Objective: To examine the impact of a 30-minute delay in school start time on adolescents’ sleep, mood, and behavior.

Design: Participants completed the online retrospective Sleep Habits Survey before and after a change in school start time.

Setting: An independent high school in Rhode Island.

Participants: Students (n = 201) in grades 9 through 12.

Intervention: Institution of a delay in school start time from 8 to 8:30 AM.

Main Outcome Measures: Sleep patterns and behavior, daytime sleepiness, mood, data from the Health Center, and absences/tardies.

Results: After the start time delay, mean school night sleep duration increased by 45 minutes, and average bedtime advanced by 18 minutes (95% confidence interval, 7-29 minutes [t14 = 3.36; P < .001]); the percentage of students getting less than 7 hours of sleep decreased by 79.4%, and those reporting at least 8 hours of sleep increased from 16.4% to 54.7%. Students reported significantly more satisfaction with sleep and experienced improved motivation. Daytime sleepiness, fatigue, and depressed mood were all reduced. Most health-related variables, including Health Center visits for fatigue-related complaints, and class attendance also improved.

Conclusions: A modest delay in school start time was associated with significant improvements in measures of adolescent alertness, mood, and health. The results of this study support the potential benefits of adjusting school schedules to adolescents’ sleep needs, circadian rhythm, and developmental stage.


A number of important biologically based changes in sleep regulation occur during adolescence. Beginning at the onset of puberty, adolescents develop as much as a 2-hour sleep-wake phase delay (later sleep onset and wake times) relative to sleep-wake cycles in middle childhood.1,2 These changes are associated with delayed

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evening onset of melatonin secretion and are expressed as a shift in circadian phase preference from “morningness” to “eveningness.” Alterations in the regulatory homeostatic sleep drive during adolescence3,4 are such that the accumulation of sleep propensity during the time awake appears to be slower relative to younger children. Thus, it is typically easier for adolescents to delay sleep onset. At the same time, adolescent sleep needs do not decrease dramatically, and optimal sleep amounts remain at about 9 to 9 1/4 hours per night. On a practical level, this means that the average adolescent has difficulty falling asleep before 11 PM, and the ideal wake time is around 8 AM.

In addition to the impact of these biological factors, environmental factors and lifestyle/social demands such as homework, extracurricular activities, and after-school jobs can significantly affect sleep patterns in adolescents.5-7 Significant variability is seen in sleep-wake patterns from weekday to weekend, often accompanied by sleeping late on weekends in an attempt to address the chronic sleep debt accumulated during the week.8 This phenomenon of weekend oversleep further contributes to circadian disruption and decreased daytime alertness levels.9

Given these findings, it is not surprising that a large number of studies have now documented that the average adolescent is chronically sleep deprived10,11 and pathologically sleepy.10 For example, a recent National Sleep Foundation poll12 found that 80% of adolescents in the United States were getting less than the recommended 9 hours of sleep on school nights. Other studies of adolescents across different environments and in different cultures have reported similar findings in regard to in-
sufficient sleep amounts and irregular sleep-wake sched-
ulates. Inadequate sleep is especially likely to take a toll on aca-
demic performance. Multiple studies have shown an asso-
ciation between decreased sleep duration and lower aca-
demic achievement at the middle school, high school, and
college levels, as well as a decreased motivation to learn.
Specific health-related effects of sleep loss may include an increased number of driving accidents related to drowsiness, a lack of exercise, an increased risk for weight gain and obesity, and an increased use of stimulants (e.g., caffeine, prescription medications).

In light of these myriad negative effects on adolescent health and well-being, the identification of potentially modifiable factors that escalate the risk of insufficient sleep in this population is an important public health issue. Multiple studies have now suggested that, in particular, the early start times of many high schools, as well as some middle schools, may significantly contribute to inadequate sleep in adolescents. Studies comparing schools with start times as little as 30 minutes earlier versus those with later start times have demonstrated the following adverse consequences: shorter sleep dura-
tion, increased sleepiness, difficulties concentrating, and behavioral problems. Conversely, several longitudi-
 nal studies have suggested that delaying school start times may have a significant positive effect on a variety of outcomes, ranging from decreased dropout and tardiness rates and increased daily attendance rates to an improvement in academic grades and standardized test scores and decreased rates of motor vehicle crashes related to drowsi-
ness while driving.

