The Teen Sleep Loss Epidemic: What Can Be Done?

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Making sense of “expert advice” is among the many challenges of parenting. With the media circulating contrasting views on the importance of sleep in adolescence, parents and practitioners would benefit from an accessible synopsis of the scientific literature. We tackled the multifaceted issue of adolescent sleep and daytime functioning, presenting the findings with their methodological limitations. Given what is known about sleep in this population, we offer guidelines that are both realistic and substantiated in empirical findings. Our aim is to put into practice the science behind adolescent sleep.

Keywords: adolescents, cognition, parent recommendations, school performance, sleep


A growing body of literature has emphasized the consequences of sleep loss in adolescence, defined by the World Health Organization (2014) as 10 and 19 years of age. Adolescence is marked by a tendency toward later bedtimes, a phenomenon known as phase delay (Crowley, Acebo, & Carskadon, 2007). Although this change in sleep timing can continue into the early 20s (Roenneberg et al., 2007), it specifically presents a problem for teenagers, who truncate their sleep for early high school classes. This resulting “sleep debt” is associated with impairments in numerous domains, such as school performance (Preckel et al., 2013; Wolfson & Carskadon, 2003; Wolfson & Carskadon, 1998), driving (Hutchens et al., 2008; Martiniuk et al., 2013; Pizza et al., 2010), and several aspects of cognition (Beebe, Rose, & Amin, 2010; Gais, Lucas, & Born, 2006; Gradisar, Terrill, Johnston, & Douglas, 2008; Telzer, Fuligni, Lieberman, & Galván, 2013). Still, other studies have shown no effect of sleep loss on daytime function (Kopasz et al., 2010; Voderholzer et al., 2011), leading some to assert that adolescents compensate for inadequate sleep (Beebe, DiFrancesco, Tlustos, McNally, & Holland, 2009) and even fare better with less sleep in certain circumstances (Eide & Showalter, 2012), issues we address in this article.

How does one interpret these findings in a well-informed approach to adolescent sleep? Here we offer a summary of the evidence to guide sleep recommendations for teens, focusing on factors contributing to the variable findings. First, we highlight the crucial characteristics of adolescent sleep, reviewing the established developmental phenomenon of adolescent phase delay. We then unpack the research investigating sleep loss and school performance, driving risk, and cognition and memory, addressing issues to consider when interpreting the research. Finally, we provide evidence-based guidelines to help teens get the most out of their sleep.

Adolescent Phase Delay

The transition from childhood to young adulthood encompasses many changes, including the penchant to delay bedtime despite having to meet early school obligations. This shift
in sleep hygiene, or healthy behaviors and attitudes toward sleep, has often been described in terms of biological and sociobehavioral influences, factors we discuss in turn.

**Biological Contributions**

Understanding adolescent sleep relies in part on conceptualizing developmental changes of two sleep-wake mechanisms: homeostatic sleep drive (Process S) and the circadian rhythm (Process C; Crowley et al., 2007). Simply put, Process S states that the longer one is awake, the more sleep becomes necessary, and that sleeping decreases this need over time. Quantifying homeostatic sleep drive involves measuring the time until sleep onset after a period of sleep deprivation, with shorter latencies indicating a larger accumulation of sleep need. Experiments using this method have demonstrated that mature adolescents take longer to fall asleep than younger children after 36 hr of sleep deprivation, indicating that sleep drive accrues more slowly as a function of pubertal development (Jenni, Achermann, & Carskadon, 2005). Adolescents' protracted accumulation of Process S is hypothesized to contribute to their propensity to stay up later and delay the sleep–wake cycle, even in circumstances of sleep loss (Crowley et al., 2007).

