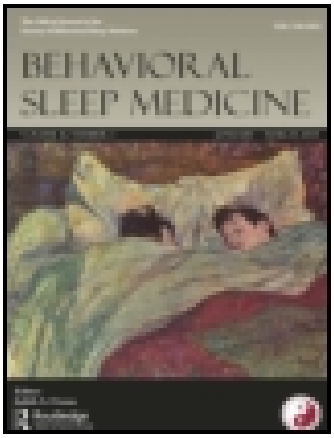

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Start Later, Sleep Later: School Start Times and Adolescent Sleep in Homeschool Versus Public/Private School Students

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Homeschooled students provide a naturalistic comparison group for later/flexible school start times. This study compared sleep patterns and sleep hygiene for homeschooled students and public/private school students (grades 6–12). Public/private school students ($n = 245$) and homeschooled students ($n = 162$) completed a survey about sleep patterns and sleep hygiene. Significant school group differences were found for weekday bedtime, wake time, and total sleep time, with homeschooled students waking later and obtaining more sleep. Homeschooled students had later school start times, waking at the same time that public/private school students were starting school. Public/private school students had poorer sleep hygiene practices, reporting more homework and use of technology in the hour before bed. Regardless of school type, technology in the bedroom was associated with shorter sleep duration. Later school start times may be a potential countermeasure for insufficient sleep in adolescents. Future studies should further examine the relationship between school start times and daytime outcomes, including academic performance, mood, and health.

Insufficient sleep duration in adolescents is common, negatively impacting cognitive functioning, emotion regulation and health (Beebe, 2011; Drake et al., 2003; Fallone, Owens, & Deane, 2002; Galland, Taylor, Elder, & Herbison, 2012; Gibson et al., 2006; Gradisar, Gardner, &

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Dohnt, 2011; Nixon et al., 2008; Sadeh, Gruber, & Raviv, 2002). While biological sleep needs may not significantly change throughout adolescence, actual sleep duration is significantly reduced, with high school seniors commonly obtaining fewer than 7 hr of sleep per night (National Sleep Foundation, 2006, 2014; Wolfson et al., 2003). One factor that contributes to insufficient sleep in adolescents is the intersection between early school start times and delayed bedtimes related to physiological changes to the circadian rhythm, as well as academic and social demands (Carskadon, Vieira, & Acebo, 1993; Danner & Phillips, 2008; Dexter, Bijwadia, Schilling, & Applebaugh, 2003; Hansen, Janssen, Schiff, Zee, & Dubocovich, 2005; Moore & Meltzer, 2008; Owens, Belon, & Moss, 2010; Wahlstrom, 2002; Wolfson, Spaulding, Dandrow, & Baroni, 2007). To compensate for insufficient sleep, many youth will sleep in on weekends. However, weekend oversleep can cause social jet lag, which further contributes to insufficient sleep during the week by dysregulating the circadian rhythm and prolonging school night sleep onset latency (Wittmann, Dinich, Merrow, & Roenneberg, 2006).

A number of studies have shown the benefits of delayed school start times for both middle and high school students (Danner & Phillips, 2008; Owens et al., 2010; Wahlstrom, 2002; Wahlstrom et al., 2014; Wolfson et al., 2007), including a longer weeknight sleep duration and less sleepiness during the day (Dexter et al., 2003; Owens et al., 2010; Wolfson et al., 2007). Recent reports have found that later school start times were also associated with improved academic functioning (Edwards, 2012; Wahlstrom et al., 2014). Other outcomes include better attendance, less tardiness, improved health and mood, and fewer drowsy driving accidents (Danner & Phillips, 2008; Owens et al., 2010; Wahlstrom, 2002; Wolfson et al., 2007). Concerns that later school start times would cause later bedtimes have not been supported, highlighting that increased sleep duration for these youth is a result of later wake times (Wahlstrom, 2002; Wolfson et al., 2007).

Unlike their public or private school peers, youth who are homeschooled do not have to wake early to catch the bus or get to school. How this difference is related to sleep, however, has not previously been studied. The prevalence of homeschool youth in the United States has rapidly increased in recent years (2–8% per year), with approximately 2 million youth homeschooled in the United States in 2010 (Ray, 2011). The most common reasons reported for homeschooling in the United States are religious beliefs, the quality of local schools, and the ability to customize the learning environment (National Center for Education Statistics, 2008; Ray, 2011). In short, homeschooled youth provide a naturalistic comparison group for public/private school students in the examination of sleep patterns.

Along with sleep patterns (i.e., bedtimes and wake times), aspects of sleep hygiene, namely caffeine use and electronics in the bedroom, also contribute to insufficient sleep in adolescents (Calamaro, Thornton, & Ratcliffe, 2009; Li et al., 2007). As many families choose to homeschool for religious reasons (National Center for Education Statistics, 2008; Ray, 2011), and increased parental supervision is seen among youth with religious affiliations (Wallace, 2003), it is possible that homeschooled students may differ in their sleep hygiene habits (e.g., less access to caffeine at home than at public school, caffeine not consumed for religious reasons, less use of television or Internet at night).