The aim of this study was to assess the impact of a de-
lay in school start time from 8 to 8:30 AM at an indepen-
dent school in the northeastern United States. Specif-
ically, student self-reported sleep patterns and behaviors and sleepiness-related variables were assessed by the administration of an online retrospective survey before and after the 2-month trial period of the change in start times. School administrative data regarding Health Center visits, dining hall statistics, and tardiness/absences were also collected before and after the intervention.

METHODS

SAMPLE

The study site was an independent coeducational college preparatory boarding and day school serving grades 9 to 12 and located in southern New England. Total enrollment for the 2008-2009 academic year was 357; 190 students (53.2%) were girls, 291 (81.5%) were boarders, and 66 (18.5%) were day students. Boarders come from more than 30 states and 20 foreign countries; about 12% are international students, and 18% are nonwhite.

The daily class schedule is from 8 AM to 3 PM, 4 days per week; 8 AM to 1 PM on Wednesday; and 8 to 11 AM on Satur-
day. From January 6 to March 6, 2009, the school start time was delayed to 8:30 AM. To avoid extending the length of the school day, academic and nonacademic periods (student life,
music programs, etc.), assemblies, and afternoon activities (athletics, theater, etc.) were reduced by 5 to 10 minutes.

For boarding students, school night lights-out schedules and procedures in the dormitories did not change. For grade 9, lights-
out time was 10:30 PM; for grade 10, 11 PM; and for grade 11, 11:30 PM. Seniors (grade 12) were required to be in their dorms
at 11:30 PM but had no official lights-out time. There was no lights-out schedule on Saturday nights: students were re-
quired to be in their dormitories by 11 PM (grades 9 and 10) or
11:45 PM (grades 11 and 12). Students were not allowed to use any electronics (e.g., computers or cell phones) after lights out and received a room restriction for any violations. There was no set wake-up time on Sunday.

PROCEDURES

Parents or legal guardians of all students were initially contacted by the school administration by e-mail approximately 2 weeks before the first survey distribution (December 25, 2008) and informed about the study. In a separate subsequent e-mail and several reminder e-mails from the principal investigator (J.A.O.), all parents were asked to give consent for their child’s participation in the study by clicking on a link in the e-mail that took them to a secure server (http://www.surveymonkey.com/).

All students were asked to bring their laptops to their regularly scheduled group advisory meeting, access an e-mail message from the research assistant (K.B.), and complete the electronic assent form for the survey. Students who agreed to participate were then asked to complete the survey online during the advisory meeting; students who declined to participate could not access the survey online. Students who had not received parental permission to complete the survey were instructed to work on classroom assignments during the survey administration period. Students who had not received parental consent to participate in the first survey were not allowed to complete the second survey (March 5, 2009).

Each survey was assigned a code number and did not contain names or other information that would identify students personally or allow them to be matched to their survey responses. Access to the data from all completed surveys was restricted to the principal investigator and research assistant. This study was approved by the institutional review board of the sponsoring organization, Lifespan Hospitals of Rhode Island.

MEASURES

The Sleep Habits Survey is a comprehensive 8-page self-report survey that has been administered to more than 3000 high school students in Rhode Island, as well as to high school students in a number of other countries. The Sleep Habits Survey asks about typical sleep and wake behaviors during the previous week and includes a Sleepiness Scale and Sleep-Wake Behavior Problems Scale, Depressed Mood Scale, and assessment of morningness/eveningness. The Sleepiness Scale is a modified version of the Epworth Sleepiness Scale, which rates sleepiness under various conditions; a higher score indicates a greater propensity to fall asleep.

