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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 paper 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.

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Keywords

adolescents; school health; sleep; school start times; policy

BACKGROUND

Sleepy adolescents have doubtlessly been a problem 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, fewer than 8% of high school students report getting this amount.[4] Less than a third of students report 8 or more hours of sleep, and this proportion decreases as school grade level increases so that fewer than a quarter 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 non-standardized measure of academic performance and did not adjust

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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 paper, 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.

LITERATURE REVIEW

Methods

An outline of the steps in identification of articles and reports included in the literature review is presented in the Figure. 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). Since 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. Additionally, 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 public or private 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

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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,[50–54] as were some studies from the education or economics literature that were not indexed by PubMed.[55–59] 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 non-duplicative 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.[59–61] Three reports included cross-sectional and longitudinal components, with data for each component presented separately.[55,57,61]

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). Five of the 38 reports were identified in this manner. Publication bias and over-representation 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 (see Table). Unfortunately, the earliest reports,[50–54] 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 two 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 two schools 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.

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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 9th-grade students in the year before the start time change with the same outcomes in 9th-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 (eg, age, sex, or socioeconomic status), and whether other explanatory variables are considered (eg, implementation of graduated drivers licensing).

Sleep and Sleepiness

Since 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.[35,36,50,53,55,56,60,62–69] 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 eleven studies.[35,50,53–55,60,62,67,68,70] However, six 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 and colleagues, 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, two 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 since 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

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significantly longer sleep duration for 7th- and 8th-grade students of only one of two 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 two 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 two minutes of difference in start time (eg, at least 30 minutes more sleep when start time was one hour later),[34,55,56,60,61,64,65,68,70,72,78] although six 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 one 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, while 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 one 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 and colleagues’ 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 and colleagues 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

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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 weak[55] 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 two 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 to 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 10th grade students' 1st period grades after a 45 minute delay in high school start times, with no change in 7th grade students' 1st 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 and colleagues observed higher grades after delaying school start times for 8th grade, although not for 7th-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 eighteenth largest public school district in the United States.[57] In the cross-sectional

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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 one hour delay in start time corresponded to a 2 percentile increase in math and 1.5 percentile increase in reading.[57] Among older students, U.S. Air Force Academy freshmen, students assigned to a first period course and therefore an earlier start to the school day had poorer grades.[58] 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.[67] 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.[80] However, in addition to the difference in the make-up 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.[70,72] In contrast, a study in Spain measured attention level via a sustained attention task among students at three schools with different start times (8:00, 8:15, and 8:30) and observed the highest average attention level at the school starting at 8:15.[77] 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 two schools.[77] 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 to no difference among students at the control (no delay) school.[78]

Several studies asked students how much time they spent on homework. There was no consistent association between school start time and homework time. Wahlstrom and colleagues found that students with later school start times reported less hours of homework,[60] whereas Edwards observed the reverse[57] and Boergers and colleagues saw no difference.[67] Interpretation of these results in difficult. An increase in time doing homework could indicate an improved ability to concentrate or less efficient studying. Since 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. A recent report found that short sleep duration was strongly associated with odds of school absences.[82] Several studies included in this review found that earlier start times were also related to more frequent tardiness and more absences.[55,57,60,61,64,65] In one study, even with delaying start times from 8:00 AM to 8:55 AM, nearly a third of students reported being late to class because of oversleeping in the 2 weeks before the survey.[61] However, one study of schools in the Minneapolis-St. Paul area found no association between school start times and overall attendance rates.[59] The report by Arlington Public Schools stated that "maturity, rather than starting time, has the biggest impact on attendance rates."[81] However, when comparing 10th graders before and after the delay in high school start times, attendance rates were lower

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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.[83] 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.[84,85] Due 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).[55,60,65,67] Incidentally, shorter REM sleep latency, such as was observed by Carskadon and colleagues after an advance in start time,[62] is also often observed in major depression.[86] One study found no difference in students' positive or negative affect with delayed school start time.[78] 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.[74] During the same time period, crash rates for this age group increased by 7.8% in the rest of the state.[74] In their 2011 report, Vorona and colleagues 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.[87] For both cities, teen crashes peaked during the morning commute time.[87] The group went on to perform similar analyses for two adjacent counties in central Virginia with different school start times.[88] During the 2009–2010 school year, crash rates among 16–18 year olds were higher ($p < .05$) in the county with the earlier school start times.[88] The following year, crash rates among 16–17 year olds were higher ($p < .05$) in the same county, but difference was not statistically significant when 18 year olds were included in comparison ($p = 0.09$).[88] Finally, Wahlstrom and colleagues 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, while one saw a small decrease (6%), and another saw a small increase (9%).[61]

