REVIEW ARTICLE

Is Insufficient Sleep in Adolescents Principally Caused by Society Rather than Physiology?

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Abstract

Insufficient sleep is a major health issue in adolescents resulting in poor academic performance, mental health problems, and increased cases of automobile accidents. An intrinsic biological phase delay with the onset of puberty influences sleep timing in this population. Moreover, increased night time use of electronic gadgets, late night socializing, etc. coupled with early school start times (SST) result in sleep-deprived teenagers. Although most of them oversleep during weekends, this hardly compensates for the sleep loss on weekdays. Various studies have shown that insufficient sleep in adolescents is caused not only by the physiological change brought about by puberty but also by various social aspects which influence their sleep. Maintaining sleep hygiene practices along with a delay in SST have shown marked improvement in adolescent sleep health. Sleep medicine practitioners can play a key role in bringing about this change through sleep health education as well as administrative reforms.

Keywords: Adolescents sleep deprivation, Insufficient sleep, Sleep practice.

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Introduction

Insufficient sleep has been recognized as a key public health issue in adolescents. Chronic sleep loss leads to daytime sleepiness and impairment in cognitive functions. As remarked by Gupta et al.,[1] there is also associated irritability, decreased attention, increased stress, forgetfulness, and motivational problems, difficulties in learning etc. all of which led to poor academic performance. Onset of adolescence is marked by major biological, cognitive, emotional, and social changes. Carskadon et al.[2] first documented the association of puberty and adolescence with an evening type circadian phase. It is commonly seen that teens stay up late at night and show a marked delay in spontaneous morning arousal. Multiple factors are responsible for this phenomenon. An intrinsic biological transformation involving the homoeostatic process or "process S" during adolescence influences the sleep timing. As per the two-process model proposed by Borbely, the "sleep wake cycle" is dependent principally one the following two factors: "Process S" or the homeostatic sleep pressure and "process C" or the circadian rhythm. It has been shown by Jenni et al.[3] that there is a slow buildup of homeostatic sleep pressure which facilitates longer wakefulness in adolescents. Carskadon et al.[4] opined that delayed circadian phase preference during adolescence is also responsible for late sleeping time. Also, as one matures, there is an increased desire for independence, greater socializing opportunities, increased response to peer pressure, greater academic responsibilities, increased involvement in extracurricular activities, etc. Today's young adults have grown up in the electronic age and have at least one electronic gadget in the bedroom. Calamaro et al.[5] showed that teenagers engage themselves in electronic activities mostly after 9 pm. Munezawa et al.[6] and Owens et al.[7] demonstrated that electronic exposure prior to bedtime disrupts sleep. Use of caffeine which is very frequent in young adults is associated with decreased total sleep time (TST), increased sleep onset latency (SOL), increased wake after sleep onset (WASO), and increased daytime sleepiness as shown in studies by Pollak et al.[8] and Orbeta et al.[9] Early SST in adolescents is a direct contrast to their normal biology and social life resulting in insufficient sleep. Carskadon et al.[10] have shown in their landmark study that early SST in adolescents is associated with significant sleep deprivation and excessive daytime sleepiness (EDS). There is significant evidence from studies by Bowers et al.[11] and Lo et al.[12] that delaying SST delays rise times improving sleep, improves school attendance, grades, mood, etc. and decreases school health visits and automobile accidents. Thus, both physiological factors and the society play a role in causing insufficient sleep syndrome (ISS) among adolescents.

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Sleep Physiology in Adolescents

Adolescent sleep electroencephalogram (EEG) patterns change significantly. Tarokh et al.[13] opined that there is a decline in sleep EEG amplitude across adolescence. This decline maybe a marker of synaptic pruning that occurs in adolescent cortex. Sleep stage distribution is also altered in this age-group. Slow-wave sleep (SWS) decreases and stage II sleep increases as compared to prepubertal children. The first rapid eye movement (REM) occurrence is also earlier in the late adolescence as compared to prepubertal and

pubertal children, where the first REM is usually skipped. As shown by Jenni et al.,[3] the dissipation of sleep pressure is same in early and mature adolescents. However, the studies by Taylor et al.[14] demonstrated that sleep pressure accumulation takes much longer in adolescents. Thus, more mature adolescents have longer sleep onset latencies than prepubertal and pubertal children even after 14–16 hours of sleep deprivation. Measurement of salivary melatonin levels in studies by Carskadon et al.[15] have shown a circadian phase delay in adolescents. As proposed by Tarokh et al.,[13] the mechanisms for the circadian delay are as follows:

