
The Consequences of Insufficient Sleep for Adolescents

Links Between Sleep and Emotional Regulation

BY RONALD E. DAHL, M.D.

Any review of adolescent lifestyles in our society will reveal more than a dozen forces converging to push the sleep/arousal balance away from sleep and toward ever-higher arousal. What harm could there be in trying to push back a little toward valuing sleep? The potential benefits, according to Dr. Dahl, seem enormous.

ADOLESCENTS often “get by” with relatively little sleep, but it may be far less than they need. The observations of many parents, educators, and clinicians are in close agreement with a wealth of scientific data about the growing frequency of this worrisome pattern of behavior. As discussed in other articles in this special section, there has been recent progress in understanding many of the factors that contribute to adolescent sleep loss, including the role of early school starting times and the role of various biological and social influences on adolescents’ self-selected bedtimes.

The increasing evidence that teenagers seem to be getting less sleep leads inevitably to the pragmatic question “How much sleep do adolescents really need?” Unfortunately, the medical/scientific answer to this question seems tautological. Sufficient sleep is defined as “the amount necessary to permit optimal daytime functioning.”

As impractical as that answer may appear, there are two important reasons for

such a definition. First, sleep requirements can be remarkably different across individuals. Second, at a physiological level, sleep and waking states are closely intertwined aspects of a larger system of arousal regulation. (Sleep researchers often use the Chinese symbol of yin/yang to designate the interrelationship of sleep/wake states.)

At the center of this discussion is a critical and pragmatic point: any evaluation of the sleep habits of adolescents must include a careful consideration of the *waking consequences* of sleep loss. The question becomes, in essence, “What are the daytime signs of diminished functioning that indicate insufficient sleep?” While there is a shortage of well-controlled research studies that seek to answer this question, this article focuses on the convergence of evidence suggesting that *changes in mood and motivation are among the most important effects of sleep loss*. Thus an important place to begin looking for evidence of insufficient sleep among adolescents is in the area of emotional or behavioral difficulties.

There is no shortage of epidemiological and clinical studies documenting recent increases in the rates of many psychiatric disorders among adolescents. Certainly many complex factors are likely to

have contributed to the emotional and behavioral problems of teenagers, but the possible link to adolescent sleep patterns bears some scrutiny. There is clear evidence that sleep loss *can* lead to the development or exacerbation of behavioral and emotional problems.¹ The key question is “How great is the contribution of sleep deprivation to these problems?” The magnitude of this link remains an open question that can only be answered through careful empirical research.

In the meantime, these issues have enormous ramifications for the fields of medicine and education with regard both to the physical and mental health of adolescents and to detriments to effective learning and social development. Many policy decisions will be influenced by our understanding and interpretation of the importance of sleep in these areas.

In this article I provide an overview of current scientific and clinical information regarding the consequences of insufficient sleep in adolescents. I pay particular attention to links between sleep and emotional regulation. The following is a brief outline of the main points to be presented:

1. *Sleepiness*. This is the most direct consequence of adolescent sleep loss, and it manifests itself most significantly in difficulty getting up on time for school and in falling asleep in school. These problems can further contribute to conflicts with parents and teachers and to poor self-esteem. Sleepiness is also associated with a strong tendency toward brief mental lapses (or microsleeps) that greatly increase the risk of motor vehicle and other kinds of accidents.

2. *Tiredness*. This is a symptom of sleep loss and includes changes in motivation — particularly difficulty initiating behaviors

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related to long-term or abstract goals and decreased persistence in working toward goals.

3. *Mood, attention, and behavior.* Sleep can have negative effects on the control of mood, attention, and behavior. Irritability, moodiness, and low tolerance for frustration are the most frequently described symptoms in sleep-deprived adolescents. However, in some situations, sleepy teenagers are more likely to appear silly, impulsive, or sad.

4. *Impact of emotional and behavioral problems.* Emotional arousal and distress can cause both difficulty falling asleep and sleep disruptions. Behavioral problems and family chaos can contribute to even later bedtimes and to sleep schedules that are ever more incompatible with school schedules.

