GENERAL ARTICLE

School Start Times, Sleep, Behavioral, Health, and Academic Outcomes: A Review of the Literature

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ABSTRACT

BACKGROUND: Insufficient sleep in adolescents has been shown to be associated with a wide variety of adverse outcomes, from poor mental and physical health to behavioral problems and lower academic grades. However, most high school students do not get sufficient sleep. Delaying school start times for adolescents has been proposed as a policy change to address insufficient sleep in this population and potentially to improve students’ academic performance, reduce engagement in risk behaviors, and improve health.

METHODS: This article reviews 38 reports examining the association between school start times, sleep, and other outcomes among adolescent students.

RESULTS: Most studies reviewed provide evidence that delaying school start time increases weeknight sleep duration among adolescents, primarily by delaying rise times. Most of the studies saw a significant increase in sleep duration even with relatively small delays in start times of half an hour or so. Later start times also generally correspond to improved attendance, less tardiness, less falling asleep in class, better grades, and fewer motor vehicle crashes.

CONCLUSIONS: Although additional research is necessary, research results that are already available should be disseminated to stakeholders to enable the development of evidence-based school policies.

Keywords: adolescents; school health; sleep; school start times; school health policy.


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Without doubt, the problem of sleepy adolescents has existed for a long time. However, it is only since the late 1980s that this issue has progressed from teachers’ anecdotes of students falling asleep in class and parental complaints of daily struggles to get their children out of bed to scientific investigations into the causes and consequences of insufficient sleep.

Most adolescents may need at least 9 hours sleep per night;1-3 however, less than 8% of high school students report getting this amount.4 Less than one-third of students report 8 or more hours of sleep, and this proportion decreases as school grade level increases so that less than one-fourth of high school seniors get this amount.4 Healthy People 2020, a national initiative designed to guide disease prevention and health promotion efforts to improve the health of all Americans (http://www.healthypeople.gov/), contains 4 objectives related to sleep, including one for adolescents.5 This objective is to “increase the proportion of students in grades 9 through 12 who get sufficient sleep (defined as 8 or more hours of sleep on an average school night).”

Insufficient sleep in children and adolescents has been shown to be associated with a wide variety of adverse outcomes in multiple aspects of their lives from poor mental and physical health to behavioral...
problems and poor academic grades. Insufficient sleep has been linked to excess weight,6-13 decreased physical activity,14 and increased food intake, possibly due to alterations in appetite-regulating hormones.12 Results of investigations into longitudinal changes in weight attributable to sleep duration, however, have been mixed.10,15

A solid body of literature has found that insufficient sleep in this young population is tied to poor mental health, including depression, depressive symptoms,8,16-22 and suicidal ideation.8,18,20,22-25 In addition, a few studies have shown an association between insufficient sleep and unhealthy risk behaviors including alcohol use,17,19,20,22 tobacco smoking,20,22 marijuana use,20,22 use of other illicit/prescription drugs,22 unhealthy weight control strategies,26 and recent sexual activity.20 Other factors that have been found to be associated with insufficient sleep include risk-taking behaviors,27 bullying,28 school violence-related behaviors,29 and physical fighting.20 Short sleep duration has also been found to be associated with a higher risk of unintentional injury.30 Finally, students who do not get enough sleep also may be more likely to have problems paying attention and poor academic performance,17,21,31-36 although not all research agrees.37,38 One of these negative studies failed to find a correlation between school night sleep duration and grade point average.37

However, class grading and subsequently grade point averages are not standardized and may vary by subject, teacher, and school. That study also did not adjust by sex of student, which was a strong predictor of grade point average. Ming et al found that “students with a sleep length of less than 7 hours on both weekdays and weekends exhibited poorer performance, while those who made up this sleep loss on weekends did not.”38 That study also relied on a nonstandardized measure of academic performance and did not adjust for variables such as grade in school, which is strongly related to prevalence of insufficient sleep.

Adolescents tend to get insufficient sleep because of a combination of late bedtimes and early rise times. External factors that contribute to later bedtimes among adolescents include an increase in schoolwork; participation in afterschool activities, including employment; fewer parent-set bedtimes; and late-night use of technology in the bedroom.39-43 Biology also plays a part in later bedtimes among adolescents. One of the early changes associated with puberty is alteration of a child’s circadian rhythms, such that adolescents are more alert in the afternoons and evenings and require morning sleep.44 Their natural body clocks can keep adolescents awake until 11 PM or later, in spite of going to bed earlier and good sleep hygiene, such as avoiding stimulating activity at night and minimizing caffeine intake in the afternoon or evening.39 School-based sleep promotion programs have been tried as a means of improving sleep hygiene among adolescents. However, these programs may improve knowledge of sleep without having a significant effect on behavior.45,46

Rise times, on the other hand, are primarily determined by a single factor—school start times.43 Delaying school start times for adolescents has been proposed as a policy change to address insufficient sleep in this population and potentially to improve students’ academic performance, reduce engagement in risk behaviors, and improve health. In 2014, the American Academy of Pediatrics published a policy statement urging middle and high schools to adjust start times to permit students to obtain adequate sleep and improve physical and mental health, safety, academic performance, and quality of life.3 This paper reviews studies examining the association between school start times, sleep, and other outcomes including academic performance, mental health, and motor vehicle collisions among adolescent students. This article, and especially the table provided, is intended to be a resource for educators, parents, and other stakeholders who wish to learn more about the impact of changing school start times for adolescents.

METHODS

An outline of the steps in identification of articles and reports included in the literature review is presented in Figure 1. To be included in the review, analyses had to include the variable of “school start time” either by comparing different schools with different start times (cross-sectional) or the same schools before and after changes in start times (longitudinal). Because the focus of this review is on the effect of school start times on adolescent students, studies that focused on elementary school (pre-middle school) students were excluded. In addition, reports had to be available in English, but could include schools either in or outside the United States. Articles for the literature review were initially identified through a PubMed search for “school start time” OR “school start times” (Step A). Some exclusions from this initial search included a study that compared students in private or public schools to homeschooled students,47 a comparison of adolescent sleep during summer and during the school year,48 and one that modeled the effect of modifying school start times on the frequency of encounters between child pedestrians and motor vehicles.49 Another broader PubMed search for “sleep” AND “adolescent” AND “school” resulted in approximately 3200 articles (Step B). Titles and abstracts were reviewed to identify studies that might meet primary inclusion criteria. Full-text review of candidate articles confirmed inclusion of articles for this review. Reference lists of articles identified in Steps A and B and reviews of the topic of school start
times were reviewed for identification of additional reports (Step C). Several of the earliest studies with results presented in abstract form only were identified in this manner. A Scopus search for “school start time” (all fields) found 320 documents (Step D), of which 3 satisfied the inclusion criteria and had not been identified in previous steps. Finally (Step E), one additional nonduplicative report was identified in the reference list for articles in Step D. Final searches in Steps A, B, and D were conducted July 1, 2015. For this review, 38 reports were reviewed for years of study, study design, sample size, students’ ages, location, school start times, outcomes, and key reported findings. Five of these reports are listed more than once in the table. Three reports included multiple study populations whose data are analyzed separately. Three reports included cross-sectional and longitudinal components, with data for each component presented separately. The primary limitation to this review is its reliance on indexing by PubMed and Scopus, which could lead to omission of reports not indexed by these databases. To address this limitation, we also examined the reference lists on previous articles on the topic of school start times (Steps C and E). Of 38 reports 5 were identified in this manner. Publication bias and overrepresentation of studies with significant results is also possible, however, some studies included in this review had results that did not agree with the majority.