- Longer intrinsic period or internal day length;
- Increased sensitivity to phase-delaying effects of evening light or phase-advancing effects of morning light.

Thus, it can be said that a slow buildup of homeostatic sleep pressure together with a circadian phase delay results in a more "evening type" teenager.

Sleep Need of Adolescents

Earlier belief that teens needed less sleep than children were put to rest by a longitudinal study in Stanford University by Carskadon et al.[16] Irrespective of their age, it was found that the subjects slept for approximately 9.25 hours which showed that the sleep need does not decrease with adolescence. Very often, however, adolescents get much less sleep, with less than 8 hours of sleep being found very common.

Sleep Pattern in Adolescents

Studies on adolescent sleep patterns across the world have shown that there is a trend to diminished sleep. Studies by Park et al.[17] from Asia; Saarenpaa–Heikkila et al.[18] from Europe; Andrade et al.[19] and Gibson et al.[20] from the USA; Warner et al.[21] from Australia; Dorofaeff et al.[22] from New Zealand; and Reid et al.[23] from Africa, all show a similar picture of insufficient sleep in adolescents. Surveys across various countries have shown that the sleep duration on school days decreased by approximately 1–2 hours on an average from sixth to twelfth grade. Similarly, rise times on non-school nights was also later and progress by 1–2 hours as the age advanced. Although this extra sleep on weekends made up partially for the sleep debt accumulated over the week, it definitely could not fully compensate for the sleep loss. Moreover, the delayed timing of weekend sleep could actually shift the endogenous clock, resulting in a mini "jetlag" on Monday mornings. Thus, the biological and social causes of delayed sleep coupled with early schools start times presents a "sleep-deprived teen" globally.

Adolescent Behavior Affecting Sleep

Adolescents love the "new-found" independence with less parental influence even on their bedtimes. They enjoy socializing with peers at night and take up extracurricular activities such as sports, part-time jobs, etc. They also get increasingly addicted to electronic media especially mobile phones, laptops, or television. As remarked by Owens et al.,[7] another common behavioral change seen in adolescents is consumption of caffeinated soft drinks. These behavioral patterns add to the already delayed circadian phase, further delaying bedtimes.

The main section of this review will focus on insufficient sleep, its prevalence in adolescents, and its causes. From the various researches, it will try to ascertain whether the physiological change alone or the society at large or both are to be blamed for the diminished sleep in teenagers.

Prevalence of Insufficient Sleep in Adolescents

Insufficient sleep syndrome, also known as chronic sleep deprivation or sleep restriction, is characterized by decreased TST than expected for age along with daily periods of intense desire to sleep or daytime lapses into sleep. Sleep time is usually curtailed by the use of alarm clock or being awakened by another person. These symptoms must be persistent for at least 3 months. When allowed to sleep as during weekends or vacations, the sleep duration normalizes and results in resolution of EDS. Actigraphy, sleep questionnaire, and a 2-week sleep diary suffices to diagnose ISS.

