

Impact of Delaying School Start Time on Adolescent Sleep, Mood, and Behavior

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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 [$t_{423}=3.36$; $P<.001$]); 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.

Arch Pediatr Adolesc Med. 2010;164(7):608-614

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 adolescence^{3,4} 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 9¼ hours per night. On a practical level, this means that the average ado-

lescent 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 deprived^{10,11} 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-

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sufficient sleep amounts and irregular sleep-wake schedules.¹³⁻¹⁵ As a result, high school students are at considerable risk for adverse consequences associated with inadequate sleep, including impairments in mood, attention, memory, behavioral control, and quality of life.¹⁵⁻²⁰ Inadequate sleep is especially likely to take a toll on academic performance.²⁰ Multiple studies have shown an association between decreased sleep duration and lower academic achievement at the middle school, high school, and college levels,²¹⁻²⁴ as well as a decreased motivation to learn.²⁵ Specific health-related effects of sleep loss may include an increased number of driving accidents related to drowsiness,²⁶ a lack of exercise,¹² an increased risk for weight gain and obesity,²⁷ and an increased use of stimulants (eg, caffeine, prescription medications).²⁸

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.^{10,13,29-32} Studies comparing schools with start times as little as 30 minutes earlier vs those with later start times have demonstrated the following adverse consequences: shorter sleep duration, increased sleepiness, difficulty concentrating, and behavioral problems.³³⁻³⁵ Conversely, several longitudinal 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 drowsiness while driving.^{26,36,37}

The aim of this study was to assess the impact of a delay in school start time from 8 to 8:30 AM at an independent school in the northeastern United States. Specifically, 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 Saturday. 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 (ie, 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 required 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 (eg, 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,²² as well as to high school students in a number of other countries.^{13,14} 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 (eg, 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

Table 1. Mean Self-reported Sleep Duration, Bedtimes, and Wake Times by Survey (S) and Grade Level on School Nights and Non-School Nights^a

	Overall		Grade 9		Grade 10		Grade 11		Grade 12	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
School nights										
Sleep duration, h:min	7:07 (0:46) ^b	7:52 (1:13) ^b	7:20 (0:50)	8:11 (0:36)	7:13 (0:47)	8:01 (0:42)	6:59 (0:41)	7:34 (0:56)	6:53 (0:42)	7:23 (0:41)
Bedtime	11:39 PM (0:51) ^b	11:21 PM (1:04) ^b	11:14 PM (0:54)	10:54 PM (0:37)	11:31 PM (0:46)	11:17 PM (0:29)	11:41 PM (0:45)	11:31 PM (0:47)	12:13 AM (0:42)	12:01 AM (0:41)
Wake time	6:54 AM (0:29) ^b	7:25 AM (0:32) ^b	6:44 AM (0:31)	7:13 AM (0:37)	6:55 AM (0:26)	7:26 AM (0:32)	6:52 AM (0:31)	7:25 AM (0:30)	7:05 AM (0:24)	7:36 AM (0:28)
Non-school nights										
Sleep duration, h:min	9:32 (1:46)	9:20 (1:27)	9:26 (1:32)	9:12 (1:08)	9:45 (1:26)	9:42 (1:11)	9:19 (1:15)	9:03 (1:18)	9:25 (1:19)	9:13 (1:29)
Bedtime	12:56 AM (1:03)	12:33 AM (0:51)	12:55 AM (1:17)	12:50 AM (1:10)	12:39 AM (0:57)	12:39 AM (0:59)	1:02 AM (0:54)	1:01 AM (1:03)	1:12 AM (1:02)	12:40 AM (3:53)
Wake time	10:22 AM (1:18)	10:20 AM (1:11)	10:17 AM (1:07)	10:02 AM (0:56)	10:23 AM (1:12)	10:31 AM (1:09)	10:30 AM (1:05)	10:08 AM (1:07)	10:18 AM (1:46)	10:39 AM (1:28)

^aData are expressed as mean (SD). For bedtimes and wake times, the standard deviations are expressed as hours:minutes.

^bSignificantly different from the other survey mean ($P < .001$).

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.

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, χ^2 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 normality, 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 across grades 9 to 12. The mean age of students participating in survey 1 was 16.4 years and in survey 2 was 16.6 years. At surveys 1 and 2, 82.2% and 87.1% of students, respectively, reported getting mostly Bs or better in academic grades, and 99.5% intended to get at least a college degree.