The circadian system, or Process C, encompasses fluctuations of internal mechanisms across the 24-hr day, informally referred to in the literature as the “biological clock.” One of the most widely used circadian indicators is the release and offset of melatonin, a light-sensitive hormone secreted in darkness to signal sleep (Crowley et al., 2007). Carskadon and colleagues have made a significant contribution to this topic, noting that melatonin offset occurs later in the 24-hr period for adolescents than younger children and adults (e.g., Carskadon, Acebo, Richardson, Tate, & Seifer, 1997). The result is a longer internal day: Whereas adult melatonin measurements depict a rhythm of about 24.1 hr, this was estimated at 24.3 hr in adolescents (Carskadon, Labyak, Acebo, & Seifer, 1999). The delay and elongation of the melatonin period is understood to account for the “eveningness” phase preference and predisposition for postponed sleep specific to this population (Crowley et al., 2007). This change is driven by age and pubertal stage, as older, more mature adolescents exhibit more pronounced melatonin delays than those who are younger and less mature (Carskadon et al., 1997). As such, phase delay peaks earlier in females due to the advanced onset of puberty (Roennebe et al., 2007).

**Sociobehavioral Contributions**

The biological drive to delay bedtimes combines with social and behavioral factors to influence sleep hygiene in adolescence. The transition to young adulthood brings increased autonomy, which translates into a decline in parental influence over teens' sleeping behavior across the ages of 13 and 18 (Short et al., 2011). When joined with the physiological need to defer sleep, teens' self-selected bedtimes become increasingly later as a function of age, with older adolescents getting less sleep than their younger counterparts (Short et al., 2011). In addition, balancing the increased social and academic commitments specific to this phase of development is likely to come at the expense of sleep. For instance, homework was identified as a primary factor affecting sleep in students ages 12–19, where greater time spent on assignments outside school predicted later bedtimes and shorter sleep (Adam, Snell, & Pendry, 2007). Similarly, Carskadon (1990) reported that 12- to 19-year-olds allocating more than 20 hr per week to after-school employment go to bed later, sleep less, and feel sleepier during the day than those working less than 20 hr. Involvement in extracurricular activities casts a similar trend; however, the problem is magnified as obligations compile, as latest bedtimes and greatest daytime sleepiness were reported in subjects who engage in both (Carskadon, 1990).

Another key factor affecting adolescent sleep is peer interaction, which has become increasingly problematic with the incorporation of technology and social media. According to a study in 2009, up to 44% of U.S. young people between 12 and 18 years of age reported accessing their mobile phones before bed, and up to 55% admitted to using the Internet at that time (Calamaro, Mason, & Ratcliffe, 2009). Hale and Guan (2014) reported that 90% of studies published on the topic of technology use in 5- to 17-year-olds noted disrupted sleep, with shortened sleep and later bedtimes showing the most consistent effects. Evening exposure is of par-
ticular concern, because 12- to 14-year-old boys who engaged in to 60 min of computer gaming before bed exhibited longer times to fall asleep and lighter sleep as a function of the evening screen time (Dworak, Schierl, Bruns, & Strüder, 2007). In adults, “exciting” shooter games increase heart rate and suppress evening sleepiness more than “boring” math games, and the games disproportionately decreased melatonin production if the screen emitted bright light (45 lux) as opposed to dim light (15 lux) (Higuchi, Motohashi, Liu, Ahara, & Kaneko, 2003). These latter results are especially pertinent when taken with findings that adolescents are particularly likely to experience phase delay in response to evening light exposure (Hagenauer, Perryman, Lee, & Carskadon, 2009).

Daytime Consequences of Adolescent Sleep Debt

With the many factors postponing bedtimes, early school start times can trigger an accumulation of sleep loss referred to as “sleep debt” (Wolfson & Carskadon, 1998). Here we elucidate some of the findings surrounding the effect of sleep debt on school achievement and driving, as well as their cognitive underpinnings.