5. *Bi-directional effects.* There are bi-directional effects between sleep and behavioral/emotional problems. It can be difficult at times to identify the causal links. For example, a depressed adolescent with severe sleep problems may be showing sleep disturbances that stem from depression or mood problems that stem from sleep disruption. Sleep loss can also contribute to a negative spiral or vicious cycle of deterioration. That is, sleep loss can have a negative effect on mood and behavior, which leads to subsequent emotional/behavioral difficulties that further interfere with sleep. This produces a sequence of negative effects in both domains. In some clinical cases, such negative spirals appear to be a pathway to withdrawal from school or serious psychiatric problems.

The Need for Sleep: An Overview

Before discussing the specific consequences of insufficient sleep in adolescents, it is necessary to begin with a general overview on what sleep is and why it is necessary at all.

Sleep is *not* simply rest. Mere rest does not create the restorative state of having slept. (Anyone who doubts this should try the following experiment tonight: spend eight hours resting in bed, with eyes closed, body relaxed, mind floating, in a deeply tranquil state, but without ever going to sleep; then keep track of your mood and performance tomorrow.) The fundamental difference between sleep and a deeply relaxed wakefulness is that sleep involves dropping into a state with a relative *loss*

of awareness of and responsiveness to the external world. This state of unresponsiveness appears to be necessary for the restorative processes that occur during sleep to take place.

Furthermore, sleep itself is an *active* process. Sleep involves dynamically changing patterns and progressive stages, with some brain regions showing a great deal of activity in some sleep stages. Moreover, there are several aspects of sleep necessary for full restoration, including the continuity, timing, and patterning of different stages of sleep, as well as the timing of the sleep in relation to other biological rhythms.

For example, if subjects are permitted a full night's sleep but are awakened every 15 minutes for brief periods, on the following day they will report tiredness, fatigue, and emotional changes similar to having obtained insufficient amounts of sleep. Similarly, if subjects are permitted as much sleep as they need but are selectively deprived of one sleep stage — such as REM (rapid eye movement) sleep or delta sleep — they also report daytime consequences. And, as anyone who has experienced jet lag can attest, sleep that occurs at the wrong circadian phase is often fragmented and inefficient at restoration.

Sleep is not some biological luxury. Sleep is essential for basic survival, occurring in every species of living creature that has ever been studied. Animals deprived of sleep die. (Experiments with rats show that they can survive without sleep for about as long as they can survive without food.) Yet the specific function of sleep — *why* it is necessary for survival — remains a scientific mystery and the focus of a great deal of investigation.

Within this scientific mystery, however, are two important clues that are relevant to discussions of sleep and adolescent health. First, sleep seems to be particularly important during periods of brain maturation. (Across species, maturing individuals sleep more than fully mature individuals.) Second, sleep is naturally restricted to times and places that feel safe. Most species have evolved mechanisms to ensure that sleep is limited to such safe places as burrows and nests and to times of relative safety from predators. In humans, there is a similar tendency for safe feelings to promote sleep while feelings of threat or stress tend to inhibit sleep.

These links between sleep and stress are an important source of sleep disruption

among adolescents. A key point can be best illustrated by a brief consideration of the evolutionary underpinnings of these biological links between sleep and emotion. For most of early human history, large nocturnal-hunting carnivores surrounded our ancestors, who had no access to physically safe sleep sites. (Humans cannot sleep in trees or on cliff edges, because we lose all muscle tone during REM sleep.) In the human ancestral environment, the main protection against predators was a close-knit social group. The human brain evolved under conditions that made this sense of social belonging and social connectedness the basis for feelings of relative safety. Natural tendencies in the human brain continue to reflect these links, so that fears of social rejection can evoke powerful feelings of threat and so lead to sleep disruption, while feelings of love, caring, and social connection create a feeling of safety and so promote sleep.

