10 Impact of Sleep Loss on Children and Adolescents

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INTRODUCTION

Recent National Sleep Foundation (NSF) polls demonstrate that both school-aged children and adolescents are obtaining less than the recommended amounts of sleep for optimal daytime functioning. In 2004, the NSF Sleep in America poll (1) reported that most school-aged children were sleeping 9.5 hours per night in comparison to the recommended 10–11 hours per night. Actigraphically documented sleep in children ages 4–8 revealed even less sleep, with an average of 8 hours, 17 minutes total sleep time (2). This chronic insufficient sleep may be even more prevalent in boys, particularly minority boys (3–5). Insufficient sleep appears to be an increasing problem as children age. Sadeh and colleagues (4), in an actigraphic study of 140 children second through sixth grade, found a significant decline in total sleep time as children aged, from approximately 8 hours, 36 minutes in second grade (mean age = 7.9 years) to approximately 7 hours, 41 minutes in sixth grade (mean age = 11.8 years).

Adolescents are at particular risk of sleep loss due to the natural delaying of the circadian rhythm that accompanies adolescent development (6). In 2006, the NSF Sleep in America poll (7) reported that adolescents were sleeping, on average, 6.9 hours per night in comparison to the recommended 9 hours in this age group. Similarly, in a large sample of Canadian adolescents, more than 70% reported sleeping less than 8.5 hours per night, and 41% had Epworth Sleepiness Scale scores above 10, reflecting significant daytime sleepiness (8). In a large survey of high-school students, self-reported school-night total sleep time continually declined across high school, from 7 hours, 42 minutes at ages 13–14 (notably similar to the sleep time of the 11.8-year-old children in Sadeh et al.'s (4) study) to 7 hours, 4 minutes at ages 17–19 (9). This decline was related primarily to the increasingly delayed bedtime across the age groups with relatively similar rise times. The sleep loss accrued during adolescence is compounded by the tendency of many adolescents to maintain even later bedtimes and rise times on weekends (10). Self-reported weekend-night total sleep time declined from 9 hours, 27 minutes at ages 13–14 to 8 hours, 38 minutes at ages 17–19 (9). Children and adolescents in our society, therefore, clearly are obtaining insufficient sleep on a chronic basis.

Partial sleep deprivation has been consistently found to impair cognitive performance and, to an even greater extent, mood in adults (11). However, the impact of chronic partial sleep restriction in children and adolescents is not entirely clear. While it is widely assumed that sleep loss can induce irritability and behavioral disturbances in children, little empirical evidence exists to demonstrate a causal link between the two. Studies that have focused on examining the impact of sleep loss on daytime functioning in children and adolescents have typically utilized one of

three methodologies: (1) naturalistic, questionnaire-based studies to relate typical sleep duration to daytime functioning; (2) laboratory-based restriction of sleep during one night followed by objective neurobehavioral assessments; or (3) partial restriction of sleep over 3–7 nights followed by objective and/or subjective neurobehavioral assessments. Certainly, one night of in-laboratory sleep restriction can be expected to have different impact on a child's daytime functioning than a more chronic course of mild sleep restriction. This chapter will examine the distinctions between these paradigms of assessing the impact of reduced sleep on children's and adolescents' functioning and will describe the impact of different forms of sleep loss on behavioral, cognitive, and affective functioning.

IMPACT OF SLEEP LOSS ON CHILDREN'S BEHAVIOR

Studies investigating the impact of sleep loss on behavior in children and adolescents have relied on naturalistic, survey methods or on chronic partial sleep restriction. No large-scale studies have specifically measured behavior in children following one night of significant sleep restriction.

Naturalistic Studies

Naturalistic studies have documented some associations between sleep duration and daytime behavior in children and adolescents. Specifically, adolescents who report obtaining less sleep and feeling sleepier on the Epworth Sleepiness Scale are also more likely to report being late to school, feeling sleepy in class, having poor grades because of sleepiness, and having impairment in social functioning (8). In younger children, those who were classified as "poor sleepers," defined as at least three awakenings per night and sleep efficiency of less than 90% over the course of five nights, had significantly higher parent-rated delinquent behavior, thought problems, and total behavior problems (12).

