The Causes of Circadian Rhythm Sleep Disorders in Adolescents

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Abstract: Circadian rhythm sleep disorders (CRSD) are increasingly prevalent among adolescents, with significant impacts on their physical and psychological health. The present paper discusses three broad etiologies of CRSD in adolescents, namely irregular eating habits, nicotine exposure, and excessive electronic device use. Unusual dietary patterns like night eating and skipping breakfast disrupt the body's internal clock and cause delayed sleep-wake phase disorder. Nicotine from active smoking and passive smoke exposure induces circadian disruption through action on neurotransmitter mechanisms, with an effect of sleep fragmentation and disrupted timing of sleep. Electronic device use over several hours prior to bedtime also disrupts melatonin release through the induction of blue light exposure, leading to increased sleep onset latency and compromised sleep quality. These create circadian misalignment and sleep deprivation, which are the basis of the need for specific treatments against healthier sleeping habits and reversing the impact of CRSD for the well-being of adolescents.

1 INTRODUCTION

Circadian rhythm sleep disorders (CRSD) are epidemic around the world because of their extreme prevalence (Kim et al. 2013). CRSD affects over 3% of adults, and 10% of adults and 16% of adolescent sleep disorder patients could be experiencing this disorder. CRSD can be confused easily with insomnia. In addition, statistics in the China National Mental Health Development Report (2019–2020) show that there are nearly 30 million Chinese teenagers with mental illness, among which the detection rate of depressive disorder is 24.6%. Of all the teenagers who have emotional disorders, more than 90% also suffer from CRSD. CRSD and depression go reciprocally, and chronic sleep disturbance can cause hippocampal atrophy and immune dysfunction. Regardless of whether it is a mental or physical issue, the impact of CRSD cannot be exaggerated. Given its influence on teenagers in particular, information regarding CRSD's etiology and prevention is of maximum global interest to the younger population.

Of the many factors causing CRSD in teenagers, three of them are of utmost importance. First, diet plays a vital role when it comes to circadian entrainment. Irregular timing of meals and negative dietary habits can destroy peripheral clocks' synchrony, subsequently causing sleep pathology. Specifically, skipping breakfast and nighttime snacking can have a great effect on the circadian rhythm and result in bedtime delay (Hu et al. 2020). Consuming some types of drinks, like coffee or functional drinks, has caffeine intakes that also generate circadian disruption through both caffeine's stimulating effect and its prolonged half-life. Second, secondhand smoking among adolescents can negatively impact sleeping quality through the stimulating effects of nicotine. Finally, overuse of electronic devices, particularly prior to bedtime, has been commonly accepted as a major sleep disruptor by virtue of the blue light emissions and the general cognitive stimulation it causes. The aim of this article is to try to examine the three key causes of CRSD in teenagers and their impacts on sleep regulation at the physiological and behavioral levels. More effective actions towards healthy sleeping habits promotion based on knowledge about these causes are developed, and the negative implications of CRSD for adolescents' well-being are reduced.

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2 CIRCADIAN ENTRAINMENT THROUGH EATING HABITS IN ADOLESCENTS

2.1 Irregular Eating Times Such as Late-Night Snacking and Breakfast Skipping

Irregular meals, particularly those eaten in the evening, tend to desynchronize the body clock. The circadian system is dependent on stable meal times so that it may control physiological activities, and dinner can disrupt the process and induce sleep disturbances. Skipping breakfast also disrupts the circadian system and is generally followed by evening snacking. Evening dining and breakfast skipping both lead to DSWPD. An experiment examined the effect of late-night feeding on physiological processes and gastrointestinal microbiota in male Wistar rats with the aim of investigating abnormal food intake patterns such as meal skipping and nocturnal food intake. The rats were assigned to four groups: standard three-meal diet (BLD), dinner meal skipping with nocturnal food intake (BLN), breakfast meal skipping with nocturnal food intake (LDN), and free-feeding (FF). Late-night eating, particularly the LDN pattern, led to increased body weight, hepatic lipid accumulation, systemic inflammation, and significant alterations in gut microbiota. Importantly, LDN feeding caused a 4-hour phase delay in the expression of key clock genes in peripheral tissues, indicating a profound misalignment of the circadian rhythm. These findings highlight how irregular late-night eating, especially skipping breakfast, disrupts circadian regulation and contributes to metabolic disorders (Ni et al. 2019).

The breakfast skipping is also prevalent among adolescents; nearly 44.9% of participants (n = 71,390, 8-18 years) in South Australia (public) schools are reported to be involved in such an issue: 17.4% reported sometimes skipping, 18.0% reported often skipping, and 9.5% reported always skipping breakfast (Sincovich et al. 2022). The prevalence of Iranian students is 21.6%, and out of 322 records, 24 articles remained for meta-analysis in this research (Ghafari et al. 2017). Similarly, approximately 41.6% of adolescents are reported to eat after 10 p.m. in a Turkish study; 32.7% reported occasionally eating in the middle of the night, and 7.3% reported usually eating (Tuncay & Sarman 2024). Coincidentally, breakfast skipping and late-night eating both present high rates among adolescents globally. Adolescents highly follow the LDN pattern, referring to skipping breakfast and eating late at night, contributing to adolescents with DSWPD along with other physiological dysregulation.