Finally, it is important to consider the ways in which the sleep and vigilance systems change during adolescent development. The maturation of humans during puberty includes physical and mental changes in preparation for taking on adult roles (with increased demands for threat appraisal and response). Changes in the vigilance system include a greater capacity for sleep disruptions from social stresses, including fears, anxieties, and emotional arousal.² Thus adolescent sleep systems appear to become more vulnerable to stress at a time when social turmoil and difficulties are often increasing.

Consequences of Insufficient Sleep in Adolescents

There is a surprising lack of controlled studies examining the effects of sleep deprivation or insufficient sleep among adolescents. However, there is extensive circumstantial evidence, clinical evidence, and research in adults that is relevant to these questions. While there is a general convergence of these findings, one important caveat is that we need a greater number of direct investigations. A second note of caution is that we lack information about *long-term* or *chronic* effects of insufficient sleep, since the limited data available have addressed only the immediate and short-term effects of sleep loss.

In brief, there are four main effects of acute sleep loss: 1) sleepiness, 2) motivational aspects of tiredness, 3) emotional

changes, and 4) alterations in attention and performance. Before discussing each of these briefly, I wish to stress one general principle that applies across categories: the influence of *effort*. That is, the effects of sleep deprivation can be offset or even overridden for *short* periods of time by increased effort (or by increasing the external motivation to perform through rewards or punishments). The good news here is that most capabilities can be maintained over a short interval if necessary, while the bad news is that everything is harder to do. In some ways this is the cardinal feature of sleep deprivation: it takes increased effort to perform the same cognitive, emotional, or physical tasks.

1. *Sleepiness*. The most obvious and direct effect of inadequate sleep is a feeling of sleepiness. Sleepiness is most problematic during periods of low stimulation, such as in the classroom, when reading or driving, or when doing repetitive activities. Highly stimulating activities — particularly those involving physical activity or emotional arousal — can often mask moderate levels of sleepiness. Thus many sleep-deprived adolescents report that they can stay out very late at night and not feel tired, whereas if they were to lie quietly reading a book, they would fall asleep in minutes. (However, see the discussion of circadian influences in the article by Mary Carskadon, page 348.)

Another important aspect of sleepiness is the tendency toward brief mental lapses or micro-sleeps. Often, an individual is not even aware of these short gaps in awareness and responsiveness. However, such a lapse in the midst of driving, operating machinery, or doing anything else that requires vigilance can have dire consequences.

Several indirect consequences of sleepiness are also worth mentioning. These include adolescent conflicts with parents and teachers that arise from the difficulty of getting up in the morning or the ease of falling asleep in class; increased use of stimulants (particularly caffeine and nicotine); and synergistic effects with alcohol (the impairments from a combination of alcohol and sleepiness appear to be more than additive, resulting in a deadly combination of influences).

2. *Tiredness*. A separate symptom of sleep loss that can be defined as a feeling of fatigue or decreased motivation is tiredness. Tiredness makes it difficult to initiate (and persist at) certain types of behav-

ior (especially tasks deemed boring or tedious). The effects of tiredness are less apparent when performing tasks that are naturally engaging, exciting, or threatening — perhaps because it is easier to recruit extra effort to offset tiredness. Conversely, the effects of tiredness are more pronounced for tasks that require motivation to be derived from abstract goals or consequences (e.g., reading or studying uninteresting material in order to increase the chances of attaining some future reward).

Tedious tasks without the imminent prospect of reward (or fear of immediate consequences) are much more difficult to initiate and complete when one has been deprived of sleep. Similarly, tasks that require planning, strategy, or a complex sequence of steps to complete are more difficult when one is tired. This general category of tasks (requiring motivation linked to abstract goals, delayed rewards/consequences, planning, strategy, and so on) involves abstract processing areas in the front of the brain (regions of the prefrontal cortex) that appear to be particularly sensitive to sleep deprivation.³ The potential relevance of these types of motivational changes to educational goals and processes seems obvious.