Several studies over the last few decades have repeatedly and consistently proved that the adolescents across the world are sleep-deprived. Huang et al.[24] investigated the prevalence of sleep problems and daytime sleepiness among Taiwanese adolescents. School goers belonging to different grades and of age-group 12–13, 14–16, and 17–18 years were analyzed. The mean duration of sleep on the weekdays was 7.35 $\pm$ 1.23 hours, while weekend sleep was 9.38 $\pm$ 1.62 hours. Sleep on school days significantly decreased with increasing age along with a trend to higher daytime sleepiness among higher grade students. Pallesen et al.[25] studied the prevalence of behaviorally induced insufficient sleep syndrome (BLISS) among adolescents. A total of 1,285 school students aged 16–19 years were assessed using self-report questionnaire. The prevalence of BLISS was found to be 10.4% and EDS was 22.3%. Moreover, 39.2% of students slept less than 420 minutes on weekdays and 60% slept 120 minutes more on the weekends. Sanderson et al.[26] in a similar study demonstrated prevalence of disturbed sleep among adolescents. Two cross-sectional surveys were done from 2000 to 2003 on more than 5,000 school students (grader 9 students). A high percentage of the participants reported disturbed sleep, sleeping less on week nights (6.9–7.3 hours), and more on weekends (approximately 7.7 hours).

A number of studies have also indicated that poor socio-economic status and racial or ethnic minorities exhibit greater risk of poor quality and insufficient sleep. Marco et al.[27] in a study on middle school students showed that timing and quality of both school days and weekend sleep worsened with decreasing socioeconomic status. This could be due to noise, overcrowding or safety issues among this social stratum. However, studies by Knutson et al.[28] and McHale et al.[29] have indicated that youth belonging to higher socioeconomic status also have shorter sleep duration which probably was more due to behavioral issues. Dodor et al.[30] in a study on adolescents, compared sleep in African–American and white subjects. Less sleep was found among African–American youth which was also a predictor of obesity. Additional environmental factors such as part-time jobs, striving for academic excellence, peer pressure for socializing, excessive screen time, and the lack of parental control over bedtimes can further interfere with sleep duration.

To summarize, short sleep duration, increased daytime sleepiness, and weekend oversleep all point to the fact that indeed adolescents are chronically sleep-deprived worldwide. This affects not only their sleep health and behavior but also results in increased

incidents of automobile accidents, depression, and significant levels of psychological stress.

Factors Contributing to Sleep Deprivation in Adolescents

Physiological Changes Influencing Adolescent Sleep

Carskadon et al.[4] first documented a physiological cause for phase delay in adolescents. Using the Morningness–Eveningness Questionnaire (MEQ) and the Pubertal Status Questionnaire, 183 boys and 275 girls in sixth grade were assessed. A significant relation was found between advanced pubertal status and preference for eveningness in girls. A similar but non-significant trend was found in boys. The study showed that physiological changes attributable to puberty were responsible for the evening preference. The limitations were that only 11–12 years students who might have just entered puberty or in case of boys might not have even entered puberty were included. Including a second or third older age-group would have definitely given better results. The fact that boys did not show significant findings were probably due to their prepubertal age-group. Second, although the MEQ is an efficient tool to evaluate phase delay, objective markers such as dim light melatonin onset (DLMO) could have been better. In a later laboratory study by Carskadon et al.,[15] circadian phase was measured using salivary melatonin and cortisol levels and development by Tanner stage. It showed significant correlation between pubertal stage and Circadian phase with older children showing a later phase of melatonin offset. The shortcoming of the study was that dim light salivary melatonin onset (DLSMO) could be measured only in few subjects.

To determine intrinsic period in adolescents, Huang et al.[25] measured salivary melatonin onset and offset phases on 27 subjects across 12 cycles in the 9–15-year age-group and all Tanner stages. However, the study failed to detect any developmental differences probably due to the small sample size and cross-sectional design of the study. Wright et al.[31] using a similar protocol demonstrated that the intrinsic period of adolescents was significantly longer as compared to adults. Sanderson et al.[26] showed that adolescents also are relatively insensitive to the phase advancing or phase delaying effects of light. Crowley et al.[32] demonstrated that melatonin was more suppressed to lowest level of light in the morning in prepubertal as compared to post pubertal individuals.

