data from the North Carolina Department of Public Instruction (NCDPI) to ask the following questions: (1) Do start times for middle grades students predict measures of engagement and achievement? (2) Do results vary by school urbanicity or students' economic status, race/ethnicity, gender, or prior achievement? To answer these questions, we estimate a series of models that allow us to focus on internal validity and additional models that let us assess the impact of school start times across a larger and more diverse population of schools and students in North Carolina. Furthermore, we estimate models with either a continuous start time measure or with a set of indicators for schools with early, middle, or late start times. This approach allows us to test for linear associations between start times and student outcomes and to assess whether there are nonlinear effects for late-starting middle schools. These nonlinear analyses are beneficial because effects may exist only if a school starts sufficiently late.

With our statewide data, range of outcome measures, and focus on student subgroups, we make important contributions to the start times literature for middle grades students. Our work provides further evidence for states and school districts to make informed start times decisions. This is especially important because start times may represent a cost-effective way to improve student engagement and achievement (Jacob and Rockoff 2011).

Background

Biological Changes in Sleep

Around the onset of puberty, many younger adolescents start to experience biological changes that affect the timing of their sleep. In particular, the secretion of nocturnal melatonin—which aids falling asleep—is delayed (Carskadon et al. 2004). As a result, circadian rhythms shift to preference nighttime hours, the pressure to fall asleep accumulates more slowly, and there is a phase delay in adolescents' sleep-wake cycle (Carskadon 2011; Carskadon et al. 2004; Jenni et al. 2005). Adolescents still require 8.5–9.5 hours of sleep, per night, but it becomes more difficult for them to fall asleep before 11:00 p.m. and wake before 8:00 a.m. (Carskadon et al. 2001). Importantly, these changes in sleep are beginning when many adolescents are in middle school—the median age for entering puberty is 11 for girls and 13 for boys (Campbell et al. 2012). This makes our focus on middle grades students particularly relevant and motivates separate start time estimates for girls and boys.

School Start Times and Student Sleep

Later school start times are more compatible with the biological changes that adolescents experience throughout puberty. However, later school start times may not address concerns about sleep duration if adolescents simply shift their bedtimes later or cannot adjust their morning wake times. As such, researchers have examined whether later school start times predict sleep duration and reports of daytime sleepiness. This work includes cross-sectional studies comparing the sleep outcomes of students attending schools with earlier versus later start times and longitudinal studies that assess student sleep before and after a start time change. Findings from this work indicate that later school start times benefit the sleep of adolescents at the middle and high school levels. In particular, these studies show that with later start times students get more sleep, due to delayed wake times, and report less daytime sleepiness (Dunster et al. 2018; Lewin et al. 2017; Minges and Redeker 2016; Owens et al. 2017; Wolfson et al. 2007).

At the middle school level, Wolfson et al. (2007) conducted a study of 205 adolescents attending urban middle schools with either an early (7:15 a.m.) or late (8:37 a.m.) start time. They found that students attending late-starting schools reported getting 50 more minutes of sleep each night and feeling less sleepy during the day. Likewise, a pre-post study in Virginia showed that when start times were advanced 30 minutes earlier, middle school students slept less and reported more daytime sleepiness (Owens et al. 2017). Results are similar at the high school level. For example, a cross-sectional study found that older adolescents starting high school at 8:30 a.m. or later exhibited significantly longer sleep times, by 21–34 minutes, when compared with peers with earlier start times (Nahmod et al. 2019). After Seattle delayed its high school start times by nearly an hour, a study of high school sophomores found that students delayed their wake time and got 34 more minutes of sleep per night (Dunster et al. 2018).

From an education perspective, these connections between school start times and sleep are important because of the connections between sleep and cognitive functioning. Memory formation and consolidation occur overnight and are impaired by insufficient sleep (Fogel and Smith 2011). Likewise, insufficient sleep is related to lower levels of alertness and attention and the need to expend greater effort on learning tasks (Hansen et al. 2005; Lufi et al. 2011). By improving cognitive functioning, sleep may positively affect adolescents' engagement with school and academic achievement.

School Start Times and Student Engagement and Achievement Outcomes

Although changes in sleep affect adolescents in middle and high school, most start times research has focused on education outcomes for high school students. There is less work on middle school students and how start times affect their education. As such, we begin by reviewing the results and limitations of studies focused on younger adolescents. Then we transition to reviewing studies focused on older adolescents at the high school level.

Two studies are particularly relevant to our analyses due to their focus on adolescents in middle grades: Edwards (2012), who examined changes in middle school start times in Wake County, North Carolina, and Heissel and Norris (2018), who used the time zone boundary in the Florida panhandle to instrument for daylight before school and estimate start time effects for students moving across the time zone boundary. Edwards (2012) found that delays in middle school start times predicted higher mathematics and reading scores. Although Edwards (2012) employed a rigorous design to isolate the effect of start times on test scores, the generalizability of his findings is limited by the focus on a single, urban district and the lack of non–test score outcomes. We add to his work by examining middle grades students across North Carolina and by considering additional student education outcomes (i.e., absences, suspensions, and course grades). Heissel and Norris (2018) found that delays in start times, relative to sunrise, predict higher test scores for postpubescent adolescents—including those in middle and high school grades—moving across the time zone boundary. Although they used a novel identification strategy, Heissel and Norris (2018) did not assess actual start time changes in schools or provide separate estimates for middle school students.[1] Their analyses also relied on the assumption that student sleep schedules are driven primarily by daylight rather than clock time. Our sample includes schools making meaningful start time changes, which is salient to officials considering their bell schedules, and our estimates are specific to middle grades students.