The purpose of the current study was to compare the sleep patterns and sleep hygiene of homeschooled students and public/private school students. Our primary hypotheses were: (a) homeschooled students will obtain greater sleep duration due to later wake times, (b) homeschooled students will have more positive sleep hygiene practices, and (c) for all students,

poorer sleep hygiene will be related to shorter sleep duration. Secondary aims were to characterize homeschooled versus public/private school student napping patterns, as well as to examine depressive symptoms as a possible outcome related to school start times and sleep duration.

METHODS

Participants and Study Design

Homeschooled students were recruited through the Homeschool.com Product Test group, a group of approximately ten thousand homeschooling families that is demographically representative of homeschooling families in the United States (R. Kochenderfer, personal written communication, August 8, 2011). Members of the Product Test group are invited to review new online educational materials, with both students and parents providing feedback. Following completion of the homeschool data collection, public/private school students were invited by an Internet panel research company to complete an online survey, with a quota system used to match the homeschool sample on gender, region of the United States, and grade. For both groups (Homeschool.com and Internet panel), potential participants received an e-mail invitation. Although families may have had more than one eligible child in the home, only one survey per household was allowed. All surveys were completed during the 2011–2012 and the 2012–2013 school years. Online survey panels have been shown to be reliable and valid compared to telephone and in-person surveys (Bethell, Fiorillo, Lansky, Hendryx, & Knickman, 2004; Klein, Thomas, & Sutter, 2007), and have been used in a variety of health-related research studies (Cella et al., 2010; Flood et al., 2010; Flood et al., 2011; Long, 2007). This study was approved by the Institutional Review Board at National Jewish Health.

Because the survey was sent out by Homeschool.com and the Internet panel company, it is unknown how many people received the invitation. Of the 1,076 families who viewed the survey consent page, 592 (55%) started the survey, with 161 (27%) of these participants ineligible with regard to matching quotas for region, gender, and grade. Of the 431 respondents who completed the survey, 24 (5.6%, 14 public/private school students, and 10 homeschooled students) were omitted from analyses due to obvious invalid responses (e.g., negative calculated sleep duration), resulting in a total sample size of 407 adolescents (245 public/private school students and 162 homeschooled students). There were no significant demographic differences between those who were included and those who were excluded.

Sleep

Questions about sleep patterns and sleep hygiene were developed by pediatric sleep experts for the 2006 (grades 6–12) National Sleep Foundation (NSF) *Sleep in America* poll (Carskadon, 2011). The survey included two parts (see Appendix). First, caregivers were asked about the presence of different types of technology in the adolescent's bedroom and school start time. Adolescents were then asked a separate series of questions about their own sleep patterns and sleep hygiene (i.e., caffeine use and activities in the hour before bed). Total sleep time was calculated from adolescent report as the duration from bedtime to wake time, less sleep onset

latency and wake after sleep onset. One question queried caffeine use. Five questions were used to inquire about depressive symptoms over the past two weeks (Wolfson & Carskadon, 1998).

Statistical Analysis

Preliminary analyses included descriptive statistics for full sample demographic variables. Group (public/private school vs. homeschool) differences on demographic variables were examined using independent sample *t*-tests for continuous variables and chi-square analyses for categorical variables. Multivariate analysis of variance (MANOVA) was used to compare sleep patterns (bedtime, wake time, and total sleep time) for the two school groups and across grade level. Chi-square analyses were used to compare the two school groups on the presence/absence of caffeine use and technology in the bedroom (television, computer, or phone). Analysis of covariance (ANCOVA) controlling for group was used to examine differences in sleep patterns by categorical variables, including school start time and the presence/absence of a television, computer, or phone in the bedroom. To control for multiple analyses, findings were considered significant if $p < .005$.

RESULTS

Participants

The full sample had a mean age of 13.6 years ($SD = 1.7$, range 11–17 years), and was 51.4% male and 81.6% White (Black 5.9%, Hispanic 5.2%). Table 1 presents demographic information for both groups. There were no significant demographic differences between groups.

TABLE 1
Demographic Variables

	Public/Private School (n = *245*)	*Homeschool* (n = *162*)	*Test Statistic*	p
Age yrs (SD)	13.7 (1.6)	13.4 (1.8)	$t(405) = 1.90$	.06
Gender			$X^2(1) = 0.42$	.40
Male	53.1%	48.9%		
Race			$X^2(3) = 4.23$	.24
White	79.6%	84.6%		
Black	7.3%	3.7%		
Hispanic	4.5%	6.2%		
Other	8.6%	5.6%		
Region			$X^2(3) = 2.71$	.44
Northeast	15.1%	13.0%		
South	27.3%	34.6%		
Midwest	31.8%	27.2%		
West	25.7%	25.3%		

Weekday Sleep Patterns

No group-by-grade interactions were found for weekday sleep patterns. Significant school group differences were found for weekday bedtime, weekday wake time, and weekday total sleep time (all $p < .001$), with public/private school students going to bed 39 min earlier but waking 85 min earlier than homeschooled students (Table 2). This resulted in public/private school students obtaining 49 min less total sleep time than homeschooled students on weekdays. Significant grade differences were found in terms of weekday bedtime and weekday total sleep time, with bedtimes getting later and total sleep time shorter with advancing grade ($p < .001$; Figure 1).

