Evaluation of The Physical and Psychosocial Consequences of Sleep Disruption in Adolescents

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Abstract

During puberty, adolescents worldwide frequently experience many forms of sleep disruption. Both homeostatic and circadian mechanisms are affected during puberty, along with other psychosocial factors such as academic pressure, mental health issues, increased autonomy, and reduced parental regulations. Various studies have explored the impacts of sleep disturbance throughout the lifespan and universally conclude that lack of sleep can have detrimental effects on the human body. Adolescents face unique consequences of sleep disruption as it is a transitory period to adulthood complicated with hormonal, emotional, and social challenges. Data has shown that lack of sleep in adolescence negatively impacts academic performance. Other aftermaths could also be detected, such as mood disturbances, behaviors and decision-making skills, daytime sleepiness, and severe physical impacts. The project will review several journal articles published by reputable sources to analyze the consequences of sleep disturbance in adolescents. Evidence will be presented to shed light on the cognitive, mental and physical aftermaths of sleep deprivation, therefore conveying the need for solutions to mitigate the effects of this alarming issue.

Keywords

Behavioral and Social Sciences; Neuroscience; Sleep deprivation; Adolescents

Introduction

Sleep is recognized as one of the crucial elements for development and survival. Sleep is a required behavior to support proper physical and mental health, especially in early developmental stages such as infancy, childhood, and adolescence. However, with the rapid, widespread use of technology, the increase in academic pressure, the development of complex social relationships, and various other factors, sleep deprivation and sleep disturbances have become common issues among adolescents, causing detrimental biological and mental impacts. Adolescence is characterized by the transitory period between childhood and adulthood, from 10 to 19 years old. Sleep deprivation, prolonged inadequate or loss of sleep, can result in negative physical and emotional impacts. In contrast, sleep disturbance is a much broader field, encompassing disorders like insomnia, sleep-wake disorder, and narcolepsy.

As most health consultants recommend, 8 - 10 hours of sleep is required to ensure normal adolescent development. During sleep, adolescents regain the energy lost throughout the day, allowing crucial developmental processes to occur. These processes can range from enhancing cognitive abilities to physiological procedures. Recent correlational studies have also identified differences in the impacts of sleep on adolescent and adult mice and recorded changes in adolescents' brains during sleep. These changes vary from memory consolidation to the escalating cycle of myelination. The results suggest that sleep is indispensable in the brain's maturation, particularly in

producing gray and white matter and several other crucial functions. Therefore, acquiring sufficient sleep is essential for adolescents, and not satisfying the body's sleep needs can lead to detrimental health and developmental impacts.

Research conducted in 2015 indicated that approximately two-thirds of US high school students were getting less than 8 hours of sleep on school nights and stayed up even later on weekends or during summer, with females reporting less sleep than males.[30] Another study also suggested that around 45% of Hispanic adolescents report experiencing frequent sleep problems in their daily lives.[1] This evidence proves the pervasive spread of sleep insufficiency and other sleep problems in adolescents, regardless of race and ethnicity.

This review explores the detrimental short-term aftermaths of sleep problems on adolescents in 3 distinct areas: physical health and safety, cognitive abilities, and emotional well-being. Through analyzing notable studies and articles related to the topic, the paper will discuss the reasons for adolescents' delayed bedtime and present evidence that further emphasizes the association between adolescents' sleep problems and the downgrade in their quality of life.

Discussion

Factors that influence sleep pattern in adolescence

The adolescent sleep pattern is influenced by two main factors: sleep/wake homeostasis and the circadian rhythm (Hagenauer et al., 2009).[29] The sleep/wake homeostasis, also known as the "sleep drive" or "sleep pressure," refers to the buildup of sleep need and acts as an alert for sleep. This pressure is driven by adenosine triphosphate (ATP), which is made up of one adenosine and three phosphate molecules. The three phosphate molecules are broken down to fuel cells, and once this energy is used up, adenosine is the only molecule left. As the amount of adenosine in the body builds up, it slows down the brain's activity, triggering the body to think it is time to sleep. After a certain period, the pressure decreases if the body has gained enough sleep and energy, causing the body to wake up (Hagenauer et al., 2009).[29] However, several factors can alter or conceal the effects of sleep/wake homeostasis. Stimulants are one of the most famous examples; they stimulate brain activities and increase hormones such as adrenaline, temporarily suppressing the effects of sleep pressure.