At the high school level, studies consider both student engagement with school (e.g., absences, suspensions, and course grades) and achievement. Regarding engagement with school, studies have shown that high school students are absent and tardy less often, earn higher course grades, and are less likely to be suspended when their school starts later (Bastian and Fuller 2018; Cortes et al. 2012; Dunster et al. 2018; Lenard et al. 2020; McKeever and Clark 2017; Wahlstrom et al. 2014). For example, Bastian and Fuller (2018) found that a 1-hour delay in start times predicts a 1.3-percentage-point reduction in the likelihood of North Carolina high school students being suspended. These results were strongest for students attending high schools starting at 8:30 a.m. or later. Likewise, McKeever and Clark (2017) found that high schools delaying their start time until after 8:30 a.m. experienced higher attendance rates.

In contrast to the student engagement results, the associations between high school start times and student achievement are less consistent—across studies, tests and subject areas, and student subgroups (Bastian and Fuller 2018; Groen and Pabilonia 2019; Heissel and Norris 2018; Lenard et al. 2020). For instance, Groen and Pabilonia (2019) found that later high school start times predict higher reading scores for female students. However, there were no statistically significant relationships for male students or for math achievement. Likewise, Bastian and Fuller (2018) found that later high school start times predicted higher Algebra I test scores but lower scores in biology. Last, multiple studies have found statistically insignificant relationships between start times and American College Test (ACT) scores (Bastian and Fuller 2018; Hinrichs 2011; Lenard et al. 2020). These high school studies suggest that positive start time results are more consistently observed for student engagement outcomes (e.g., attendance, course grades) that are more directly affected by sleep. Outcomes that are influenced less directly, such as test scores, have mixed results.

School Start Times and Outcomes for Student Subgroups

In addition to estimating average start time effects across all students, several studies generate separate estimates for student subgroups. These analyses build from work showing that girls and boys enter puberty at different ages (Campbell et al. 2012) and that disadvantaged subgroups are more vulnerable to a lack of sleep and its effects (El-Sheikh et al. 2010; Hanson and Chen 2010). Although these subgroup results are not always consistent, they suggest that disadvantaged students—at the middle and high school level—particularly benefit from later start times (Bastian and Fuller 2018; Dunster et al. 2018; Edwards 2012; Lenard et al. 2020). For example, Edwards (2012) found that later middle school start times primarily affect the achievement of students at the low end of the test score distribution. Likewise, analyses in Seattle showed that later start times predict reduced absences at a high school with higher concentrations of economically disadvantaged and minority students (Dunster et al. 2018).

More work is necessary to replicate and deepen subgroup analyses by student gender, race/ethnicity, economic status, and prior performance, especially given the possibility that later start times may reduce gaps in engagement and achievement. Further work is also needed to assess how start time impacts vary among urban versus rural environments. Given the need for a tiered busing schedule, urban districts typically have very early or late start times for middle and high schools (Bastian and Fuller 2018). As such, start time changes may particularly influence the education outcomes of students in urban environments.

Method

In this quasiexperimental study, we assess whether start times predict measures of engagement and achievement for middle grades students and whether those start times results differ by school urbanicity or student characteristics (e.g., economic status, race/ethnicity, gender, prior performance). Given the research on adolescent sleep and school start times, we hypothesize that middle grades students will be more engaged in school—that is, fewer absences and suspensions, higher course grades—and will score higher on standardized tests when their school starts later. Likewise, we hypothesize that later start times will particularly benefit certain student subgroups, including those attending middle schools in urban areas and those from historically marginalized populations.

Research Data

Our analyses include all sixth-, seventh-, and eighth-grade students attending public (noncharter) schools in North Carolina in the 2011–12 through 2016–17 academic years.[2] This includes students attending traditional middle schools (i.e., defined as those serving grades 6–8) and schools with other grade configurations (e.g., K–6, K–8).[3] We prefer to analyze data for all middle grades students, rather than just those attending traditional middle schools, because the onset of puberty and biological changes in sleep are related to student age and not the grade configuration of a school.[4] The data for our analyses come from administrative records collected by public schools and districts and reported to the NCDPI. In particular, these data include student demographics, program participation measures (e.g., special education, limited English proficiency, subsidized school meals), attendance, disciplinary incidents, course grades, and test scores. The data also include school-level characteristics. The administrative data do not include measures of students' family and home life or information on students' sleep duration or daytime alertness.

Table 1 displays descriptive data for North Carolina middle grades (6–8) students and the schools they attend in the 2011–12 through 2016–17 school years. We present these data for all middle grades students (overall) and for middle grades students attending schools starting before 8:00 a.m., from 8:00 to 8:29 a.m., and at 8:30 a.m. or later. Importantly, this last category aligns with the AAP's 2014 recommendation that middle and high schools start no earlier than 8:30 a.m. (Owens et al. 2014).