Chronic Partial Sleep Restriction

After one week of extending sleep by one hour or remaining on their typical sleep schedule, young children exhibited parent-reported improvements in hyperactivity and anxiety. Those whose sleep was extended also had parent-reported improvements in an index of attention-deficit/hyperactivity disorder (ADHD) and psychiatric symptoms. In contrast, children whose sleep was restricted by one hour each night over the course of one week exhibited no parent-reported differences in behavior (13).

Adolescents whose sleep was restricted to 6.5 hours in bed versus extended to 10 hours in bed over the course of five nights had both self- and parent-reported increased sleepiness, oppositionality, and irritability (14). Dahl and Lewin (15) have speculated that the consequences of insufficient sleep in children and adolescents impair their emotional regulation and may either contribute to and/or exacerbate developmental psychopathology.

IMPACT OF SLEEP LOSS ON CHILDREN'S COGNITION

The majority of studies that have focused on impaired daytime functioning in children and adolescents following sleep loss have assessed subsequent cognitive impairments.

A substantial amount of data from naturalistic, chronic partial sleep restriction, and acute sleep restriction paradigms suggests that reduction of total sleep time significantly affects cognition and learning in children and adolescents.

Naturalistic Studies

The majority of naturalistic studies examining relationships between sleep duration and cognitive functioning have focused on adolescents. Sadeh and colleagues (4) assessed daytime function of second through sixth grade students in relation to their actigraphically recorded sleep over five nights. They found significantly reduced sustained attention and psychomotor vigilance in children who obtained less sleep than their same age peers. Interestingly, this relationship was much greater for the second grade children than for the older age groups.

In their review examining the effects of sleep loss on adolescents from middle school through the first year of college, Wolfson and Carskadon (16) concluded that across studies, adolescents with reduced total sleep time, irregular sleep schedules, and increased sleep onset latencies tended to have poorer academic achievement. Adolescents with lower grades (mostly Cs, Ds, and Fs) reported lower school-night total sleep time, later school- and weekend-night bedtimes, and later weekend-morning rise times than students with higher grades (mostly As and Bs). Some of the contribution in poor grades may be attributed to the increased likelihood of arriving late to school because of oversleeping reported by adolescents sleeping less than 6 hours, 45 minutes on school nights (9). Furthermore, 21% of poor sleepers had school failures and were behind in grade level by one or more years. In fact, the best predictors of school failure were adolescents' fatigue (difficulty rising in the morning and requiring a daytime nap) and parents' education levels (17).

Chronic Partial Sleep Restriction

After one week of one hour sleep restriction, young children demonstrated a lack of expected practice effects on a standardized measure of visual attention, reflecting a potential lack of expected learning for a task. In contrast, those children whose sleep was extended or who remained on their typical sleep schedule showed expected practice effects (13). This difference in ability was highlighted by decreased brainwaves as measured by event-related potentials (ERPs) in these subjects. Those children whose sleep was restricted had ERP amplitudes on a directional Stroop task that were reduced from their baseline week (18). This difference appeared to reflect an increase in cognitive effort during processing of stimuli (19).

By extending 9- to 12-year-old children's sleep by at least 30 minutes over a period of three nights, Sadeh and colleagues (20) demonstrated reduced reaction time on a measure of continuous performance, reflecting improved sustained attention and vigilance, and improvement in short-term memory. Those children who had their sleep restricted, and those who remained on their typical sleep schedule, exhibited no change in reaction time or short-term memory. On a measure of simple reaction time, children who had their sleep restricted and those who remained on their typical sleep schedule, showed decreased performance after three nights; whereas children whose sleep times had been extended showed no change. Fallone and colleagues (21) restricted children's sleep over the course of one week and demonstrated decreased teacher-reported academic performance, attention,

processing speed, and memory in comparison to both the baseline and optimized sleep weeks. However, while children were in both the restricted and optimized weeks, teachers reported greater total school-related problems than during the baseline condition (21).

