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ORIGINAL RESEARCH

Sleep Insufficiency, Sleep Health Problems and Performance in High School Students

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Abstract: A survey on sleep schedule, sleep health, school performance and school start times was conducted in 1,941 adolescents. A high level of early and circadian-disadvantaged sleep/wake schedules during weekdays was observed. Shorter sleep duration on weekdays was reported, especially in upper classmen. Complaints of inadequate sleep and sleepiness during weekdays, alarm clock use, and napping were prevalent. Night awakening and prolonged sleep onset were common and associated with poor school performance. 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. The total number of poor sleep factors in an individual also correlated with poor school performance. Earlier school start times were associated with a perception of poor sleep quality, shorter sleep duration and more sleep health problems. We conclude that sleep inadequacies and sleep health problems were prevalent in this population, especially in those who started school earlier in the morning, and that these poor sleep factors were associated with school performance.

Keywords: sleep deprivation, sleep health problem, adolescents, performance, school start time

Introduction

Sleep is an integrated part of human health and life and is crucial for learning, performance, and physical and mental health.[1] Traffic accidents, performance errors, and exacerbation of disease states have all been linked to poor sleep quality. Furthermore, individuals who must perform during their disadvantaged circadian hours (such as shift workers) are more prone to accidents and health problems.[2]

There has been an increased awareness of insufficient and/or poor quality sleep among adolescents. In general, adolescents prefer to retire and rise late, especially when their melatonin release is delayed during puberty.[3] This preference is reflected by later bedtimes and longer sleep durations on holidays or weekends.[4–8] However, current high school schedules are not favorable for adolescents in many school districts within the United States. For example, one study showed that the average adolescent's school night bedtime is 22:33 and rise time is 06:06. During weekends, the bedtime and rise time are delayed until 00:25 and 09:32, respectively,[8] suggesting that the sleep/wake schedule during school days was adjusted to school demands, rather than a more natural circadian rhythm. Many high schools start earlier than elementary schools, adding a greater demand to align sleep/wake schedules with adolescents' delayed circadian rhythm.

In addition to a delayed circadian rhythm, a typical adolescent requires 9 hours of sleep each night.[7,9] However, this requirement is difficult for adolescents to fulfill as it has been reported that they sleep an average of less than 8 hours during school nights.[5–7] Concerns about the effects of sleep deprivation led to studies regarding its impact on school performance. It was observed that poor sleep quality, reduced total sleep time and excessive daytime sleepiness negatively affected academic performance, behavior, and social competence in adolescents.[1,5,7] However, it is not known whether multiple unfavorable sleep problems are more likely to be associated with poor school performance. In addition, it is equally unclear whether early school start times directly contribute to sleep insufficiency. Accordingly, the first objective of this study was to assess whether multiple indicators of poor sleep were more likely to be associated with a poorer school performance. School performance was compared among students who had more than one sleep problem to those with only a single problem or

none. The second objective was to evaluate the sleep patterns of students to identify sleep habits that were not associated with poor school performance. Finally school start time was analyzed against sleep duration, quality of sleep, and symptoms of sleep disorders for possible associations of an earlier start time and sleep insufficiency. We hope that the results of this preliminary study increase public awareness of sleep problems among high school students.

Method
The questionnaire

The questionnaire was developed after a review of the literature,[4–9] and interviews of volunteer high school students and teachers. The anonymous questionnaire consisted of 13 categories of questions regarding sleep habits and schedules, symptoms of sleep disorders, school performance and school start time. There were sub-categories or more than one question within each category. The students were asked to complete the questions based on their typical daily schedules. Sleep schedules, including bedtime and rise time on weekdays and weekends, were grouped for participants to check one answer within each schedule. Morning rise time schedules were listed as "before 6 AM", "6:00–6:30 AM", "6:30–7 AM", "7–7:30 AM", "after 7:30 AM" and "highly irregular". Likewise, bedtime schedules were listed as "before 10 PM", "10–11 PM", "11–11:30 PM", 11:30–12 midnight", "after midnight", or "highly irregular". Other questions asked about sleep duration in hours, the students' own perception of their sleep adequacy, sleep disorder symptoms such as prolonged sleep onset (longer than one hour), regular night awakening (once or more), excessive sleepiness while in school, use of an alarm clock, and naps after school (with a weekly frequency check list). Self-reported average academic grades (A, B, C, D, or Fail), and school start time were also included. The questions were in a format of multiple choice, checklist, or fill-in where students were required to self-report their answers.