In total, there are 626 unique schools and 824,000 unique middle grades students in our analyses. The average school start time is 8:06 a.m., and the average student age is 12.62 years. Approximately 47% of students are a racial/ethnic

TABLE 1

Descriptive Statistics, Overall and by School Start Time Categories

Characteristics	Overall	Before 8:00 a.m.	8:00–8:29 a.m.	8:30 a.m. and After
School start time	8:06 a.m.	7:39 a.m.	8:09 a.m.	8:50 a.m.
Average age:	12.62	12.63	12.63	12.59
% Male	50.62	50.70	50.64	50.42
% American Indian	1.37	.65	2.30	.90
% Asian	2.73	2.16	2.72	3.76
% Black	24.95	24.00	22.50	31.16
% Hispanic	14.56	15.24	14.23	14.00
% Multiracial	3.82	4.17	3.58	3.66
% White	52.57	53.78	54.67	46.52
% Economically disadvantaged	51.52	54.15	52.37	45.35
% Limited English proficient	3.71	3.85	3.74	3.43
% Previously limited English proficient	8.44	8.34	8.45	8.63
% Gifted	19.20	18.76	18.40	21.50
% Special education	11.08	12.06	11.09	9.37
% Underage for grade	.89	.79	.77	1.29
% Overage for grade	19.06	20.28	19.13	16.82
% Structural mobility	29.86	30.06	28.88	31.33
% Moved between year	7.37	7.45	7.29	7.39
% Moved within year	4.81	4.82	5.16	4.13
School enrollment	623.97	583.75	600.24	792.38
Per-pupil expenditures ($)	8410.77	8543.92	8486.45	7861.23
Avg. teacher salary supplements ($)	3165.89	2935.11	2985.97	4253.82
City/suburb	33.89	31.52	29.90	50.98
Std. math score	.035	−.049	.034	.183
Std. reading score	.024	−.027	.013	.132
Days absent:	6.79	7.02	6.89	6.18
% Suspended in current year	17.76	18.82	17.82	15.79
Course grades	2.79	2.75	2.81	2.82
Unique student count	824,050	335,018	356,696	194,451
Unique school count	626	283	312	114
School-by-year count	3,562	1,434	1,565	563

NOTE.—This table displays descriptive data for middle grades (6–8) students in North Carolina from 2011–12 through 2016–17. We display these data across all middle grades students in our analyses and by the start time of their school.

minority (nearly 25% Black and 15% Hispanic), and 52% of students are economically disadvantaged. The largest category of schools are those starting from 8:00 to 8:29 a.m. (approximately 44% of the school-year records); the smallest category of schools are those starting at 8:30 a.m. or later (nearly 16% of the school-year records). When compared with schools starting earlier, we see that late-starting schools (8:30 a.m. or later) enroll a higher percentage of racial/ethnic minority students and a lower percentage of economically disadvantaged students. These late-starting schools are also more likely to be in a city or suburb and to enroll more students.

Outcome Measures

In these analyses, our outcome measures focus on student engagement with school and student achievement on standardized exams. Our engagement measures are student absences, suspensions from school, and course grades. Absences are a count of the number of days a student did not attend school, for excused or unexcused reasons, during the school year. Our suspension measure is an indicator equal to 1 if a student received an in-school or out-of-school suspension during the year and equal to 0 if a student was not suspended during the year. For course grades, we focus on academic subject areas—for example, English language arts, mathematics, science, and social studies—and convert students' course grades into unweighted grade points on a 0–4 scale. Last, for student achievement, we assess test scores from statewide End-of-Grade (EOG) exams in mathematics and reading. Specifically, we standardized EOG scores to have a mean of 0 and a standard deviation of 1. We standardized scores by subject, grade, and year across all test takers in grades 6–8 in North Carolina.

The bottom panel of table 1 presents descriptive data on these outcomes across all middle grades students and for middle grades students attending schools with early, middle, and late start times. Overall, middle grades students are absent 6.79 days a year, nearly 18% are suspended during the school year, and average course grades are a 2.79 (on a 0–4 scale). Importantly, the bottom panel of table 1 shows that as schools start later, middle grades students' test scores and course grades increase, and their absences and likelihood of being suspended decrease.

Table 2 displays descriptive statistics on our engagement and achievement measures by student characteristics and school urbanicity. We code students as (1) economically disadvantaged if they qualify for subsidized school meals; (2) a racial/ethnic minority if they identify as Black, Hispanic, American Indian, Asian, or multiracial; (3) low-performing if they scored more than one standard deviation below the statewide mean on prior-year EOG exams; and (4) attending a school in an urban area if their school is located in an environment

TABLE 2

Student Engagement and Achievement Outcomes by Middle Grades Student Subgroups

	Economically Disadvantaged		Student of Color		Gender		Low-Performing		Urbanicity	
	Yes	No	Yes	No	Boys	Girls	Yes	No	Urban	Rural
Days absent:	7.90	5.61	6.56	6.99	6.87	6.70	8.48	6.25	6.62	6.93
% Suspended in current year	25.61	9.41	24.17	11.96	23.63	11.74	32.39	13.15	16.18	19.09
Course grades	2.44	3.16	2.54	3.02	2.59	2.99	1.95	3.05	2.80	2.78
Std. math score	−.336	.429	−.262	.303	.008	.062	−.989	.356	.121	−.038
Std. reading score	−.333	.403	−.283	.301	−.058	.107	−1.033	.356	.089	−.032

NOTE.—This table displays descriptive data on student engagement and achievement outcomes for middle grades students in North Carolina. We display these data by students' economic status, student of color status, gender, low-performing status, and urbanicity.

classified as urban or suburban (relative to a school located in an environment classified as town or rural). These data show that there are often sizable differences in our engagement and achievement measures by students' economic, race/ethnicity, gender, and low-performing status. For example, economically disadvantaged students are absent more often, are more likely to be suspended, and have lower course grades and test scores than their non–economically disadvantaged peers. Likewise, there are often sizable differences in outcomes for middle grades students attending an urban versus rural school. These differences help motivate our subgroup analyses to determine whether later start times particularly benefit certain students.