Types of School Start Time Studies

We reviewed 38 reports on the impact of changes in school start time (Table 1). Unfortunately, the earliest reports which have been cited frequently, were only published in abstract form. However, since they seem to have provided the impetus for much of the subsequent research and are fairly detailed, we have included them in this review. The studies presented in this review can be categorized as either cross-sectional or longitudinal. The cross-sectional studies simply compared characteristics for students at 2 or more schools having different start times, such that School A had an earlier start time than School B and compared how students at the 2 schools differed with respect to such outcomes as sleep duration, school attendance, academic performance, and morning traffic accidents among teens.

Changing school start times is often a major endeavor that involves coordination between school faculty and staff, transportation resources, parents, students, and administration, and can take years to accomplish. Cross-sectional studies can be conducted without having to wait for a school or school district to undertake a change in school start time. However, as with all cross-sectional studies, only associations between school start times and other variables can be shown—not cause and effect. Other school characteristics, such as socioeconomic status of students, can also have effects on sleep and other outcomes but is often not reported.
<table>
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<tr>
<th>Study Author(s) (Year)</th>
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<td>Carskadon et al (1998)</td>
<td>Longitudinal</td>
<td>26 (same students)</td>
<td>Grades 9-10</td>
<td>Rhode Island</td>
<td>Year 1: 9th grade: 0825 Year 2: 10th grade: 0720</td>
<td>Sleep schedules (sleep diaries and data from electronic wrist monitors), multiple sleep latency tests, polysomnography</td>
<td>Earlier SST associated with earlier rise time (p &lt; .05), shorter sleep duration (p &lt; .05), shorter REM latency (p &lt; .05), shorter sleep latency on multiple sleep latency tests (p = .04), and more students with REM sleep during multiple sleep latency tests (p = NR)</td>
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<td>Epstein et al (1998)</td>
<td>Cross-sectional</td>
<td>572</td>
<td>Grade 5</td>
<td>18 schools throughout Israel</td>
<td>Early risers: 0710 (2+ times/week) Regular risers: 0800</td>
<td>Sleep duration, bedtime, rise time (weekdays and weekends), sleepiness, daytime functioning, sleep difficulties</td>
<td>Early risers reported shorter weekday sleep duration (p = .0004), more complaints of feeling tired throughout the day (p = .045), more daytime sleepiness (p = .004), and more difficulty concentrating and paying attention (p = .0001)</td>
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<td>Wahlstrom et al (1998)</td>
<td>Cross-sectional (3 districts)</td>
<td>NR</td>
<td>Grades 10-12</td>
<td>Minnesota</td>
<td>School Sleep Habits Survey (study, work, sleep, and school habits and preferences)</td>
<td>Similar associations as in HS students. Later SST corresponded to longer sleep duration (p &lt; .05 for A versus C), same bedtime, and longer weeknight sleep duration (p &lt; .0001). Later SST also associated with less daytime sleepiness (p &lt; .0001), less struggling to stay awake during academic tasks (p &lt; .01 for A versus C), fewer tardies (p &lt; .001), less falling asleep in morning classes (p &lt; .005), fewer depressive symptoms (p &lt; .001 for A versus C), less time spent at work during school week (p &lt; .05), and higher self-reported grades (p &lt; .05)</td>
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<tr>
<td>Wahlstrom et al (1998)</td>
<td>Cross-sectional (3 districts)</td>
<td>NR</td>
<td>Grades 7-8</td>
<td>Minnesota</td>
<td>School Sleep Habits Survey (study, work, sleep, and school habits and preferences)</td>
<td>Similar associations as in HS students. Later SST corresponded to longer sleep duration (p &lt; .05 for A versus C), same bedtime, and later rise time (p &lt; .05 for A versus C). Later SST also associated with less daytime sleepiness (p &lt; .05 for A versus B), less struggling to stay awake during academic tasks (p &lt; .05 for A versus B), lower depression scores (p &lt; .05 for A versus B), and less hours of homework (p &lt; .05 for A versus B and C)</td>
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<td>Wolfson and Carskadon (1998)</td>
<td>1994</td>
<td>Cross-sectional (students in 4 schools in 3 public school districts)</td>
<td>31-20</td>
<td>Grades 9-12</td>
<td>Rhode Island</td>
<td>0710-0730</td>
<td>School Sleep Habits Survey (study, work, sleep, and school habits and preferences)</td>
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<td>Baldus (2002)</td>
<td>Not specified</td>
<td>Longitudinal (before versus after SST change)</td>
<td>31 (same recruits, 2 sleep schedules)</td>
<td>US Navy recruits (mean 21.3 years)</td>
<td>Great Lakes, Illinois</td>
<td>Early reveille: 2100-0500 sleep time. Later reveille: 2200-0600 sleep time</td>
<td>Sleep duration</td>
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<td>Wahlstrom (2002)</td>
<td>1994-2000</td>
<td>Longitudinal (before versus after SST change)</td>
<td>&gt;12,000 (7 HS)</td>
<td>Grades 9-12</td>
<td>Minneapolis, Minnesota</td>
<td>Pre-change: 0715. Post-change: 0840</td>
<td>Class grades, attendance, tardiness, graduation rates, rates of continuous enrollment</td>
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<td>Wahlstrom et al (2002)</td>
<td>1997-2001</td>
<td>Cross-sectional (Minneapolis HS versus District B)</td>
<td>467 (Minneapolis HS) 169 (District B)</td>
<td>Grades 9-12</td>
<td>Minneapolis, Minnesota</td>
<td>Minneapolis HS 0840 District B 0730</td>
<td>School Sleep Habits Survey (study, work, sleep, and school habits and preferences)</td>
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<td>Dexter et al (2003)</td>
<td>2002</td>
<td>Cross-sectional (2 schools with different SSTs)</td>
<td>193 (School 1) 587 (School 2)</td>
<td>Grades 10-11</td>
<td>Altoona (1) and Chippewa Falls (2), Wisconsin</td>
<td>School 1 0750 School 2 0835</td>
<td>Weeknight sleep duration, Epworth Sleepiness Scale</td>
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<td>Adam et al (2007)</td>
<td>Cross-sectional</td>
<td>2454</td>
<td>5-19 years</td>
<td>Nationally (USA) representative</td>
<td>NR</td>
<td>Sleep duration, bedtime, rise time (weekdays and weekends)</td>
<td>For older children (12-19 years), an hour later SST was associated with 0.57 hour more weekday sleep ($p &lt; .01$), a 0.62 hour later rise time ($p &lt; .01$), and no difference in bedtime</td>
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<td>Wolfson et al (2007)</td>
<td>Cross-sectional (2 schools with different SSTs)</td>
<td>205</td>
<td>Grades 7-8</td>
<td>Urban New England school district</td>
<td>Early school: 0715, Late school: 0837</td>
<td>School Sleep Habits Survey(35) (sleep duration, bedtime, rise time—weekdays and weekends, sleepiness, sleep-wake behavior problems, sleep hygiene scale), official academic performance, attendance, tardiness</td>
<td>Late SST associated with later bedtimes (in autumn only) ($p &lt; .05$), later rise times ($p &lt; .001$), longer sleep duration (65 minutes) ($p &lt; .001$), less weekend oversleep (in autumn only) ($p &lt; .001$), less daytime sleepiness in the autumn ($p &lt; .05$), fewer sleep-wake behavior problems in the spring ($p &lt; .05$), higher grades (eighth grade only) ($p &lt; .01$), and fewer tardies ($p &lt; .001$). Weekend sleep patterns were similar compared to Year 1, in Year 2 students reported longer average sleep duration ($p &lt; .001$), less catch-up sleep on weekend nights ($p &lt; .001$), and lower scores on the Epworth Sleepiness Scale(35), how time spent before and after school, motor vehicle crash rates among 17- and 18-year-old students</td>
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<td>Danner and Phillips (2008)</td>
<td>Longitudinal (before versus after SST change)</td>
<td>9966 (Year 1), 10,666 (Year 2)</td>
<td>Grades 6-12</td>
<td>Kentucky</td>
<td>Year 1 (Y1): 0730 (HS), Year 2 (Y2): 0830 (HS)</td>
<td>Bedtime and rise time (weekdays and weekends), number of naps, Epworth Sleepiness Scale(35), how time spent before and after school, motor vehicle crash rates among 17- and 18-year-old students</td>
<td>Compared to Year 1, in Year 2 students reported longer average sleep duration ($p &lt; .001$), less catch-up sleep on weekend nights ($p &lt; .001$), and lower scores on the Epworth Sleepiness Scale ($p &lt; .001$). Crash rates in the study county decreased after the SST delay ($p &lt; .01$)</td>
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<td>O'Malley and O'Malley (2008)</td>
<td>Longitudinal (before versus after SST change)</td>
<td>297 (pre-delay), 977 (post-delay)</td>
<td>Grades 9-12</td>
<td>Wilton, Connecticut</td>
<td>Pre-delay: 0735, Post-delay: 0815</td>
<td>Condensed School Sleep Habits Questionnaire(35)</td>
<td>Later SST corresponded to longer weeknight sleep duration ($p &lt; .001$), later rise time ($p &lt; .001$), later bedtime ($p = .03$), and fewer problems with sleepiness ($p &lt; .001$)</td>
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<td>Owens et al (2010)</td>
