Sleep effects on adolescent memory and cognitive ability

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ABSTRACT

Sleep deprivation is currently one of the most prevalent problems in adolescents. High schoolers with 5-6 hours of sleep is almost normalized in high schools. Other than educating students about getting sleep, school systems have not done much to address the issue. Sleep deprivation has many drawbacks such as lower attention spans and focus levels, short-term cognitive impairment like slower daytime processing, and sometimes even long-term cognitive decline like Alzheimer's, higher risks of depression and anxiety, and weaker memory power. Delaying start times is an applicable solution and has the capacity, depending on the delay time of increasing high schoolers' sleep by an hour or more, positively affecting their memory capacity, concentration time, and overall performance. Nap times can also help adolescents manage sleep durations and improve cognitive abilities as well. Sleep duration, however, changes depending on different individual factors. Women are more susceptible to sleep deprivation-caused problems than men, African Americans are more susceptible than European Americans, and children and the elderly are more susceptible than adults. By understanding these differences and impacts, drawbacks of sleep deprivation can be combated by more practical solutions.

INTRO

Sleep plays a fundamental role in cognitive performance for individuals of all ages. A sufficient amount of sleep is required for people to be able to perform their daily activities without difficulty. The exact amount of sleep that would be considered as sufficient, though, varies from across the lifespan. For adults, this amount would be about seven hours of sleep a night. However, for teenagers, this amount is greater, with a recommendation of eight hours of sleep a night. Despite this increased sleep demand, teenagers are naturally less tired in the evening, specifically because sleep pressure accumulates slower compared to adults and children. Due to their late sleep timings clashing with early school start times, teenagers are often unable to get a sufficient amount of sleep in preparation for the following school day. As a result, teenagers tend to oversleep on weekends to compensate for their sleep loss. In consequence, they are not able to reach their minimum weekly sleep duration for optimal cognitive and physical health. For example, in elementary and middle school students, sleep deprivation has been shown to cause a decrease in academic functioning as well as mental health. Moreover, sleep deprivation has been reported to also have noticeable effects on the elderly. As this population is naturally more vulnerable because of their age, sleep deprivation causes a significantly higher risk of nocturnal sleep disorders and lowers their attention and

concentration levels compared to healthy adults. Although these age groups are vastly different, they are all negatively affected by sleep deprivation.

Sleep is not only important for many age groups, but is also important in many aspects of health, including mental health, physical well-being, and cognitive functioning. Because sleep is so crucial for learning and memory, students' unhealthy and unbalanced sleep schedules lead to worse academic performance in school and result in long-term impacts on overall health. This can be an increased risk for diseases, worsened mood and emotional well-being, and increased alcohol consumption and smoking. Students grow more vulnerable to depression and anxiety, and they show increased tardiness and behavioral issues in school in relation to insufficient sleep. By understanding exactly what effects sleep deprivation has on a teenager's academic performance and overall health and the benefits of sufficient sleep, we can develop better solutions to this societal problem. For example, pushing back school timings to later times has proved to positively affect high schoolers' sleep schedules and overall performance in many different studies.

Finally, although sleep deprivation can have a negative effect on people, with permanent impact found in high school students' populations, the benefits of sufficient sleep can be rewarding as well. With ample amounts of sleep, students show healthier behavioral patterns and demonstrate fewer disciplinary problems. Importantly, students do better in school in terms of academic performance as well. Additionally, sufficient sleep leads to an overall healthier lifestyle with less risk for diseases. In the end, it is important to study the disadvantages of sleep deprivation and its relationship within-school cognitive performance, as well as the overall benefits of sufficient sleep during the teenage years. This review article will provide an overview of these three topics and interconnect multiple studies to emphasize the relationship between sleep and the cognitive function of a high-school student.

Effects of Sleep Deprivation on Education Performance

Looking to address what components out of three basic cognitive processes, attention, working memory, and executive functions, are most likely to be harmed by a 24 hour sleep deprivation period, an experiment was conducted in which 23 undergraduates were split into two groups to test the effects of sleep deprivation(García et al., 2021). The groups had different tasks to do, assessing their cognitive abilities. The control group was able to perform these tasks three days in a row at noon with the ability to sleep freely, while the experimental group had to do the same tasks with one day of sleeping freely, 24 hours of no sleep, and one night of recovery. According to the result of this study, the 24 hour sleep deprivation period reduces tonic alertness, selective and sustained attention, components of attention, and component of executive function. Further, a group of adolescents who did not have a habit of sleeping less was put in two separate groups(Lo et al., 2016). The sleep-restricted group was allowed to sleep 9 hours for 3 nights, 5 hours (sleep deprivation) for 7 nights, and then three more nights of 9