Weekend Sleep Patterns

No group-by-grade interactions were found for weekend sleep patterns. No significant school group differences were found for weekend bedtime, weekend wake time, or weekend total sleep time (Table 2). A significant grade difference was found for both weekend bedtimes and weekend wake times, suggesting later bedtimes and later wake times with advancing grade ($p < .001$; Figure 2). No grade difference was found for weekend total sleep time, $F(1, 392) = 1.34$, $p = .24$. As a proxy measure of circadian phase, midsleep period was calculated. No group difference was found for midsleep period, $F(1, 404) = 1.46$, $p = .23$. However, a significant grade difference was found, suggesting a later midsleep period with advancing grade, $F(6, 399) = 15.08$, $p < .001$.

To examine weekend oversleep, the difference between weekday and weekend total sleep time was calculated. For weekend oversleep, a significant difference was found for both school group and grade, with public/private school students having greater weekend oversleep (88 min vs. 32 min for homeschooled students), $F(1, 392) = 31.28$, $p < .001$, $\eta_p^2 = .07$, and weekend

TABLE 2
Means and Standard Error for Weekday and Weekend Sleep Patterns by School Group

	Public/Private		*Homeschool*				
Weekday	*Mean*	*SE*	*Mean*	*SE*	*F(1,393)*	p	η_p^2
Bedtime	21:59	0:04	22:38	0:05	13.81	< .001	.03
Wake time	06:31	0:04	07:56	0:05	181.61	< .001	.32
Total sleep time	8.10	0.08	8.92	0.09	48.68	< .001	.11
	Public/Private		*Homeschool*				
Weekend	*Mean*	*SE*	*Mean*	*SE*	*F(1,393)*	p	η_p^2
Bedtime	23:15	0:06	23:25	0:06	1.30	.26	.003
Wake time	09:16	0:07	09:28	0:08	1.35	.25	.003
Total sleep time	9.57	0.10	9.45	0.12	.56	.45	.001

Note. Bedtimes and wake times reported in military clock time, total sleep time in hours. η_p^2 is a measure of effect size (small = .02, medium = .13, large = .26).

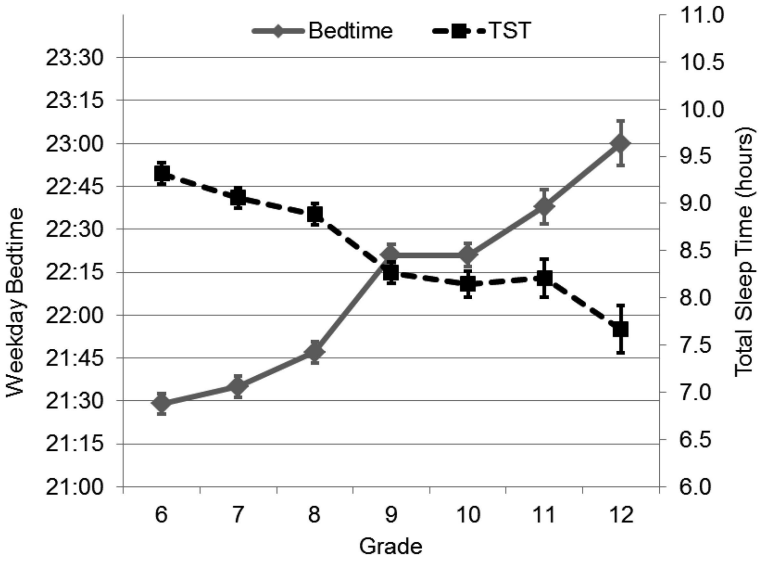

FIGURE 1 Weekday bedtime and weekday total sleep time (hours) by grade. *Note.* Shaded grey diamonds (◆) show the increasingly later bedtime that occurs with advancing grade, while the black squares (■) show the decrease in total sleep time with advancing grade. Significant difference in weekday bedtime, $F(6, 393) = 18.05, p < .001, \eta_p^2 = .22$, and weekday total sleep time, $F(6, 393) = 17.01, p < .001, \eta_p^2 = .21$.