<td>Longitudinal (before versus after SST change)</td>
<td>201 (mostly boarders)</td>
<td>Grades 9-12</td>
<td>Rhode Island</td>
<td>Pre-change: 0800, Post-change: 0830</td>
<td>Bedtime and rise time (weekdays and weekends), sleepiness-related behaviors, health center visits, absences/tardies</td>
<td>Delayed SST associated with longer school night sleep durations ($p &lt; .001$), earlier bedtimes ($p &lt; .001$), later rise times ($p &lt; .001$), greater sleep satisfaction ($p &lt; .001$), less sleepiness ($p &lt; .001$), less sleepiness-related behaviors ($p &lt; .001$), less depressed mood ($p &lt; .001$), fewer visits to health center for fatigue-related symptoms ($p = .003$), and fewer absences/tardies ($p &lt; .05$)</td>
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<td>Zhang et al (2010)<strong>6</strong></td>
<td>Not specified</td>
<td>Cross-sectional</td>
<td>4470 (mother-father-child community-based trios)</td>
<td>Mean age 9.2 ± 1.8 years</td>
<td>Hong Kong</td>
<td>Morning school: ~0735</td>
<td>Bedtime, rise time, time-in-bed (weekday, weekend, and long holidays), napping</td>
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<td>Carrell et al (2011)<strong>58</strong></td>
<td>2004-2009</td>
<td>Cross-sectional</td>
<td>6165 US Air Force Academy freshmen</td>
<td>Colorado Springs, Colorado</td>
<td>Early (2004-2005, 2006-2007): 0700 Middle (2006-2007): 0730 Late (2007-2008, 2008-2009): 0750</td>
<td>Academic grades by scheduling characteristics</td>
<td>Students assigned to a first period course had poorer grades; however, this association became weaker and became statistically insignificant as the start time moved from 0700 to 0750. Students performed worse in first period classes compared with other periods, but those with first period classes also performed worse in their subsequent classes on that schedule day</td>
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<td>Hinrichs (2011)<strong>59</strong></td>
<td>1999-2002</td>
<td>Cross-sectional (primarily, but with a longitudinal component)</td>
<td>196617 observations (may include repeat test takers) (students from 73 schools)</td>
<td>Grades 10-12</td>
<td>Twin Cities metropolitan area (Minneapolis-St. Paul, Minnesota)</td>
<td>0715-0840</td>
<td>ACT scores, attendance rates</td>
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<tr>
<td>Hinrichs (2011)<strong>59</strong></td>
<td>2000-2006</td>
<td>Cross-sectional</td>
<td>Approximately 400 public high schools</td>
<td>Grades 10-12</td>
<td>Kansas (public high school in the state)</td>
<td>Mean (SD): 0759 (0015)</td>
<td>School-level test score data on Kansas Mathematics Assessment, Reading Assessment, Science Assessment, and Social Studies Assessment</td>
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<tr>
<td>Hinrichs (2011)<strong>59</strong></td>
<td>2000-2007</td>
<td>Cross-sectional</td>
<td>75 schools</td>
<td>Grades 9-12? (not specified in report, but described as high schools)</td>
<td>Virginia suburbs of Washington, D.C.</td>
<td>NR</td>
<td>Scores on standardized end-of-course exams</td>
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<td>Lufi et al (2011)<strong>70</strong></td>
<td>Not specified</td>
<td>Longitudinal (before versus after SST change—short-term change only)</td>
<td>47</td>
<td>Grade 8</td>
<td>Israel</td>
<td>Early class: 0730</td>
<td>Sleep duration, bedtime, rise time, sleep efficiency (data from electronic wrist monitors), attention tests</td>
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<td>Ming et al (2011)</td>
<td>Cross-sectional</td>
<td>1941 (students from 2 public high schools, 1 vocational high school, and 2 extracurricular high school programs whose students came from various high schools throughout the state)</td>
<td>Grades 9-12</td>
<td>New Jersey</td>
<td>Varied from 0700 to 0845</td>
<td>Sleep duration, bedtime, rise time, napping, perceived sleep adequacy, night awakenings, prolonged sleep onset</td>
<td>Early SST associated with short weekday sleep duration (&lt;7 hours, p &lt; .0001), lower likelihood of receiving adequate night sleep (p &lt; .0001), and higher likelihood of afterschool naps (p &lt; .0001) and night awakenings (p = NR)</td>
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<tr>
<td>Vorona et al (2011)</td>
<td>Cross-sectional (2 cities with different SSTs in public schools)</td>
<td>NR 16-18 years</td>
<td>Virginia Beach and Chesapeake, Virginia</td>
<td>Early schools (Virginia Beach): 0720-0725. Late schools (Chesapeake): 0840-0845</td>
<td>Motor vehicle crash rates in each city</td>
<td>Crash rates among 16- to 18-year-olds were higher (p &lt; .01) in Virginia Beach (which has earlier SSTs)</td>
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<td>Yilmaz et al (2011)</td>
<td>Cross-sectional</td>
<td>3441 15-18 years</td>
<td>Gaziantep, Turkey</td>
<td>Early: 0700-0800 (morning). Late: 1200-1240 (afternoon)</td>
<td>Bedtime, rise time, sleep latency (weekdays and weekends), ideal night sleep time, napping, sleep hygiene</td>
<td>Compared with those with afternoon SSTs, students with morning SSTs reported shorter night time sleep on weekdays and weekends (p &lt; .001) and shorter ideal night time sleep (p &lt; .01). Early SST students were more likely to report daytime napping and needing help to awaken in the morning (p &lt; .001) and less likely to report a long sleep latency (&gt;30 minutes) on weekdays and weekends (p &lt; .001)</td>
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<tr>
<td>Vedaa et al (2012)</td>
<td>Cross-sectional</td>
<td>55 students (intervention school) 51 students (control school)</td>
<td>Grade 10</td>
<td>Norway</td>
<td>Intervention school: 0930 (Mondays), 0830 (rest of week) Control school: 0880 (all days)</td>
<td>Karolinska Sleepiness Scale;92 reaction time tests, Positive and Negative Affect Schedule; sleep diary</td>
<td>Compared to control school students, students at intervention school slept &gt; 1 hour longer on Sunday night (p &lt; .05), had a smaller difference between Saturday and Sunday night sleep duration (p = .04), and shorter sleep latency on Sunday night. Students at the intervention school had fewer lapses on reaction time tests (p = .02) and faster reaction times (p = .02) on Monday than Friday compared to the control students. No differences in sleepiness or positive or negative affect</td>
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<td>Edwards (2012)97</td>
<td>Cross-sectional component</td>
<td>20 530 students (1999-2000)</td>
<td>Grades 6-8</td>
<td>Wake County, North Carolina</td>
<td>0730-0845 (53% of students start at 0730, 22% start at 0815)</td>
<td>End of year standardized test scores in reading and math; time spent watching television and doing homework; absences</td>
<td>Later SST corresponded to higher standardized test scores on both math and reading tests (1 hour later corresponded to 3 percentile increase), less time watching television, more time doing homework, and fewer absences</td>
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<tr>
<td>Edwards (2012)97</td>
<td>Longitudinal component (before versus after SST change for schools that changed SST between 1999 and 2006)</td>
<td>20 530 students (1999-2000)</td>
<td>Grades 6-8</td>
<td>Wake County, North Carolina</td>
<td>0730-0845 (some schools started earlier and some started later after SST change)</td>
<td>End of year standardized test scores in reading and math; time spent watching television and doing homework</td>
<td>Later SST corresponded to higher standardized test scores on both math and reading tests (1 hour later corresponded to 2 percentile increase in math and 1.5 percentile increase in reading), less time watching television, and more time doing homework</td>
</tr>
<tr>
<td>Borlase et al (2013)99</td>
<td>Longitudinal (before versus after SST change in 2006)</td>
<td>212 students in Grades 9 and 12 (1999)</td>
<td>13-17 years</td>
<td>Wellington, New Zealand</td>
<td>Senior students (Grade 12): 0900 (pre), 1030 (post) Junior students (Grades 9, 11): 0800 (no change)</td>
<td>School Sleep Habits Survey (study, work, sleep, and school habits and preferences), technology use, Epworth Sleepiness Scale, morningness-eveningness preference, sleep/fatigue problems</td>
<td>Grade 12 students after the SST delay (2008) had longer sleep duration (p &lt; .01), earlier bedtime (p &lt; .01), later rise time (p &lt; .001), less sleep discrepancy (sleep duration on school nights versus non-school nights) (p &lt; .01), and less sleepiness (p &lt; .01) compared to Grade 12 students before the delay or Grade 11 students (2008)</td>
</tr>
<tr>
<td>Li et al (2013)36</td>
<td>Cross-sectional/longitudinal (6 schools before versus after SST change)</td>
<td>525 (baseline)</td>
<td>Grades 4-5</td>
<td>Shanghai, China</td>
<td>2 control schools, no change in SST: 0730</td>
<td>Sleep duration, bedtime, rise time, daytime sleepiness (Chinese version of Children’s Sleep Habits Questionnaire)</td>
<td>At baseline, students at the 6 schools had similar sleep characteristics. At follow-up, later SST associated with later bedtime (p &lt; .05), rise time (p &lt; .001), longer sleep duration (p &lt; .001), and less daytime sleepiness. Comparing baseline to follow-up, mean sleep duration decreased for students at control schools (no change in SST) but increased for students at intervention schools</td>
</tr>
<tr>