Table 1 and **Table 2** show self-reported mean sleep duration, bedtimes, and wake times. There was a significant increase in sleep duration on school nights of 45 minutes (7 hours 52 minutes vs 7 hours 7 minutes; 95% confidence interval [CI] -49 to -27 minutes; $t_{320} = -6.35$;

$P < .001$) after the change in school start time. As expected, this was partially explained by a later average wake time at survey 2 (7:25 vs 6:54 AM at survey 1; 95% CI, -36 to -24 minutes [$t_{420} = -10.10$; $P < .001$]). However, the average bedtime on school nights was significantly earlier (18 minutes; 95% CI, 7-29 minutes [$t_{423} = 3.36$; $P < .001$]) 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 ($\chi^2 = 96.83$; $P < .001$) (**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 [$t_{240} = 0.79$; $P = .43$]; difference in bedtime: -23 minutes; -2 to 48 minutes; [$t_{240} = 1.79$; $P = .07$]) (Table 1). The distribution of sleep amounts was also not significantly different for non-school nights ($\chi^2 = 3.96$; $P = .56$) (**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 [$t_{418} = 0.34$; $P = .73$]). Week-end 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 [$t_{411} = 4.74$; $P < .001$]).

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%).

Table 2. Mean Self-reported Sleep Duration, Bedtimes, and Wake Times by Survey (S) and Day vs Boarding Students^a

	Boarding Students				Day Students			
	School Nights		Non-School Nights		School Nights		Non-School Nights	
	S1	S2	S1	S2	S1	S2	S1	S2
Sleep duration, h:min	7:08 (0:46) ^b	7:51 (0:46) ^b	9:26 (1:26) ^c	9:13 (1:18) ^c	7:03 (0:47) ^b	7:51 (0:51) ^b	9:49 (1:16) ^c	9:45 (1:11) ^c
Bedtime	11:43 PM (0:51) ^b	11:30 PM (0:43) ^b	1:05 AM (0:59)	1:07 AM (0:58)	11:30 PM (0:50) ^b	11:05 PM (0:45) ^b	12:32 AM (1:06)	12:11 AM (1:12)
Wake time	6:58 AM (0:27) ^b	7:30 AM (0:30) ^{b,d}	10:23 AM (1:22)	10:23 AM (1:11)	6:44 AM (0:31) ^b	7:05 AM (0:35) ^{b,d}	10:20 AM (1:08)	10:10 AM (1:11)
Sleep duration, % of students ^e								
≥9.0 h	0	9.6	75.2	66.2	3.3	18.2	80.0	79.5
8.0-8.9 h	18.2	46.5	13.9	21.7	8.3	31.8	15.0	11.4
7.0-7.9 h	50.9	34.4	5.5	7.6	46.7	38.6	3.3	2.3
6.0-6.9 h	27.3	5.7	3.0	1.9	40.0	6.8	0	2.3
≤6.0 h	3.6	0.6	1.2	0.6	1.7	2.3	0	0

^aUnless otherwise indicated, data are expressed as mean (SD).

^bSchool night sleep duration and bedtime and wake times were significantly different at surveys 1 vs 2 in day and boarding students ($P < .001$).

^cDay students had significantly longer sleep times on non-school nights ($P < .02$).

^dAt survey 2, wake times for boarding vs day students were significantly different ($P < .001$).

^eWe were unable to calculate sleep durations for all students. Percentages that do not total 100 reflect missing values (eg, in boarding student non-school night sleep duration at S1, 1 student [1.2%] had missing data).

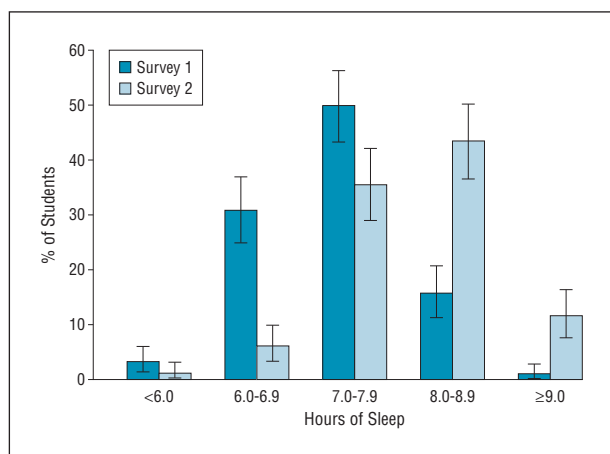


Figure 1. Percentage of students in each self-reported school night sleep duration category at surveys 1 and 2 (χ^2 test, $P < .001$). Limit lines represent 95% confidence intervals.