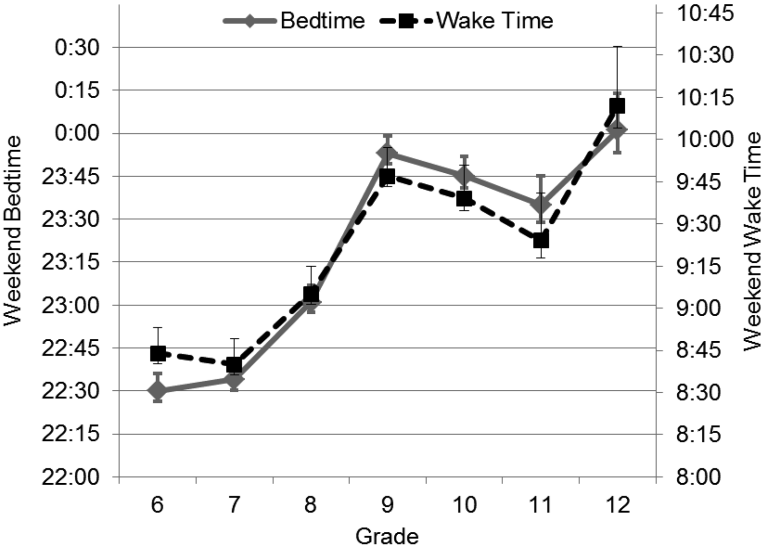

FIGURE 2 Weekend Bedtime and Weekend Wake Time by Grade. *Note*. Shaded grey diamonds (◆) show the increasingly later bedtime that occurs with advancing grade, while the black squares (■) show the increasing later wake time with advancing grade. Significant difference in weekend bedtime, $F(1, 392) = 16.74, p < .001, \eta_p^2 = .20$, and weekend wake time, $F(1, 392) = 8.28, p < .001, \eta_p^2 = .11$.

oversleep getting greater with advancing grade (24 min in grade 6, 129 min in grade 12), $F(1, 392) = 5.20$, $p < .001$, $\eta_p^2 = .07$.

Napping and Optimal Sleep

No group-by-grade interaction was found for napping (number of days in past two weeks). A significant school group difference was found for napping, suggesting that public/private school students nap more frequently than homeschooled students (1.52 vs. 0.83 days napped in past two weeks), $F(1, 392) = 9.61$, $p = .002$, $\eta_p^2 = .02$. In addition, nap frequency increased with grade (days napped in past two weeks: 0.57 in grade 6; 2.12 in grade 12), $F(1, 392) = 4.66$, $p < .001$, $\eta_p^2 = .07$.

Using the National Sleep Foundation's categories of "optimal sleep" (> 9 hours) and "insufficient sleep" (< 8 hours); (National Sleep Foundation, 2006), a significant school group difference was found, with only 28.2% of public/private school students obtaining optimal sleep on weekday nights compared to 58.0% of homeschooled students, $\chi^2(2) = 41.33$, $p < .001$, phi = .32. Notably, 34.3% of public/private school students obtained insufficient sleep on weekday nights compared to only 12.1% of homeschooled students.

School Start Times

There was a significant difference between school type for school start times, with later start times (mean = 9:00 a.m.) for the homeschooled students compared to the public/private school students (mean = 7:57 a.m.), $t(213) = -13.70$, $p < .001$, Cohen's $d = 1.3$. Notably, the public/private school start time was nearly identical to the average wake time of homeschooled students (mean = 7:56 a.m.). In other words, homeschooled youth were waking up to start their day around the time public/private school students were starting school.

To address potential dose response effects of school start time on sleep duration, we examined the difference in sleep variables for students who started school before 8:00 a.m., between 8:00 and 8:30 a.m., between 8:31 and 9:00 a.m., and after 9:00 a.m. (Table 3). Students who started school after 9:00 a.m. had a significantly later bedtime than the other three groups, with wake time significantly later for each later school start time category. This resulted in longer total sleep duration with later school start time (before 8:00 a.m. compared to 8:00–8:30 a.m. difference of 25 min, 8:00–8:30 a.m. compared to 8:31–9:00 a.m. difference of 26 min).

Depressive Symptoms

There was no significant difference between school groups for depressive symptoms scores (homeschool mean = 7.15, public/private school mean = 6.84), $t(405) = -1.36$, $p = .17$. While depressive symptoms were not correlated with school start time for either group (public/private $r = -.05$; homeschooled $r = .05$), depressive symptoms were significantly correlated with weekday total sleep time for public/private school students ($r = -.23$, $p < .001$), but not for homeschooled students ($r = -.11$, $p < .18$), suggesting that public/private school students with shorter sleep duration report more depressive symptoms.

TABLE 3
Means and Standard Error for Weekday Sleep Patterns by School Start Time and the Presence/Absence of Technology in the Bedroom

	Before 8:00 a.m. (n = *106*)		*8:00–8:30 a.m.* (n = *177*)		*8:31–9:00 a.m.* (n = *74*)		*After 9:00 a.m.* (n = *50*)				
School Start Time	*Mean*	*SE*	*Mean*	*SE*	*Mean*	*SE*	*Mean*	*SE*	*F(1,402)*	p	η_p^2
Bedtime	21:46	0:06	21:48	0:04	21:55	0:07	22:39	0:09	9.63	<.001	.07
Wake time	6:03	0:04	6:51	0:03	7:29	0:05	8:40	0:06	99.82	<.001	.43
Total sleep time	8.16	0.11	8.57	0.08	9.01	0.13	9.32	0.16	13.27	<.001	.09

	None (n = *187*)		*One Per Day* (n = *123*)		*More Than One/Day* (n = *97*)				
Caffeinated Beverages	*Mean*	*SE*	*Mean*	*SE*	*Mean*	*SE*	*F(1,404)*	p	η_p^2
Bedtime	21:42	0:04	22:03	0:05	22:10	0:06	9.24	<.001	.04
Wake time	07:03	0:04	07:06	0:06	07:10	0:07	0.20	.82	.001
Total sleep time	8.83	1.11	8.51	1.19	8.42	1.11	6.99	<.001	.03

Note. Bedtimes and wake times reported in military clock time, total sleep time in hours. η_p^2 is a measure of effect size (small = .02, medium = .13, large = .26).