Another factor which favors the altered sleep timing and late nights across adolescence is the slow development of sleep pressure. Jenni et al.[3] compared buildup of homeostatic sleep pressure in prepubertal versus post pubertal adolescents using polysomnography (PSG) and Tanner staging. Although the decline in homeostatic sleep pressure was comparable, a significant difference in the buildup of sleep pressure during wakefulness was seen between Tanner 1/2 adolescents and Tanner 5 adolescents, the latter being significantly slower. The buildup of homoeostatic sleep pressure in Tanner 5 adolescents was approximately 15.4 $\pm$ 2.5 hours as compared to Tanner 1/2 (8.9 $\pm$ 1.2 hours). One of the shortcomings of this study was use of an indirect evidence, that is, sleep deprivation for sleep pressure measurement. Direct measure of sleep pressure as by examining theta activity across extended periods of wakefulness (wake EEG) could be better.

Adolescents during maturation are thus subjected to physiological changes in their endogenous circadian rhythm as well as homeostatic sleep pressure both of which regulate the sleep wake cycle. As a result, they face a major challenge to fall asleep at routine bedtimes and wake up refreshed to attend school. Insufficient sleep on school days results in an accumulation of sleep debt which leads to over-sleeping on weekends. Delayed sleep timing and catchup sleep on weekends further accelerates the delay in signal for the biological night, that is, melatonin secretion and also decreases sleep pressure. This cycle continues throughout the adolescent period resulting in chronic sleep deprivation.

Influence of Electronic Media Use on Adolescent Sleep

A substantial number of studies over the past two decades have reported that use of electronic devices affects sleep quality. Munezawa et al.[6] in a study on Japanese adolescents reported association between use of mobile phones at night and sleep disturbances. They used questionnaires to survey 95,680 students for their duration of sleep, subjective sleep quality, insomnia, daytime consequences, mental health status, and use of mobile phones after lights out and also during the day. As compared to the junior adolescents (grade 7–9 students) the senior (grades 10–12 students) ones used mobiles more frequently. A total of 8.3% of the population used the phone for calling after lights out and 17.6% for sending text messages. They also reported that the use of mobile phones after lights out was significantly associated with sleep disturbance. However, as it was a self-reporting study there may have been some degree of bias. Moreover, as it was a cross-sectional study, a causal relationship cannot be drawn. A longitudinal study would have been better. Baiden et al.[33] in a similar study showed the association between excessive screen time use and insufficient sleep in adolescents. It was found that, of the 14,603 adolescents studied, 74.8% had less than 8 hours of sleep on school nights and 43% engaged in excessive screen use. Odds ratio was 1.34 times higher for adolescents with excessive screen-time behavior as compared to controls. The study did not distinguish between the use of video and computer games to smart phones, tablets, etc. Another limitation was that it was a secondary data from Youth Risk Behavior Surveillance.

Zou et al.[34] in a recent study in Chinese adolescents reported an association of insufficient sleep with watching TV, movies, use of smart phones, etc. The study concluded that sedentary screen lifestyle profile may have influence on sleep duration in adolescents.

Loughran et al.[35] examined whether electromagnetic fields emitted by digital mobile phone handsets affect sleep architecture. A total of 50 participants were exposed for 30 minutes to electromagnetic fields prior to sleep. A decrease in REM latency and increase in EEG spectral power during initial part of sleep was noted. Mobile phone use may increase REM sleep and modify non rapid eye movement (NREM) sleep it was noted.

Wood et al.[36] in another study investigated whether exposure to emissions from digital mobile phones prior to sleep altered the secretion of melatonin. A total of 55 adult volunteers using a double-blind cross-over design were either exposed or sham exposed to 30 minutes mobile phone use prior to bed. Both pre- and post-bedtime urinary melatonin were measured. Although total melatonin output did not vary, a significant reduction in melatonin metabolite aMT6 onset time was seen the active group.

Thus, use of mobile phones may alter sleep physiology by altering sleep architecture and causing a phase delay. Another mechanism is that the young adults may simply enjoy media use to communicate with friends. Similar effects have also been observed with the use of computers before bedtime or watching favorite television shows till late evening. Studies have shown that these result in longer SOL, decreased TST, later wake up

times, and daytime sleepiness. The present COVID situation has only added fuel to the fire. The adolescents now mostly attend online classes, have less physical activity, and more interaction with electronic devices.