The second factor that influences sleep is the circadian clock. Circadian rhythms follow the "internal clock" inside the brain to regulate physical, mental, and behavioral changes on a 24-hour cycle. This system regulates alertness and sleepiness throughout the day, sensing light changes in the surrounding environment. The rhythm is naturally synchronized with the day and night cycle; however, it can easily be disrupted by

various factors, such as exposure to artificial light or irregular sleep patterns, confusing the rhythm's ability to approximate the time of the day.

Psychosocial factors also contribute significantly to adolescents' sleep patterns. These factors could include external factors, such as the early school start time or the academic pressure caused by demanding academic tasks, and internal factors, such as socializing or using stimulants during the day. Both external and internal factors can influence adolescents' bedtime, either by taking up too much time at night or by suppressing adolescents' sleepiness.

Biological factors that impact sleep in adolescence

Sleep/wake homeostasis

Evidence has suggested that more mature adolescents might be less affected by sleep pressure than younger adolescents (Illingworth, 2020).[2] This phenomenon results from the build-up of sleep pressure that gets progressively slower with age. By measuring the brain's response to sleep loss and the speed of falling asleep, it is evident that older adolescents might be able to stay up later and demonstrate a slower pace of falling asleep after extended waking (Illingworth, 2020).[2] Therefore, it is possible that an alteration in adolescents' sleep/wake homeostasis slows down their build-up speed and gets progressively slower as they emerge into later phases of puberty. However, whether this alteration extends beyond pubertal phases remains undiscussed.

Another article by Crowley and colleagues proposed evidence to support the hypothesis that sleep pressure builds up more slowly in older adolescents (Crowley et al., 2018).[6] By measuring the slow wave activity of the brain (the frequency pattern that increases during waking and dissipates during sleep), studies have shown that older adolescents can stay up longer compared to younger adolescents due to their slower accumulation of sleep pressure (Crowley at al., 2018; Taylor et al., 2005).[6,31] To specify, early pubertal adolescents (mean age = 11.1) fell asleep about 14.5 hours after waking, 2 hours earlier than postpubertal adolescents (mean age = 13.9) (Taylor et al., 2005).[31] These results suggest that slow wave activity increases slower in older adolescents than younger ones, strengthening the hypothesis that adolescent age determines the amount of sleep pressure.

However, the dissipation of sleep pressure remains stable across adolescent development (Crowley et al., 2018).[6] This stability implies that the need for sleep does not change as adolescents develop, explaining why older adolescents might have later wake time than pre or early adolescents. An early study by Carskadon established that sleep time does not change regardless of adolescent age. Carskadon allowed adolescents ages 10 to 17 to sleep for 10 hours undisturbed and showed that adolescents slept for about 9 hours and 20 minutes regardless of their age group (Carskadon, 2011).[41] This finding further indicates that adolescents require the same

amount of sleep each night regardless of age. Therefore, as older adolescents' bedtime gets later at night, their opportunity to gain enough sleep to fulfill their sleep needs decreases.

Circadian rhythm

During adolescence, the circadian rhythm undergoes a phase delay, increasing daytime and delaying nighttime. This phase delay causes adolescents to have a later sleep/wake time, progressively worsening with age. It maximizes at around 19.5 years of age in females and around 21 years of age in males, causing adolescents to be described as having "evening chronotypes" or being called "night owls" (Roenneberg et al., 2004).[5] This delay in circadian rhythm could occur earlier or later in the pubertal phase, and the end time can also vary among individuals (Illingworth, 2020).[2] This delay is demonstrated clearly by observing adolescents' sleep/wake time on weeknights and weekends, with a consistently later bedtime on weekend nights. It is suggested that since adolescents are given more autonomy in choosing their bedtime on weekends and are less interrupted by external factors (such as waking up early before school starts), their bedtime is approximately two or more hours later than on weeknights. They also show an increase in the total amount of sleep acquired (Gradisar et al., 2011).[4] These findings indicate that adolescents, when allowed, have a later sleep and wake time, highlighting a delay in their circadian rhythm.