Academic Performance

A substantial amount of attention has been paid to inadequate sleep in the classroom. In one of the most widely cited works on this topic, Wolfson and Carskadon (1998) found that sleep amount declined by 40 min across age in a sample of high school students, with those getting Cs, Ds, and Fs sleeping on average 25 min less on school nights than those getting As and Bs. Inadequate sleep in this sample was also related to increased sleepiness, greater incidence of behavioral problems, and higher scores on a scale of depressive mood (Wolfson & Carskadon, 1998). These findings have since prompted a surge of investigations on sleep and classroom behavior, which generally agree that less total sleep time, later bed- and rise times, irregular sleep schedules, sleep disturbances, and daytime sleepiness correlate negatively with measures of school achievement, teacher behavior ratings, and self-assessed mood (Wolfson & Carskadon, 2003). The sleep–school relationship is largely attributed to the mismatch between the adolescent biological clock and the early demands of school. In the seminal study by Wolfson and Carskadon (1998), sleep amount declined across age as a function of delayed bedtimes, since wake times remained relatively consistent across older and younger children. Furthermore, a study of high school students by Preckel et al. (2013) found that the predisposition to postpone bedtime predicts lower grade point average even when other factors like conscientiousness, work avoidance, and motivation are controlled.

However, a few analyses have indicated that the connection between school and sleep may not be so robust. A study of Maryland high school students failed to find an effect of sleep on grade point average, an important consideration given the costly effects of reforming school start times (Eliasson, Eliasson, King, Gould, & Eliasson, 2002). Furthermore, one study has suggested that too much sleep may be detrimental to adolescent daytime functioning. Eide and Showalter (2012) compared standardized test scores of 16- to 18-year-olds based on their response to the question: “How many hours of sleep do you usually get a night?” The results indicated that the amount of sleep needed for optimal performance was just under 7 hr, although the authors remarked that using a solitary indicator of “usual” sleep may have been too restrictive to capture the wide variations in sleep habits within a single participant (Eide & Showalter, 2012).

The latter study illustrates the importance of comprehensive sleep and academic performance assessments when interpreting the results of these studies. Although some self-report methods have been validated against objective measures of sleep in children and adolescents (e.g., Sleep Habits Survey; Wolfson & Carskadon, 1998), use of these surveys and methods has varied widely across research groups. Furthermore, Wolfson and Carskadon (2003) commented on the ambiguity of “academic performance,” noting that although some equate it with single measures (e.g., grade point average, standardized assessment), others rely on student reports or lump these with other factors, such as absenteeism and graduation rate. This ill-defined variable is also subject to a number of factors co-occurring with sleep, including but not limited to behavioral problems, socioeconomic status, family structure, and life stress.
In conclusion, although the connection between sleep and school functioning appears well supported, the nature of these assessments may leave the results open to interpretation.

### Car Crash Risk

Young drivers are a national safety concern due to the dangerous cocktail of inexperience and immaturity (Groeger, 2006). This problem is intensified with sleep loss, because more than half of drowsiness-related accidents involve drivers under the age of 25 (National Sleep Foundation, 2000). An analysis of crash risk factors in the United States found that 17- to 22-year-old drivers sleeping fewer than 8 hr per night were 1.28 times more likely to have been involved in a motor vehicle accident than drivers who sleep 8 hr or more (Hutchens et al., 2008). Further, driving drowsy and alone was associated with a 36% greater accident risk in this sample (Hutchens et al., 2008). Data from other cohorts have indicated that threat posed by adolescent sleep debt on the road is widespread. Australian drivers aged 17 to 24 who sleep less than 6 hr per night are 20% more likely to have been involved in a motor vehicle crash (Martiniuk et al., 2013). In a survey of Italian high school students, drivers with a history of at least one motor vehicle crash attributed the accident to sleepiness 15% of the time, and reported poorer sleep and an increased a tendency to drive while drowsy than those with no crash history (Pizza et al., 2010). The acquisition and use of driving skills relies on attention and cognitive control, which are impaired in adolescents getting inadequate levels of sleep (Groeger, 2006; Telzer et al., 2013; Wolfe et al., 2014). For instance, Telzer et al. (2013) demonstrated that poor sleep quality predicts increased impulsivity in 14- to 16-year-olds on computerized tasks of inhibition. Functional magnetic resonance images (fMRI) during the task also revealed reduced activation in the prefrontal cortex in subjects sleeping poorly, an area of the brain associated with executive control processes (Telzer et al., 2013).