In the only study examining chronic partial sleep restriction in adolescents, Beebe and colleagues (14) found decreased parent- and self-reported attention and poorer metacognition in adolescents while within the five-night sleep restriction condition in comparison to both the baseline and sleep extension conditions.

Acute Sleep Restriction

Acute significant restriction during one night of sleep in the laboratory has resulted in impaired attention, verbal creativity, abstract thinking, and concept formation in children and adolescents (22,23). This level of impairment reflects impaired executive functioning, as each of the areas of impairment were tied to frontal lobe functioning (23).

Notably, after one night of sleep deprivation, Carskadon and colleagues (24) discovered significant individual variability in cognitive performance among adolescents. Decrements observed in memory, in particular, were typically associated with brief sleep episodes occurring during the testing protocol. For subjects who did not fall asleep while the test was administered, performance was virtually identical to that of the baseline condition, indicating individual susceptibility to sleep loss in adolescents.

IMPACT OF SLEEP LOSS ON CHILDREN'S MOOD

A large amount of data on the relationship between impaired mood and sleep loss exists from the naturalistic studies. Recent data are also emerging from chronic partial sleep restriction studies indicating that there may be a causal link between loss of sleep and impaired mood in adolescents, though there are no clear data regarding this relationship in younger children. No large-scale studies have specifically examined mood in children and adolescents following one night of significant sleep restriction.

Naturalistic Studies

Oginska and Pokorski (25), in a large survey across age groups, reported that adolescents had a much greater discrepancy between self-reported perceived need for sleep and actual sleep time than did adults. In fact, adolescents in their sample reported obtaining 106 minutes less sleep per weeknight than they required to feel refreshed and well-rested. Furthermore, almost half of the adolescent sample reported feeling fatigued upon awakening. When daytime functioning was assessed in these adolescents, apathy was strongly associated with sleep loss. Finally, the authors reported that the discrepancy between perceived need for sleep and actual sleep time predicted daytime impairments significantly better than did total sleep time as measured independently (25). Similarly, 87% of adolescents in Wolfson and Carskadon's (9) study reported that they obtained less sleep than they needed. Those adolescents with self-reported total sleep times of less than 6 hours,

45 minutes reported significantly more depressive symptoms than adolescents who reported sleeping more than 8 hours, 15 minutes.

In Meijer et al.'s (26) study of Dutch children and adolescents ages 9–14, those who reported higher quality sleep and feeling more rested also reported feeling more receptive of their teachers, more positive self-images, higher motivation to achieve in school, and better control over their aggression. Interestingly, however, the self-reported length of time in bed did not significantly predict academic functioning.

In addition to typical mood impairments observed in children and adolescents with restricted sleep, sleep loss can exacerbate clinically significant mood symptoms. Dahl and Lewin (15) delineate the link between sleep loss and depression in adolescents. They indicate a bidirectional relationship between sleep habits and daytime functioning, whereby behavioral and/or emotional disturbances can precede sleep disturbance, while sleep disruption may trigger or exacerbate daytime behavioral and emotional distress. Both insomnia and hypersomnia are noted in children and adolescents with major depressive disorder, and hypersomnia becomes more prevalent as children enter adolescence. Because of this bidirectional relationship, it is often difficult for clinicians to clearly delineate between depressive symptoms and delayed circadian rhythms in adolescents.

Among children and adolescents with mood disorders, those with self-reported sleep disturbance have been reported to have more prolific and severe depressive symptoms and more comorbid anxiety disorders than those children with mood disorders who do not have sleep disturbance. Within the group of children with depression and sleep disturbance, those with both insomnia and hypersomnia were more likely on a structured clinical interview to report a long history of psychiatric illness, more severe depression, anhedonia, weight loss, psychomotor retardation, and fatigue than those with either insomnia or hypersomnia alone (27).