The Sleep-Wake Behavior Problems Scale contains 15 items that reflect a combination of difficulties with sleep initiation and maintenance, as well as other sleep-related problems (e.g., nightmares); a higher score indicates more sleep problems. Minor modifications were made to some of the items for the study population. The survey took approximately 25 minutes to complete.

To assess the effect on health outcomes, during the 2 weeks before the first and second survey administrations, the Health Center created a report regarding Health Center visits, missed morning appointments, overnight admissions, late pass requests (for a first-period class), and requests to rest in the Health

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Center for the academic day or in the afternoon during sports. Food Services also recorded the types and numbers of foods consumed at breakfast during the months of December and February. In addition, the office of the Dean of Students tracked first-period tardies/absences during both time periods. Tests for skewness when data were not normally distributed were performed; for all non-normal distributions, data were transformed to achieve normalcy, and both the transformed and nontransformed data were analyzed. Because there were no significant differences in the results, analyses on the nontransformed data were preserved. Significance level was set at P < .001.

### STATISTICAL ANALYSES

Descriptive statistics were calculated for the different components of the survey instrument. We used appropriate parametric and nonparametric statistics, including independent samples t tests, χ² analyses, regressions, and correlations to compare sleep patterns and behaviors, daytime sleepiness, and mood before and after the delay of the start time. Tests for skewness when data were not normally distributed were performed; for all non-normal distributions, data were transformed to achieve normalcy, and both the transformed and nontransformed data were analyzed. Because there were no significant differences in the results, analyses on the nontransformed data were preserved. Significance level was set at P < .05.

### RESULTS

A total of 278 students received parental permission and were eligible to complete the study (77.9% of all students); 54.3% were girls. Of those students who had received consent, 225 (80.9%) completed survey 1 (57.3% were female) and 201 students completed survey 2 (89.3% of students completing survey 1; 57.2% were female). There were no significant differences in participation rates between non–school nights and school nights of 45 minutes (7 hours 52 minutes vs 7 hours 7 minutes; 95% confidence interval [CI] −49 to −27 minutes; t₁₄₀ = −6.35; P < .001) after the change in school start time. As expected, this was partially explained by a later average wake time at survey 2 (7:25 AM vs 7:52 AM at survey 1; 95% CI, −36 to −24 minutes [t₁₄₀ = −10.10; P < .001]). However, the average bedtime on school nights was significantly earlier (18 minutes; 95% CI, 7-29 minutes [t₁₄₀ = 3.36; P < .001]) at survey 2 than at survey 1. The percentage of students getting at least 9.0 hours, 8.0 to 8.9 hours, 7.0 to 7.9 hours, 6.0 to 6.9 hours, and less than 6.0 hours of sleep in surveys 1 and 2 also differed significantly across surveys for school nights (χ² = 96.83; P < .001) (Figure 1).

Although non–school night sleep duration was less and average bedtime was earlier at survey 2 compared with survey 1, these differences did not reach statistical significance (difference in sleep duration: −12 minutes; 95% CI, −11 to 25 minutes [t₁₄₀ = 0.79; P = .43]; difference in bedtime: −23 minutes; −2 to 48 minutes; [t₁₄₀ = 1.79; P = .07]) (Table 1). The distribution of sleep amounts was also not significantly different for non–school nights (χ² = 3.96; P = .36) (Figure 2). The difference between non–school night and school night bedtimes was also not significant at surveys 1 or 2 (1 hour 17 minutes vs 1 hour 12 minutes; 95% CI, −21 to 30 minutes [t₁₄₀ = 0.34; P = .73]). Weekend oversleep (the difference between school day and non–school day wake times), however, was significantly greater at survey 1 (3 hours 28 minutes vs 2 hours 55 minutes; 95% CI, 19-46 minutes [t₁₄₀ = 4.74; P < .001]). There was a significant main effect of grade level on sleep duration (regardless of survey; F = 28.32; P < .001), with 11th and 12th graders getting significantly less sleep than 9th and 10th graders on school nights; there was a difference of nearly 40 minutes between 9th and 12th graders (P < .001). There was no sex difference in average duration of school night sleep, and there were no interactions among sex, grade, and survey. Self-reported sleep needs were identical across surveys (8.9 hours); most of the students rated themselves as definitely or closer to being an evening type than a morning type (survey 1, 73.2%; survey 2, 75.7%).
School night sleep duration did not differ significantly between boarding and day students (Table 2 [F = 2.52; P = .08]), although there was an equally significant main effect of survey time in both groups (F = 30.12; P < .001). However, day students had significantly longer sleep times on non–school nights (P < .02).