<td>Perkinson-Gloor et al (2013)34</td>
<td>Cross-sectional</td>
<td>2573 (early)</td>
<td>Grades 8-9</td>
<td>Midsize city in northwestern Switzerland</td>
<td>Early, not specified. Delayed: 20 minutes later</td>
<td>Sleep duration, bedtimes, rise times (weekdays and weekends), daytime sleepiness, behavioral persistence attitude toward life school grades (mathematics and German language)</td>
<td>Later SST associated with longer weekend sleep duration (p &lt; .001), later weekend bedtimes (p &lt; .04 boys, p &lt; .01 girls), later weekday rise times (p &lt; .001), and less daytime sleepiness (p &lt; .001 boys, p = .03 girls)</td>
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<tr>
<td>Study Author(s) (Year)</td>
<td>Study Design</td>
<td>Sample Size</td>
<td>Age</td>
<td>Location</td>
<td>School Start Times</td>
<td>Outcomes</td>
<td>Key Findings</td>
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<td><strong>Short et al (2013)</strong>&lt;sup&gt;26&lt;/sup&gt; 1997-2000 (US) 200B-2010 (Australia)</td>
<td>Cross-sectional</td>
<td>302 (US) 385 (Australia)</td>
<td>Grades 9-12 (mean age 160 years) (US) Years 9-11 (mean age 156 years) (Australia)</td>
<td>Rhode Island (US) South Australia (Australia)</td>
<td>US: ~0745 Australia: 0820-0900</td>
<td>School Sleep Habits Survey&lt;sup&gt;25&lt;/sup&gt; (study, work, sleep, and school habits and preferences), 8-day sleep diary</td>
<td>School night sleep duration correlated with SST ($r = .29$, $p &lt; .001$). SST had largest effect on sleep duration (compared with parent-set bedtimes and extracurricular load)</td>
</tr>
<tr>
<td><strong>Boergers et al (2014)</strong>&lt;sup&gt;67&lt;/sup&gt; 2010-2011</td>
<td>Longitudinal (before versus after SST change)</td>
<td>197 (boarding students)</td>
<td>Grades 9-12</td>
<td>Rhode Island</td>
<td>Pre-delay: 0800 Post-delay: 0825</td>
<td>School Sleep Habits Survey&lt;sup&gt;25&lt;/sup&gt; (study, work, sleep, and school habits and preferences), caffeine intake questionnaire</td>
<td>After SST delay, mean wake times (school days) were later ($p &lt; .001$), mean school night sleep duration was longer ($p &lt; .001$), school night bedtimes did not change. The percentage that slept ≥ 8 hour on school nights increased from 18% to 44% ($p &lt; .001$). There were no changes in nonschool night sleep patterns. After delay, sleepiness scores ($p &lt; .001$), depression scores ($p &lt; .001$), and caffeine use decreased ($p &lt; .05$). No changes in number of hours engaged in athletics, extracurricular activities, and homework were reported. No changes in self-reported grades were reported. Weekday sleep duration decreased to baseline after reverting to pre-delay SST</td>
</tr>
<tr>
<td><strong>Escribano and Diaz-Morales (2014)</strong>&lt;sup&gt;77&lt;/sup&gt; Not specified</td>
<td>Cross-sectional (students in 3 schools)</td>
<td>669</td>
<td>12-16 years</td>
<td>Madrid, Spain</td>
<td>0800, 0815, 0830</td>
<td>Bedtimes, rise times, sleep duration, attention task (at 3 times during school day on 2 consecutive wednesdays), morningness/eveningness, inductive reasoning</td>
<td>Average school night sleep was more than 30 minutes longer for 0830 SST than 0800 SST ($p &lt; .001$). Attention level highest for 0815 SST on first wednesday ($p &lt; .001$), but no difference by SST on second wednesday. Inductive reasoning score was lowest for 0800 SST ($p &lt; .01$)</td>
</tr>
<tr>
<td><strong>Chen et al (2014)</strong>&lt;sup&gt;79&lt;/sup&gt; 2009</td>
<td>Cross-sectional</td>
<td>4801 (students from 12 senior HS and 12 junior HS)</td>
<td>11-20 years</td>
<td>Shanghai, China</td>
<td>Dichotomized: Before 0700 versus 0700 or later</td>
<td>Adolescent Sleep Wake Scale&lt;sup&gt;81&lt;/sup&gt; (bedtimes, wake-up times, sleep duration (weekdays &amp; weekends), parents’ sleep habits</td>
<td>SST before 0700 associated with sleeping &lt; 8 hours ($p = .015$).</td>
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<tr>
<td>Study Author(s) (Year)</td>
<td>Study Design</td>
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<tr>
<td>Vorona et al (2014)</td>
<td>Cross-sectional (2 counties with different SST in public schools)</td>
<td>16-18 years</td>
<td>Chesterfield County, Virginia and Henrico County, Virginia</td>
<td>Early (Chesterfield): 0700</td>
<td>Late (Henrico): 0845</td>
<td>Weekday motor vehicle crash rates during the school years (September-May) 2009-2010 and 2010-2011</td>
<td>In 2009-2010, crash rates among 16- to 18-year-olds were higher (p &lt; .05) in Chesterfield County (which has earlier SST). In 2010-2011, crash rates among 16- to 17-year-olds were higher (p &lt; .05) in Chesterfield County, but difference was not statistically significant when 18-year-olds were included in comparison (p = .09). Adult crash rates for the same time periods did not differ between the 2 counties.</td>
</tr>
<tr>
<td>Milić et al (2014)</td>
<td>Cross-sectional</td>
<td>821 (students from 4 HS)</td>
<td>15-19 years</td>
<td>Osijek, Croatia</td>
<td>Early: 0700 or 1300 (alternating weeks)</td>
<td>Epworth Sleepiness Scale, morningness/eveningness, napping, academics (final semester grade)</td>
<td>Students with earlier SST performed better academically and had earlier chronotypes (morning preference) (p &lt; .001). No difference in sleepiness</td>
</tr>
<tr>
<td>Wahlstrom et al (2014)</td>
<td>Cross-sectional</td>
<td>9089</td>
<td>Grades 9-12</td>
<td>5 HS in Minnesota, 2 HS in Colorado, 1 HS in Wyoming</td>
<td>After delay, SST varied from 0800 to 0855</td>
<td>Sleep duration, bedtimes, rise times (weekdays and weekends), sleep-related tardiness, sleeping during class</td>
<td>SST associated with percent of students sleeping ≥ 8 hours/school night ($R^2 = .8878$, &lt; 50% for schools starting before 0830, 66% for school starting at 0855)</td>
</tr>
<tr>
<td>Wahlstrom et al (2014)</td>
<td>Longitudinal (before versus after SST change)</td>
<td>446 (pre-delay)</td>
<td>Grades 9-12</td>
<td>Jackson Hole, Wyoming</td>
<td>Pre-delay: 0735</td>
<td>Sleep duration, bedtimes, rise times (weekdays and weekends)</td>
<td>Average school night sleep increased from 7.5 hours to 8.2 hours. Average weekend sleep decreased from 9.3 hours to 9.0 hours. Most schools saw a decrease in tardiness and an increase in GPA. Two out of the 4 areas for which car crash data was available saw a major decrease in car crashes involving 16- to 18-year-old drivers (≥65%). One saw a small decrease (6%), while another saw a small increase (9%).</td>
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<tr>
<td>Wahlstrom et al (2014)</td>
<td>Longitudinal (before versus after SST change)</td>
<td>NR</td>
<td>Grades 9-12</td>
<td>5 HS in Minnesota, 2 HS in Colorado, 1 HS in Wyoming</td>
<td>Before delay, SST varied from 0730 to 0750</td>
<td>Attendance, academic performance, car crashes</td>
<td>Later SST associated with later bedtime (10-minute later bedtime for each 30 minute delay in SST). Later SST associated with longer sleep duration for SST before 0801 only (11 minutes for each 30-minute delay in SST). Difference among boys only and varied by urbanicity. Sleep duration increased for boys in major metropolitan areas and decreased for boys in nonurban counties. SST not associated with weekend compensatory sleep.</td>
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<tr>
<td>Study Author(s) (Year)</td>
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<tr>
<td>Allen and Mirabile (1989)</td>
<td>Cross-sectional</td>
<td>61</td>
<td>Grades 10-12 (mean age 17.1 years)</td>
<td>NR</td>
<td>Early school: 0730</td>
<td>Later SST corresponded to later rise times (p &lt; .05), but no difference in bedtimes. Sleep duration difference not significantly different</td>
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<tr>
<td>Allen (1992)</td>
<td>Cross-sectional</td>
<td>102</td>
<td>Grade 12</td>
<td>NR</td>
<td>Early school: 0740</td>
<td>Earlier SST corresponded to shorter weeknight sleep duration (p &lt; .03), more sleep problems (p = .04), and later weekend rise times (p = .03)</td>
<td></td>
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<tr>
<td>Carskadon et al (1995)</td>
<td>Longitudinal (before versus after SST change)</td>
<td>7</td>
<td>Grade 9-10</td>
<td>Rhode Island</td>
<td>Early (Grade 9): 0825</td>
<td>Earlier SST (65 minutes) corresponded to shorter sleep duration (38 minutes, p &lt; .02) due to earlier rise times (59 minutes, p &lt; .005). No significant difference in school night sleep start time</td>
<td></td>
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<tr>
<td>Kowalski and Allen (1995)</td>
<td>Cross-sectional</td>
<td>97 (early school) 119 (late school)</td>
<td>Grades 11-12</td>
<td>NR</td>
<td>Early school: 0720</td>
<td>Earlier SST corresponded to shorter weeknight sleep duration (p = .002)</td>
<td></td>
</tr>
<tr>
<td>Wolfson et al (1995)</td>
<td>Longitudinal (before versus after SST change)</td>
<td>15 (may have included students in Carskadon et al&lt;sup&gt;33&lt;/sup&gt;)</td>
<td>Grade 9-10</td>
<td>Rhode Island</td>
<td>Early (Grade 9): 0825</td>
<td>Earlier SST (65 minutes) corresponded to shorter sleep duration (39 minutes, p &lt; .001). No significant difference in school night sleep start time or sleep efficiency. YSR total problems and externalizing scores decreased with earlier SST</td>
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</table>