Effect of Adolescent Habits on their Sleep

Adolescents, especially those in their late teens sometimes acquire habits of smoking tobacco, drinking alcohol, or a lot of caffeinated drinks. Pollak et al.[8] and Orbeta et al.[9] in their studies showed that higher caffeine intake is associated with increased SOL and WASO as also EDS. Higher caffeine intake in the evenings results in delayed sleep onset which in turn leads to daytime sleepiness and again caffeine intake to counteract the sleepiness. Caffeine as it is well known acts by blocking adenosine receptors. Adenosine is a marker of homeostatic sleep pressure. Thus, increased coffee consumption in the evening leads to increased alertness and delays sleep.

Pallesen et al.[25] reported the prevalence of BLISS in adolescents to be 10.4% approximately. The study found that use of alcohol and urban living correlated positively to BLISS. Moreover, BLISS was also associated with poor grades in school and more incidence of anxiety and depression. However, this study being a cross-sectional study, a conclusion on causality cannot be drawn.

Influence of SST on Adolescent Sleep

During puberty, the circadian rhythm shifts towards an evening preference. Early SST therefore directly interferes with the natural sleep wake cycle and homeostatic sleep regulation process of the typical adolescent. Carskadon et al.[10] in one of their earliest studies on the effect of early SST on adolescent's sleep reported significant sleep deprivation. The results showed that although tenth graders woke earlier on school days than ninth graders they did not sleep early and therefore slept less. The DLSMO was later in tenth than in ninth graders, multiple sleep latency test (MSLT) showed shorter SOL in tenth as compared to ninth graders including sleep onset REM (SOREM) episodes. The authors opined that both physiological changes in sleep and psychosocial influences may limit adolescent's capacity to make adequate adjustments to early school times.

Owens et al.[37] examined the effect of a 30-minute delay in SST on adolescents' sleep, mood, and behavior. The findings suggest that even a modest delay in SST was associated with a significant increase in self-reported sleep duration and decrease in daytime sleepiness. The limitations of the study were self-reported subjective measures of sleep and absence of control group.

Wolfson et al.[38] in a study on middle school students, compared the effect of early SST (7:15 am) with late SST (8:37 am) on their sleep. Students with later SST reported obtaining 50 minutes more sleep each night with less daytime sleepiness. The study demonstrated that even middle school students benefit significantly from delayed SST. The limitations of this study were as follows: Students were mostly from a homogenous group. Reports of the study are also entirely based on retrospective self-reports and not on any objective results or continuous monitoring with diaries and actigraphy.

Danner F et al.[39] highlighted the positive effects of delaying SST on the incidents of car crashes by adolescents over a 2-year study period. It showed that not only was there improvement in sleep duration but also a decrease in car crashes. Longitudinal and cross-sectional studies as by Bowers et al.[11] and June et al.[12] also demonstrate significant and sustained benefits of delaying SST.

To summarize, early SST in adolescents is a direct contrast to their natural shift in the circadian rhythm. Studies have shown when middle and high schools institute corrective measures such as delaying SST, students obtain more sleep which is also associated with improvement in their behavior, mood, academic progress and safety.

Miscellaneous Causes of ISS in Adolescents

A number of other factors also contribute to sleep deprivation in adolescents. Meldrum et al.[40] examined whether perceptions of school and neighborhood safety are associated with ISS in adolescents. It was reported that adolescents who felt unsafe both at school and in their neighborhood had 129% greater incidence of ISS as compared to those who felt safe. It was 39% greater for those who felt unsafe only at school, while 71% greater for those who felt unsafe only in the neighborhood. The data in this study were, however, obtained from another survey and the sleep duration was assessed using subjective measures. However, it emphasizes that feelings of threat and distress due to school or neighborhood safety issues can also contribute to insufficient sleep among adolescents.