Other findings have portrayed adolescents as cognitively resilient in the face of sleep loss. Although Kopasz et al. (2010) found sleepiness increased in 14- to 16-year-olds as a function of a single night of sleep restriction, sleep loss did not significantly predict performance on executive functioning, psychomotor vigilance, attention, and memory retention. Likewise, no post-sleep performance differences were observed in 14- to 16-year-old teenagers for skills and word pairs learned before four nights of sleep restricted to 9, 8, 7, 6, or 5 hr (Voderholzer et al., 2011). Finally, Beebe et al. (2009) demonstrated that five days of sleep restriction in adolescents (13–17 years) elicited working memory performance comparable to normally...
sleeping age-matched controls. Although their sample \((N = 6)\) may have been too small to capture differences between groups, fMRI obtained during the task revealed more pronounced activation in compensatory areas such as the prefrontal cortex in sleep-restricted subjects, which may have contributed to their performance (Beebe et al., 2009).

Differences in methodology across this literature render these findings difficult to interpret. First, there is a lack of consistency in the tasks used to assess certain types of cognitive functioning. Given that children and young adolescents are most susceptible to sleep loss under high cognitive load (Steenari et al., 2003), differences in task difficulty will yield variations in performance across sleep studies. Second, morning testing periods conflict with the delayed phase preference of these subjects. Evening types function better cognitively in the latter part of the day (Preckel et al., 2013), a crucial consideration when interpreting studies that test in the morning or throughout the day. Finally, during adolescence, neural density declines and the prefrontal cortex becomes more connected with the rest of the brain, leading to faster, more efficient execution of cognitive processes (Feinberg & Campbell, 2010). Given that this brain maturation correlates to both age (Feinberg & Campbell, 2010) and puberty (Peper et al., 2009), studies that differ in the ages and developmental range of their samples are susceptible to individual variability that obscures the effect of sleep.

**Parental Recommendations**

So far, we have summarized the behavioral consequences of adolescent sleep loss from the standpoint of academic problems, car crash risk, and cognitive impairment. Next, we outline empirically supported ways to improve teen sleep hygiene (see Table 1).

**Setting Bedtimes**

Parents hold a romanticized picture of their children’s sleep habits. According to a study of 13- to 17-year-olds, teens sleep on average 35 to 45 min less than their parents estimate, which was largely ascribed to parental misperceptions about when their child goes to bed (Short et al., 2013). In contrast, adolescents whose parents monitor their bedtimes go to sleep earlier and sleep more at night than those without parent-set bedtimes (Gangwisch et al., 2010; Short et al., 2011), and show increased daytime alertness and fewer complaints of fatigue (Short et al., 2011). Furthermore, bedtimes of 10:00 p.m. or earlier have been associated with a lower risk of depression and suicidal thoughts in adolescents than later or no bedtimes (Gangwisch et al., 2010). Evidence has suggested that early parent involvement in sleep habits can have a persisting effect, even offsetting phase delay in adolescence. Subjects, especially males, whose parents set bedtimes during childhood are less prone to eveningness in adolescence, suggesting that parental influence on bedtimes can calibrate phase preference later in life (Takeuchi et al., 2001).

Yet, parental involvement in their children’s sleep raises some concerns about feasibility. First, how likely are youngsters to comply with earlier bedtimes? Interestingly, Gangwisch et al.’s (2010) findings have indicated that all adolescent subjects in their study went to sleep on average within 5 min of their bedtime, and Short et al. (2011) found no significant difference in self-reported sleep latency between teenagers with and without parent-set bedtimes. Another issue is the effect of economic standing and family structure on parent supervision over bedtimes. However, analyses by Short et al. (2011) indicated that teen sleep as a function of bed setting is not affected by socioeconomic status, parent education or employment, or whether the child belongs to a two-parent household. In other words, parental regulation appears to be a practical and effective mediator of sleep hygiene in adolescents, which persists along a diverse demographic spectrum.