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 ($p < .05$).[60] More time working has been linked to poorer academic performance.[89] 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

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less time watching television.[57] When he limited his analyses to schools that changed start times over the time course of the study, he confirmed that students at schools that delayed their start times reported significantly less time watching television.[57] 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.[67] Finally, in a small study of 15 students who transitioned from grade 9 (school start time 8:25) to grade 10 (school start time 7:20), self-reported conduct problems and aggressive behaviors decreased with the change to an earlier start time.[54] 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.[54]

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.[3] 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

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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.[90] 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 (for example http://www.startschoollater.net/success-stories.html) to provide ideas to other districts contemplating change.

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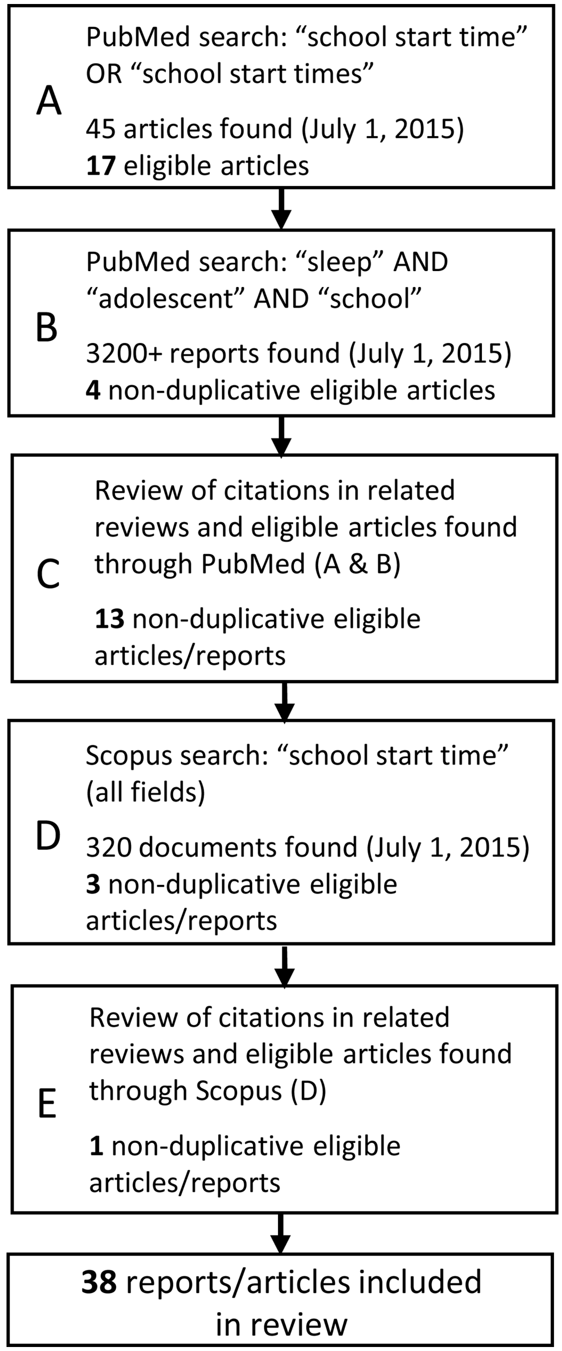

Figure.
Identification of Reports for Review

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Table

Descriptions of School Start Time (SST) Studies in Preadolescents, Adolescents, and College-Age Students

