COMMENTARY

The Cumulative Impact of Adolescent Sleep Loss: Next Steps

Commentary on Lo et al. Cognitive performance, sleepiness, and mood in partially sleep deprived adolescents: the need for sleep study. *SLEEP* 2016;39(3):687–698.

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It is well recognized that developmental shifts in sleep physiology and societal pressures shorten the typical sleep of adolescents on school nights.[1] Adolescents have also shown a steeper decline in sleep duration over the past century than younger children or adults.[2,3] However, the implications of these trends are hotly debated. Two papers published in 2012 stoked unrest in the pediatric sleep community. One questioned the evidence base underlying sleep recommendations.[4] The other suggested "optimal" sleep durations that were much less than the prevailing recommendation of 9 hours,[5] and instead corresponded closely to the average sleep of United States adolescents on school nights.[6] There have been three primary responses to those challenges: (1) media coverage that oversimplified the conversation[7]; (2) re-analysis of existing data that broadened the range of what is considered "recommended"[8]; and (3) expansion of the scientific knowledge base to incorporate alternative analytic approaches and more sophisticated research designs.

In this issue, Lo and colleagues[9] take the third route, and propel the field forward by examining, for the first time, day-to-day changes in the effects of experimentally induced chronic partial sleep restriction on adolescents' attention, working memory, processing speed, subjective sleepiness, and mood. Although not an exact replication, the findings are reminiscent of work with adults published a decade ago and since cited nearly 1,000 times.[10] As in adults, adolescents show consistently worsening attention and, to a lesser degree, working memory after each cumulative night of restricted sleep. This effect shows no sign of leveling off across a full week, even though subjective sleepiness and mood level off (but do not reverse) after a few days. This disconnect between subjective experience and objective deficits could lead to a progressive underestimation of impairment,[10] which could affect not only learning and social interactions, but also safety (e.g., automobile accidents by adolescent drivers.[11])

Lo and colleagues' pioneering work[9] clearly shows that there is a cumulative cost associated with partial sleep restriction in adolescents that is objectively verifiable, progressive, reflects a true cause-effect relationship, and may take multiple recovery nights to reverse (though even a single recovery night results in striking improvements). These are critical contributions to the debate over adolescent sleep recommendations. Nevertheless, as seems invariably true, the findings raise new questions, the answers to which will have very practical implications.

First, the field must determine the degree to which the findings can be generalized. As Lo and colleagues note, the elite students who participated in their study are an important group to understand in their own right, but they are a unique minority. It is hard to know whether struggling students and demographically dissimilar adolescents will show a greater, lesser, or similar effect. For example, there are data that show that children from low-income or ethnic minority families in the United States are more vulnerable[12] or less vulnerable[13] to the effects of poor sleep on their functioning. The answer to the generalizability question tempers how much current findings impact sleep recommendations, since those are intended for broad populations. Further, sleep patterns differ cross-culturally (even within a country), and there may be multiple equally effective ways to meet sleep needs. This does not argue against making sleep recommendations, but rather emphasizes a need to be culturally sensitive in doing so.

Second, much work remains to be done to understand the dose-response effect of chronic sleep restriction in adolescents. This is enormously important to move the dialogue beyond "get more sleep" to supporting concrete recommendations.[4,14] The current study did not parametrically vary sleep duration, and the < 5 hour nightly sleep period in the sleep restriction condition is considerably less than what most adolescents receive on school nights.[6] To my knowledge, only one experimental chronic sleep restriction study has systematically varied sleep duration.[15,16] It found dose-response effects on daytime sleepiness, but not on tests of cognition, though the sample size and simple pre-post testing schedule may not have offered statistical power to detect time-by-condition interaction effects. Lo and colleagues' study[9] was also longer than the conventional 5-night school week. Although there were progressive effects across the first 5 nights, extending exposure beyond that timeframe complicates interpretation of subsequent recovery.

Third, while chronic partial sleep restriction appears to be endemic among adolescents, there is more to the sleep story. For example, epidemiologic studies have suggested that *variability* and/or *continuity* in sleep have effects that are independent of an adolescent's *average* sleep duration.[17–20] No pediatric study has systematically induced sleep variability or disruption, and such studies remain rare with adults as well. This is not an obscure academic issue; night-to-night sleep variability and/or disruption is quite common in the general population, is especially evident in certain clinical populations (e.g., attention deficit hyperactivity disorder[21]) and may be particularly relevant to underserved—and often understudied—low-income and minority youth who more often live in environments that do not promote sleep continuity.[19,22,23]

On a related point, it can be challenging to answer very reasonable parent questions about adolescent sleep on *weekends*. Given social and biological pressures towards a later sleep phase, yet school start times that are earlier than conventional "office hours,"[24] what is the realistic balance between promoting longer sleep via "sleeping in" versus creating "jet lag" as adolescents re-enter the school week? Experimental studies have

a unique role to play in answering this very practical question, because in correlational studies it is difficult to untangle the effects of adolescents' weekend sleep from the carryover of the previous weeknights. Those experimental studies have yet to be done.

Fourth, while Lo and colleagues[9] used a number of different cognitive tests, they simply could not test all possible outcomes. Even within the realm of one-on-one cognitive tests, there are domains left untapped, and current findings hint at effects that warrant explication. For example, adolescents in the control condition made steady day-to-day gains on tests of processing speed. This "practice effect" reflects learning, probably both procedural (without conscious awareness) and declarative (e.g., verbalizable "tricks" learned from prior practice) in nature. Because the test scores changed very little day-to-day in the sleep restriction condition, it is hard to know how much the observed cross-condition effect on those tests reflects slowed processing versus suppression of the practice effect during sleep restriction. One night of recovery sleep led to a score jump that was equivalent to several days of practice in the control condition, so some form of "latent" learning seems to have occurred that had been suppressed during sleep restriction. This may partially explain Voderholzer and colleagues' findings of a lack of effect of chronic sleep restriction on adolescents' memory test scores,[16] as their post-testing was done after recovery sleep.

Further, the extensive literature on pediatric sleep apnea provides an important lesson: in youth, real-world outcomes such as quality of life and classroom functioning are often far more sensitive than office-based tests, possibly because the structure and support offered during one-on-one testing, coupled with the brief and interactive nature of test stimuli, tend to mitigate sleepiness.[25–28] Results from the smaller number of pediatric sleep experiments suggest a similar pattern,[27] so it is important to consider real-world and office-based measures to be complementary, not equivalent. The answer to the question of optimal sleep need may depend on the outcome measure. Even within an applied setting, it stands to reason that more sleep might be needed to maintain vigilance to a dry lecture than an engaging, interactive classroom activity. And optimal sleep for either might differ from the optimal level to prevent obesity in the general population. Further, inadequate sleep might have effects that are uniquely relevant to certain populations, such as youth with asthma.[29]

Lo and colleagues are to be commended for executing a logistically challenging and carefully designed study, the results of which clearly demonstrate that chronic partial sleep restriction causes adolescents to have progressively worsening attention, even after effects on subjective sleepiness and mood level off. They have done the field a service. It now is incumbent for the field to build upon this progress to better understand the causal impact of different aspects of sleep, at different doses, in different populations, and with different outcome measures. The results are not academic; they directly inform practical recommendations with real-world health consequences.

CITATION

Beebe DW. The cumulative impact of adolescent sleep loss: next steps. *SLEEP* 2016;39(3):497–499.

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DISCLOSURE STATEMENT

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