ACT, originally American College Testing - 1 of 2 standardized tests commonly used in college admissions in the United States; HS, high school; MS, middle school; NR, not reported; SST, school start time.
In the longitudinal studies, data are collected on students and schools before and after a change in start time. Some data that are regularly collected by schools, such as attendance and grades, can be obtained retroactively by researchers. Other data, such as those obtained from student sleep surveys, need to be collected before the start time change is implemented, and including these data can increase the duration of the study. Some studies evaluate characteristics of the same students before and after the change. Others evaluate the student population (either the entire school or specific grades in school) before and after the change. This second method, for instance, could compare outcomes in ninth-grade students in the year before the start time change with the same outcomes in ninth-grade students in the year after the change. Both of these methods have their drawbacks. Although it would seem to be preferable to evaluate the same students before and after a change, individual students can undergo significant changes from year to year that could exaggerate or diminish the effect of changing start times. However, by being able to evaluate changes in variables for individual students, researchers are able to address questions such as, “Did the students who got more sleep after the start time’s change have improved outcomes?” Although longitudinal studies may provide stronger evidence of causation than cross-sectional studies by addressing the issue of temporality, it is important to assess whether appropriate control conditions are used, whether analyses account for covariates (e.g., age, sex, or socioeconomic status), and whether other explanatory variables are considered (e.g., implementation of graduated drivers licensing).