Another factor governing sleep health in adolescence is optimal parent-child bonding. Connectedness with parents and warmth in relationship promote feelings of safety and security. A study by Rojo–Wissar et al.[41] has demonstrated that better parental bonding is associated with longer duration and less disturbed sleep in children and adolescents. Inappropriate sleep habits and non-adherence to good sleep hygiene practices may also lead to insufficient sleep. A recent study by Kadzikowska–Wrzosek et al.[42] explored the relationship between bedtime procrastination and sleep duration in adolescents. The authors suggest that improving the skills of going to bed as planned maybe quite challenging for adolescents with eveningness circadian rhythm, but can be improved with development of autonomous motivational skills for regulating sleep related behavior.

A few other factors such as chronic medical illness, mental health issues, chronic medication use, respiratory diseases such as asthma or obstructive sleep apnea due to obesity, migraine etc. may all result in ISS. Also, the present-day competitive society thrusts additional academic responsibilities on the students. This is particularly important in developing nations where young adults face the challenge of a dearth of jobs and need to excel academically to secure the few available ones. Thus, they sacrifice their sleep in an attempt to keep up their performance and grades.

Conclusion

Chronic sleep deprivation, daytime sleepiness, and impairment are a serious threat to adolescents' health, academic success and safety and is also an important public health issue. Adolescents often compromise their sleep need to accommodate a vast array of social, academic and extracurricular demands. Early SST along with a transition to pubertal phase delay, significantly affect the quality of sleep, sleep-wake schedule and daytime behavior. Thus, it can be opined that ISS in adolescents is caused not only by the physiological change brought about by puberty but also by various social aspects which influence their sleep.

An increasing number of studies have shown that delaying SST by about an hour improves both the quality and quantity of adolescent sleep thus minimizing the adverse effects of chronic sleep loss. Moreover, maintaining healthy sleep hygiene practices such as avoiding late night electronic media use and

caffeine consumption are also potential modifiable factors. Sleep practitioners have the opportunity to make significant influences to address the problem of chronic sleep deprivation in adolescents through health education and screening. Indeed, sleep health education should become a part of compulsory curriculum at the beginning of middle school. While the physiological factors contributing to poor sleep cannot be modified, educational, administrative, and health policies to promote healthy sleep and reduce the risk of ISS in adolescents can be achieved and needs global attention.