Study							
Author(s)(Year) Year(s) of Study	**Study Design**	**Sample Size**	**Age**	**Location**	**School Start Times**	**Outcomes**	**Key Findings**
Carskadon et al. (1998)[62] Not specified	Longitudinal (before vs after SST change)	26 (same students)	Grades 9–10	Rhode Island	Year 1–9th grade: 8:25 Year 2–10th grade: 7:20	Sleep schedules (sleep diaries and data from electronic wrist monitors), multiple sleep latency tests, polysomnography.	Earlier SST associated with earlier rise time ($p < .05$), shorter sleep duration ($p < .05$), shorter REM latency ($p < .05$), shorter sleep latency on multiple sleep latency tests ($p = .004$), and more students with REM sleep during multiple sleep latency tests (p NR).
Epstein et al. (1998)[72] Not specified	Cross-sectional (students in 18 schools)	572	Grade 5	18 schools throughout Israel	Early risers: 7:10 (2+ times/week) Regular risers: 8:00	Sleep duration, bedtime, rise time (weekdays and weekends), sleepiness, daytime functioning, sleep difficulties.	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 ($p = .0001$).
Wahlstrom et al. (1998)[60] Not specified	Cross-sectional (3 districts)	NR	Grades 10–12	Minnesota	District A (Minneapolis): 8:30 District B: 7:25 District C: 7:15	School Sleep Habits Survey[35] (study, work, sleep, and school habits, and preferences).	Later SST corresponded to later rise time ($p < .0001$), same bedtime, and longer weeknight sleep duration ($p < .0001$). Later SST also associated with less daytime sleepiness ($p < .0001$), less struggling to stay awake during academic tasks ($p < .01$ for A vs C), fewer tardies ($p < .001$), less falling asleep in morning classes ($p < .005$), fewer depressive symptoms ($p < .001$ for A vs C), less time spent at work during school week ($p < .05$), and higher self-reported grades ($p < .05$).
Wahlstrom et al. (1998)[60] Not specified	Cross-sectional (3 districts)	NR	Grades 7–8	Minnesota	District A (Minneapolis): 7:35	School Sleep Habits Survey[35] (study,	Similar associations as in HS students. Later SST

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Study							
Author(s)(Year) Year(s) of Study	**Study Design**	**Sample Size**	**Age**	**Location**	**School Start Times**	**Outcomes**	**Key Findings**
					District B: 8:00 District C: 8:00	work, sleep, and school habits, and preferences).	corresponded to longer sleep duration ($p < .05$ for A vs C), same bedtime, and later rise time ($p < .05$ for A vs C). Later SST also associated with less daytime sleepiness ($p < .05$ for A vs B), less struggling to stay awake during academic tasks ($p < .05$ for A vs B), lower depression scores ($p < .05$ for A vs B), and less hours of homework ($p < .05$ for A vs B and C).
Wolfson & Carskadon (1998)[35] 1994	Cross-sectional (students in 4 schools in 3 public school districts)	3120	Grades 9–12	Rhode Island	7:10 – 7:30	School Sleep Habits Survey (study, work, sleep, and school habits and preferences)	Students at school with earliest SST (7:10) reported earlier rise times than students at the other schools ($p < 0.001$). Other sleep related differences did not meet effect size criterion.
Baldus (2002)[63] Not specified	Longitudinal (before vs after SST change)	31 (same recruits, 2 sleep schedules)	US Navy recruits (mean 21.3 years)	Great Lakes, Illinois	Early reveille: 9PM-5AM sleep time Late reveille: 10PM-6AM sleep time	Sleep duration.	Later reveille associated with longer sleep duration ($p = .01$). The 10PM bedtime—6AM rise time resulted in 22 more minutes of sleep per night per recruit.
Wahlstrom (2002)[55] 1994–2000	Longitudinal (before vs after SST change)	>12 000 (7 HS)	Grades 9–12	Minneapolis, Minnesota	Pre-change: 7:15 Post-change: 8:40	Class grades, attendance, tardiness, graduation rates, rates of continuous enrollment.	After SST change, % continuously enrolled increased ($p < .05$), attendance rates increased (among students not continuously enrolled) ($p < .001$), and letter grades increased slightly (not significant).
Wahlstrom (2002)[55] 1997–2001	Cross-sectional (Minneapolis HS vs District B)	467 (Minneapolis HS) 169 (District B)	Grades 9–12	Minneapolis, Minnesota	Minneapolis HS: 8:40 District B: 7:30	School Sleep Habits Survey[35] (study, work, sleep, and school habits and preferences).	Later SST corresponded to longer sleep duration ($p < .001$), same bedtime, and later rise time ($p < .001$). Later SST also associated with less daytime sleepiness ($p < .01$), less struggling to stay awake during academic tasks ($p < .01$), fewer tardies (p <