hours recovery sleep. The sleep-restricted group showed a decrease in sustained attention, working memory, positive mood, and executive function, along with an increase in subjective sleepiness, and they were not able to recover in the recovery time given to them. Another study attempted to identify the relationship between the duration and quality of sleep and children's performance in important developmental domains, including cognitive functioning, academic performance, and mental health(El-Sheikh et al., 2019). Two-hundred and eighty two children participated in this experiment. Their sleep for seven consecutive nights, actigraphy-based sleep duration, and self-reported sleep quality were collected. The children, their mothers, and their teachers also reported the childrens' mental health, and they were given cognitive performance tests. Finally, teachers reported academic functioning and schools provided academic achievement data. The results of this experiment showed that the relationship between sleep and childrens' cognitive functioning, academic achievement, and mental health are nonlinear, and the relationship between externalizing behaviors and sleep duration and quality is nonlinear negative, meaning that children have less behavioral problems with more sleep time and better sleep quality.

Sleep Deprivation Effects Across Demographics

Sleep deprivation involves the condition of physical and psychological distress resulting from a lack of sleep. This lack of sleep leads to different effects for a variety of different demographics, such as gender, age, and health conditions. For example, infants need 12-16 hours of sleep a day, while 1-2 year olds need 11-14 hours, 3-5 year olds need 10-13 hours, 6-12 year olds need 9-12 hours, 13-18 need 8-10 hours, and adults need 7 or more hours a night. Even within the age group of adults, older adults may need more sleep time, because they tend to fall asleep slower and sleep lighter than younger adults. Also, women tend to have more sleep-related complaints than men because of natural gender differences. Further, factors such as disease states, sleep quality, previous sleep deprivations, and pregnancy also affect these basic sleep requirements. Thus, the effects from sleep deprivation are tailored to the individual. As such, the requirements for daily sleep also vary in a similar manner.

Over the period of 12 months, the sleep times and depression levels of a group of 3,071 adolescents (aged 13-18 years) were measured through biannual online surveys from October 2009 to December 2012(Conklin et al., 2018). Because of developmental changes in this stage along with various environmental factors, it was noted that there were significant differences in measured CESD scores between genders. It was reported that there was no specific pattern in men, but in women, sleep deprivation increased the risk of depression significantly. Although this study was subject to bias because of its self-reported sleep times, its results still stand true because they adjusted for multiple confounders in their overall estimates. Sleep duration and quality is also affected by race(El-Sheikh et al., 2019). African Americans, for example, have poorer sleep quality and shorter sleep durations than Europeans Americans due to a variety of

factors such as discrimination and prejudice that contribute to their poorer sleep qualities. Another study looked at the relationship between cognitive and emotional function, sleep time, and sleep quality in the elderly(Liao et al., 2022). 150 elderly patients over 65 years old were divided into a normal cognitive function group and a cognitive impairment group. In the results, the total score of PSQI, sleep quality, falling asleep time, sleep time, and sleep efficiency of patients with cognitive impairment were higher than those of patients with normal cognitive function.

Descriptive characteristics of young people in the BASUS cohort across levels of cumulative sleep deprivation

	History of Sleep Deprivation		
	None (n=2141)	Occasional (n=533)	Chronic (n=397)
Baseline (Wave 4* or 5)			
Female	51%	54%	61%
Age (years), mean (SD)	14.8 (0.7)	14.8 (0.7)	14.8 (0.7)
White ethnicity	54%	47%	38%
Post-pubertal stage	9%	7%	12%
High family income	44%	39%	37%
Highest maternal education	41%	37%	37%
Excellent/Good health	62%	52%	51%
BMI (kg/m^2), mean (SD)	21.0 (4.0)	20.9 (3.9)	20.8 (3.8)
Sleep duration (hr), mean (SD)	9.0 (0.8)	8.2 (0.9)	7.3 (0.8)
CESD score, mean (SD)	15.2 (10.5)	17.6 (11.0)	18.4 (11.3)
Mid-point (Wave 6)			
Sleep duration (hr), mean (SD)	8.9 (0.8)	7.9 (0.9)	7.0 (0.7)

Follow-up (Wave 7)			
Sleep duration (hr), mean (SD)	8.9 (0.8)	7.7 (0.9)	7.1 (0.7)
CESD score, mean (SD)	15.0 (10.4)	18.2 (11.0)	19.0 (11.9)
Depressed, (CESD ≥ 24)	20%	28%	32%

Data on imputed sample (n=3071). *Data on BMI from Wave 4 only. BMI, body mass index (kg/m^2); high family income was perceived as far above average/quite a bit above average relative to peers; CESD, Centre for Epidemiologic Studies Depression Scale score; Depressed (CESD≥24)
This table was recreated from Conklin et al., BMC Public Health. 2018.