The relative percentage of students at survey 1 vs 2 reporting rarely or never getting enough sleep (69.1% vs 33.7%), never being satisfied with their sleep (36.8% vs 9.2%), and never getting a good night’s sleep (28.6% vs 11.9%) was significantly different (odds ratio [OR], 0.10; 95% CI, 0.05-0.20; χ² = 51.76; P < .001). In contrast, the percentage of students reporting difficulty falling asleep at least several times a week vs never was not significantly different at surveys 1 and 2 (OR, 0.90; 95% CI, 0.49-1.34; χ² = 0.12; P = .76). The mean (SD) score on the Sleep-Wake Behavior Problems Scale was significantly higher at survey 1 (31.5 [6.92]) than at survey 2 (25.6 [7.63]; 95% CI, 4.38-7.31; t₁₀₀ = 7.86; P < .001). Table 3 details changes in students’ perception of daytime sleepiness and related impairments across surveys; all these differences were all highly significant across time (P < .001 for all). Differences in the Sleepiness Scale scores were also highly significant (28.5 vs 22.9; mean difference, 5.65; 95% CI, 4.05-7.25; t₂₈₁ = 6.85; P < .001) but did not differ by grade or between day and boarding students; girls had higher Sleepiness Scale scores compared with boys (F = 22.46; P < .001). The number of students who required assistance with waking on school mornings (ie, alarm clock, parents/dormitory monitor, or roommate) compared with those who reported waking without assistance was also highly significant (23.7% vs 8.2%; mean difference, 15.4%; 95% CI, 7.65-23.15; t₁₁₀ = 3.50; P < .01).

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average grades of B or better increased slightly at survey 2. Although the percentage of students self-reporting other after-school activities was similarly high at both surveys, students reporting participating in sports, homework, and tardiness or lack of motivation at survey 2, the percentage of significantly fewer students reported being affected by fatigue-related symptoms at survey 1 vs survey 2 (15.3% vs 8.6%; \( \chi^2 = 8.65; P = .003 \)) (Table 3).

Figure 3 shows the percentage of students who reported being bothered by feeling too tired and unmotivated somewhat or much of the time at surveys 1 and 2. Although significantly fewer students reported being affected by fatigue or lack of motivation at survey 2, the percentage of students reporting participating in sports, homework, and other after-school activities was similarly high at both surveys. Although the percentage of students self-reporting average grades of B or better increased slightly at survey 2 (87.1% vs 82.2%), this difference was not statistically significant (OR, 0.70; 95% CI, 0.41–1.20; \( \chi^2 = 1.71; P = .22 \)).

Scores on the Depressed Mood Scale were significantly negatively correlated with school night sleep amounts for surveys 1 (\( r = -0.26; P < .001 \)) and 2 (\( r = -0.16; P = .03 \)) but not with non-school night sleep amounts (survey 1: \( r = -0.011, P = .87 \); survey 2: \( r = -0.11, P = .13 \)). The percentage of students rating themselves as at least somewhat unhappy or depressed also decreased significantly from survey 1 (65.8%) to 2 (45.1%; OR, 0.43; 95% CI, 0.29–0.64; \( \chi^2 = 17.81; P < .001 \)), as did the percentage feeling irritated or annoyed (84.0% vs 62.6%; OR = 0.32; 95% CI, 0.20–0.51; \( \chi^2 = 24.62; P < .001 \)), and Depressed Mood Scale average scores decreased (1.84 vs 1.56; \( F = 27.80; P < .001 \)). Higher depression scores were also found in 11th and 12th graders (\( F = 8.06; P = .005 \)) and in girls compared with boys (\( F = 5.22; P = .02 \)) at survey 1; however, at survey 2 the differences in depression scores between grades (\( F = 0.54; P = .46 \)) and between girls and boys (\( F = 2.06; P = .15 \)) were not significant.