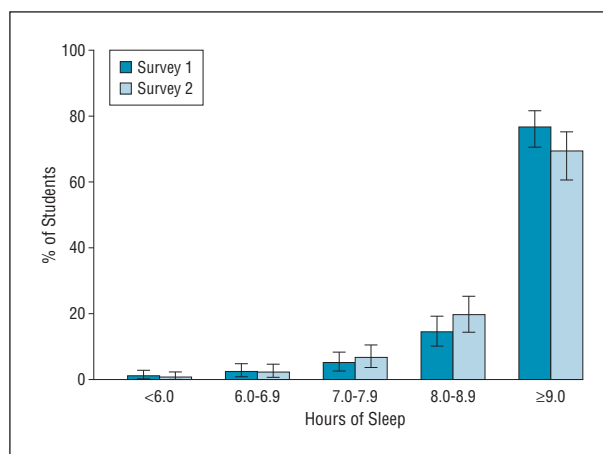


Figure 2. Percentage of students in each self-reported non-school night sleep duration category at surveys 1 and 2 (χ^2 test, $P = .56$). Limit lines represent 95% confidence intervals.

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 (approximately 28 minutes; 95% CI, 17-77 minutes; $t_{416} = 3.07$; $P = .02$; mean difference, 47 minutes), presumably largely due to earlier bedtimes (survey 1: 12:32 vs 1:05 AM; 95% CI, -51 to -14 minutes; $t_{220} = -3.50$; $P = .001$; survey 2: 12:11 AM vs 1:07 AM; 95% CI, -1 hour 19 minutes to -31 minutes; $t_{196} = -4.60$; $P < .001$).

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; $\chi^2 = 51.76$; $P < .001$). In contrast, the percentage of students reporting diffi-

culty 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; $\chi^2 = 0.12$; $P = .76$). 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; $t_{381} = 7.86$; $P < .001$).

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; $t_{392} = 6.85$; $P < .001$) 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 wak-

Table 3. Percentage of Students Reporting Daytime Sleepiness-Related Behaviors in the Past Week at Surveys (S) 1 and 2

Behavior	% of Students	
	S1	S2
Daytime sleepiness (at least more than a little)	49.1	20.0 ^a
Struggled to stay awake, fell asleep, or both during class	85.1	60.5 ^a
At least somewhat bothered by feeling too tired to do homework	90.0	66.2 ^a
Fell asleep during morning class (at least once)	38.9	18.0 ^a
Arrived late (at least once)	36.7	22.6 ^a
Takes naps at least sometimes (sometimes on school days, sometimes on weekends, or every day)	52.4	36.3 ^a
Required assistance to wake up in the morning (alarm clock, parents/dormitory monitor, or roommate)	96.6	89.0 ^a

^aSignificantly different from S1 ($P \leq .001$).

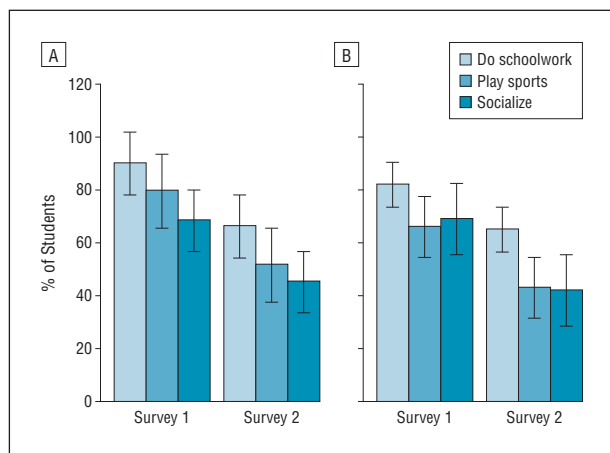


Figure 3. Percentage of students reporting that they felt too tired (A) and unmotivated (B) to engage in various activities somewhat or much of the time at surveys 1 and 2. Limit lines represent standard errors.

ing spontaneously also decreased significantly (OR, 3.49; 95% CI, 1.45-8.42; $\chi^2=8.65$; $P=.003$) (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 to do schoolwork, play sports, or socialize 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

Table 4. Actual Number of Health Center Visits and Teacher-Reported First Class Absences/Tardies at Surveys (S) 1 and 2

Event	No. of Events	
	S1	S2
Physician visits	54	48
Missed morning appointments at Health Center	21	16
Late pass requests	4	2
Rest visits	69	30 ^a
Health Center overnight admissions	15	27
Late to class owing to oversleeping	80	44 ^a

^aSignificantly different from S1 ($P \leq .05$).