### Table 1

**Recommendations**

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<thead>
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<th>Teen sleep recommendations for parents</th>
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<td>- Set bedtimes for 10:00 p.m. or earlier</td>
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<td>- Restrict technology use before bedtime and in the bedroom</td>
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<td>- Limit caffeine and energy drinks, especially in the evening</td>
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<td>- Keep sleep schedules consistent</td>
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<td>- Consider advocating for later school start times</td>
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Technology

Adolescents hold misguided attitudes about nighttime media use and their sleep. One study found that nearly a third of seventh and 10th graders use television and computer games to fall asleep (Eggermont & Van den Bulck, 2006); however, evening screen time seems to have the opposite of the desired effect, which has been attributed to dampened melatonin release associated with exposure to bright light displays before bed (Higuchi et al., 2003). Although there is certainly a concern for worsening phase delay, the relationship has also been attributed to a permissive familial climate that affects nighttime media exposure as well as sleep hygiene (Eggermont & Van den Bulck, 2006).

In addition to disturbed sleep, late night screen time has been associated with cognitive deficits the following morning as a function of sleep loss (Dworak et al., 2007; Wolfe et al., 2014). We previously referenced Dworak et al.’s (2007) study, which illustrated that an hour of computer gaming elicits lighter sleep and longer sleep onset latency compared with passive television viewing. Interestingly, the computer group also showed impaired postsleep retention of vocabulary words learned before sleep, whereas the television group did not (Dworak et al., 2007). Similarly, 15- to 20-year-olds allowed up to 5 hr of gaming before sleep exhibited impaired performance on a test of sustained attention the following day, an effect that was wholly mediated by decreased sleep (Wolfe et al., 2014).

Caffeine

Another barrier to sleep is caffeine: Ninety-five percent of high school students admit to using caffeine in the past week, usually consuming their first beverage in the evening (Ludden & Wolfson, 2010). Heavy caffeine use in adolescence is associated with increased daytime sleepiness (Ludden & Wolfson, 2010), which may reflect a need to combat the lethargy that inevitably follows sleep debt. However, frequent consumption in this age group is also associated with sleep disturbances (Seifert, Schaechter, Hershorin, & Lipshultz, 2011), pointing to a carryover effect that further disrupts sleep and increases dependence on the substance (Ludden & Wolfson, 2010). In addition, a growing number of energy drinks are now marketed to children and young adults, with a third of adolescents reporting consuming them on a daily basis (Seifert et al., 2011). Although caffeine is typically the primary ingredient in these beverages, energy drinks contain additional plant-based ingredients that are poorly regulated by the U.S. Food and Drug Administration (Seifert et al., 2011). The half-life of caffeine has been estimated at 3–7 hr (Kaplan et al., 1997); however, compounds found in energy drinks can interact with caffeine to extend duration of activity (Seifert et al., 2011).

Weekend Sleep

Due to the disparity between their biological clock and early weekday obligations, adolescents sometimes use weekends to “catch up” on lost sleep (Crowley et al., 2007; O’Brien & Mindell, 2005; Wolfson & Carskadon, 1998). Although this provides a reprieve from the sleep debt accumulated Monday through Friday, evidence in young adults has suggested that delaying weekend wake time leads to a significant postponement in melatonin the following week (Taylor, Wright, & Lack, 2008). Given that adolescents do not readily adjust to advances in sleep schedule (Carskadon, Wolfson, Acebo, Tzischinsky, & Seifer, 1998), this oversleeping behavior is likely to exacerbate phase delay and further suppress sleep initiation (Taylor et al., 2008). In addition to consistent wake times, bedtime stability from week to weekend contributes to phase alignment: In a study of 10th and 11th graders, postponing bedtime by 1.5 hr on Friday and Saturday resulted in a delayed melatonin phase onset the following Sunday, whether or not sleep duration was extended on the experimental nights (Crowley & Carskadon, 2010).