Subjects

The subjects were selected from five New Jersey high school programs: one public high school in Union county, one public high school and one vocational high school in Monmouth county, and two extracurricular high school programs in the New Jersey Medical

School in Newark. A total of 2307 anonymous questionnaires were distributed to students in grades 9th–12th of the participating programs during school hours while students were in class, and 2147 questionnaires were collected.

Data analysis

Of the 2147 questionnaires collected, 206 questionnaires were excluded due to large number of unanswered questions (more than 6 individual questions). The total number of questionnaires included for data analysis was 1941. Results of each question were coded and imported into an Excel spreadsheet. Quantitative results such as "duration of sleep" were categorized into groups such as "less than 5 hours", "5–6.5 hours", and so forth. Blank answers were treated as missing data for each question. The frequency of variables of each question was tallied. SAS version 8.0 was used for statistical analysis. *Chi* square and Fisher's exact tests were used to determine statistical significance of association. Odds ratios were calculated when *P* values reached <0.05. Pearson's correlation tests were performed to assess the correlation between multiple unfavorable sleep schedules/habits and performance.

This study was approved by the Institutional Review Board of The University of Medicine and Dentistry of New Jersey—New Jersey Medical School. The informed consent process was waived due to the anonymous nature of this study. All the participating high school programs gave permission to conduct the survey.

Results

Participants

Of the 1941 participants, 1054 (54.3%) were female and 860 (44.3%) were male students, and 27 (1.4%) students did not report their genders. The grade distribution of the students was 360 9th graders, 487 10th graders, 579 11th graders, and 505 12th graders. Eleven students did not report their grades. The median age for 9th grade is 14 years old, 10th grade 15 years old, 11th grade 16 years old, and 12th grade 17 years old.

Sleep schedules

The sleep/wake cycles of the participants showed different patterns during weekdays versus weekends. The percentage of students who reported their morning rise

times and night bedtimes in each of schedule periods was tallied and expressed as bar graph in Figure 1. During weekdays, 60% of students arose before 6:30 and over 80% of students arose before 7:00. In contrast, only 0.2% of students arose before 7:00 during weekends and 64% of the students reported a weekend rise time after 9:00. With regard to the bedtime schedule, the majority of students went to bed between 22:00 and 24:00 during weekdays. Although a small proportion of students stayed awake after midnight, an even smaller percent of students went to bed before 22:00. However, their bedtime schedules were shifted to significantly later hours during weekends. Almost half of the students stayed awake after midnight, and 72.6% of the students went to bed after 23:30. There was a tendency to have irregular rise and bedtime schedule during weekends.

Sleep durations

We evaluated the total night sleep time on weekdays and weekends. The self estimated nightly sleep
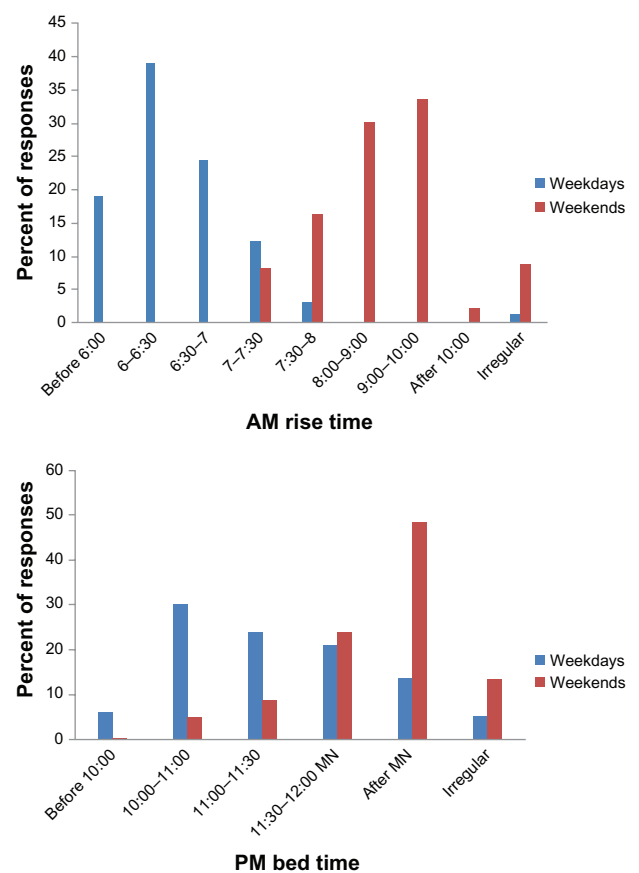