However, circadian delays may not be unique to adolescents. A study by Crowley and Eastman partially contradicts the idea that adolescents have a more delayed circadian rhythm than other periods in one's life. The study observed two groups of individuals, one of adolescents and one of adults ages 30.8 - 45.8, who experienced the same laboratory protocols. They found that the average circadian period of both groups was around 24.2 hours per day (Crowley & Eastman, 2018),[6] suggesting that there is little to no difference in adolescents and adults' circadian rhythms and that the delay in circadian rhythm might not be unique to the pubertal period. These findings may suggest that the pubertal period is the beginning of changes in sleep patterns, which might develop into sleep abnormalities that continue in adulthood.

Another circadian rhythm factor that could influence the delay is sensitivity to light. It is commonly postulated that the delay might be caused by an increase in adolescents' sensitivity to light, as it can cause them to experience suppression of melatonin. However, a study by Crowley and colleagues refutes this hypothesis by showing that the early to mid-pubertal adolescents group is significantly more sensitive to light than the late to postpubertal group, with a notable difference in melatonin suppression. To be precise, at the three levels of light tested (15, 150, and 500 lux), the early to mid-pubertal group experienced the amount of melatonin suppression of 9.2 ± 20.5%, 26.0 ± 17.7% and 36.9 ± 11.4%, respectively. In contrast, the late to postpubertal group lay at only -5.3 ± 17.7%, 12.5 ± 17.3%, and 23.9 ± 21.7%, respectively (Crowley et al.,

2015).[7] These data suggest that light sensitivity is not increased synchronously with the progression of the pubertal period. Therefore, light sensitivity may not be one of the factors contributing to the delay of the circadian rhythm.

To conclude, two biological factors influence adolescents' sleep patterns: sleep/wake homeostasis and the circadian rhythm. In the case of sleep/wake homeostasis in adolescents, several studies agree that the ability to stay up later increases as adolescents enter later maturational phases during their development. The ability to stay up later is due to the slowed pace of sleep pressure build-up, delaying their need to sleep after an extended waking period. The circadian rhythm is also proven to experience a delay during adolescence. However, it is unclear whether this delay is unique for adolescents since other studies suggest similar findings in adulthood. Studies also found that light sensitivity might not cause this delay because it does not increase synchronously with adolescents' development, as more robust suppression of melatonin is measured in younger adolescents and decreases in older ones. Both factors, the homeostatic sleep drive, and the circadian rhythm, contributed significantly to the delayed bedtime of adolescents. The homeostatic sleep drive extends the wake period, while the circadian rhythm adjusts adolescents' natural awareness of time. However, it is unclear whether one factor has more influence than the other, even when the homeostatic sleep drive does seem to have a more substantial effect by increasing adolescents' ability to stay wakeful.

Psychosocial factors that influence sleep in adolescence

As stated by Gaby Illingworth, one of the reasons behind teenagers' sleep deprivation is the early school start time (Illingworth, 2020).[2] Generally, while adolescents' bedtime gets progressively later, school start time does not adjust for this change. Hence, early school start time restricts teenagers' opportunity to get enough sleep, causing them to experience sleep deprivation. School start time can also confuse adolescents' circadian rhythm, as they develop the habit of sleeping in during weekends to compensate for their sleep debt on weeknights. This problem is not newly developed; in fact, Carskadon and colleagues' study in 1998 identified school start time as a significant barrier for adolescents to acquire their required sleep (Carskadon et al., 1998).[8] A study conducted by Wahlstrom shows that a delay in school start time does have a positive influence. They found that over 9,000 high school students in schools with a start time of 8:30 AM or later experienced significant attendance and improvement in academic performance (Wahlstrom et al., 2014).[9] These results strengthen the association between early school start time and adolescent sleep deprivation and intensify the importance of change.