[a]Post-hoc analyses (controlling for school group) show significantly later bedtimes for both caffeine use groups compared to no caffeine, as well as significantly shorter sleep duration for both caffeine use groups compared to no caffeine.

SLEEP HYGIENE

Public/private school students reported engaging in poorer sleep habits compared to homeschooled students. Specifically, in the hour before bed, compared to homeschooled students, more public/private school students reported doing homework, $X^2(1) = 44.1$, $p < .001$, phi = −.33, watching television, $X^2(1) = 12.2$, $p < .001$, phi = −.17, talking on the phone, $X^2(1) = 13.9$, $p < .001$, phi = −.19, and using the Internet, $X^2(1) = 29.6$, $p < .001$, phi = −.27. Although not a statistically significant difference, homeschooled students reported more leisure reading in the hour before bed compared to public/private school students, $X^2(1) = 7.5$, $p = .006$, phi = .14. No group difference was found for the use of video games in the hour before bed, $X^2(1) = .43$, $p = .51$, phi = −.03.

In terms of technology in the bedroom, although not statistically different, public/private school students were more likely than homeschooled students to have televisions, computers, and phones in the bedroom (Table 4). Controlling for group, adolescents with a TV in the bedroom reported 11 min less total sleep on weekday nights; adolescents with a computer in the bedroom reported 17 min less total sleep on weekday nights; and adolescents with a telephone in the bedroom reported 26 min less total sleep on weekday nights.

During the day there were no significant school group differences in the frequency of caffeine use, $X^2(2) = .66$, $p = .72$, phi = .04. Collapsing across school groups, adolescents who

TABLE 4
Frequency and Percent of Students with Technology in the Bedroom and Total Sleep Time for Students With/Without Technology in the Bedroom

	Public/Private School		*Homeschool*			*Total Sleep Time*		
	n	%	n	%		*Mean*	*SE*	
Television in bedroom					$X^2(1) = 7.20, p = .008, F = .13$			$F(1, 404) = 3.01, p = .08, \eta_p^2 = .007$
Yes	136	55.5	68	42.0		8.54	0.08	
No	109	44.5	94	58.0		8.73	0.08	
Computer in bedroom					$X^2(1) = 3.52, p = .06, F = .09$			$F(1, 404) = 6.33, p = .01, \eta_p^2 = .02$
Yes	98	40.0	50	30.9		8.46	0.09	
No	147	60.0	112	69.1		8.74	0.07	
Phone in Bedroom					$X^2(1) = 3.89, p = .05, F = .10$			$F(1, 404) = 14.50, p < .001, \eta_p^2 = .04$
Yes	78	31.8	37	22.8		8.32	0.10	
No	167	68.2	125	77.2		8.76	0.06	

Note. Bedtimes and wake times reported in military clock time, total sleep time in hours.

consumed at least one caffeinated beverage per day had later weekday bedtimes, $F(2, 404) = 9.45$, $p < .001$, $\eta_p^2 = .05$, and shorter total sleep time, $F(2, 404) = 5.35$, $p = .005$, $\eta_p^2 = .03$ (Table 3).

DISCUSSION

This study is the first to use homeschooled students as a naturalistic comparison group in order to examine the impact of early school start times on the sleep of public/private school students. Without the early wake times required to catch the bus or get to school on time, homeschooled students (grades 6–12) averaged 49 min more sleep per night on weeknights. Over the course of a typical school week, this translates to 4 hr of additional sleep for homeschooled students. Figure 3 provides an extrapolation of the differences in cumulative sleep time and sleep lost over the course of a typical week. While weekend oversleep slightly reduces the cumulative difference between groups, after one week the difference between groups remains 3.8 hr, contributing to the sleep debt of public/private school students.

As found in previous studies, delayed weekday bedtimes (and midsleep period time on weekends) were evident with advancing grade, particularly during adolescence, regardless of school type, highlighting the circadian delay that occurs during puberty (Carskadon, Acebo, & Jenni, 2004; Carskadon et al., 1993). Public/private school students had slightly earlier bedtimes on weeknights; however, this could not compensate for the significantly earlier weekday wake times and subsequent shorter total sleep time. On weekends, when wake times were not a factor, both school groups achieved the recommended sleep for their age, with similar bedtimes and wake times. Similar to previous studies, public/private school students with later school start times (after 8:00 a.m.) did not have significantly later bedtimes (Wahlstrom,