Analyses

To isolate the independent associations between start times and middle grades students' engagement and achievement, we estimate linear regression models that include either a school or student fixed effect.[5] With a school fixed effect, we assess the extent to which within-school changes in start times predict within-school changes in engagement and achievement. With a student fixed effect, we assess the extent to which within-student changes in start times—due to their school changing start times or the student switching schools—predict within-student changes in engagement and achievement.[6] We prefer these fixed-effect models, relative to those that compare across units (schools or students), because they better adjust for school or student characteristics that may be associated with start times and outcomes. This is particularly important given the descriptive statistics in table 1, which show differences in the demographics, program participation, and outcomes of middle grades students attending late-starting schools.

$$Y_{ist} = \alpha + \beta \text{StartTime}_{st} + \delta \text{Student}_{ist} + \omega \text{School}_{st} + \mu_s + \rho_t + \varepsilon_{ist} \qquad (1)$$

Equation (1) presents our fixed-effect models. Here, Y_{ist} is an engagement or achievement outcome for student *i* in school *s* at time *t*. StartTime_{st} represents either a continuous variable for the number of hours past midnight that a school starts (e.g., 7.75 for a school starting at 7:45 a.m.) or a set of indicator variables. We make schools starting before 8:00 a.m. the reference category and include separate indicators for schools starting from 8:00 to 8:29 a.m. or at 8:30 a.m. or later. With these focal measures, we assess (1) how a 1-hour delay in start times predicts student engagement and achievement and (2) whether there are nonlinear start time effects for late-starting schools. Student_{ist} represents a vector of student-level indicators, including grade-level, gender, race/ethnicity, economic disadvantage, limited English proficiency, special education, gifted education, underage or overage for grade, and student mobility (i.e., structural, within-year, and between-year). $School_{st}$ represents a vector of school-level covariates, including enrollment, per-pupil expenditures, average teacher salary supplements, the percentage of economically disadvantaged and racial/ethnic minority students, an indicator for urban (city/suburb), and indicators for the school's grade configuration.[7] The variable ρ_t is a year fixed effect and μ_s is a school fixed effect—replaced by σ_i in our student fixed-effect models. Because start times are a school-level treatment, we adjust standard errors for clustering at the school level.

Although fixed-effect models more convincingly isolate start time impacts, they are dependent on within-unit (school/student) variation. If relatively few schools (students) change start times and start time changes are small in magnitude, it will be difficult to estimate start time effects. To address this concern, we identified the number of schools in our analytical sample that changed start times during our study period, calculated the magnitude of their start time changes, and examined characteristics of these schools. The top panel of table 3 shows that 81% of the schools in our analyses did not change start times during the study period. Of the 75 schools switching to an earlier start time, the average start time change was 25 minutes, and more than half of these schools (42 of 75) made a start time change of 15–29 minutes. Of the 45 schools switching to a later start time, the average start time change was 36 minutes, and more than 60% of these schools (28 of 45) delayed their start times by 30 minutes or more.[8]

The bottom panel of table 3 presents the characteristics of schools retaining their start time relative to those switching to an earlier or later start time. Schools switching to an earlier start time tend to enroll fewer students, are less likely to be in a city or suburb, and have fewer racial/ethnic minority students. Conversely, schools switching to a later start time enroll more students, are more likely to be in a city or suburb, have fewer economically disadvantaged students, and have more racial/ethnic minority students. These schools also have much larger teacher salary supplements.

Given the relatively small number of schools that change start times and the differences between schools that do and do not change start times, we estimate an additional set of models to assess whether later start times are beneficial across a broader range of North Carolina schools. To accomplish this objective, we start by estimating a multilevel model where middle grades students are nested within schools. This approach allows us to adjust for the nested nature of schools and pool data across all middle grades students and schools in North Carolina. Beyond the multilevel model approach, we also estimate a range of propensity score weighting models that allow us to compare outcomes among observationally similar students attending schools with different start times.[9] In particular, our propensity score models compare outcomes for middle grades students

TABLE 3

Within-School Variation in Start Times

	No Within-School Variation	Switches to an Earlier Start Time	Switches to a Later Start Time
Number of schools	506	75	45
Average start time before change	–	8:08 a.m.	7:48 a.m.
Average start time after change	–	7:43 a.m.	8:24 a.m.
Average difference (in minutes)	–	25	36
Start time change <15 minutes (# of schools)	–	11	4
Start time change 15–29 minutes (# of schools)	–	42	13
Start time change 30–59 minutes (# of schools)	–	18	21
Start time change ≥60 minutes (# of schools)	–	4	7
School enrollment	621.46	580.24	724.81
City/suburb:	34.75	19.46	48.87
% Economically disadvantaged students	58.34	58.45	53.28
% Racial/ethnic minority students	48.88	40.57	53.36
Per-pupil expenditures ($)	8449.83	8395.85	8011.53
Avg. teacher salary supplements ($)	3147.77	2780.48	4010.41

NOTE.—The top panel of this table displays counts of schools with middle grades students that switch to an earlier or later start time during our study period. The bottom panel of this table displays school-level characteristics for schools that did not change their start time and for schools that switched to an earlier or later start time.

attending (1) middle-start-time (8:00–8:29 a.m.) versus early-start-time (before 8:00 a.m.) schools and (2) late-start-time (8:30 a.m. or later) versus early-start-time schools. We estimate variants of these propensity score models that generate average treatment effects on the treated (ATT) and average treatment effects on the control (ATC). These two propensity score models allow us to explore whether the projected impact on the control group is similar to the estimated impact on the treated group.

Our multilevel and propensity score analyses control for the same set of student and school covariates included in equation (1). To the extent that the estimates from these models are similar to those from our fixed-effect analyses, this strengthens our ability to draw clear implications regarding a shift to later start times for middle schools.