3. *Emotional changes*. The emotional changes that are secondary effects of sleep loss are very important but very complex. There are at least three factors that make this a complicated area for investigators: 1) the emotional effects of sleep deprivation appear to be highly variable across individuals and across situations, 2) emotion and emotional regulation are very hard to measure accurately, and 3) there are bidirectional interactions between mood and sleep disturbances (this third aspect was noted above and will be addressed separately below).

One of the main sources of information in this area comes from clinical descriptions of children and adolescents with various sorts of sleep disorders or transient sleep disruptions. There are also a few studies (including ongoing research in our laboratory) that obtain measures of emotion before, during, and after a single night of sleep deprivation, and then a gain following a recovery sleep.

The major theme across these studies is evidence suggesting *mood lability*. Not only does there appear to be greater variability in emotional states following sleep loss, but there also appears to be less con-

trol over emotional responses in many adolescents. For example, if faced with a frustrating task, a sleep-deprived teenager is more likely to become angry or aggressive. Yet, in response to something humorous, the same subject might act more silly or inane. Several adolescents reported increased crying reactions during sad scenes in videotaped movies when they were sleep-deprived. Many subjects reported increased irritability, impatience, and low tolerance for frustration when asked to perform tedious computer tasks. In general, these findings often looked like a decrease in inhibition or conscious control over emotions following sleep loss. It is also important to point out that some subjects seemed to show no measurable changes in any emotion when sleep-deprived.

These results are quite preliminary, include a high degree of variability across individuals, and will require replication with larger samples to establish statistical significance. However, these findings fit very well within a general pattern of similar observations regarding *effortful control*. That is, the primary emotional changes following sleep loss suggest a decrease in the ability to control, inhibit, or modify emotional responses to bring them into line with long-term goals, social rules, or other learned principles. Effortful control over emotion involves regions of the prefrontal cortex of the brain that are similar to those discussed previously with regard to abstract goals.

Changes in emotional regulation that result in decreased control following sleep loss could have serious consequences in terms of many high-risk behaviors among adolescents. The inability to control emotional responses could influence aggression, sexual behavior, the use of alcohol and drugs, and risky driving. Clearly, additional research will be needed to better delineate these complex but important issues relevant to adolescent health.

4. *Changes in attention and performance*. Following sleep loss, changes in attention and performance also represent a complex area of investigation in children and adolescents. There are three main points. First, sleep loss is associated with brief mental lapses in attention during simple tasks that can be partially offset by increased effort or motivation. Second, sleep deprivation can sometimes mimic or exacerbate symptoms of ADHD (attention deficit/hyperactivity disorder), including distractibility, impulsivity, and difficulty with effortful

control of attention. Third, there is also emerging evidence that sleep deprivation has marked influences on the ability to perform complex tasks or tasks that require attention in two or more areas at the same time.

While the first point about brief mental lapses has already been addressed, the latter two points warrant some discussion. A potential link between ADHD symptoms and sleep deprivation has received considerable discussion from several investigators.⁴ Both ADHD and sleep deprivation are associated with difficulty with self-control of behavior, attention, and impulses. Both ADHD and the daytime symptoms of sleep deprivation will often respond to stimulant medication. Furthermore, ADHD symptoms are more frequent in children with sleep disorders, and there has been some reported improvement in ADHD symptoms in children following treatment of sleep problems. Finally, other studies have reported increased rates of sleep complaints and disorders in children diagnosed with ADHD. This is a very complex area, and disentangling the connections and relative contributions across these domains will require additional careful studies.

One pragmatic recommendation, however, is quite simple. For any child or adolescent who exhibits symptoms of ADHD, the importance of a good night's sleep and a regular sleep/wake schedule should be emphasized to avoid the consequences of sleep loss that could exacerbate symptoms.

One of the most interesting areas of study is evidence that some types of complex tasks may be particularly sensitive to the effects of sleep deprivation. James Horne has presented extensive evidence showing that dual tasks and tasks that require creative or flexible thinking are sensitive to sleep loss.⁵ (These tasks all require abstract processing in areas of the prefrontal cortex.) Our own research group has generated similar findings in its examination of dual tasks following sleep deprivation in adolescents and young adults. For example, students with one night of sleep deprivation exhibited no significant changes in performance on a difficult computer task and showed no effect on postural balance. However, when the students performed both tasks simultaneously, sleep deprivation had a marked effect on balance.⁶ In recent pilot studies we have also found the same pattern of results in adolescents performing cognitive and emotional tasks. Performance at either task

could be maintained following sleep deprivation — but not both.