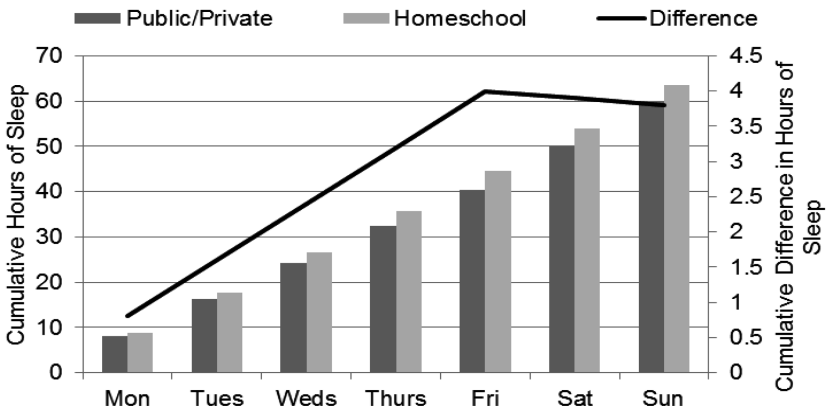

FIGURE 3 Representation of cumulative sleep duration comparison by group and cumulative difference in total sleep time over the course of a week. *Note.* Dark shaded bars represent cumulative sleep duration in public/private school students, light shaded bars represent cumulative sleep duration in homeschooled students. The solid black line represents cumulative difference in sleep duration between the two school groups, increasing over the course of the school week, and slightly decreasing with weekend catch-up sleep.

2002; Wolfson et al., 2007). This study adds value to the preponderance of evidence suggesting that later school start times allow students to obtain more optimal sleep duration on school nights (Dexter et al., 2003; Owens et al., 2010; Wahlstrom, 2002; Wahlstrom et al., 2014; Wolfson et al., 2007). Further, with no group differences in midsleep period time on weekends, the difference in total sleep duration is more likely due to these early school start times rather than a circadian phase difference in homeschooled versus public/private school youth.

Also similar to previous studies (Li et al., 2007; Mindell, Meltzer, Carskadon, & Chervin, 2009; National Sleep Foundation, 2011, 2014), this study showed an association between the presence of technology in the bedroom and shorter total sleep time on weeknights for all students, with more technology present for public/private school students. This is of great concern given the rapid rise in technology use in the past five years with smart phones and tablets. To highlight this issue, the American Academy of Pediatrics recently recommended that parents should be advised to keep television and Internet-connected devices out of the bedroom (Council on Communications and the Media, 2013). Further, parents should enforce a curfew for media devices for all family members (parents included; Council on Communications and the Media, 2013).

Limitations

There are several limitations that should be noted. First, we only included self- (and parent-) reported data, with no objective measure of sleep. However, adolescents have been shown to be good reporters of their sleep patterns (Wolfson et al., 2003). In addition, no measures of socioeconomic status (SES) were collected.

Second, it is possible that the difference in nap frequency may mitigate some of the total sleep duration differences over the course of a school week. However, we did not measure nap duration, the median number of naps was 0 for both groups, with more than 65% of youth in both groups not napping in the previous two weeks. This suggests that napping alone is unlikely to fully compensate for deficient weekday sleep.

Third, while later wake times account for differences in weekday sleep duration, it is also possible that other factors contribute to these differences. For example, increased parent-child interactions for homeschooled families may result in increased parental involvement around bedtime and sleep routines, which has been shown to increase sleep duration in adolescents (Short et al., 2011). Another consideration is that some of the homeschooled youth were no longer attending school due to increased sleep needs that had previously resulted in academic or social difficulties. Further, it is possible that certain religious beliefs or practices (e.g., no caffeine use) may have also influenced sleep hygiene and sleep duration findings, independent of parental supervision.

Fourth, other than depressive symptoms, this study did not include daytime functioning outcomes, so we cannot draw any conclusions about the impact of school start times or sleep duration on the academic performance, sleepiness, or health of these students. Finally, because of the cross-sectional study design, it is possible that the changes across grades were due to a cohort effect rather than developmental changes to sleep. Despite these limitations, this study adds to the growing body of literature demonstrating the potential value of delayed school start times on sleep duration, in particular for adolescents. The results of this study

provide further evidence and support for those working to change school start times. With the American Academy of Pediatrics recommending middle and high schools start no earlier than 8:30 a.m. (American Academy of Pediatrics, 2014), it is critical for health care professionals to partner with students, families, teachers, administrators, and advocacy organizations to continue working toward changing school start times across the United States (Iber et al., 2014). In addition, further empirical evidence is needed to demonstrate the benefits of later school start times in multiple outcome areas, including academic performance, school attendance and matriculation, adolescent mood and quality of life, sports performance, and health outcomes. While the importance of changing school start times has received increased recognition in recent years, there remain a number of schools around the country where change will not occur until further scientific evidence demonstrates the benefits of later school start times for adolescents.

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REFERENCES

American Academy of Pediatrics: Adolescent Sleep Working Group, Committee on Adolescents, and Council on School Health. (2014). School start times for adolescents. *Pediatrics, 134,* 642–647.