Results

Do Start Times for Middle Grades Students Predict Measures of Engagement and Achievement?

Table 4 presents engagement and achievement results from our preferred models that include a school or student fixed effect. Regarding absences, estimates from our school and student fixed-effect models are negative—suggesting fewer absences with later start times—but statistically insignificant. Of note, the estimates for schools starting at 8:30 a.m. or later are more than two times as large as those for schools starting from 8:00 to 8:29 a.m. Suspension results differ by fixed-effect approach. Specifically, our school fixed-effect models show that a 1-hour delay in start times is associated with a 1.7-percentage-point decrease in the likelihood of a middle grades student being suspended. To better contextualize the magnitude of this estimate, we note that nearly 18% of middle grades students (table 1) are suspended at least once during the school year. Estimates from our student fixed-effect models are near zero and statistically insignificant. One explanation for this difference is that our student fixed-effect models parse variation over a shorter time period (grades 6–8 for a respective student) than our school fixed-effect models. This means that our student fixed-effect models capture more immediate start time impacts.[10] Considering course grades, we find little relationship between school start times and middle grades students' grade point averages (GPAs). Students attending a school that switches to a start time between 8:00 and 8:29 a.m. have course grades that are 0.050 quality points higher. This value is small in magnitude—that is, 0.050 quality points is less than 2% of the average GPA for middle grades students. Course grades results are not statistically significant for late-starting schools (8:30 a.m. or later) or in other school or student fixed-effect analyses.[11]

Estimates for our achievement outcomes are robust and show strong relationships between start times and test scores. Comparing within schools, we find that a 1-hour delay in start times predicts math and reading scores 0.077 and 0.038 standard deviation units higher, respectively. These estimates are modest, relative to the unadjusted differences in achievement shown in table 2, but compare favorably to other policy relevant measures. For instance, the average difference in effectiveness between first and second year teachers is 0.050 standard deviation units in math and 0.012 standard deviation units in reading.[12] Test score estimates from our student fixed-effect models are smaller in magnitude but remain statistically significant. Comparing within middle grades students, we find that a 1-hour delay in start times predicts math and reading scores that are 0.039 and 0.026 standard deviation units higher, respectively.

TABLE 4

Student Engagement and Achievement Results for Middle Grades (6–8) Students

	Student Absences		Suspended		Course Grades		Math		Reading	
	School FE	Student FE	School FE	Student FE	School FE	Student FE	School FE	Student FE	School FE	Student FE
Start time	−.366	−.330	−.017*	−.002	−.000	−.008	.077**	.039**	.038*	.026**
	(.247)	(.182)	(.008)	(.006)	(.032)	(.022)	(.026)	(.012)	(.017)	(.009)
8:00–8:29 a.m.	−.136	−.143	−.014*	−.002	.050*	.026	.061**	.030**	.035*	.025**
	(.210)	(.168)	(.007)	(.005)	(.022)	(.017)	(.021)	(.011)	(.014)	(.008)
8:30 a.m. or later	−.325	−.325	−.022	−.010	−.016	−.019	.072**	.031*	.011	.022*
	(.242)	(.207)	(.012)	(.008)	(.037)	(.030)	(.025)	(.015)	(.019)	(.010)
Observation count	1,717,925		1,717,925		1,717,925		1,717,925		1,717,925	

NOTE.—This table presents results from linear regression models with a school or student fixed effect. Models control for time-varying student and school characteristics and cluster standard errors at the school level. FE = fixed effect.

* $p < .05$.

** $p < .01$.

Although the results in table 4 address our primary analysis aim—internal validity—we are also concerned about the impact of school start times on a larger and more diverse set of North Carolina schools. As such, table 5 displays results from multilevel and propensity score weighting models. Here, we are initially interested in whether the estimates from multilevel and ATT propensity score models (the top and middle panels of table 5) are similar to those in table 4. We find that results are largely consistent between these models and our fixed-effect

TABLE 5

Student Engagement and Achievement Results for Middle Grades (6–8) Students

	Student Absences	Suspended	Course Grades	Math	Reading
Multilevel models:					
Start time	−.403	−.017**	.004	.080**	.043**
	(.210)	(.002)	(.005)	(.005)	(.005)
8:00–8:29 a.m.	−.133	−.012**	.048**	.058**	.032**
	(.184)	(.002)	(.004)	(.004)	(.004)
8:30 a.m. or later	−.358	−.022**	−.012*	.075**	.017**
	(.211)	(.003)	(.006)	(.005)	(.006)
Observations	1,717,925	1,717,925	1,717,925	1,717,925	1,717,925
Propensity score models: Average treatment effect on the treated (ATT):					
8:00–8:29 vs. before 8:00 a.m.	−.164	−.000	.038*	.056**	.019
	(.099)	(.005)	(.015)	(.015)	(.013)
Observations	1,345,627	1,345,627	1,345,627	1,345,627	1,345,627
8:30 a.m. or later vs. before 8:00 a.m.	−.594**	−.005	.019)	.131**	.058**
	(.127)	(.007)	(.020)	(.024)	(.018)
Observations	1,023,015	1,023,015	1,023,015	1,023,015	1,023,017
Propensity score models: Average treatment effect on the control (ATC):					
8:00–8:29 vs. before 8:00 a.m.	−.088	−.004	.025	.044**	.016
	(.085)	(.005)	(.017)	(.015)	(.011)
Observations	1,345,627	1,345,627	1,345,627	1,345,627	1,345,627
8:30 a.m. or later vs. before 8:00 a.m.	−.428**	−.015*	.009	.085**	.054**
	(.158)	(.007)	(.019)	(.025)	(.017)
Observations	1,023,015	1,023,015	1,023,015	1,023,015	1,023,017

NOTE.—The top, middle, and bottom panels of this table display estimates from multilevel; ATT propensity score weighting; and ATC propensity score weighting models, respectively. Models control for student and school characteristics.