References

1. Gupta R, Pandi–Perumal SR. "Sleep well, sleep on time" and insufficient sleep: a need for more research and public health policies. Sleep Vigilance 2019;3(2):91–93. https://doi.org/10.1007/s41782-019-00078-0.
2. Carskadon MA, Acebo C, Seifer R. Adolescent sleep on long nights with and without prior sleep deprivation. Sleep 1998;21(8):871–881. https://doi.org/10.1093/sleep/21.8.871.
3. Jenni OG, Achermann P, Carskadon MA. Homeostatic sleep regulation in adolescents. Sleep 2005;28(11):1446–1454. DOI: 10.1093/sleep/28.11.1446.
4. Carskadon MA, Vieira C, Acebo C. Association between puberty and delayed phase preference. Sleep 1993;16(3):258–262. DOI: 10.1093/sleep/16.3.258.
5. Calamaro CJ, Mason TB, Ratcliffe SJ. Adolescents living the 24/7 lifestyle: effects of caffeine and technology on sleep duration and daytime functioning. Pediatrics 2009;123(6):e1005–e1010. DOI: 10.1542/peds.2008-3641.
6. Munezawa T, Kaneita Y, Osaki Y, et al. The association between use of mobile phones after lights out and sleep disturbances among Japanese adolescents: a nationwide cross-sectional survey. Sleep 2011;34(8):1013–1020. DOI: 10.5665/SLEEP.1152.
7. Owens J, Adolescent Sleep Working Group. Insufficient sleep in adolescents and young adults: an update on causes and consequences. Pediatrics 2014;134(3):e921–e932. DOI: 10.1542/peds.2014-1696.
8. Pollak CP, Bright D. Caffeine consumption and weekly sleep patterns in US seventh-, eighth-, and ninth-graders. Pediatrics 2003;111(1):42–46. DOI: 10.1542/peds.111.1.42.
9. Orbeta RL, Overpeck MD, Ramcharran D, et al. High caffeine intake in adolescents: associations with difficulty sleeping and feeling tired in the morning. J Adolesc Health 2006;38(4):451–453. DOI: 10.1016/j.jadohealth.2005.05.014.
10. Carskadon MA, Wolfson AR, Acebo C, et al. Adolescent sleep patterns, circadian timing, and sleepiness at a transition to early school days. Sleep 1998;21(8):871–881. DOI: 10.1093/sleep/21.8.871.
11. Bowers JM, Moyer A. Effects of school start time on students' sleep duration, daytime sleepiness, and attendance: a meta-analysis. Sleep Health 2017;3(6):423–431. DOI: 10.1016/j.sleh.2017.08.004.
12. Lo JC, Lee SM, Lee XK, et al. Sustained benefits of delaying school start time on adolescent sleep and well-being. Sleep 2018;41(6):zsy052. DOI: 10.1093/sleep/zsy052.
13. Tarokh L, Raffray T, Van Reen E, et al. Physiology of normal sleep in adolescents. Adolesc Med State Art Rev 2010;21(3):401–417. PMID: 21302851.
14. Taylor DJ, Jenni OG, Acebo C, et al. Sleep tendency during extended wakefulness: insights into adolescent sleep regulation and behavior. J Sleep Res 2005;14(3):239–244. DOI: 10.1111/j.1365-2869.2005.00467.x.
15. Carskadon MA, Acebo C, Richardson GS, et al. An approach to studying circadian rhythms of adolescent humans. J Biol Rhythms 1997;12(3):278–289. DOI: 10.1177/074873049701200309.
16. Carskadon MA. The second decade. In Guilleminault C, editor. Sleeping and waking disorders: Indications and techniques. Menlo Park: Addison Wesley 1982. pp. 99–125.
17. Park YM, Matsumoto K, Seo YJ, et al. Changes of sleep or waking habits by age and sex in Japanese. Percept Mot Skills 2002;94 (Suppl. 3; Pt. 2):1199–1213. DOI: 10.2466/pms.2002.94.3c.1199.
18. Saarenpää–Heikkilä OA, Rintahaka PJ, Laippala PJ, et al. Sleep habits and disorders in Finnish schoolchildren. J Sleep Res 1995;4(3):173–182. DOI: 10.1111/j.1365-2869.1995.tb00166.x.
19. Andrade M, Menna–Barreto L. Sleep patterns of high school students living in São Paulo, Brazil. In: Carskadon MA, editor. Adolescent Sleep Patterns: Biological, Social, and Psychological Influences. Cambridge University Press; 2002. pp. 118–131.
20. Gibson ES, Powles AC, Thabane L, et al. "Sleepiness" is serious in adolescence: two surveys of 3235 Canadian students. BMC Public Health 2006;6(1):116. https://doi.org/10.1186/1471-2458-6-116.
21. Warner S, Murray G, Meyer D. Holiday and school-term sleep patterns of Australian adolescents. J Adolesc 2008;31(5):595–608. DOI: 10.1016/j.adolescence.2007.10.005.
22. Dorofaeff TF, Denny S. Sleep and adolescence. Do New Zealand teenagers get enough? J Paediatr Child Health 2006;42(9):515–520. DOI: 10.1111/j.1440-1754.2006.00914.x.
23. Reid A, Maldonado CC, Baker FC. Sleep behavior of South African adolescents. Sleep 2002;25(4):417–421. PMID: 12071543.
24. Huang YS, Wang CH, Guilleminault C. An epidemiologic study of sleep problems among adolescents in North Taiwan. Sleep medicine 2010;11(10):1035–1042. https://doi.org/10.1016/j.sleep.2010.04.009.
25. Pallesen S, Saxvig IW, Molde H, et al. Brief report: behaviorally induced insufficient sleep syndrome in older adolescents: prevalence and correlates. J Adolesc 2011;34(2):391–395. DOI: 10.1016/j.adolescence.2010.02.005.
26. Sanderson M, Reininger B, Aguirre–Flores MI. Disturbed Sleep Among Adolescents Living in 2 Communities on the Texas–Mexico Border, 2000–2003. Prev Chronic Dis 2010;7(2):A40. PMID: 20158968.
27. Marco CA, Wolfson AR, Sparling M, et al. Family socioeconomic status and sleep patterns of young adolescents. Behav Sleep Med 2012;10(1):70–80. DOI: 10.1080/15402002.2012.636298.
28. Knutson KL, Lauderdale DS. Sociodemographic and behavioral predictors of bed time and wake time among US adolescents aged 15 to 17 years. J Pediatr 2009;154(3):426–430. DOI: 10.1016/j.jpeds.2008.08.035.
29. McHale SM, Kim JY, Kan M, et al. Sleep in Mexican–American adolescents: social ecological and well-being correlates. J Youth Adolesc 2011;40(6):666–679. DOI: 10.1007/s10964-010-9574-x.
30. Dodor BA, Shelley MC, Hausafus CO. Adolescents' health behaviors and obesity: does race affect this epidemic? Nutr Res Pract 2010;4(6):528–534. DOI: 10.4162/nrp.2010.4.6.528.
31. Wright Jr KP, Hughes RJ, Kronauer RE, et al. Intrinsic near-24-h pacemaker period determines limits of circadian entrainment to a weak synchronizer in humans. Proceed Natl Acad Sci U S A 2001;98(24):14027–14032. DOI: 10.1073/pnas.201530198.
32. Crowley SJ, Cain S, Burns AC, et al. Increased sensitivity of the circadian system to light in early/mid-puberty. The J Clin Endocrinol Metab 2015;100(11):4067–4073. https://doi.org/10.1210/jc.2015-2775.
33. Baiden P, Tadeo SK, Peters KE. The association between excessive screen-time behaviors and insufficient sleep among adolescents: findings from the 2017 youth risk behavior surveillance system. Psychiatr Res 2019;281:112586. DOI: 10.1016/j.psychres.2019.112586.
34. Zou Y, He MJ, Su DT, et al. The current status of insufficient sleep duration and its influencing factors among children and adolescents: a household based cross-sectional study in Zhejiang Province, China. J Pediatr Nurs 2021;60:e1–e5. DOI: 10.1016/j.pedn.2021.02.009.
35. Loughran SP, Wood AW, Barton JM, et al. The effect of electromagnetic fields emitted by mobile phones on human sleep. Neuroreport 2005;16(17):1973–1976. DOI: 10.1097/01.wnr.0000186593.79705.3c.