Biological Processes Disrupted by Sleep Deprivation

Sleep deprivation hinders immune response(Garbarino et al., 2021). Sleep deprivation leads to an increased risk for infectious/ inflammatory pathologies including cardiometabolic, neoplastic, autoimmune and neurodegenerative diseases. As sleep normally promotes defense against infections and diseases, the lack of it has detrimental effects on health as it makes people more prone to these diseases.Furthermore, periods of sleep deprivation negatively impact dendrites and their structure(Havekes et al., 2016). A minimal amount like five hours of sleep deprivation can decrease dendritic spine numbers in selective areas of the brain. This has been proven to lead to a weaker memory as well.

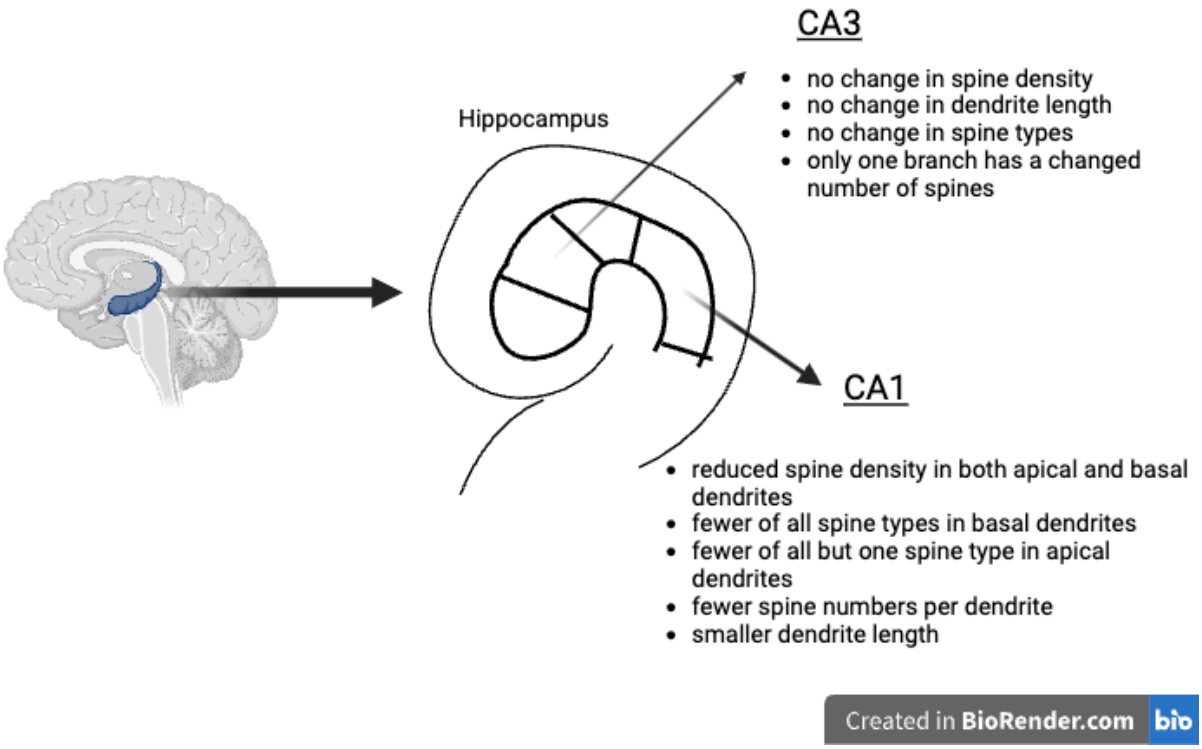

Figure 1 represents the effects of sleep deprivation on hippocampal sub-structures, CA1 and CA3. This figure was created on BioRender.

Delaying School Start Times

When students (grades 10-12) were given a choice to start school at 8:00 or 8:50, they only chose the later start minimally(Biller et al., 2022). However, when chosen, students were able to gain an hour of sleep and they showed better sleep quality leading to improved motivation, concentration, and study quality. Specifically, 45-59% of students, each time, had achieved 8 hours of sleep when picking the later start compared to 3-15% with normal school times. When elementary students' start times were delayed by 1 hour, they showed earlier weekday bedtimes and wake times with an 11 minute sleep decrease(Meltzer et al., 2021). With different start times, elementary students' sufficient sleep duration, poor sleep quality, or daytime sleepiness did not change. Middle and high school students showed a noticeable increase in sleep duration and a decrease in daytime sleepiness. Another study, with a total of 455 students, measured the sleep duration with later school timings (Widome et al., 2020). Students got about 43 minutes more sleeping time and slept a lot less on the weekends. They also had similar bedtimes 2 years after the start time delay. Finally, a study further measured the impact a

45-minute school start time delay affected sleep, health, mood, behavior, and academics (Thacher & Onyper, 2016). This study, unlike the others, students delayed their sleep time but did not get more sleep. Regardless, they showed less tardiness and decreased disciplinary incidents.