* $p < .05$.

** $p < .01$.

approaches. In particular, our multilevel models show that later start times predict a reduction in the likelihood of being suspended and higher test scores in math and reading. Likewise, the ATT propensity score models indicate that later start times—especially 8:30 a.m. or later—predict higher test scores and fewer absences. This similarity across models suggests that the impact of later start times likely extends to a broad range of North Carolina schools.

To further project the impact of later start times across a diverse set of schools, we estimated ATC propensity score models. Results from these models—see the bottom panel of table 5—indicate that late start times (8:30 a.m. or later) predict fewer absences, a reduction in the likelihood of being suspended, and higher test scores. In combination, the results from table 5 suggest that the benefits of later start times are not limited to the students and schools that switch start times; rather, the benefits likely extend to those that have not yet delayed start times.

Do Results Vary by School Urbanicity or Students' Economic Status, Race/Ethnicity, Gender, or Prior Achievement?

Although it is important to determine whether later start times benefit all middle grades students, prior work suggests that certain student subgroups may particularly benefit from opportunities to get more sleep and start school later (Edwards 2012; Lenard et al. 2020). These differences across student subgroups may be because of differences in the age at which puberty is entered (particularly by gender) and of differences in the level of stressors in the students' environment (Campbell et al. 2012; El-Sheikh et al. 2010; Hanson and Chen 2010). To estimate start time effects for student subgroups, we estimate our preferred fixed-effect models (school and student fixed-effect models) and interact our continuous start time measure with indicators for each subgroup of interest. For example, in analyses focused on gender, we interact the school start time with an indicator for male students and an indicator for female students. Likewise, in analyses focused on student performance, we interact the start time measure with an indicator for low-performing students and an indicator for non-low-performing students.[13] These analyses indicate whether the start time estimate for a given subgroup is significantly different from zero. However, these analyses do not directly test whether the start time estimate for a given subgroup (e.g., economically disadvantaged students) is different from the start time estimate for the other subgroup (e.g., non–economically disadvantaged students). As such, we supplemented these regression analyses with postestimation tests to assess whether the start time estimates differ across subgroups.

Table 6 presents subgroup results for middle grades students. Regarding absences, the subgroup results are comparable with those from our main models—that is, estimates are negative in direction but generally insignificant. In our school

TABLE 6

Subgroup Analyses for Middle Grades (6–8) Students (School or Student Fixed Effects)

	Student Absences		Suspended		Course Grades		Math		Reading	
	School FE	Student FE	School FE	Student FE	School FE	Student FE	School FE	Student FE	School FE	Student FE
Start time: urban	−.247	−.253	−.006	.007	−.049	−.013	.028	.023	.038	.019
	(.341)	(.191)	(.009)	(.007)	(.034)	(.026)	(.034)	(.014)	(.025)	(.011)
Start time: rural	−.505	−.402	−.031*	−.019	.056	−.005	.134**	.062**	.038	.031*
	(.352)	(.331)	(.014)	(.010)	(.052)	(.037)	(.035)	(.019)	(.024)	(.014)
Start time: EDS	−.489	−.344	−.021*	−.002	.001	−.005	.059*	.034**	.036*	.023*
	(.251)	(.182)	(.009)	(.006)	(.033)	(.023)	(.027)	(.012)	(.019)	(.009)
Start time: non-EDS	−.251	−.309	−.013	−.003	−.001	−.012	.096**	.045**	.041*	.030**
	(.249)	(.191)	(.009)	(.006)	(.033)	(.022)	(.027)	(.013)	(.018)	(.010)
Start time: minority	−.339	−.330*	−.020*	−.001	−.021	−.012	.055*	.025*	.028	.015
	(.246)	(.130)	(.009)	(.007)	(.033)	(.024)	(.027)	(.013)	(.019)	(.010)
Start time: nonminority	−.396	−.328	−.014	−.004	.020	−.003	.097**	.056**	.047*	.039**
	(.253)	(.293)	(.009)	(.007)	(.033)	(.025)	(.027)	(.014)	(.019)	(.012)

Start time: female	−.381	−.331	−.009	−.005	−.003	.002	.079**	.038**	.041*	.023*
	(.246)	(.186)	(.009)	(.006)	(.032)	(.023)	(.026)	(.013)	(.017)	(.010)
Start time: male	−.351	−.330	−.025**	0	.002	−.018	.074**	.039**	.035*	.028*
	(.249)	(.188)	(.009)	(.008)	(.032)	(.024)	(.026)	(.012)	(.018)	(.012)
Start time: low-performing	−.409	−.396*	−.018*	−.005	−.017	.001	.006	.032**	−.001	.031**
	(.253)	(.192)	(.009)	(.007)	(.032)	(.024)	(.025)	(.011)	(.017)	(.010)
Start time: non-low-performing	−.318	−.302	−.015	−.001	−.017	−.012	.074**	.043**	.023	.025**
	(.242)	(.180)	(.008)	(.006)	(030)	(.022)	(.023)	(.012)	(.015)	(.009)
Observation count	1,717,925		1,717,925		1,717,925		1,717,925		1,717,925	

NOTE.—This table presents results for middle grades student subgroups from school and student fixed-effect models. Cells shaded in gray denote statistically significant differences between the subgroups. EDS = economically disadvantaged student; FE = fixed effect.