Another academic-related reason behind adolescents' sleep deprivation is their academic pressure. As they enroll in higher grades, coursework can be much more demanding, extracurriculars are also required, and competition among students increases, forcing adolescents to work harder to achieve high grades while balancing

with other daily activities. They are then required to allocate more time to their academic tasks, especially during exam seasons, reducing the amount of sleep they can obtain. To illustrate, a self-reported study in 3 US high schools demonstrated that 47% of students interviewed stated homework as their reason for staying up late (Gaarde et al., 2018),[3] particularly students engaged in procrastination, multitasking, or other out-of-school extracurricular activities. This finding further emphasizes the impact of academic pressure on adolescents' lack of sleep, especially when they are not only trying to meet and maintain academic standards but also having to devote themselves to extracurricular activities.

Because of their emotional development, adolescents also spend lots of time at night socializing with others, primarily online, in order to satisfy their need to communicate and interact with their peers. In a survey by Jenna Gaarde and colleagues, 53% of participants reported "sometimes" when asked if socializing is a barrier to sleep at night, suggesting that adolescents' lack of sleep is partially caused by interacting with peers (Gaarde et al., 2018).[3] This situation not only restricts their opportunity to obtain the amount of sleep required but also raises a new factor that might disrupt their ability to fall asleep: Exposure to short-wavelength screen light, which is the type of light that the circadian rhythm is particularly sensitive to (Cajochen et al., 2011).[10] This exposure to light portrays the risk of suppressed melatonin production, making it harder for adolescents to fall asleep. Furthermore, as activities before sleep can play a crucial role in determining the quality of one's sleep, it is proven that the use of digital devices 2 hours before going to sleep can contribute to a low-quality sleep night with later sleep time and reduced sleep duration (Orzech et al., 2016).[38]

The use of stimulants, especially caffeine, should also be mentioned as one of the factors contributing to adolescents' sleep deprivation (Illingworth, 2020).[2] Caffeine can increase brain activity and trigger alertness, which is usually effective in combating daytime sleepiness. A study by Ludden and Wolfson in 2010 indicated that among the sample size of 197 high school students, 95% reported regular caffeine use (primarily sourced from soda), with the first dose typically taken in the evening (Ludden & Wolfson, 2010).[39] According to Illingworth, caffeine negatively affects sleep duration and quality. Caffeine does not affect sleep time and the speed of falling asleep, as its ability to maintain wakefulness can also increase sleep pressure. However, using stimulants can create a cycle of exhaustion and sleepiness for adolescents since stimulants do not allow them to get the quality of sleep needed to regain energy; hence, they enter a continuous cycle of experiencing sleep disruptions, then depending on stimulants to stay alert, then facing problems with their sleep again.

In summary, various psychosocial problems are potential factors in adolescents' sleep deprivation. These factors can include academic pressure, socialization, and the use of electronic devices, which delay adolescents' sleep time and reduce the quality of their sleep. Early school start time is also a factor, but it restricts adolescents' opportunity to acquire the needed sleep. Another notable factor is the use of stimulants, particularly

caffeine. This factor restricts adolescents' ability to acquire the quality of sleep needed, therefore entering a continuous cycle of exhaustion and being dependent on these stimulants. As mentioned in several studies, the factors mentioned above all contribute to adolescents' sleep deprivation, hence lowering their quality of life. Sleep deprivation caused by these factors can leave detrimental effects on adolescents cognition ability, as well as their physical and mental health, as illustrated in Figure 1.