On one hand, detriments in performing a dual task (like controlling thoughts and feelings at the same time) might sound like an esoteric or subtle effect of sleep deprivation; on the other hand, it is important to point out that fluency in such dual tasks is the foundation of social competence. These are the daily challenges that must be balanced in the everyday life of adolescents: thinking and solving problems while navigating the emotional reactions of complex social situations, using self-control over impulses and emotions while pursuing goals, experiencing anger yet weighing the long-term consequences of actions. If further research substantiates the marked effects of insufficient sleep on these types of complex tasks in adolescents, then we should have significant concerns about the importance of sleep patterns in the normal development of social competence.

Sleep and Emotional Disorders in Adolescents

It is essential to underscore the complex intersection between sleep regulation and behavioral and emotional problems in adolescents. Clearly, there are two-way interactions between these systems. The regulation and timing of sleep can be altered by behavioral or emotional disorders, while cognitive, behavioral, and emotional control during daytime hours can be influenced by the way adolescents sleep. Furthermore, daytime activities, changes in the environment, and stressful events can have profound transient effects on sleeping patterns in the absence of any clear-cut psychopathology. In addition, medications used to treat psychiatric disorders often affect sleep, and sleep loss can exacerbate mood and behavioral symptoms.

Perhaps the best-studied example of such interactions is the relationship between sleep and depression. Subjective sleep complaints are very common in children and adolescents who have been diagnosed with Major Depressive Disorder (MDD). Symptoms include insomnia (75% of cases) and hypersomnia (25%). Hypersomnia difficulties are reported more frequently after puberty. Insomnia symptoms usually include difficulty falling asleep and a subjective sense of not having slept deeply all night.

Recently, clinicians and researchers have seen increasing numbers of adolescents

with overlapping phase delay disorders or other sleep/wake schedule disorders associated with depression. Depressed adolescents frequently have difficulty falling asleep, are unable to get up or refuse to go to school, sleep until late in the day, complain of extreme daytime fatigue, and, over time, shift to increasingly more delayed sleep/wake schedules. Likewise, surveys reveal that adolescents who get less than 6¼ hours of sleep each school night or report more than a two-hour difference between school night and weekend bedtimes have a higher level of complaints of depressed mood than adolescents who get more sleep or who sleep on more regular sleep/wake schedules.

Clinicians who are experienced with these problems have pointed out that in many cases it is difficult to differentiate decreased motivation, school refusal/anxiety, delayed circadian phase, attention difficulties, and depressive symptomatology. Clearly, both sleep patterns and behavioral symptoms must be carefully assessed in an effort to prevent the problems, diagnose them accurately, and plan successful treatment.

There is also evidence of changes in the sleeping electroencephalograms (EEGs) of depressed adolescents, including increased time to fall asleep and altered patterns of REM sleep. Furthermore, changes in EEG measures of sleep predicted an increased recurrence of depressive episodes during longitudinal follow-ups in early adulthood.⁷

In some cases, treatment of sleep complaints and problems — including regularizing the sleep/wake schedule, cognitive behavioral therapy for insomnia, and short-term treatment with medication for severe insomnia — can have a positive impact on depressive symptoms.⁸ On the other hand, effective treatment of depression can also be a critical aspect of improving sleep.

Negative Spirals?

As I described above, one area of concern with regard to the interconnections between sleep and emotional disturbances is the potential for a progressive sequence or spiral of negative effects. Insufficient sleep can amplify emotional difficulties, which can then produce further sources of distress and increased disruption of sleep. The reason for this concern arises more from clinical experience than from any controlled studies, and so the concern is

perhaps best illustrated by describing a case.