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Study							
Author(s)(Year) Year(s) of Study	**Study Design**	**Sample Size**	**Age**	**Location**	**School Start Times**	**Outcomes**	**Key Findings**
							.01)/absences ($p < .05$), less falling asleep in morning classes ($p < .001$), and fewer depressive symptoms ($p < .05$).
Dexter et al. (2003)[73] 2002	Cross-sectional (2 schools with different SSTs)	193 (School 1) 587 (School 2)	Grades 10–11	Altoona (1) and Chippewa Falls (2), Wisconsin	School 1: 7:50 School 2: 8:35	Weeknight sleep duration, Epworth Sleepiness Scale[91].	Mean weeknight sleep duration was longer in School 2 compared to School 1 ($p = .039$).
Arlington Public Schools (2005)[81] 2000–2002	Longitudinal (before vs after SST change)	3 HS, 5 MS	Grades 7–11	Arlington County, Virginia	HS: 7:30 (2000–2001), 8:15 (2001–2002) MS: 8:10 (2000–2001), 7:50 (2001–2002)	Academic grades (1st period), attendance, survey of students' perceptions of how alert and prepared to start school day, survey of teachers' perceptions of student behavior. Surveys were conducted in 2002 only. Respondents were asked to recall prior to SST changes.	10th grade students' 1st period grades improved after 45 minute SST delay ($p < .001$), but attendance appeared to decrease. No significant change in 7th grade students' 1st period grades after 20 minute SST advance.
Adam et al. (2007)[68] 2002–2003	Cross-sectional	2454	5–z19 years	Nationally (USA) representative	NR	Sleep duration, bedtime, rise time (weekdays and weekends).	For older children (12–19 years), an hour later SST was associated with 0.57 hour more weekday sleep ($p < .01$), a 0.62 hour later rise time ($p < .01$), and no difference in bedtime.
Wolfson et al. (2007)[64] 2003–2004	Cross-sectional (2 schools with different SSTs)	205	Grades 7–8	Urban New England school district	Early school: 7:15 Late school: 8:37	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.	Late SST associated with later bedtimes (in autumn only) ($p < .05$), later rise times ($p < .001$), longer sleep duration (65 minutes) ($p < .001$), less weekend oversleep (in autumn only)($p < .001$), less daytime sleepiness in the autumn ($p < .05$), fewer sleep-wake behavior problems in the spring ($p < .05$), higher grades (8th grade only) ($p < .01$), and fewer tardies ($p < .001$). Weekend sleep patterns were similar.