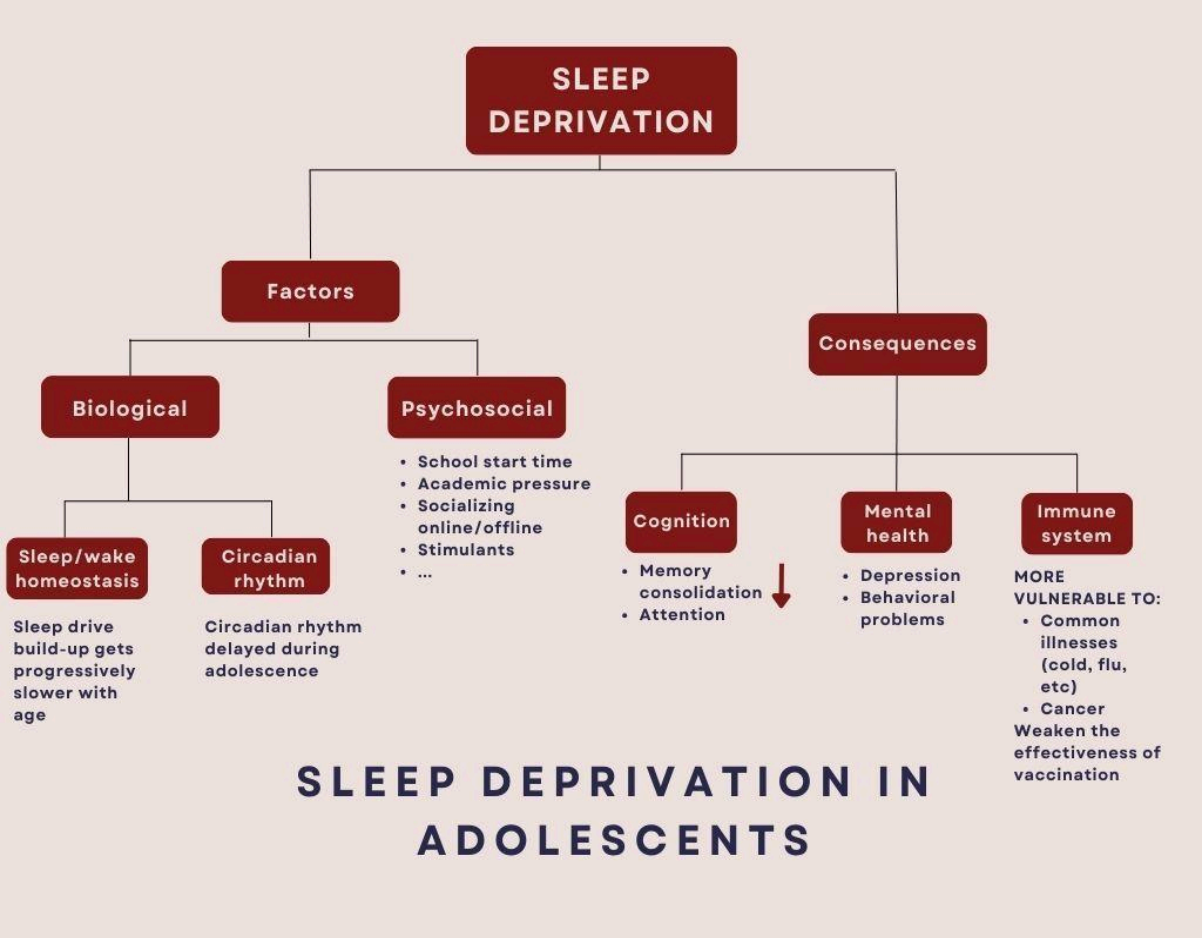

Figure 1. Factors and consequences of sleep deprivation in adolescence.

Sleep deprivation negatively affects cognition, mental health, and physical health in adolescents

Cognition is uniquely affected by sleep loss

Sleep deprivation is commonly associated with adverse effects on cognitive abilities, especially memory consolidation and attention, as suggested in a review by Taehuyn Kim and colleagues (Kim et al., 2022).[11] They claimed that neural activities during sleep, particularly slow wave sleep (SWS) and rapid eye movement (REM) sleep stage, are crucial in memory consolidation. During SWS and REM, memories are replayed several times, consolidating memory traces. Hence, the effectiveness of the memory consolidation process could be altered by lack of sleep. Reports also have shown a decrease in sleep-deprived individuals' ability to maintain vigilant attention, thus proving that attention is affected by sleep deprivation. However, the neurological explanation behind this phenomenon remains unclear.

The effects of sleep loss on memory consolidation

According to Kim and colleagues, sleep deprivation adversely affects declarative and non-declarative memories (Kim et al., 2022).[11] Declarative or explicit memories are retrieved intentionally and can be consciously recalled. Some of the most common forms of declarative memories are verbal, visual, and episodic memories. In daily life, declarative memory represents knowledge and facts learned at school. On the other hand, non-declarative memories, also known as implicit memories, refer to memories that are recalled unconsciously and typically manifested automatically. One of the most common forms of non-declarative memories is procedural memories, such as riding a bike or showering.