* $p < .05$.

** $p < .01$.

fixed-effect model, postestimation tests indicate that economically disadvantaged students benefit more from later start times than their non–economically disadvantaged peers. The difference in estimates by students' economic status—approximately 0.25 days—is roughly 10% of the unadjusted difference in absences between these student subgroups.

Comparing within schools, analyses of disciplinary incidents indicate that students in rural areas and economically disadvantaged, minority, male, and low-performing students are all less likely to be suspended with a later school start time. There are also statistically significant differences within economic status and gender subgroups. In particular, the difference in suspension estimates between male and female students is especially large—that is, a 1.6-percentage-point difference is approximately 13% of the unadjusted difference in suspension rates between male and female students. The subgroup estimates from student fixed-effect analyses are not statistically significant. However, there is evidence that later start times especially benefit the suspension outcomes of middle grades students in rural versus urban areas.[14]

Analyses of math scores indicate that nearly all subgroups—in school and student fixed-effect models—benefit from a later start time. The main exception to this is middle grades students in urban areas, whose math scores do not increase with later start times. Postestimation tests suggest that students in rural areas and nondisadvantaged students (i.e., non–economically disadvantaged, White, non-low-performing) benefit more from a later start time than peers in the paired subgroup. For instance, there are statistically significant differences between the math estimates for racial/ethnic minority and nonminority students in both fixed-effect models. Last, the subgroup estimates in reading show that several groups have statistically significant results—that is, economically disadvantaged, non–economically disadvantaged, White, female, and male students all benefit from later start times. Unlike the math results, however, postestimation tests return little evidence that later start times differentially affect the reading achievement of one subgroup versus another.

Discussion

Summary

Few studies rigorously assess whether start times affect the educational outcomes of middle grades students (Edwards 2012; Heissel and Norris 2018). We addressed this gap in the literature by analyzing statewide data, considering a range of student engagement and achievement outcomes, and estimating start time effects for all middle grades students and for key student subgroups. Our focus on middle grades students is particularly important because biological changes in sleep often begin when adolescents are in middle school (Campbell et al. 2012) and because middle school is a time in which many students struggle (Cook et al. 2008; Rockoff and Lockwood 2010).

Overall, we have three main findings. First, although the results are somewhat inconsistent, we find that later start times are related to middle grades students' school engagement outcomes. In our preferred fixed-effect approaches, later start times predict a reduction in the likelihood of being suspended (when comparing within schools) but are not significantly associated with absences or course grades. Results from models that consider the impact of start times across a larger and more diverse set of North Carolina schools show that later start times—especially 8:30 a.m. or later—predict a reduction in the likelihood of being suspended and fewer absences. These suspension results are consistent with prior work on high school start times in North Carolina (Bastian and Fuller 2018). Further analyses are necessary to understand the mechanism(s) explaining our suspension results and to assess whether certain types of student misconduct particularly decrease with later start times. For example, it is possible that later start times enable students to be more alert and agreeable and that this benefits their interactions with teachers and peers. Mechanisms behind our absence results may be highlighted in figure A1 (figure A1 and table A1 are available online). Specifically, that figure shows a rise in absences after schools shift to an earlier start time. This is consistent with several studies (Bastian and Fuller 2022; Lenard et al. 2020) showing that absences increase after schools advance their start time. This suggests that it is difficult for students and families to adjust to an earlier schedule—that is, students are more likely to miss school if the bus is arriving earlier or if families need to drop their child off at school earlier.

Second, we find that later start times predict higher test scores in math and reading. Our results are consistent across school fixed-effect, student fixed-effect, multilevel, and propensity score models. These results suggest that later start times may improve middle grades students' cognitive functioning (as indicated by test scores) through improvements in sleep, alertness, attention, and memory formation (Hansen et al. 2005; Lufi et al. 2011). Our test score results are also consistent with prior start times work in middle schools (Edwards 2012). However, relative to Edwards (2012), we have an advantage because we examine all school districts in North Carolina. Importantly, our estimates for a 1-hour start time delay compare favorably to other policy relevant measures to boost student achievement but may come with much less of a financial cost (Jacob and Rockoff 2011).

Finally, our subgroup analyses return mixed results. Specifically, our subgroup analyses suggest that later start times particularly benefit the school engagement outcomes of traditionally disadvantaged student populations. Conversely, later start times have a greater impact on the math scores of nondisadvantaged student groups. For example, estimates indicate that a 1-hour delay in start times reduces economically disadvantaged students' absences and likelihood of being suspended significantly more than for non–economically disadvantaged students. Part of an explanation for these results may be differences between groups at baseline—that is, economically disadvantaged students are more likely to be absent and suspended than their non–economically disadvantaged peers. This pattern of results may also reflect the more direct relationship between later start times and engagement outcomes. It may take longer for a later start time to affect achievement outcomes, particularly for groups of students that face many potential barriers to improving academic performance. Our results also suggest that students in rural areas benefit more than students in urban areas, especially regarding their likelihood of being suspended and math test scores, from later middle school start times. This finding differs from our hypothesis that students in urban environments would benefit more and is interesting because urban schools are more likely to have early start times. It may be that early start times are particularly detrimental in rural areas, especially with North Carolina's large, county-based school districts, given increased travel time to schools and the need for students to wake up earlier in a rural district (relative to an urban district) to reach their school at the same starting time. Further work is needed to understand the mechanism(s) behind our rural start time results.