Beebe, D. W. (2011). Cognitive, behavioral, and functional consequences of inadequate sleep in children and adolescents. *Pediatric Clinics of North America, 58,* 649–665.

Bethell, C., Fiorillo, J., Lansky, D., Hendryx, M., & Knickman, J. (2004). Online consumer surveys as a methodology for assessing the quality of the United States health care system. *Journal of Medical Internet Research, 6,* e2.

Calamaro, C., Thornton, B., & Ratcliffe, S. (2009). Adolescents living the 24/7 lifestyle: Effects of caffeine and technology. *Pediatrics, 123,* e1005–e1010.

Carskadon, M. A. (2011). Sleep in adolescents: The perfect storm. *Pediatric Clinics of North America, 58,* 637–647.

Carskadon, M. A., Acebo, C., & Jenni, O. G. (2004). Regulation of adolescent sleep: Implications for behavior. *Annals of the New York Academy of Science, 1021,* 276–291.

Carskadon, M. A., Vieira, C., & Acebo, C. (1993). Association between puberty and delayed phase preference. *Sleep, 16,* 258–262.

Cella, D., Riley, W., Stone, A., Rothrock, N., Reeve, B., Yount, S., ... PROMIS Cooperative Group. (2010). The Patient-Reported Outcomes Measurement Information System (PROMIS) developed and tested its first wave of adult self-reported health outcome item banks: 2005–2008. *Journal of Clinical Epidemiolology, 63,* 1179–1194.

Council on Communications and the Media. (2013). Children, adolescents, and the media. *Pediatrics, 132,* 958–961.

Danner, F., & Phillips, B. (2008). Adolescent sleep, school start times, and teen motor vehicle crashes. *Journal of Clinical Sleep Medicine, 4,* 533–535.

Dexter, D., Bijwadia, J., Schilling, D., & Applebaugh, G. (2003). Sleep, sleepiness and school start times: A preliminary study. *Wisconsin Medical Journal, 102,* 44–46.

Drake, C., Nickel, C., Burduvali, E., Roth, T., Jefferson, C., & Pietro, B. (2003). The pediatric daytime sleepiness scale (PDSS): Sleep habits and school outcomes in middle-school children. *Sleep, 26,* 455–458.

Edwards, F. (2012). Early to rise? The effect of daily start times on academic performance. *Economics of Education Review, 31,* 970–983.

Fallone, G., Owens, J. A., & Deane, J. (2002). Sleepiness in children and adolescents: Clinical implications. *Sleep Medicine Reviews, 6,* 287–306.

Flood, E. M., Rousculp, M. D., Ryan, K. J., Beusterien, K. M., Divino, V. M., Toback, S. L., … Mahaderia, P. J. (2010). Parents' decision-making regarding vaccinating their children against influenza: A web-based survey. *Clinical Therapeutics, 32,* 1448–1467.

Flood, E. M., Ryan, K. J., Rousculp, M. D., Beusterien, K. M., Block, S. L., Hall, M. C., & Mahaderia, J. P. (2011). A survey of children's preferences for influenza vaccine attributes. *Vaccine, 29,* 4334–4340.

Galland, B. C., Taylor, B. J., Elder, D. E., & Herbison, P. (2012). Normal sleep patterns in infants and children: A systematic review of observational studies. *Sleep Medicine Reviews, 16,* 213–223.

Gibson, E. S., Powles, A. C., Thabane, L., O'Brien, S., Molnar, D. S., Trajanovic, N., … Chilcott-Tanswer, L. (2006). "Sleepiness" is serious in adolescence: Two surveys of 3235 Canadian students. *BMC Public Health, 6,* 116.

Gradisar, M., Gardner, G., & Dohnt, H. (2011). Recent worldwide sleep patterns and problems during adolescence: A review and meta-analysis of age, region, and sleep. *Sleep Medicine, 12,* 110–118.

Hansen, M., Janssen, I., Schiff, A., Zee, P. C., & Dubocovich, M. L. (2005). The impact of school daily schedule on adolescent sleep. *Pediatrics, 115,* 1555–1561.

Iber, C., Wahlstrom, K., Beebe, D., Carskadon, M., Payne, J., Phillips, B., & Short, M. (2014, June). *Teens and sleep health*. Symposium conducted at Sleep 2014, the Annual Meeting of the Associated Professional Sleep Societies, Minneapolis, MN.

Klein, J. D., Thomas, R. K., & Sutter, E. J. (2007). Self-reported smoking in online surveys: Prevalence estimate validity and item format effects. *Medical Care, 45,* 691–695.

Li, S., Jin, X., Wu, S., Jiang, F., Yan, C., & Shen, X. (2007). The impact of media use on sleep patterns and sleep disorders among school-aged children in China. *Sleep, 30,* 361–367.

Long, A. A. (2007). Findings from a 1000-patient internet-based survey assessing the impact of morning symptoms on individuals with allergic rhinitis. *Clinical Therapeutics, 29,* 342–351.

Mindell, J. A., Meltzer, L. J., Carskadon, M. A., & Chervin, R. D. (2009). Developmental aspects of sleep hygiene: Findings from the 2004 National Sleep Foundation Sleep in America Poll. *Sleep Medicine, 10,* 771–779.