Several studies have proven that sleep disruptions adversely affect explicit memories. In a study by Drosopoulos et al , individuals were asked to study a word list unfamiliar to them before 3 hours of either sleep (slow wave sleep or REM sleep) or wakefulness. They were then asked to recognize the words. The result indicated that explicit memory consolidation was significantly enhanced by sleep, particularly slow-wave sleep (Drosopoulos et al., 2005).[12] A study by Diekelmann et al also suggested that sleep deprivation can alter retrieved memories and produce false memory traces (Diekelmann et al., 2008).[13] In their study, individuals memorized associated words without the strongest common word (for instance, "night," "dark," and "coal" without the word "black"), then attended recognition testing after 9, 33, and 44 hours of either sleep-deprived or healthy sleep period. As expected, sleep-deprived subjects had a much higher chance of getting the theme word incorrectly, proving that sleep deprivation can produce false memories.

Non-declarative memory has also been shown by various researchers to be altered by sleep deprivation, according to Kim and colleagues (Kim et al., 2022).[11] A meta-analysis in Kim's review showed that in all six studies analyzed (three studies of finger tapping task, two studies of visual texture discrimination task, and one study of visual orientation discrimination task), individuals under sleep-deprived condition consistently performed worse than those who gained enough sleep, further strengthened the claim (Walker et al., 2002; Korman et al., 2003; Debas et al., 2010; Aeschbach et al., 2008; Stickgold et al, 2000; Mascetti et al, 2013).[32-37] All presented evidence agreed that sleep deprivation

negatively influences memory consolidation, suggesting that the hypothesis could be true.

The effects of sleep loss on attention

Kim and colleagues' review also suggested that sleep deprivation has an adverse effect on maintaining sustained attention. Numerous reports showed that individuals under sleep-deprived conditions struggled with tasks requiring high top-down attention. The Bocca and Denise study evaluated ten healthy young males twice on a simple saccade task. The first task occurred after a normal night of sleep and the second after a sleep-deprived night. The result showed that a longer latency time is observed after a sleep-deprived night compared to a normal night (Bocca & Denise, 2006),[14] suggesting that attention is affected by the lack of sleep.

A review by Hudson and colleagues also agrees that sleep deprivation can alter an individual's ability to maintain vigilant attention. They examined studies utilizing the psychomotor vigilance test (PVT), a popular methodology among studies regarding sleep deprivation and sustained attention. The PVT is a 10-minute reaction time task that requires quick responses to randomly appear visual stimuli, with around 2-10s inter-trial intervals. The performance of test takers relies on the number of lapses of attention and some other outcome measures (Hudson et al., 2019).[15] In a figure adapted from Whitney and colleagues' study, performances in the PVT of individuals under sleep-deprived and normal conditions were compared. Sleep-deprived individuals underwent two baseline days of 10-hour sleep opportunities, a 62-hour interval of sleep deprivation, and two days of 10-hour recovery sleep. In contrast, individuals in the control group had 10 hours of sleep opportunities every day throughout the study. Performance remained constant for the control group, while impaired performance was observed in the sleep-deprived group, with increases in deficits across days. Notably, the group's performances under sleep deprivation recovered instantly after having recovered sleep, suggesting the effect of sleep deprivation on attention might only be a short-term influence (Whitney et al., 2015).[16] This evidence suggests that lack of sleep can alter the ability to remain vigilantly attentive, though the neurological reasons behind this remain unclear.

Specifically for adolescents, the decrease in memory consolidation and the ability to maintain sustained attention can have several detrimental effects on their academic abilities. Without the ability to stay focused and memorize knowledge, adolescents experience a notable decline in academic achievement, affecting their daily lives and negatively impacting their future. To illustrate, a study by Dean W. Beebe and colleagues tested the impact of sleep deprivation on sixteen healthy adolescents. Participants were asked to experience five sleep-deprived nights (around 6.5 hours of sleep) versus five healthy nights (around 10 hours of sleep). After each condition, participants attended a simulated classroom where they were shown educational videos and assessed by related quizzes. Some adolescents also participated in EEG monitoring to evaluate their level of attentiveness. Results showed that adolescents

under sleep-deprived conditions performed consistently worse on the quiz than those in healthy conditions and illustrated more inattentive behaviors, suggesting that sleep deprivation negatively impacts adolescents' academic achievements (Beebe et al., 2010).[17]

In summary, sleep deprivation alters adolescents' process of memory consolidation and produces false memory traces. It also negatively influences adolescents' ability to maintain sustained attention. However, it is unclear whether this influence is directly due to sleep deprivation or a consequence of the fatigue caused by lack of sleep. These negative aftermaths of sleep deprivation on adolescents' cognition can leave detrimental influences on teenagers' academic performance by altering their ability to stay focused and memorize knowledge.