Chronic Partial Sleep Restriction

In Beebe and colleagues' (14) study, adolescents' affect was impacted by sleep restriction to a much greater extent than was behavior. Specifically, adolescents who were sleep restricted exhibited poorer emotional regulation, impulse control, and flexibility. In fact, the authors speculated that the irritability that is traditionally associated with adolescents may, in fact, be attributed to the chronic sleep deprivation present during this developmental period (7).

IMPLICATIONS FOR DELAYED SCHOOL START TIMES

As the evidence for the impact of restricted sleep on children and adolescents' daytime functioning accumulates, policy issues such as school start times become crucial to address. In their review of studies addressing school start times on adolescents' functioning, Wolfson and Carskadon (16) reported that delayed sleep onset coupled with early school start times are associated with excessive daytime sleepiness, falling asleep in class, inattention, and decreased school performance. When adolescent students were monitored by actigraphy while transitioning from ninth grade in a later-starting school (8.25 a.m.), to tenth grade in an earlier-starting school (7.20 a.m.), no differences were found in schoolnight bedtimes.

Rise times advanced, however, while total sleep time significantly decreased from 7 hours, 9 minutes to 6 hours, 50 minutes, clearly below the recommended 9 hours of sleep in this age group. When assessed with Multiple Sleep Latency Tests (MSLT), significant decreases were seen in mean sleep onset latency time across naps after entering tenth grade in comparison to ninth grade. This difference was strikingly apparent during the first nap attempt given at 8.30 a.m., in which the mean sleep onset latency was 5.1 minutes during the tenth grade academic year. Additionally, 12.5% of ninth-graders had at least one rapid eye movement (REM) onset, while 48% of tenth graders had one and 16% had two REM onset periods, indicative of clinically significant hypersomnia (28).

In the 1997–1998 academic year, school start times were delayed for high schools in the Minneapolis Public Schools from 7.15 a.m. to 8.40 a.m. Students did not have later bedtimes than those with earlier start times but did, however, have later rise times, resulting in increased total sleep time of almost one hour per night. Furthermore, attendance rates and continuous enrollment improved, while those students in the later starting schools reported significantly fewer symptoms of depression and excessive daytime sleepiness than those in the earlier starting schools. Of note, while it had previously been a concern that students would be less available to participate in after-school extra-curricular activities if the school start time was delayed, teacher reports indicated that the number of students participating in after-school activities did not change (29).

CONCLUSIONS

While naturalistic studies have postulated a relationship between shortened sleep time and poorer cognition, behavior, and mood in children and adolescents, experimental designs inducing sleep extension versus restriction paradigms have begun to establish a causal link between reduced total sleep time and impaired daytime functioning. An overview of these studies is presented in Table 1. Specifically, experimental manipulation of sleep times has indicated that children and adolescents with restricted sleep are at greater risk for increased oppositionality and irritability, as well as reduced attention, executive functioning, processing speed, memory, behavioral/emotional regulation, motivation, and academic achievement. Interestingly, while clinical lore suggests that sleepy children may be more hyperactive, there is little evidence to support this. Studies that have assessed both parent- and teacher-reported hyperactivity in children and adolescents who are sleep restricted have found no consistent reports of increased hyperactivity, but rather, sleep loss is more commonly associated with inattention.

Certainly, this causal link between sleep loss and impaired functioning in children and adolescents provides the impetus for consideration of delaying school start times, particularly for adolescents, who are experiencing a natural delay in circadian rhythm. Students in schools who have delayed their start times have not delayed their bedtimes significantly but have been provided with the opportunity to obtain more sleep by sleeping later in the morning. This then provides a pathway whereby these students are better rested at school, have better attendance, and report better mood. Such policy changes may have a major impact on the health and education of adolescents.