In terms of health consequences, significantly more students self-reported visiting the Health Center for fatiguerelated symptoms at survey 1 vs survey 2 (15.3% vs 4.6%; \( \chi^2 = 14.50; P = .03 \)), whereas there was no difference in the number of students visiting the Health Center for medical or psychological concerns. Actual Health Center statistics (Table 4) showed a decline in missed morning appointments and late pass requests at survey 2; there was also a 56% decrease in requests for rest passes. Overnight admissions to the Health Center, however, increased, although this was believed to be at least partially owing to an influenza outbreak at the school during winter term. Food Services data showed a substantial increase in consumption of hot foods (ie, eggs and breakfast meats) at breakfast from December to February (35% vs 83 servings a month). Finally, teacher-reported first class absences/tardies decreased by 45.0% (Table 4).

The results of this survey study of students from an independent school support those of previous research studies examining the impact of delaying high school start times in public high school settings. A modest (ie, 30-minute) start time delay was associated with a significant increase in self-reported sleep duration and a decrease in a number of ratings of daytime sleepiness. Perhaps more important, students rated themselves as less depressed and more motivated to participate in a variety of activities and were less likely to seek medical attention for fatigue-related concerns in conjunction with the change in start times. Furthermore, as in previous studies, depressive symptoms overall were negatively correlated with school night sleep amounts for surveys 1 (\( r = -0.26; P < .001 \)) and 2 (\( r = -0.16; P = .03 \)) but not with non-school night sleep amounts (survey 1: \( r = -0.011, P = .87 \); survey 2: \( r = -0.11, P = .13 \)). The
tively correlated with reported sleep duration and increased in groups of students (ie, 11th- and 12th-grade students and girls) who reported getting less sleep or being more sleepy or both. Given the recent concerns raised regarding the relationship between insufficient sleep and both depressive symptoms and suicidal ideation in adolescents, this positive effect on mood associated with delaying the start time is particularly noteworthy.

In the original school start times experiment,34,35 comparison students from 2 different schools with earlier and later start times. For example, there was much less variability among this group of students in regard to after school activities and homework requirements (as well as a virtual absence of after-school employment demands) compared with those in a typical high school environment. In addition, the high percentage of students living on campus also ensured considerable consistency in sleep practices (ie, evening electronic media exposure and lights-out timing) across surveys. We were also able to systematically collect data on a number of health-related outcomes, which would have been extremely challenging in a public school setting.

Additional study limitations include the lack of a control group of students who did not experience the change in school start times; as a result, we cannot attribute the positive changes in sleep duration and sleepiness to the change in start times alone. Because of confidentiality procedures, it was not possible to match individual presurvey and postsurvey responses, and thus we could assess changes in the aggregate only. Although data regarding frequency of napping were collected, we did not specifically ask for nap duration and thus were not able to assess changes in 24-hour sleep duration. Specific data were also not collected in regard to symptoms of sleep disorders, the presence of which may have affected sleepiness levels. Finally, the study was also based on retrospective subjective self-report data rather than objectively measured sleep variables. However, a previous study comparing Sleep Habits Survey self-report data with sleep diary–reported and actigraphically derived sleep patterns found a high correlation among measures.

The ongoing debate regarding the more widespread institution of later start times for middle and high schools is a controversial one, and the logistical considerations in implementing delayed school start times in high schools are far from trivial. Thus, it is particularly important to continue to rigorously assess outcomes in those schools that have instituted these changes. The results of this study add to the growing literature supporting the potential benefits of adjusting school schedules to adolescents’ sleep needs, circadian rhythm, and developmental stage and of optimizing sleep and alertness in the learning environment.

Accepted for Publication: January 12, 2010.

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Financial Disclosure: None reported.

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