Sleep and Sleepiness

Because delaying school start times is primarily intended to address the problem of insufficient sleep among adolescents, most of the studies focused on the association between school start times and sleep variables. Not surprisingly, students at schools with later start times got out of bed later on school days than those at earlier starting schools. \(35,36,38,55,56,60,62-69\) The association between school start times and bedtimes, however, was mixed. Of 19 studies that evaluated the association between school start times and bedtime, there were no start time-associated differences in weekday bedtimes in 11 studies. \(35,50,53-55,60,62,67,68,70\) However, 6 studies observed a later bedtime among students in schools that started at later times. \(34,36,56,64,66,71\) It should be noted that in the study by Wolfson et al, this bedtime difference was observed only in the autumn. \(64\) Two studies unexpectedly reported earlier bedtimes after a delay in start times. \(65,69\) In the study by Owens et al some students stated that after seeing the benefits of getting more sleep with the delay in school start times, they sought to further increase their sleep by going to bed earlier. \(65\) In Paksarian et al, bedtimes were delayed by only 10 minutes for each 30 minute delay in school start times. \(71\) In 29 reports, a later start time was found to be associated with longer weekday sleep duration, \(34,36,38,51-56,60-79\) including the studies that noted later bedtimes. \(34,36,56,64,66,71\) In contrast to the majority of studies that observed longer sleep duration in later starting schools, 2 studies comparing students from schools with different start times did not observe a significant difference in sleep duration. \(35,50\) For one of these, the difference in sleep duration did not meet the authors’ effect size criterion, although the difference would not have been expected to be large because the difference in school start times was only 20 minutes. \(35\) The other study observed longer sleep duration for students at the later starting school, but the difference was not statistically significant. \(50\) Another study observed a significantly longer sleep duration for seventh- and eight-grade students of only 1 of 2 later-starting districts. \(60\) Sleep duration for the second later-starting district was also longer than for the early-starting district, but the difference was not statistically significant. \(60\) Paksarian et al observed longer sleep durations with later school start times (11 minutes for each 30-minute delay in school start times), but only for schools that started before 8:01 AM. \(71\) In further analysis, the authors found the longer sleep duration for boys only (20 minutes for each 30 minute delay in school start times) and that there was variation by urbanicity, with an increase in sleep duration for boys in major metropolitan areas and a decrease for boys in nonurban counties. \(71\) The authors suggested that the different association according to urbanicity may be due to differences in mode of transportation to school and time spent traveling to school, but they did not have data to investigate the possible role of transportation in their study. Although nearly all the studies reviewed used self-reported sleep data either from sleep diaries or survey questions, the 2 studies that used data from electronic wrist monitors (actigraphs) worn during sleep confirmed the general finding of longer weeknight sleep duration for students with later start times. \(62,70\) Eleven of the positive studies found that students got at least one additional minute of sleep for every 2 minutes of difference in start time (e.g., at least 30 minutes more sleep when start time was 1 hour later). \(34,55,56,60,61,64,65,68,70,72,78\) although 6 other studies observed smaller, yet statistically significant, differences. \(51,52,62,63,73,74\)