Evidence has suggested that daytime impairment caused by weekend sleep delay parallels that of insufficient sleep. Wolfson and Carskadon’s (1998) survey demonstrated that high school students delaying bedtime by 2 hr or more on weekends were sleepier during the day, got lower marks in school, and reported more behavioral problems than those with more consistent sleep schedules. O’Brien and Mindell (2005) replicated these results, but found that
weekend bedtime delays were the only significant predictor of academic performance compared with school night sleep restriction and weekend oversleep. In addition to poorer grades, weekend sleep-delayed adolescents showed more daytime behavioral impairment and were at higher risk for smoking, alcohol use, marijuana use, and sexual conduct (O’Brien & Mindell, 2005). A mechanism for this relationship was demonstrated by Hasler et al. (2012), who found that variability in weekend to weekday sleep timing predicts altered brain responses during a monetary reward-processing task, even when sleep duration is controlled. Namely, reduced activity in the ventral striatum, a reward-sensitive region, and the prefrontal cortex during anticipation and attainment of reward was observed in larger shifts (Hasler et al., 2012).

School Start Times

Although there are behavioral changes adolescents can make to improve their sleep, another avenue to reduce the problem of sleep debt is to delay school start times. The American Academy of Pediatrics (Adolescent Sleep Working Group, Committee on Adolescence, & Council on School Health, 2014) recently released a statement encouraging later bell schedules, citing the mounting evidence linking daytime impairments to sleep loss. Meanwhile, students in districts that have already adjusted their start time to 8:35 a.m. or later have reported positive outcomes, such as an average increase of 1 hr of sleep on weeknights, better attendance, and improvements in grades compared with those starting at 7:15 a.m. and 7:30 a.m. (Wahlstrom et al., 2014). Data from schools with varying start times have also projected an average 3-point improvement in standardized test scores if districts institute a 1-hr delay (Edwards, 2012). Even a slight delay of 30 min has been associated with increased alertness, better grades, decreased depressive mood, and fewer health clinic visits in high school students (Owens, Belon, & Moss, 2010). School schedules have also been implicated in driving risk. In Wahlstrom et al.’s (2014) report, two of the delayed schools observed a 65%–70% drop in the crash rate of 16- to 18-year-olds in the corresponding geographical location. Similarly, Danner and Phillips (2008) found a 16.5% reduction in adolescent crashes over 2 years following a 1-hr delay, accompanied by student reports of increased in sleep and reduced daytime sleepiness (Danner & Phillips, 2008). Furthermore, mass traffic data of two adjacent districts with an hour difference in start times has shown a higher accident rate for drivers aged 16 to 18 years in the region corresponding to the earlier starting school (Vorona et al., 2011).

Despite such findings, there are a number of economic and logistic issues plaguing the decision to restructure school schedules. Kirby, Maggi, and D’Angiulli (2011) outlined the primary concerns associated with policy change, such as rerouting bus schedules, disruption to caregiver schedules, and impact on afterschool activities. Moreover, the associated costs are not trivial: One district projected a yearly loss of $150 per student in transportation costs alone (Edwards, 2012; Jacob & Rockoff, 2011). Nonetheless, Jacob and Rockoff (2011) have argued that starting school later is an investment in student achievement, estimating an average $17,500 gain in student earnings due to higher grades and graduation rates.

Conclusion

Learning to lead a healthy lifestyle is central to the successful transition from childhood to young adulthood, so what can be done within the framework of sleep? First, implementing a set bedtime gives youngsters a longer opportunity to sleep, which can alleviate plauging sleepiness and fatigue during the school day. Steps can also be taken to avoid worsening the troubling issue of phase delay, such as educating and monitoring adolescents in order to curb media and caffeine use before bed. In addition, encouraging a consistent sleep schedule from week to weekend can lessen the doldrums associated with Monday mornings. Finally, parents and teens can become involved in the initiative to delay school start times. More information is available on the National Sleep Foundation’s website (http://www.sleepfoundation.org).

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