Introducing Nap Times Into Sleep Schedules

When 53 adolescents were given either an 8 hour Nap schedule (6.5 hour nocturnal sleep with a 90-minute daytime nap) or an 8 hour No-Nap, nocturnal-only sleep schedule, the regular nap opportunities benefited building of robust and flexible schemas, facilitating recall of the subsequently rearranged and expanded structured knowledge (Aghayan Golkashani et al., 2022). When looking at how effective short daytime naps can be to help with sleep deprivation, nineteen adults were restricted to 7 nights of 5 hours of sleep(Saletin et al., 2017). Ten of those adults were unable to take naps and the other 9 were allowed a daily 45 minute nap. Their sleepiness was measured using the multiple sleep latency test and a visual analogue scale at 2-hour intervals. The results showed that the short daytime nap did decrease sleepiness, but only for a limited period of time. Thus, naps may help with sleep deprivation, but they are not a long-term solution.

CONCLUSION

Overall, sleep time and quality significantly affect the cognitive function of people of all ages, especially high school students. Without enough sleep, people cannot perform their daily activities to the best of their ability. Society does not emphasize the importance of sleep quite enough, as despite the prominent effect of sleep deprivation on students' lives, due to factors like school start times and workloads, students are still forced to sacrifice their sleep.

Throughout the multiple studies mentioned, results were collected in many different methods including self-reported questionnaires. These approaches included controlling sleep while monitoring cognitive effects when comparing control groups with experimental groups, and monitoring types of different sleep habits. Because of this variety, the studies chosen can be considered generalizable to the overall beneficial effects of sleep. A variety of additional data was collected that aimed to assay factors such as academic achievement data, multiple sleep latency tests, mock assignment results, PSQI (Pittsburgh Sleep Quality Index), in-school behavior, daytime sleepiness, executive function, working memory, disease risks, depression, and attention. With all of these different types of data measurements, this review connected concepts and unanswered questions across studies to understand a greater perspective on the relationship of sleep time and sleep quality specifically in a young population. Furthermore, the studies outlined in this review explored the effects of certain variables like gender, age, different start/end times, different sleep times, and different sleep schedules, which are all factors to consider when attempting to draw general conclusions to populations at large. By piecing

together a variety of different study methods and experiments, this literature review uncovered certain limitations of existing primary research, however, our findings nonetheless support the existing hypothesis that sleep is crucial to the proper cognitive functioning of human beings during development.

In considering major weaknesses in existing literature covering this topic, however, we found that a major limitation to the experiments mentioned in this review primarily focus on low sample sizes. This is a considerable issue to those that want to use these findings to support systemic change in the way in which schooling is structured as it relates to students' sleep schedules. For instance, because the entire population can vary significantly compared to chosen subjects, the data may fall short of accounting for variability in lifestyles across the world and thus cannot be completely accurate. Also, while an attempt was made in these studies to account for regional variability, all of these studies did not account for variability as it relates to minority groups, including racial, ethnic, and gender minorities. Despite these limitations, however, these studies presented findings that are in the cutting edge of understanding the relationship between sleep and memory from as close to a biological perspective as currently possible. For instance, one study detailed that in healthy adults the stages of REM and slow wave sleep play major roles in memory consolidation.

In conclusion, the research detailed in this review presents data that could provide possible solutions to how sleep deprivation is present in a student population. For example, a source of chance can be to alter school hours which definitely affect the amount of sleep a student receives. However, this is not a fool-proof solution to students' sleep deprivation, as it is a more systemic approach that does not get at individual variability in student sleep schedules. These data also point to potential additional causes of sleep deprivation in youthful populations, such as addiction to social media or screen usage in the late hours. Future work should approach sleep deprivation from an angle of how internet usage or addiction to social media may be a cause for sleep pattern disturbance in high school aged students. Potential limits on the use of these types of technologies during sleep hours may standardize sleep schedules and may thus contribute to an improvement in sleep time and quality. There are many more possible solutions that can help with sufficient sleep, and as a result of the implementation of such solutions students will exhibit better overall grades, longer attention spans, more concentration, better behavior, less risks of depression, anxiety and other health problems as well as an overall stronger memory. While the biological root of sleep disturbances in high school age students is still not completely known, we now have plenty of evidence that can drive systemic change in how students manage their sleep schedule.

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