Sleep loss strongly influences mental health

One of the most commonly associated consequences of sleep deprivation is its impact on an individual's mental health. This association could come from the significantly high number of individuals with mental illnesses, particularly teenagers, who also experience sleep deprivation and other sleep problems. Hence, research has been conducted to determine whether there is a link between sleep deprivation and mental illnesses and whether sleep deprivation could be considered a cause of mental illnesses.

The bidirectional link between sleep loss and depression

Depression is one of the most common mental illnesses among adolescents due to their sensitive developing nature. According to the World Health Organization, in November 2021, around 2.8% of teenagers ages 15-19 experience depression around the world. Therefore, the community needs to address the root causes of depression, especially in teenagers, to determine realistic solutions to the problem. In several studies, a link between depression and sleep deprivation has been slightly observed. However, several aspects of this link have not been explored and scientifically proven, so it is becoming a popular topic among psychologists and neurologists.

Gradisar and colleagues suggested that sleep problems usually appear prior to symptoms of depression, proposing that sleep problems could be a cause of depression in adolescents (Gradisar et al., 2022).[18] Even though a bidirectional link between sleep disruption and depression has been proven by logical reasoning and evidence, a meta-analysis by Nicole Lovato and Michael Gradisar pointed out that there is a greater tendency for sleep problems to lead to depression than the other way around (Lovato & Gradisar, 2014).[19] They also pointed out a potential unreliability in several studies that concluded that depression leads to sleep problems, highlighting the use of self-report methodology. Michelle Short and colleagues' review also proposed that sleep-deprived condition is associated with a 55% increase in experiencing low mood (anger, depression, anxiety, and more) among 74 studies comprising 361,505 adolescents (Short et al., 2020).[20] This result further confirms sleep deprivation's impact on

adolescents' emotion regulation. Therefore, emotions, predominantly negative feelings, can have a more severe impact on sleep-deprived adolescents compared to those with healthy sleeping habits. The inability to regulate emotions healthily could be a repercussion of the alterations in hormones, such as the secretion or instability of the level of melatonin, which affects the variations in energy levels and alertness.

Gradisar and colleagues also indicated that the delayed circadian rhythm in adolescents can also contribute to the development of depression. Individuals with a reported preference for evening activities and showed a delayed circadian rhythm experience more symptoms of depression (Nguyen et al., 2019).[21] Simultaneously, other studies also concluded that individuals showing signs of depression also report delayed circadian timing (Dolsen & Harvey, 2018),[22] suggesting that there is a bidirectional link between sleep deprivation and the development of depression. Another idea mentioned in Gradisar and colleagues' review of Antypa's study is that later bedtime and more wakefulness at night allow adolescents to get more caught up in rumination, which is an influential factor in the development of depression (Antypa et al., 2017).[23]

Sleep loss and behavioral outcomes

The effect of sleep deprivation on adolescents' mental health could also influence inappropriate and usually dangerous behaviors. Several articles agreed with the hypothesis that sleep deprivation influences risk-taking behaviors in adolescents. According to research by Merikanto and colleagues, a preference for eveningness is associated with behavioral problems, particularly rule-breaking behaviors.[24] Another review by Porras-Segovia and colleagues also suggested that sleep deprivation could be significantly linked to suicidal behaviors (Porras-Segovia et al., 2019).[25] The association between these two problems is the contribution of several factors, including alterations in circadian rhythms, the regulation of emotion, mental disorders, and countless more. Another study by Johnson and Breslau also presented evidence to strengthen the association further. They suggested that the use of cigarettes, alcohol, and illicit drugs was associated with adolescents reporting sleep problems (Johnson & Breslau, 2001).[40]

To summarize, sleep deprivation affects adolescents' sensitive mental health by altering their ability to regulate emotions. Sleep loss in adolescents makes them more prone to depression, as studies have recorded a bidirectional link between these two situations. However, there is still an ongoing debate on whether one of the two phenomena is a symptom of the other. Sleep loss could also influence behavioral problems, particularly rule-breaking or dangerous behaviors such as the use of illicit drugs or suicidal behaviors. Several factors could explain the association, including emotional regulation or mental disorders.