Study							
Author(s)(Year) Year(s) of Study	**Study Design**	**Sample Size**	**Age**	**Location**	**School Start Times**	**Outcomes**	**Key Findings**
Danner and Phillips (2008)[74] 1998–1999	Longitudinal (before vs after SST change)	9966 (Year 1) 10 656 (Year 2). Sample size included HS and MS students, but results only presented for HS students.	Grades 6–12	Kentucky	Year 1 (Y1): 7:30 (HS) Year 2 (Y2): 8:30 (HS)	Bedtime and rise time (weekdays and weekends), number of naps, Epworth Sleepiness Scale[91], how time spent before and after school, motor vehicle crash rates among 17- and 18-year-old students.	Compared to Year 1, in Year 2 students reported longer average sleep duration ($p < .001$), less catch-up sleep on weekend nights ($p < .001$), and lower scores on the Epworth Sleepiness Scale ($p < .001$). Crash rates in the study county decreased after the SST delay ($p < .01$).
O'Malley and O'Malley (2008)[56] 2001–2004	Longitudinal (before vs after SST change)	297 (pre-delay) 977 (post-delay)	Grades 9–12	Wilton, Connecticut	Pre-delay: 7:35 Post-delay: 8:15	Condensed School Sleep Habits Questionnaire[35].	Later SST corresponded to longer weeknight sleep duration ($p < .001$), later rise time ($p < .001$), later bedtime ($p = .03$), and fewer problems with sleepiness ($p < .001$).
Owens, Belon, Moss (2010)[65] 2008–2009	Longitudinal (before vs after SST change)	201 (mostly boarders)	Grades 9–12	Rhode Island	Pre-change: 8:00 Post-change: 8:30	Bedtime and rise time (weekdays and weekends), sleepiness-related behaviors, health center visits, absences/tardies.	Delayed SST associated with longer school night sleep durations ($p < .001$), earlier bedtimes ($p < .001$), later rise times ($p < .001$), greater sleep satisfaction ($p < .001$), less sleepiness ($p < .001$), less sleepiness-related behaviors ($p < .001$), less depressed mood ($p < .001$), fewer visits to health center for fatigue-related symptoms ($p = 0.03$), and fewer absences/tardies ($p < .05$).
Zhang et al. (2010)[66] Not specified	Cross-sectional	4470 (mother-father-child community based trios)	Mean age 9.2 ± 1.8y	Hong Kong	Morning school: ~7:35 Whole-day school: ~8:08 Afternoon school: ~12:54pm	Bedtime, rise time, time-in-bed (weekday, weekend, & long holidays), napping	Students in morning schools (earliest SST) had earliest bedtimes & rise times, shortest time-in-bed, most weekend sleep compensation, and largest proportion of daytime napping.
Carrell et al. (2011)[58] 2004–2009	Cross-sectional	6165	U.S. Air Force Academy freshmen	Colorado Springs, Colorado	Early (2004–2005, 2005–2006): 7:00. Middle (2006–2007): 7:30. Late (2007–	Academic grades by scheduling characteristics.	Students assigned to a first period course had poorer grades; however, this association became

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Study							
Author(s)(Year) Year(s) of Study	**Study Design**	**Sample Size**	**Age**	**Location**	**School Start Times**	**Outcomes**	**Key Findings**
					2008, 2008–2009): 7:50. For each schedule, some students had a first period class while others did not.		weaker and became statistically insignificant as the start time moved from 7:00 AM to 7:50 AM. Students performed worse in first period classes compared to other periods, but those with first period classes also performed worse in their subsequent classes on that schedule day.
Hinrichs (2011)[59] 1993–2002	Cross-sectional (primarily, but with a longitudinal component)	196,617 observations (may include repeat test takers) (students from 73 schools)	Grades 10–12	Twin Cities metropolitan area (Minneapolis-St. Paul, Minnesota)	7:15–8:40	ACT scores, attendance rates	No association between SST and ACT scores or attendance rates.
Hinrichs (2011)[59] 2000–2006	Cross-sectional	Approximately 400 public high schools	Grades 10–12	Kansas (public high schools in the state)	Mean (SD): 7:59 (0:15)	School-level test score data on Kansas Mathematics Assessment, Reading Assessment, Science Assessment, and Social Studies Assessment.	No association between SST and scores on reading, mathematics, science, and social studies assessments.
Hinrichs (2011)[59] 2000–2007	Cross-sectional	75 schools	Grades 9–12? (not specified in report, but described as high schools)	Virginia suburbs of Washington D.C.		Scores on standardized end-of-course exams.	No association between SST and test scores.
Lufi et al. (2011)[70] Not specified	Longitudinal (before vs after SST change—short term change only)	47	Grade 8	Israel	Early class: 7:30 Late class: 8:30	Sleep duration, bedtime, rise time, sleep efficiency (data from electronic wrist monitors), attention tests.	Later SST associated with longer sleep duration ($p < .01$) and improved attention ($p < .01$).
Ming et al. (2011)[38] Not specified	Cross-sectional	1941 (students from 2 public high schools, 1 vocational high school, and two extracurricular high school programs whose students came from various high	Grades 9–12	New Jersey	Varied from 7:00 to 8:45 For analyses, early SST (before or at 7:30) vs late SST (after 7:30)	Sleep duration, bedtime, rise time, napping, perceived sleep adequacy, night awakenings, prolonged sleep onset	Early SST associated with short weekday sleep duration (<7 hours, $p < .0001$), lower likelihood of receiving adequate night sleep ($p < .0001$), and higher likelihood of afterschool naps ($p < .0001$) and night awakenings ($p = NR$).