Figure 1. Sleep/wake patterns on weekdays and weekends.

duration in hours was grouped and the percent of students in each sleep duration group is shown in Figure 2. During weeknights, 12.6% of the students reported 5 or less hours of sleep, 31% slept 5.5–6.5 hours, 50.6% reached 7–8 hours sleep, 4.9% reported 8.5–9.5 hours of sleep, and a negligible 0.7% of students reported 10 or more hours of sleep. The majority of students slept less than 8 hours during school nights. In contrast, 26.6% and 37.6% of students reported 8.5–9.5 hours and 10 or more hours of sleep, respectively, during weekend nights.

In addition, we looked at the impact of age on sleep duration. Analysis of sleep duration across grades (a surrogate for age) revealed a change of sleep duration pattern among the students. The percent of the students in each of sleep duration groups was graphed in Figure 3. 50% of 11th or 12th graders slept less than 6.5 hours during school nights, as compared to 30% of 9th graders and 39% of 10th graders with a similar sleep duration. Upperclassmen suffered a greater sleep deprivation. The sleep durations on weekends were longer and less variable across all age groups, demonstrating that most students had "caught-up" on their sleep over the weekend.

Sleep health problems

The results gathered from the questions regarding sleep quality and symptoms of poor sleep health showed that a significant number of students suffered from insomnia at night and hyper-somnolence during the day (Table 1). Only 34% of the students reported adequate sleep during school nights. On the other hand, 80% of the students reported adequate sleep during weekends, suggesting that they had "caught up" on their sleep during the weekend. 80% of the students reported sleepiness during school days, while less than one fourth of the students felt sleepy on weekends. Almost half of the students napped after school to relieve sleepiness. In support of the subjective complaints, 69% of the students slept less than 7 hours during school nights while almost 86% of the students slept for more than 7 hours on weekends. Furthermore, 80% of students reported sleep termination by an alarm clock during school nights. Conversely 86% of the students did not use an alarm device on weekends. In addition to poor quality and inadequate quantity of sleep and daytime sleepiness, students exhibited symptoms of insomnia. 36% of the students reported night awakenings, or taking longer than one hour to fall asleep (see Table 1). Taken together, these results showed that many students suffered from *poor sleep quality*.