In addition to reporting longer sleep durations, students with later start times were less likely to report daytime sleepiness or falling asleep in class in nearly all studies that assessed these outcomes. \(34,36,55,56,60,64,65,69,72,74\) Two studies observed no difference in sleepiness based on school start times. In the Norwegian study, \(78\) start times were delayed
from 8:30 AM to 9:30 AM on Mondays only. The lack of association could have been due to either the change being in effect only 1 day a week or the earlier start time already being late enough. In the Croatian study,80 the students at the earlier starting schools were predominantly boys, whereas girls made up most of the population at the later starting schools. That study found that girls had later chronotype (evening preference) and more sleepiness. In addition, the schools in the Croatian study alternated their schedule weekly, with schools starting in the morning 1 week and in the afternoon the next. Even with a delay in start time, falling asleep during class appears to remain a major problem, however. In Wahlstrom et al’s survey of students post-start time change, 27% reported falling asleep in a morning class in the previous 2 weeks, and 29% fell asleep in an afternoon class.61

Other methods for assessing students’ degree of sleep-deficiency were used in various studies. Students in a study by Carskadon et al underwent polysomnography (a type of sleep study that measures multiple factors such as electrical activity in the brain, heart rate, movements of the eyelids and legs, and respiratory airflow) and multiple sleep latency tests.62 After an advance in start time from 8:25 AM to 7:20 AM, students had a shorter REM sleep latency (time between sleep onset and onset of REM sleep) on polysomnography and a shorter sleep latency (time to sleep onset during a standard testing protocol).62 Both of these results indicate sleep-deficiency. Differences in sleep patterns between weeknights and weekend nights can also indicate insufficient weeknight sleep as students try to make up for lost sleep on the weekends. Seven reports that evaluated weekend sleep patterns found more “catch-up” sleep on the weekends for earlier start times.51,61,64,66,69,74,78 although one found no difference in this outcome.71 One study assessed weeknight and weekend sleep and observed longer weeknight sleep duration and no change in weekend sleep patterns after a delay in school start time, which could be interpreted as a decrease in “catch-up” sleep.67 However, the difference between weeknight and weekend sleep was not analyzed. Three studies that included information about daytime naps noted that students with earlier school start times reported more napping,38,66,75 presumably in an attempt to make up for insufficient nighttime sleep. Sleepy adolescents may also attempt to lessen sleepiness with caffeine. One study asked students about caffeine consumption and observed that caffeine use decreased after a 25-minute delay in school start time.67

Academics and Cognition

An outcome of particular interest to school administrators, teachers, and parents is academic performance; however, evaluating how delayed start times affect school grades or academic performance is difficult for several reasons. Class grading is not standardized and varies by subject, teacher, and school. Standardized tests such as the Scholastic Aptitude Test or the ACT are not taken by all students and are more likely to be taken by students planning to attend college. Finally, students with very good academic performance before a delay in school start time do not have much room for improvement. Given these limitations, however, some evidence suggests a positive association between later school start time and academic performance.57,58,60,61,64,81 although the association may be relatively weak55 and not universal.59,67,80

The first cross-sectional school start time study by the University of Minnesota found higher self-reported grades for students in later starting schools.60 Mean self-reported grades for the 2 districts that started before 7:30 AM were 6.4 and 6.5 (on a scale from 1 = mostly F’s to 9 = mostly A’s) compared with 7.1 for the district starting at 8:30 AM (p < .05). However, the increase in grades observed from this group’s subsequent longitudinal study was small and not statistically significant.55 In their latest longitudinal study including 8 schools, the same group noted that most schools saw an increase in grade point average after delaying school start times.61 Arlington Public Schools (Arlington County, Virginia) observed an improvement in tenth-grade students’ first period grades after a 45-minute delay in high school start times, with no change in seventh-grade students’ first period grades after a 20 minute advance in middle school start times.81 Hinrichs’ investigation into ACT scores and school start times in the Minneapolis-St. Paul area, which included school districts that did not delay school start times, controlled for various covariates and found no association between school start times and ACT scores.59 The annual ACT participation rate among Minnesota high school graduates varied from 59% to 66% during the study period (1993-2002).59 Hinrichs also evaluated the association between school start times and standardized test scores in Kansas (Kansas State Assessments) and the Virginia suburbs of Washington, DC.59 Again, he found no association between school start times and academic achievement in these analyses.59 Wolfson et al observed higher grades after delaying school start times for eighth grade, although not for seventh grade students.64 Another study linked school start times and standardized test scores for middle school students (grades 6-8) from 1999 to 2006 in the 18th largest public school district in the United States.57 In the cross-sectional component of that study, an hour later start time corresponded to higher test scores on both math and reading (on the order of 3 percentile points).57 The longitudinal component of the same report looked at schools that had changed school start times over the course of
the study and found that a 1-hour delay in start time corresponded to a 2 percentile increase in math and 1.5 percentile increase in reading. Among older students, US Air Force Academy freshmen, students assigned to a first period course and therefore an earlier start to the school day had poorer grades. A longitudinal study of nearly 200 boarding school students did not see a change in self-reported grades after a 25-minute delay in school start times. In Milic et al’s study in Croatia, students with an earlier school start time performed better academically than students at the schools with later start times. However, in addition to the difference in the makeup of the student populations (more boys at earlier schools and more girls at later schools) in that study, students were also aware of the school schedule at enrollment and the response rate was low.

Several studies have investigated the association between school start time and cognitive outcomes. Two studies found that students with later start times reported fewer problems concentrating and paying attention. In contrast, a study in Spain measured attention level via a sustained attention task among students at 3 schools with different start times (8:00, 8:15, and 8:30 AM) and observed the highest average attention level at the school starting at 8:15 AM. However, it should be noted that the mean inductive reasoning score, a measure of intelligence which is positively associated with attention, was significantly lower for the latest-starting school than the other 2 schools. The Norwegian study that delayed start times on Mondays included reaction time tests and found that students at the school with delayed start time had significantly fewer lapses and faster reaction times on Monday than Friday compared with no difference among students at the control (no delay) school.