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		schools throughout the state)					
Vorona et al. (2011)[87] 2007–2008	Cross-sectional (2 cities with different SSTs in public schools)	NR	16–18 years	Virginia Beach and Chesapeake, Virginia	Early schools (Virginia Beach): 7:20–7:25 Late schools (Chesapeake): 8:40–8:45	Motor vehicle crash rates in each city.	Crash rates among 16-to 18-year-olds were higher ($p < .01$) in Virginia Beach (which has earlier SSTs).
Yilmaz et al. (2011)[75] 2008	Cross-sectional	3441	15–18 years	Gaziantep, Turkey	Early: 7:00–8:00 (morning) Late: 12:00–12:40 pm (afternoon)	Bedtime, rise time, sleep latency (weekdays & weekends), ideal night sleep time, napping, sleep hygiene	Compared to those with afternoon SSTs, students with morning SSTs reported shorter night time sleep on weekdays and weekends ($p < .001$) and shorter ideal night time sleep ($p < .001$). Early SST students were more likely to report daytime napping and needing help to awaken in the morning ($p < .001$) and less likely to report a long sleep latency (>30 minutes) on weekdays and weekends ($p < .001$).
Vedaa et al (2012)[78] Not specified	Cross-sectional	55 students (intervention school) 51 students (control school)	Grade 10	Norway	Intervention school: 9:30 (Mondays), 8:30 (rest of week) Control school: 8:30 (all days)	Karolinska Sleepiness Scale[92], reaction time tests, Positive and Negative Affect Schedule, sleep diary	Compared to control school students, students at intervention school slept >1 hour longer on Sunday night ($p < .05$), 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.
Edwards (2012)[57] 1999–2006	Cross-sectional component	20,530 students (1999–2000) 27,686 students (2005–2006)	Grades 6–8	Wake County, North Carolina	7:30–8:45 (53% of students start at 7:30, 22% start at 8:15)	End of year standardized test scores in reading and math; time spent watching	Later SST corresponded to higher standardized test scores on both math and reading tests (1 hour later corresponded to 3 percentile increase), less time

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						television and doing homework; absences	watching television, more time doing homework, and fewer absences.
Edwards (2012)[57] 1999–2006	Longitudinal component (before vs after SST change for schools that changed SST between 1999-2006)	20,530 students (1999–2000) 27,686 students (2005–2006)	Grades 6–8	Wake County, North Carolina	7:30–8:45 (Some schools started earlier and some started later after SST change)	End of year standardized test scores in reading and math; time spent watching television and doing homework	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.
Borlase et al (2013)[69] 1999–2008	Longitudinal (before vs after SST change in 2006)	212 students in Grades 9 and 12 (1999) 455 students in Grades 9, 11, and 12 (2008)	13–17 years	Wellington, New Zealand	Senior students (Grade 12): 9:00 (pre), 10:30 (post) Junior students (Grades 9, 11): 9:00 (no change)	School Sleep Habits Survey[35] (study, work, sleep, and school habits, and preferences), technology use, Epworth Sleepiness Scale[91], morningness-eveningness preference, sleep/fatigue problems	Grade 12 students after the SST delay (2008) had longer sleep duration ($p < .01$), earlier bedtime ($p < .01$), later rise time ($p < .001$), less sleep discrepancy (sleep duration on school nights vs. non-school nights)($p < .01$), and less sleepiness ($p < .01$) compared to Grade 12 students before the delay or Grade 11 students (2008).
Li et al. (2013)[36] 2007–2009	Cross-sectional/ Longitudinal (6 schools before vs after SST change)	525 (baseline) 553 (2-year follow-up)	Grades 4–5 (mean age 10.8y)	Shanghai, China	2 control schools, no change in SST: 7:30 2 schools, intervention 1: 7:30 (pre), 8:00 (post) 2 schools, intervention 2: 7:30 (pre), 8:30 (post)	Sleep duration, bedtime, rise time, daytime sleepiness (Chinese version of Children's Sleep Habits Questionnaire)	At baseline, students at the 6 schools had similar sleep characteristics. At follow-up, later SST associated with later bedtime ($p < .05$), rise time ($p < .001$), longer sleep duration ($p < .001$), 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.
Perkinson-Gloor et al. (2013)[34] 2010–2011	Cross-sectional	2373 (early) 343 (delayed start)	Grades 8–9	Mid-size city in northwestern Switzerland	Early: not specified Delayed: 20 minutes later	Sleep duration, bedtimes, rise times (weekdays and weekends), daytime	Later SST associated with longer weeknight sleep duration ($p < .001$), later weeknight bedtimes (p =