Association of Sleep Habits or Health with Performance

The possible impact of sleep habits or health problems was assessed by whether these had any association with school performance (Table 1). The students were asked to self-report their current average grades based on their report cards. The grades were grouped as "B or better" vs. "C or worse". *Chi* square tests (and odds ratios when appropriate) were used to evaluate
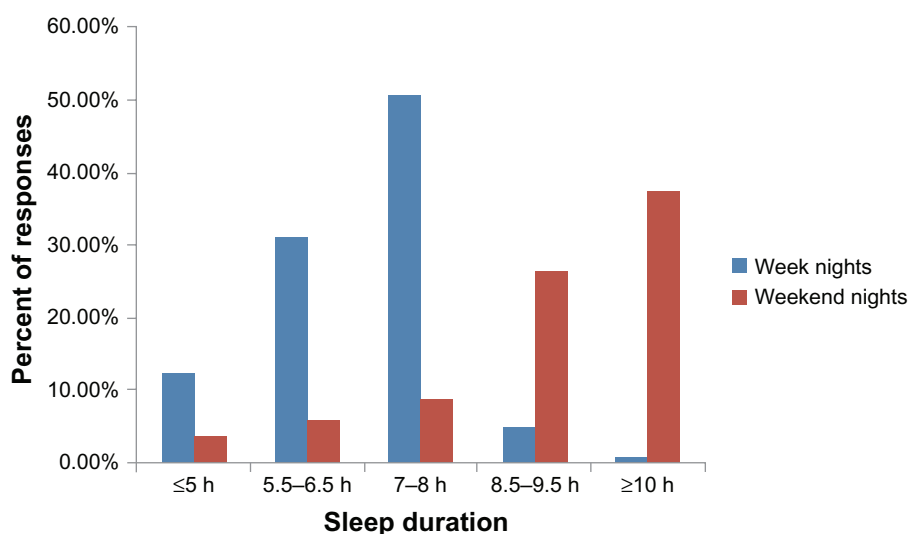
Figure 2. Sleep durations of all participating students (percent of responses).
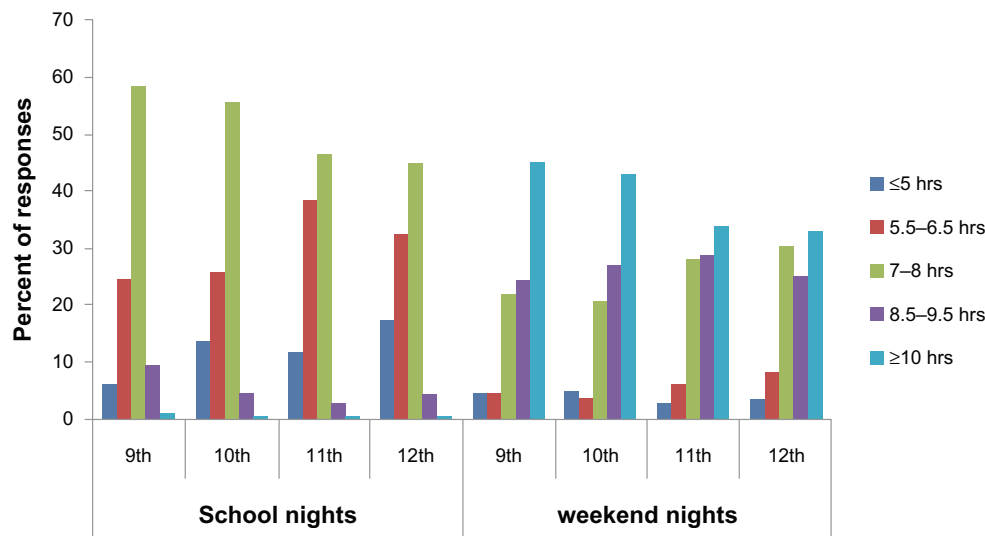
Figure 3. Sleep durations of students by grades (percent of responses).

the association between grades and each of the following: adequate sleep, daytime sleepiness, sleep duration, nap after school, prolonged sleep onset and night awakening. Sleep habits and health problems during weekdays and weekend were analyzed independently. To evaluate the effect of shortened sleep duration on daytime performance, sleep duration was grouped as less than or more than 7 hours nightly, and then analyzed against school performance. Sleep duration on weekdays did not show any association with school performance. However, sleep duration of less than 7 hours on weekends or both weekdays and weekends was significantly associated with poorer

school performance ($P < 0.0005$ with an odds ratio 1.95, and $P < 0.05$ with an odds ratio of 1.66, respectively).

In addition to shorter sleep duration, symptoms of insomnia were also associated with a poorer school performance. Prolonged sleep onset and night awakenings were each independently associated with a worse school performance ($P < 0.0001$ with an odds ratio 2.35, $P < 0.05$ with an odds ratio of 1.39 respectively), suggesting that poor sleep quality also contribute to worse performance. Perception of sleep adequacy, daytime subjective sleepiness, or napping after school was not associated with performance.

Table 1. Association of school performance or school start with sleep habits and problems.

Sleep health problems	Yes N, (%)	No N, (%)	Performance P values/odds ratio[1]	School start times P values/odds ratio[2]
Adequate sleep				
Weekday	644 (33.7)	1266 (66.3)	0.5160	0.0001**/0.67
Weekend	1547 (80.6)	366 (19.4)	0.0832	0.9348
Daytime sleepiness				
Weekday	1541 (80.3)	377 (19.7)	0.1627	0.5423
Weekend	465 (23.9)	1442 (76.1)	0.5419	0.8493
<7 hours sleep duration				
Weekday	1287 (69.2)	574 (30.8)	0.5401	<0.0001**/2.02
Weekend	254 (14.2)	1541 (85.8)	0.0005**/1.95	0.3651
Weekday and Weekend	173(9.2)	1701(90.8)	0.0271*/1.66	0.5001
Nap after school	952 (49.5)	972 (50.5)	0.1464	<0.0001**/1.623
Night awakening	688 (36.2)	1214 (63.8)	<0.0001**/2.35	0.0135*/1.26
Prolonged sleep onset	711 (36.9)	1214 (63.1)	0.0353*/1.39	0.4220

Notes: [1]Association with school performance (using a cutoff of "average B or better" vs. "C or worse"). Odds ratios were calculated when *P* values were significant; [2]association with school start times (on or before vs. after 7:30 AM).