Moore, M., & Meltzer, L. J. (2008). The sleepy adolescent: Causes and consequences of sleepiness in teens. *Paediatric Respiratory Reviews, 9,* 114–120.

National Center for Education Statistics. (2008). *2007 National Household Education Surveys Program.* Washington, DC: U.S. Department of Education.

National Sleep Foundation. (2006). Sleep in America Poll. Retrieved March 31, 2006, from http://www.sleepfoundation.org/

National Sleep Foundation. (2011). Sleep in America Poll. Retrieved April 30, 2011, from http://www.sleepfoundation.org/

National Sleep Foundation. (2014). Sleep in America Poll. Retrieved March 3, 2014, from http://www.sleepfoundation.org/

Nixon, G. M., Thompson, J. M., Han, D. Y., Becroft, D. M., Clark, P. M., Robinson, E., … Mitchell, E. A. (2008). Short sleep duration in middle childhood: Risk factors and consequences. *Sleep, 31,* 71–78.

Owens, J. A., Belon, K., & Moss, P. (2010). Impact of delaying school start time on adolescent sleep, mood, and behavior. *Archives of Pediatric and Adolescence Medicine, 164,* 608–614.

Ray, B. D. (2011). Research facts on homeschooling. Retrieved July 31, 2011, from www.nheri.org/research/research-facts-on-homeschooling.html

Sadeh, A., Gruber, R., & Raviv, A. (2002). Sleep, neurobehavioral functioning, and behavior problems in school-age children. *Child Development, 73,* 405–417.

Short, M. A., Gradisar, M., Wright, H., Lack, L. C., Dohnt, H., & Carskadon, M. A. (2011). Time for bed: Parental-set bedtimes associated with improved sleep and daytime functioning in adolescents. *Sleep, 34,* 797–800.

Wahlstrom, K. (2002). Changing times: Findings from the first longitudinal study of later high school start times. *Official Journal of the National Association of Secondary School Principals, 86,* 3–21.

Wahlstrom, K., Dretzke, B., Gordon, M., Peterson, K., Edwards, K., & Gdula, J. (2014). *Examining the impact of later school start times on the health and academic performance of high school students: A multi-site study*. St. Paul: Center for Applied Research and Educational Improvement, University of Minnesota.

Wallace, J. M. (2003). *Is religion good for adolescent health? A national study of American high school seniors.* Philadelphia: University of Pennsylvania Center for Research on Religion and Urban Civil Society.

Wittmann, M., Dinich, J., Merrow, M., & Roenneberg, T. (2006). Social jetlag: Misalignment of biological and social time. *Chronobiology International, 23,* 497–509.

Wolfson, A. R., & Carskadon, M. A. (1998). Sleep schedules and daytime functioning in adolescents. *Child Development, 69,* 875–887.

Wolfson, A. R., Carskadon, M. A., Acebo, C., Seifer, R., Fallone, G., Labyak, S. E., & Martin, J. L. (2003). Evidence for the validity of a sleep habits survey for adolescents. *Sleep, 26,* 213–216.

Wolfson, A. R., Spaulding, N. L., Dandrow, C., & Baroni, E. M. (2007). Middle school start times: The importance of a good night's sleep for young adolescents. *Behavioral Sleep Medicine, 5,* 194–209.

APPENDIX

SURVEY QUESTIONS

(Answer choices or response format in parenthesis.)

Parent-Report Questions

1. Does your child have any of the following in his or her bedroom (please select all that apply)?
   a. Television
   b. Computer
   c. Telephone
   d. None
2. On most days, what time does your child start school? (HH:MM)

Adolescent-Report Questions

1. On a typical school night in the past two weeks, what was the usual time you tried to go to sleep for the night? (HH:MM)
2. Thinking about your sleep habits within the past two weeks on school nights, how often have you done the following in the hour before you went to bed? (Every night or almost every night; A few nights a week; A few nights a month; Rarely; Never)
   a. Did homework or studied
   b. Watched TV
   c. Talked on the phone
   d. Instant messaged or went on the Internet
   e. Read for fun
   f. Played electronic or video games
3. On most school nights, how long does it usually take you to fall asleep? (minutes)
4. At what time do you usually get up on school days? (HH:MM)
5. On a typical nonschool night such as weekends, in the past two weeks, what was the usual time that you tried to go to sleep for the night? (HH:MM)
6. On most nonschool nights, how long does it usually take you to fall asleep? (minutes)
7. At what time do you usually get up on nonschool days? (HH:MM)

8. In the past two weeks, how many days did you take a nap?
9. In the last two weeks, how often were you bothered or troubled by ... (Not at all; Somewhat; Much)
   a. Feeling unhappy, sad, or depressed
   b. Feeling hopeless about the future
   c. Feeling nervous or tense
   d. Worrying too much about things
   e. Being stressed or anxious
10. How many cups or cans of caffeinated beverages such as soda, energy drinks, coffee, tea, iced coffee, or iced tea do you typically drink each day? (number)