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						sleepiness, behavioral persistence, attitude towards life, school grades (mathematics and German language).	.04 boys, p < .001 girls), later weekday rise times (p < .001), and less daytime sleepiness (p < .001 boys, p = .03 girls).
Short et al. (2013)[76] 1997–2000 (U.S.) 2008–2010 (Australia)	Cross-sectional	302 (U.S.) 385 (Australia)	Grades 9–12 (mean age 16.0y) (U.S.) Years 9–11 (mean age 15.6y) (Australia)	Rhode Island (U.S.) South Australia (Australia)	U.S.: ~7:45 Australia: 8:20–9:00	School Sleep Habits Survey[35] (study, work, sleep, and school habits and preferences), 8-day sleep diary	School night sleep duration correlated with SST (r = .29, p < .001). SST had largest effect on sleep duration (compared with parent-set bedtimes and extra-curricular load).
Boergers, Gable, and Owens (2014)[67] 2010–2011	Longitudinal (before vs after SST change)	197 (boarding students)	Grades 9–12	Rhode Island	Pre-delay: 8:00 Post-delay: 8:25	School Sleep Habits Survey[35] (study, work, sleep, and school habits and preferences), caffeine intake questionnaire	After SST delay, mean wake times (school days) were later (p < .001), mean school night sleep duration was longer (p < .001), school night bedtimes did not change. The percentage who slept ≥8 hour on school nights increased from 18% to 44% (p < .001). There were no changes in nonschool night sleep patterns. After delay, sleepiness scores (p < .001), depression scores (p < .001), and caffeine use decreased (p < .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.
Escribano & Diaz-Morales (2014)[77] Not specified	Cross-sectional (students in 3 schools)	669	12–16 years	Madrid, Spain	8:00, 8:15, 8:30	Bedtimes, rise times, sleep duration, attention task (at 3 times during school day on 2 consecutive Wednesdays), morningness/eveningness, inductive reasoning	Average school night sleep was more than 30 minutes longer for 8:30 SST than 8:00 SST (p < .001). Attention level highest for 8:15 SST on first Wednesday (p < .001), but no difference by SST on

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							second Wednesday. Inductive reasoning score was lowest for 8:30 SST (p < .01).
Chen et al. (2014)[79] 2009	Cross-sectional	4801 (students from 12 senior HS and 12 junior HS)	11–20 years	Shanghai, China	Dichotimized: Before 7:00 vs. 7:00 or later	Adolescent Sleep Wake Scale[93], bedtimes, wake-up times, sleep duration (weekdays & weekends), parents' sleep habits	SST before 7:00 associated with sleeping <8 hours (p = .015).
Vorona et al. (2014)[88] 2009–2011	Cross-sectional (2 counties with different SST in public schools)		16–18 years	Chesterfield County, Virginia and Henrico County, Virginia	Early (Chesterfield): 7:20 Late (Henrico): 8:45	Weekday motor vehicle crash rates during the school years (September-May) 2009–2010 and 2010–2011.	In 2009–2010, crash rates among 16–18 year olds were higher (p < .05) in Chesterfield County (which has earlier SST). In 2010–2011, crash rates among 16–17 year olds were higher (p < .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 two counties.
Milic et al. (2014)[80] 2011	Cross-sectional	821 (students from 4 HS)	15–19 years	Osijek, Croatia	Early: 7:00 AM or 1:00 PM (alternating weeks) Late: 8:00 AM or 2:00 PM (alternating weeks)	Epworth Sleepiness Scale[91], morningness/eveningness, napping, academics (final semester grade)	Students with earlier SST performed better academically and had earlier chronotypes (morning preference) (p < .001). No difference in sleepiness.
Wahlstrom et al. (2014)[61] 2011–2013	Cross-sectional	9089	Grades 9–12	5 HS in Minnesota, 2 HS in Colorado, 1 HS in Wyoming	After delay, SST varied from 8:00 to 8:55	Sleep duration, bedtimes, rise times (weekdays and weekends), sleep-related tardiness, sleeping during class.	SST associated with percent of students sleeping ≥8 hours/school night (R^2 = .8878, <50% for schools starting before 8:30, 66% for school starting at 8:55).
Wahlstrom et al. (2014)[61] 2011–2013	Longitudinal (before vs after SST change)	446 (pre-delay) 459 (post-delay)	Grades 9–12	Jackson Hole, Wyoming	Pre-delay: 7:35 Post-delay: 8:55	Sleep duration, bedtimes, rise times (weekdays and weekends).	Average school night sleep increased from 7.5h to 8.2h. Average weekend sleep decreased from 9.3h to 9.0h.