Individual subjects could suffer from a combination of multiple unfavorable sleep habits or problems (risk factors) such as reduced sleep duration, sleep during an unfavorable circadian schedule, or insomnia. To evaluate whether multiple risk factors had a greater effect on performance, Pearson's correlation test between the numbers of risk factors and the school performance was utilized. The risk factors included in the test were rising before 6:30, sleep duration less than 7 hours, sleep latency of more than one hour, and night awakenings. The school performance grades used were the students' current average grades ("B or better" vs. "C or worse"). There was a significant correlation between the number of risk factors and poor school performance, thus *the more risk factors, the more likely the report of poor performance* (correlation efficient = 0.07, *P*-value = 0.01).

School Start Times and the Sleep Habits or Problems

The school start times of three of the five schools were 7:15; 7:25, 8:08. The two extracurricular programs consisted of high school students from various high schools throughout the state of New Jersey. The school start times of these participants varied from 7:00 to 8:45. School start times were grouped as "before or at 7:30" vs. "after 7:30" for statistical analysis.

We examined whether night sleep duration was influenced by morning school start time (Table 1). *Chi* square tests (odds ratios when appropriate) were used to evaluate associations between the presence of each of the sleep problems and the school start time. Earlier school start time was found to be associated with a shorter sleep duration (<7 hours) during weekdays ($P < 0.0001$ with an odds ratio of 2.02), suggesting that students with an earlier school start time tended to have a shorter sleep duration on weekdays. These students did make up their sleep on weekends as reflected by the lack of association between weekday school start time and weekend sleep duration.

We then evaluated whether poor sleep health/quality was more likely to be reported in students whose school started earlier. Adequate night sleep was inversely associated with a school start time before 7:30 ($P < 0.0001$ with an odds ratio of 0.67). Naps after school were more likely to be reported in students whose school

start times were before 7:30 ($P < 0.0001$, odds ratio 1.623). Likewise, night awakenings were associated with an earlier school start time.

Discussion

This study evaluated the association of poor school performance in high school students with multiple sleep risk factors. In addition, this study identified healthy sleep habits that were not associated with poor performance but rather offset the deleterious effects of sleep risk factors. Finally school start time was examined for its contribution to sleep health problems.

This study shows the following important trends among the participating high school students: (1) a correlation between the number of poor sleep risk factors and school performance; (2) an association of earlier start time with poor sleep quality and quantity; (3) a forward shift of sleep/wake cycles towards earlier rising time during weekdays; (4) reduced sleep quantity on weekdays; (5) poor sleep quality, especially during weekdays; (6) an association of reduced sleep quantity and/or quality with poor school performance; (7) the observation that students who compensated for shortened weekday sleep times by sleeping longer on weekends were less likely to have school performance deficits.

The exact consequences of sleep health problems are difficult to quantify. It is now widely accepted that sleep deprivation is associated with reduced alertness and poor performance,[5–7,17] and these effects are exacerbated by a superimposed circadian disadvantage.[18] In the present study, those students who did not make up for their weekday sleep loss on weekends, or who had one or more sleep health problems, self-reported poorer school performance. It is also important to point out that multiple sleep health risk factors within the same subjects were more likely to result in reports of poor school performance. An equally important finding of this study is that short sleep duration on weekdays did not compromise school performance, while chronic sleep deprivation on weekdays and weekends was detrimental. Although school performance is determined by many factors, this study suggests that adequate sleep is important to maximize one's potential for better performance.

High schools in New Jersey tend to start early, requiring an adjustment of the sleep/wake cycle for the majority of students. Such an adjustment may not be achieved or sustained by all of the students. Our finding of more complaints on sleep quantity, quality, and poor sleep health among students whose schools started earlier in the morning demonstrated such a difficulty in adjustment. Others have also found that high school start times contribute to sleep deprivation among adolescents.[19] A study in Rhode Island found that a delay in school start time was associated with improvements in high school students' alertness, mood, and health.[20] Advocacy for a delay in high school start time will likely improve students' sleep health, thereby maximizing their potential for academic achievement.