TABLE 1 Synopsis of Studies Investigating Relationships Between Sleep Loss and Daytime Functioning in Children and Adolescents

Study	Sample size	Age	Methods	Findings
Beebe et al. (14)	20	13–16	1 baseline week 1 week restriction: 6.5 hours 1 week extension:10 hours (naturalistic setting)	SD: increase in homeostatic sleep drive; greater problems with sleepiness, attention, oppositionality/irritability, behavior regulation, metacognition
Carskadon et al. (24)	12	11–14	1 adaptation day, 2 BSLN days, 1 SD day, and 2 REC days(sleep lab)	SD: related to decrease in performance
Crabtree et al. (13)	74	4–8	1 baseline week; 1 week of 1 hour sleep restriction vs. extension vs. control	SE and control: reduced hyperactivity; Improved visual attention; No change in psychomotor skills SR: no change in hyperactivity, visual attention, or psychomotor skills
Fallone et al. (22)	82	8–15	5 nights baseline (naturalistic), random assignment to one overnight 10 hour sleep or 4 hour sleep condition in laboratory	SR: associated with shorter daytime sleep latency, increased subjective sleepiness, increased inattentive behaviors; not associated with hyperactive-impulsive behavior or impaired performance on response inhibition or sustained attention tests
Fallone et al. (21)	74	6–12	Naturalistic setting, BSLN week, optimized week, restricted week	SR: increased academic problems, attention problems, slower processing speed, impaired memory function and daytime sleepiness; no evidence of increase in hyperactivity
Kahn et al. (17)	972	8–10	Parent report of good sleepers vs. poor sleepers	Poor sleepers demonstrate more school problems; show higher incidence of somnambulism, somniloquia, and night fears; fatigue and parent education best predictors for school failure

Continued

TABLE 1 Synopsis of Studies Investigating Relationships Between Sleep Loss and Daytime Functioning in Children and Adolescents (*continued*)

Study	Sample size	Age	Methods	Findings
Liu et al. (27)	553	7–14	Psychiatric evaluation using the ISCA-D	Children with both hypersomnia and insomnia were most severely depressed; children with and without different sleep disturbances manifest features of clinical depression
Meijer et al. (26)	449	9–14	Questionnaires	Good sleep quality: direct positive relationship with school satisfaction factors and achievement
Oginska and Pokorski (25)	432 (adolescent group=191) (university students=115) (young employees=126)	Adolescent 14–16; Student 20–27; Employees 30–45	Self-report questionnaire	Adolescents: reported feeling tired on awakening, nervousness, general weakness; no difference was observed in fatigue, mood, or cognitive symptoms
Randazzo et al. (23)	16	10–14	3 BSLN nights, 1 night in selected group SR (5 hr in bed); 1 group (11 hr in bed); 1 CRL group; laboratory setting	SR: verbal creativity and abstract thinking are impaired
Sadeh et al. (20)	77	9–12	2 BSLN nights, 1 group extended by 1 hr; 1 group restricted by 1 hr	SR: lead to improved sleep quality, increase in night awakenings, reduction of sleep percent, reduced alertness; neurobehavioral functioning impaired
Spilsbury et al. (5)	755	8–11	Sleep questionnaire and journal	Ethnic minority children likely to sleep less than others
Wahlstrom (29)	18,000	14–18	Self-report questionnaires	Later school start times: improved attendance, slight improvement in grades, increased TST

TABLE 1 Synopsis of Studies Investigating Relationships Between Sleep Loss and Daytime Functioning in Children and Adolescents (*continued*)

Study	Sample size	Age	Methods	Findings
Wolfson and Carskadon (16)	3120	13–19	School Sleep Habits Survey completed	Short-sleepers: poor grades, daytime sleepiness, depressive mood, sleep/wake behavior problems

BSLN = Baseline; REC = Recovery; SD = Sleep Deprivation; SE = Sleep Extension; SR = Sleep Restriction; ISCA-D = Interview Schedule for Children and Adolescents—Diagnostic Version; TST = Total Sleep Time.

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