36. Wood AW, Loughran SP, Stough C. Does evening exposure to mobile phone radiation affect subsequent melatonin production? Int J Radiat Biol 2006;82(2):69–76. DOI: 10.1080/09553000600599775.
37. Owens JA, Belon K, Moss P. Impact of delaying school start time on adolescent sleep, mood, and behavior. Arch Pediatr Adolesc Med 2010;164(7):608–614. DOI: 10.1001/archpediatrics.2010.96.
38. Wolfson AR, Spaulding NL, Dandrow C, et al. Middle school start times: the importance of a good night's sleep for young adolescents. Behav Sleep Med 2007;5(3):194–209. DOI: 10.1080/15402000701263809.
39. Danner F, Phillips B. Adolescent sleep, school start times, and teen motor vehicle crashes. J Clin Sleep Med 2008;4(6):533–535. PMID: 19110880.
40. Meldrum RC, Jackson DB, Archer R, et al. Perceived school safety, perceived neighborhood safety, and insufficient sleep among adolescents. Sleep Health 2018;4(5):429–435. DOI: 10.1016/j.sleh.2018.07.006.
41. Rojo–Wissar DM, Owusu JT, Nyhuis C, et al. Parent–child relationship quality and sleep among adolescents: modification by race/ethnicity. Sleep Health 2020;6(2):145–152. DOI: 10.1016/j.sleh.2019.12.010.
42. Kadzikowska–Wrzosek R. Insufficient sleep among adolescents: the role of bedtime procrastination, chronotype and autonomous vs. controlled motivational regulations. Curr Psychol 2018;39(3):1031–1040. DOI: 10.1007/s12144-018-9825-7.