Jay had a history of poor sleep habits (e.g., bedtimes past midnight, erratic sleep/wake schedule) beginning in about seventh grade. In ninth grade the problems became worse as he struggled to get to sleep at night (usually falling asleep at 1 a.m.) and to wake up in the morning and then had problems with distractibility and behavior at school. He also reported some symptoms of depression, including loss of interest in some activities, daytime fatigue, and worsening performance at school. His symptoms improved transiently in the summer, when he slept from 3 a.m. until noon.

In 10th grade Jay began attending a high school that started at 7:30 a.m., which required him to wake up at 6 a.m. to meet the school bus at 6:30 a.m. He had a very difficult time getting up for school at that hour because his average bedtime was 2 a.m. He made several attempts to go to bed earlier but found himself unable to fall asleep. He was never able to follow through in a way that would permit him to establish an earlier pattern of bedtime, and he quickly reverted to his 3 a.m.-to-noon sleep schedule on all weekends and holidays. Jay sometimes stayed up working at his computer or watching television—he says this was because he hated the feeling of lying in bed trying unsuccessfully to fall asleep. Before long, he was regularly missing school or arriving late and falling asleep in class.

Jay, who had at one time been identified as a gifted student, was failing most of his classes and appeared increasingly lethargic, subdued, and uninterested in school. His school counselor referred him to a mental health clinic. Over the course of several months, he was diagnosed as having depression with some ADHD symptoms (e.g., difficulty finishing tasks, distractibility). Trials of antidepressants and stimulant medication resulted in small transient improvements in some symptoms, but Jay was never able to reestablish good sleep patterns that were compatible with his school schedule. Eventually he withdrew from school, became increasingly

depressed and withdrawn, and was hospitalized after a serious suicide attempt.

At the time of hospitalization, Jay had severe chronic insomnia and a major depressive disorder. Despite multiple interventions, these problems persisted. He showed very little motivation to return to school and appeared to have chronic depressive symptoms. At discharge his long-term prognosis was not promising.

In a case such as Jay's, it is impossible to disentangle the relative contributions of the sleep and mood dysregulations. While no general conclusions can be drawn from this single case, it does illustrate the complexity of these interactions and the importance of obtaining a better understanding in these areas.

Policy Decisions for Today And Direction for the Future

Frequently in this article I have cautioned readers about the need for additional research to improve our understanding of the complex issues arising from the consequences of insufficient sleep among adolescents. Our current knowledge is preliminary and based on a paucity of controlled data. Furthermore, we are probably at an equally early stage in our understanding of the behavioral and emotional problems of adolescents.

Nonetheless, behavioral and emotional difficulties are currently the largest source of morbidity and mortality among adolescents. While it is possible that sleep loss makes only a minuscule contribution to adolescents' problems with emotional regulation, it is extremely likely that it plays some role. It is also quite possible that insufficient sleep plays a significant role in leading up to some of these problems in a vulnerable set of individuals.

Identifying vulnerability to sleep loss may represent an important future direction for research, since there appear to be such large individual differences in the effects of acute sleep loss. Such vulnerability could be related to a tendency to need more sleep, to being a "night owl," or to a biological vulnerability toward emotion-

al disorders.

Clearly, more research is needed to help inform policy makers, whose decisions will further affect adolescent sleep patterns. Cost-benefit analyses regarding the relative importance of sleep will require more precise quantification in these areas. In the meantime, one might make a reasonable case that the odds are heavily in favor of sleep as an increasingly important health concern among adolescents.

To reiterate the main point with which I began, adequate sleep is defined as the amount necessary for optimal daytime functioning. It appears that the potentially fragile underpinnings of adolescent social competence (controlling thoughts and feelings at the same time) may be most sensitive to the effects of inadequate sleep. Any review of adolescent lifestyles in our society will reveal more than a dozen forces converging to push the sleep/arousal balance away from sleep and toward ever-higher arousal. What harm could there be in trying to push back a little toward valuing sleep? The potential benefits seem enormous.

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