Physical effects of sleep loss on the immune system

The effects of sleep disruptions on individuals' physical health can be adverse. Studies have examined the association between sleep disruptions and several health-related issues and found that low-quality sleep can cause countless problems in the human body. Health-related issues due to sleep disruptions could include immune-related diseases like infection and cancer.

The immune system plays a crucial role in the human body. It is the shield to protect an individual against diseases and infections by eliminating the causes of these diseases. However, as sleep deprivation develops, it can weaken the immune system, making individuals more vulnerable to several health-related issues. According to Garbarino and colleagues, sleep-deprived individuals, especially those with habitually short sleep durations, are much more vulnerable to common illnesses such as colds and flu or respiratory infections (Garbarino et al., 2021).[28] Furthermore, the article indicates that infections in individuals experiencing sleep deprivation usually have dreadful outcomes. The article also reviewed the effects of certain vaccinations. Sleep supports the formation of immunological memory, which is the mechanism of vaccinations. Conversely, sleep deprivation impedes the formation of immunological memory and, therefore, weakens the effectiveness of vaccinations.

In Garbarino and colleagues' review, it is also stated that sleep deprivation could suppress the effectiveness of anti-tumor responses, leading to a higher risk of cancer (Garbarino et al., 2021).[28] The suppression of anti-tumor responses could be due to the reduced duration of melatonin secretion, which produces anti-cancer properties. The association is further strengthened by Wu and colleagues' research, where they found a 42% higher level of melatonin in participants with 9+ hours of sleep versus those who sleep less than 6 hours (Wu et al., 2008).[26] However, melatonin is not the only potential factor. Lorenzo and colleagues' study suggests that the natural killer cells, immune cells with anti-tumor effects, experience reduced activity after sleep deprivation (Lorenzo et al., 2018).[27] Specifically, mice with a 72-hour sleep deprivation reported reduced activity of natural killer cells compared to controlled mice. This experiment on mice suggests that sleep deprivation might have a negative influence on immune cells with anti-tumor effects, leading to a higher risk of cancer. However, human studies are necessary to corroborate these findings.

Conclusion

In adolescents, sleep deprivation has long been a widespread phenomenon with countless detrimental repercussions. Sleep in adolescents is influenced by several factors, including physical factors, such as the alterations in their sleep/wake homeostasis or the delay in their circadian rhythm, and several psychosocial factors, such as academic-related reasons and the use of stimulants like caffeine or nicotine. Since early school start time significantly contributes to adolescents' sleep deprivation, schools and governments could consider adjusting school schedules according to adolescents' biological needs. Additionally, avoiding stimulants, such as caffeine or nicotine, before bedtime could contribute to a healthier sleep. Sleep disruption

adversely affects adolescents' physical and mental health and cognitive abilities. It has been proven through several studies that sleep deprivation impairs the process of memory consolidation in adolescents, as well as decreasing the ability to maintain vigilant attention. Sleep disruptions also encourage the development of depression and behavioral problems in adolescents, leading to an increase in the amount of negative emotions experienced and several risk-taking behaviors. The physical health of adolescents can also be negatively influenced by sleep deprivation, leading to a higher vulnerability to common illnesses or cancer. The physical, mental, and cognitive effects of sleep deprivation in adolescents cause these emerging individuals to have a lower quality of life and, therefore, a lower level of life satisfaction. Possible solutions could include actively avoiding electronic devices such as TVs, phones, tablets, or laptops at bedtime by placing them outside their bedroom or away from their bed. Family members could also help adolescents build healthier sleeping habits by helping them remove distractions or stimulants before bedtime. Adolescence is a crucial time of development. Hence, positive solutions are required to refine the situation, ensuring adolescents' healthy development.

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