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 12 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 fatigue-related 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).

COMMENT

The results of this survey study of students from an independent school support those of previous research studies^{10,22,26,33,35,36} examining the impact of delaying high school start times in public high schools 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,^{15,22} depressive symptoms overall were nega-

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,³⁸ this positive effect on mood associated with delaying the start time is particularly noteworthy.

Similar to the finding of previous studies,^{35,36} students in this study reported that their wake time was later after the start time change had been instituted, resulting in an increase in sleep duration. In contrast to the Minnesota studies,^{35,36} which found that bedtimes did not change, in this study students reported going to bed earlier after start times were delayed, resulting in a greater-than-expected increase in average school night sleep duration of 45 minutes. Although this may have been partly owing to seasonal variations in bedtime, anecdotal student comments suggest that the perceived benefits of additional sleep motivated students to further modify their sleep-wake behaviors to optimize sleep duration (eg, "Well for me, ever since the 8:30 start, I have seen how much good 30 minutes of extra sleep does for me, so I have been inspired to . . . get an additional half hour on top of the 30 minutes."). Furthermore, despite the initial considerable resistance voiced by the faculty and athletic coaches to instituting the start time delay and the original intentions of the school administration to return to the 8 AM start time after the trial period, students and faculty overwhelmingly voted to retain the 8:30 AM start for the spring term (a faculty quotation: "On a more personal note, I have found the 8:30 start to be the single most positive impact to my general quality of life at [the school] since I started 12 years ago.").

One of the concerns raised in regard to the potentially negative effects of delaying school start times is that the resultant opportunity for increased time in bed will not necessarily translate to an increase in sleep duration but rather to an increase in sleep onset latency and night wakings (ie, decreased sleep consolidation). However, students at survey 2 did not report an increase in difficulty falling asleep, and the Sleep Habits Survey Sleep-Wake Behavior Problems subscale score was actually lower at survey 2, implying that the increase in sleep duration and earlier reported bedtimes at survey 2 did not come at the expense of poorer quality of sleep and increased difficulty initiating sleep.

The percentage of students getting less than 7 hours of sleep after the change in school start time decreased by 79% (from 33.8% to 7.0%), and the percentage of students getting at least 8 hours of sleep increased from 16.4% to 54.7%. However, it should be pointed out that, even with this significant increase in average sleep duration, only a small minority of students (11%) reported getting the recommended 9 or more hours of sleep on school nights at survey 2. A weekend oversleep of almost 3 hours persisted, and a substantial percentage of students continued to report significant daytime sleepiness after the school start time change (eg, 66.2% reported being sleepy doing homework, 18.0% reported falling asleep in a morning class, and 36.3% reported napping). Thus, although the positive impact associated with delaying school start time by 30 minutes was striking and broad in scope, it fell far short of achieving the

ideal, and additional schedule modifications and education of students regarding the impact of sleep loss and fatigue should be considered.

Clearly, the generalizability of these findings is limited by the setting in which they occurred; that is, there are limited parallels between a relatively small, independent, largely boarding school and the average American public high school. However, the highly structured environment and the unique student body of the study school offered some advantages in terms of assessing the impact of the start time change. We were able to compare the same group of students before and after the start time change, removing some confounds inherent in studies that have compared students from 2 different schools with earlier and later start times.^{34,35} 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.³⁹ 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.⁴⁰

The ongoing debate regarding the more widespread institution of later start times for middle and high schools is a controversial one,⁴¹ 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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Author Contributions: Dr Owens had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. **Study concept and design:** Owens, Belon, and Moss. **Acquisition of data:** Owens, Belon, and Moss. **Analysis and interpretation of data:** Owens, Belon, and Moss. **Drafting of the manuscript:** Owens and Belon. **Critical revision of the manuscript for important intellectual content:** Owens and Moss. **Administrative, technical, and material support:** Belon and Moss. **Study supervision:** Owens and Moss. **Financial Disclosure:** None reported.

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As a teenager you are at the last stage in your life when you will be happy to hear that the phone is for you.

—Fran Lebowitz, *Social Studies*