Limitations

Before considering implications, it is important to highlight the assumptions and limitations of this work. Our primary assumption involves the mechanisms underlying our results. We assume that later start times allow middle grades students to get more sleep and that with more sleep, students are more engaged with and successful in school. We do not have the data to test this mechanism—that is, sleep data is not available to assess how start times predict the sleep duration or quality of middle grades students in North Carolina. However, given prior work on school start times and adolescent sleep, we feel confident that later start times are leading to more sleep (Dunster et al. 2018; Lewin et al. 2017; Minges and Redeker 2016; Owens et al. 2017; Wolfson et al. 2007).

Methodologically, we controlled for a rich set of covariates and estimated a range of models to better isolate start time effects. The consistency in our estimates across model specifications strengthens our confidence in the validity of our results. Nevertheless, we acknowledge that these results are not causal and that there may be other factors, such as district/school policies or school/student characteristics, influencing the validity of estimates. Given the consistency of results across our fixed-effect, multilevel, and propensity score models (including ATC analyses), we are confident that our estimates generalize to different schools and student populations in North Carolina with different probabilities of having a later start time. It is unclear, however, how well these results will generalize outside of the state. Last, given our use of statewide administrative data, we note that there are many important outcomes that we did not assess in this study. These include perceptions of start time changes (from students, families, and school personnel), student social-emotional well-being, and impacts of start time changes on teachers. These outcomes warrant attention in future work.

Implications for Policy and Practice

Our findings introduce implications for state and district-level stakeholders. At the state level, officials can aid future research by requiring that each school report their start time in a standardized fashion and by authorizing the collection and analysis of additional data points (e.g., sleep measures, social-emotional measures). This could greatly advance the field's knowledge of start time impacts. States can also instigate start time changes by incentivizing districts to delay start times (e.g., providing additional funds or granting districts greater flexibility) or requiring that districts delay start times (e.g., recent legislation regarding middle and high school start times in California).

School districts do not need to wait on state-level actors because they can take independent action to delay start times. In doing so, it is important that district officials take the time to build support for the policy change across stakeholder groups and think comprehensively about the start times of all district schools. Certain districts are already starting to do this when they delay their middle and high school start times to align with research evidence.[15] Other districts have only delayed their high school start times and are missing an opportunity to better align their start times with research evidence. Although it is not a focus of the present study, there is also some evidence that early start times may modestly reduce the sleep duration and school attendance of elementary grades students (Bastian and Fuller 2022; Heissel and Norris 2018). To accommodate later secondary school start times, earlier elementary school start times are likely advisable. However, it is important for local education officials to make start time decisions that balance the needs of all students.

Finally, for officials at the state, district, and school levels, our results emphasize the broader connections between adolescent health and educational outcomes. Initiatives to improve student health—later start times, free school meals, school-based health clinics—may also be effective approaches to improve student engagement and achievement.

Notes

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Public Instruction for providing administrative data for this research and our anonymous reviewers for constructive feedback that improved the quality of the article.

1. Heissel and Norris (2018) provide estimates for prepubescents and adolescents based on the median puberty entry age (11 for girls and 13 for boys). This means that some middle grades students are included in their prepubescent category whereas others are included in their adolescent category.

2. Our analyses end with the 2016–17 school year because that is the last year of statewide start time data that we received from the North Carolina Department of Public Instruction.

3. Approximately 91% of the students in our analyses attend a school that North Carolina classifies as a middle school. The remaining students attend schools that North Carolina classifies as an elementary school or as an elementary/middle school combination.

4. In table A1, we present results from school fixed-effect analyses and student fixed-effect analyses limited to schools that North Carolina classifies as a middle school. These results are similar to those for all middle grades students.

5. Fixed-effect analyses may be biased if the schools that change their start times have different pretreatment trends in outcomes than schools that retain their start times. That is, results may not be due to start time changes but rather preexisting trends in student engagement and achievement. To assess this concern, we identified the schools that switched to an earlier or later start time and estimated event study models to examine nonparametric trends in our outcome measures. These event study models include a school fixed effect and control for the same set of covariates as in equation (1). The results, displayed in figure A1, indicate that differences in pretreatment trends, particularly for schools switching to a later start time, are not statistically significant. This supports the validity of our fixed-effect approaches.

6. Student fixed-effect models help address a concern that students might change schools in response to a start time change.

7. Our student and school covariates are a mixture of time-invariant and varying characteristics. Time-invariant school (student) characteristics are omitted from school (student) fixed-effect models.

8. The 120 schools making start time changes are not clustered within a small number of school districts. Of the 115 school districts in North Carolina, 40 had at least one school making a start time change in our sample, and 18 school districts had at least one school making a start time change of 30 minutes or more.

9. We calculate propensity scores with probit models where the start time category is the outcome, and we control for student and school characteristics. We assign individual student observations weights using inverse propensity score weighting. We generate coefficients through second stage doubly robust models.

10. This is consistent with our event study results in figure A1. Specifically, that figure shows that it takes several years for suspensions to decrease in schools delaying their start times.

11. Separate analyses for course grades in math and reading return similar findings to the estimates in table 4—that is, positive results for schools starting between 8:00 and 8:29 a.m. and insignificant results in other school or student fixed-effect analyses.

12. These returns to teacher experience estimates come from teacher fixed-effect models with first-year teachers as the reference group. We included single-year experience

indicators for teachers with 1–10 years of experience and a single indicator for teachers with more than 10 years of experience.

13. These analyses do not include a main effect for school start time.

14. Like the overall results for course grades, there is little indication that later start times improve the GPAs of particular subgroups or differentially affect one subgroup versus another.

15. In recent years, Cherry Creek, Colorado; St. Paul, Minnesota; and Seattle, Washington have all delayed their middle and high school start times to better align with the AAP's recommendation.

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