In general, adolescents and young adults have a naturally delayed sleep phase circadian rhythm characterized by late retiring and rising.[3] The earlier rise times on school days in this cohort were probably demanded by school start schedules, as suggested by the observation that many of the students required alarm use, thereby desynchronizing sleep/wake cycle with circadian rhythm. The delayed sleep/wake schedules on weekends reflect a more natural circadian rhythm for these ages. Circadian rhythm has been shown to influence a wide range of physiologic and psychological functions.[10–12] Many aspects of cognition such as decision making, memory, processing speed, selective attention and vigilance are modulated by the time of day in relation to circadian rhythm.[10,13–15] In addition, numerous studies have shown that physiologic and pathological states are affected by circadian rhythm. These include disorders of sleep such as difficulty falling asleep, shortened sleep duration, sleepiness, anxiety and irritability.[16] Unfortunately, the weekdays' sleep/wake cycles of many of the students in this study fell within their disadvantaged circadian rhythm.

Most adolescents require 9 hours of sleep nightly.[8,9] The majority of students in this study did not achieve the required length of sleep during weekdays, leading to an accumulation of sleep debt. Many students in this study paid off this debt by catching-up on sleep during weekends; however, others did not compensate for this sleep insufficiency on weekends (chronic sleep deprivation). The misalignment of sleep/wake cycles

with the circadian rhythm, coupled with shortened sleep duration, further compromised sleep health in this population. Some students failed to adjust their sleep/wake cycle to the demanding school schedules, resulting in highly irregular sleep/wake patterns. In American high schools, the academic and social burdens tend to be greater in the more advanced grades. Our results reflect a greater sleep insufficiency in the upperclassmen, suggesting that academic demands, at least in part, contributed to the sleep deprivation in this cohort.

Although a good night's sleep is perceived subjectively, sleep quality is defined by tiredness upon waking and throughout the day, feeling rested and restored upon waking, and the number of awakenings experienced throughout the night.[10] Perceptions of inadequate sleep or non-refreshed sleep, daytime sleepiness, use of alarm-devices to terminate sleep, need for a daytime nap within this age group, prolonged sleep onset and fragmented sleep are all symptoms of insufficient sleep disorders and/or insomnia. Insufficient sleep, daytime sleepiness, night awakenings and prolonged sleep onset are symptoms of sleep disorders or poor sleep health. Using an alarm to wake up may lead students to feel unrefreshed, and taking naps after school suggests significant daytime sleepiness. These individuals may perceive their sleep as inadequate or of poor quality. These sleep health problems were prevalent among the high school students in this study and many students had more than one of the sleep health problems listed in Table 1. Of note, the majority of students experienced daytime sleepiness during school days. More than one third of students reported at least one sleep health problem during school days. Sleep problems such as night awakenings and prolonged sleep onset may further compromise sleep integrity and quality, especially if combined with insufficient sleep duration and undesirable sleep schedules.

Acknowledging the unique sleep physiology of adolescents, recognizing potential sleep health problems and learning how to avoid adverse effects of sleep deprivation are important to adolescents and their educators. Current high school curricula may not always include sleep health education. We believe that integration of sleep education, at least sometime

during the high school years, will help high school students to adjust their sleep/wake cycles.

Our results on different patterns of sleep/wake schedules, sleep quality and quantity on weekdays and weekends, sleep health problems, and the impact of sleep on performance are consistent with reports from other adolescent populations in the USA,[7,8] Canada,[6] Germany,[5] and China.[21] The high school student population in this study is typical of American high school students. This study included small and large sized, urban and suburban high schools, and high schools of different school start times. The findings of this study can be applied to a larger population of high school students. This study has its potential limitations. The study relied on self reports. The student population was heterogeneous. The school performance was not standardized. Future studies using the results of statewide standardized test results in more homogenous group adolescents will strengthen the study. In addition, studies on the impact of a later school start time on sleep health of high school students will better address solutions for the sleep problems in adolescents.

In summary, this study raised a few important points:

1. High school students suffer from insufficient sleep during school days.
2. Sleep health problems are prevalent among high school students.
3. Poor sleep, especially chronic and severe, can impact performance; catching-up sleep during weekends may help to avoid the adverse effects.
4. Sleep health education should be a part of high school curriculum to increase awareness.
5. Delayed high school start times could be beneficial for adolescent health.

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Disclosures

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