Several studies asked students how much time they spent on homework. There was no consistent association between school start time and homework time. Wahlstrom et al found that students with later school start times reported less hours of homework, whereas Edwards observed the reverse and Boergers et al saw no difference. Interpretation of these results is difficult. An increase in time doing homework could indicate an improved ability to concentrate or less efficient studying. Because the value of homework is hotly debated, this outcome should not be taken out of context.

Attendance/Tardiness

School attendance is also important for academic success. One report found that short sleep duration was strongly associated with odds of school absences. Several studies included in this review found that earlier start times were also related to more frequent tardiness and more absences. In one study, even with delaying start times from 8:00 AM to 8:55 AM, nearly one third of students reported being late to class because of oversleeping in the 2 weeks before the survey. However, one study of schools in the Minneapolis-St. Paul area found no association between school start times and overall attendance rates. The report by Arlington Public Schools stated that “maturity, rather than starting time, has the biggest impact on attendance rates.” However, when comparing tenth graders before and after the delay in high school start times, attendance rates were lower after the delay. Despite this finding, academic performance improved for those students. The report also noted that the attendance reporting procedures changed during the course of the study.

Depression

Sleep is strongly linked with many psychiatric disorders, including depression and anxiety. Although sleep problems may be symptoms of mental health disorders such as depression, there is also evidence of a causal relationship between insufficient sleep and depression, as well as mood in general. Owing to this observation, some school start time studies included depression symptoms as part of their student assessments. Students at later-starting schools appeared to experience fewer depression symptoms (lower depression scores). Incidentally, shorter REM sleep latency, such as was observed by Carskadon et al after an advance in start time, is also often observed in major depression. One study found no difference in students’ positive or negative affect with delayed school start time. However, in that study, the start time was delayed on Mondays only.

Motor Vehicle Crashes

Four studies also investigated motor vehicle crashes among young drivers (aged 18 years or younger) in areas served by schools with different start times. In a Kentucky county, Danner and Phillips saw a 16.5% decrease (p < .01) in motor vehicle crash rates for 17- and 18-year-old students in the 2 years following a 1-hour delay in school start time by county high schools. During the same time period, crash rates for this age group increased by 7.8% in the rest of the state. In their 2011 report, Vorona et al compared crash rates for teen drivers aged 16 to 18 years in 2 neighboring, demographically similar cities (in eastern Virginia) with different start times. In 2007 and 2008, the teen crash rates were significantly higher in the city with an earlier school start time. For both cities, teen crashes peaked during the morning commute time. The group went on to perform similar analyses for 2 adjacent counties in central Virginia with different school start times. During the 2009-2010 school year, crash rates among 16-
to 18-year-olds were higher (p < .05) in the county with the earlier school start times. The following year, crash rates among 16- to 17-year-olds were higher (p < .05) in the same county, but the difference was not statistically significant when 18-year-olds were included in comparison (p = 0.09). Finally, Wahlstrom et al investigated crash rates among 16- to 18-year-old students in 4 areas near schools that underwent delays in start time. Two areas saw major decreases (≥65%) in teen crash rates after the delays, one saw a small decrease (6%), and another saw a small increase (9%).

**Other Outcomes**

There are a handful of other outcomes that have been reported by only one study each. One study saw that students at schools with later start times spent less time at work during the school week (p < .05). More time working has been linked to poorer academic performance. However, the start time study was cross-sectional and other variables such as socioeconomic status may explain the difference in time spent at work. In the cross-sectional component of his study, Edwards found that students at schools that started later reported less time watching television. Among 197 boarding school students, no change in time spent in athletics or extracurricular activities was reported after a 25-minute delay in start time. Finally, in a small study of 15 students who transitioned from grade 9 (school start time 8:25 AM) to grade 10 (school start time 7:20 AM), self-reported conduct problems and aggressive behaviors decreased with the change to an earlier start time. However, within each grade, these behaviors were associated with shorter sleep duration, which indicates that at least some of the decrease in these behaviors may be due to maturation.

**Conclusion**

Delaying school start times for adolescents has been proposed as a policy change to address insufficient sleep among adolescents, a largely sleep-deprived population, and potentially to improve students’ academic performance, reduce engagement in risk behaviors, and improve health. Nearly all studies to date provide evidence that delaying school start time accomplishes the goal of increasing sleep duration among these students, primarily by delaying rise times. Most of the studies saw a significant increase in sleep duration even with relatively small delays in start times of half an hour or so. Later school start times also generally corresponded to improved attendance, less tardiness, less falling asleep in class, fewer depression symptoms, and fewer motor vehicle crashes. Although not all studies found that later start times corresponded to improved academic performance, no studies found a negative impact of later school start times on academics.

**IMPLICATIONS FOR SCHOOL HEALTH**

In 2014, the American Academy of Pediatrics published a policy statement urging middle and high schools to adjust start times to permit students to obtain adequate sleep and improve physical and mental health, safety, academic performance, and quality of life, and suggested that middle and high schools not start before 8:30 AM. Schools and school districts cannot make evidence-based policy decision without data. Therefore, research results such as those presented in this review, as well as the recent recommendations by the American Academy of Pediatrics, should be disseminated to school districts, teachers, parents, and other stakeholders. The field still needs rigorous research, including trials with controls, if possible. Many questions remain, such as the issue of how late is late enough? Much of the focus has been on high school students, but biological changes begin earlier, so further research into middle-school students is warranted. More qualitative research about overcoming obstacles to delaying school start times would also be valuable.

Schools contemplating a change in school start time may consider partnering with researchers before a decision is even made. Baseline data on student sleep characteristics, tardiness due to sleepiness, and prevalence of falling asleep during class may be used in the initial decision of whether to delay school start times. Parents and administrators may not realize the extent of the problem of insufficient sleep among their students and this data may help persuade them that some action is necessary. If school start times are delayed, everyone would benefit from collection of detailed data before and after a time change. Not only would other schools or school districts contemplating a change benefit from expanded evidence, the district that undertook the start time change would be able to evaluate the impact of the change and communicate their findings to their stakeholders. Data collected should include not only sleep-related variables and academic achievement measures but also measures of mental health (such as depression and anxiety symptoms), behavioral problems, risk behaviors, safety statistics such as motor vehicle crash rates and pedestrian injuries, and information on mode of transportation and travel time. Several obstacles to implementing start time delays are often cited, including costs of changing bus schedules, possible impact on athletics.
and extracurricular activities, and school faculty and staff resistant to change. However, as recently reported by Owens et al.\(^9\) in their examination of school districts that have delayed school start times, many anticipated problems fail to materialize or are only temporary. Several school districts have seen savings in transportation costs after changes made to facilitate delayed start times.\(^90\) Success stories describing how districts creatively overcame obstacles to school start time changes should be shared (eg, http://www.startschoollater.net/success-stories.html) to provide ideas to other districts contemplating change.

Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the US Centers for Disease Control and Prevention.

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