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Wahlstrom et al. (2014)[61] 2004–2013	Longitudinal (before vs after SST change)	NR	Grades 9–12	5 HS in Minnesota, 2 HS in Colorado, 1 HS in Wyoming	Before delay, SST varied from 7:30 to 7:50 After delay, SST varied from 8:00 to 8:55	Attendance, academic performance, car crashes.	Most schools saw a decrease in tardiness and an increase in GPA. Two out of the four 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%).
Paksarian et al. (2015)[71] 2001–2004	Cross-sectional	7216 (245 schools)	13–18 years	Nationally (USA) representative	Mean: 8:01 Range: 7:05–9:22	Weeknight bedtime, sleep duration (weeknight and weekend), weekend compensatory sleep	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 8:01 only (11 minutes for each 30 minute delay in SST). Difference only 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.
Only Abstracts Available							
Allen and Mirabile (1989)[50] Not specified	Cross-sectional	61	Grades 10–12 (Mean age 17.1 years)	NR	Early school: 7:30 Late school: 8:00	Sleep duration, bedtimes, rise times (weekdays and weekends).	Later SST corresponded to later rise times ($p < .05$), but no difference in bedtimes. Sleep duration difference not significantly different.
Allen (1992)[51] Not specified	Cross-sectional	102	Grade 12	NR	Early school: 7:40 Late schools: 8:30	Sleep duration, bedtimes, rise times (weekdays and weekends).	Earlier SST corresponded to shorter weeknight sleep duration ($p < .035$), more sleep problems ($p = .04$), and later weekend rise times ($p = .03$).
Carskadon et al. (1995)[53] 1994	Longitudinal (before vs after SST change)	7	Grade 9–10	Rhode Island	Late (Grade 9): 8:25 Early (Grade 10): 7:20	Sleep duration, sleep start time, sleep offset time (measured with actigraphy)	Earlier SST (65 minutes) corresponded to shorter sleep duration (38 minutes, $p < .02$) due to earlier

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							rise times (59 minutes, $p < .005$). No significant difference in school night sleep start time.
Kowalski and Allen[52] Not specified (1995)	Cross-sectional	97 (early school) 119 (late school)	Grades 11–12	NR	Early school: 7:20 Late school: 9:30	Sleep duration, bedtimes, rise times (weekdays and weekends).	Earlier SST corresponded to shorter weeknight sleep duration ($p = .002$).
Wolfson et al. (1995)[54] 1994	Longitudinal (before vs after SST change)	15 (May have included students in Carskadon et al.[53])	Grade 9–10	Rhode Island	Late (Grade 9): 8:25 Early (Grade 10): 7:20	Sleep duration, sleep start time, sleep efficiency (measured with actigraphy); emotional/behavioral problems from Youth Self Report (YSR) summary.	Earlier SST (65 minutes) corresponded to shorter sleep duration (39 minutes, $p < .001$). No significant difference in school night sleep start time or sleep efficiency. YSR total problems and externalizing scores decreased with earlier SST.

Abbreviations: ACT, originally American College Testing – one of two standardized tests commonly used in college admissions in the United States; HS, high school; MS, middle school; NR, not reported; SD, standard deviation; SST, school start time.