2.2 Dietary Content Such as Caffeine

Caffeine is a central nervous system stimulant that can significantly impact sleep quality. Its half-life can last several hours, meaning that consumption, especially in the evening, can delay the onset of sleep and reduce total sleep time. Adolescents who consume coffee or other caffeine-containing beverages close to bedtime are at higher risk of developing sleep disorders. As reported by the Washington Post in 2015, global daily coffee consumption reaches two billion cups; the consumption among adolescents is undoubtedly high as well. Indeed, coffee has some appealing qualities that make it inevitable to consume. Studies have shown that caffeine helps learning and memory in tasks where passive information is presented, improves performance on tasks that rely on working memory to some extent, and in small doses can reduce anxiety levels and increase pleasure (Fiani et al. 2021). Consequently, consuming caffeine products can help adolescents to reduce pressure easily and to increase their passive learning efficiency and effectiveness. In addition, due to the pressure coming from different sources, the students in puberty have to face the pressure of study, busy tackling the heavy assignments. Consuming coffee is an option to maintain the study state. Adolescents may also consume some kinds of beverages, such as cola sodas and energy drinks, which also contain caffeine. According to the Brazilian Caffeine Content Table (BraCaffT), brewed coffee and instant coffee (diluted) both contain an average of 36 mg of caffeine per 100 mL, cappuccino has 32 mg/100 mL, energy drinks average 30 mg/100 mL, and cola soda contains 9 mg/100 mL (Rocha et al. 2022). Due to the irregular intake of caffeine, the sleep-wake time can be delayed and result in CRSD. Limiting caffeine intake, particularly in the late afternoon and evening, can help improve sleep quality and align circadian rhythms more effectively.

3 SECONDHAND SMOKE EXPOSURE AND SMOKING PREVALENCE AMONG ADOLESCENTS

3.1 Secondhand Smoke Exposure among Adolescents

Nicotine is a potent neuroactive substance that works primarily by acting on nicotinic acetylcholine receptors (nAChRs) in the central nervous system. Nicotine's mechanism of action involves multiple neurotransmitter systems, particularly the dopamine and glutamate systems, which play key roles in reward, motivation, and addiction. As a neuroactive substance, nicotine may result in circadian disturbance; a study presents several drugs, including nicotine, that can lead to drug-entrained anticipatory activity. In this study, female Wistar rats were exposed to constant dim light to eliminate external time cues and subjected to rate-limited feeding to prevent meal entrainment (Gillman et al. 2019). Rats received daily injections of nicotine, methamphetamine (MA), or fentanyl at fixed 24-hour or 31-hour intervals. The experiments demonstrated that nicotine, like MA and fentanyl, induced anticipatory wheel-running activity preceding the injection, with activity persisting for 24 hours after the final injection, suggesting a drug-entrainable circadian oscillator. Notably, rats were entrained only to the first nicotine injection of the day, mirroring the importance of the "first cigarette" in nicotine dependence and relapse. These findings highlight the role of nicotine in modulating circadian rhythms and suggest that drug-entrained anticipatory activity may contribute to craving and relapse in addiction, offering potential targets for therapeutic interventions. Therefore, whether secondhand smoking exposure or smoking, which generates nicotine intake, would lead to drug-entrained anticipatory activity, resulting in an irregular sleep schedule.

Secondhand smoke contains numerous harmful chemicals that can irritate the respiratory system and disrupt normal physiological functions. Exposure to secondhand smoke, especially in confined environments like homes or vehicles, can lead to increased alertness and difficulty in falling asleep. This is because of the effect of nicotine and other poisons in tobacco smoke, which may disrupt the normal sleep-wake cycle. Another study revealed that the prevalence of Japanese adolescents' exposure to secondhand smoke declined but was persistent from 2008-2017 (Kuwabara et al. 2023). Adolescents were exposed to SHS anywhere in 2008 at a prevalence of 51.0%, at home at a prevalence of 37.2%, and at public places at a prevalence of 36.5%. By 2017, these rates declined to 36.3% for any setting, 23.8% indoors, and 27.0% outdoors. Although the rate decreased, nearly one-third of the adolescents had been exposed to SHS in 2017, reflecting the ongoing public health burden of SHS exposure among Japanese youths. The exposure to SHS on a large scale leads to passive absorption of nicotine on a large scale during adolescence. Sleep disturbance aside, secondhand smoke is a major causative factor for respiratory disease, cardiovascular disease, and generally compromised health in adolescents. Secondhand smoke exposure reduction is important in improving sleep quality as well as general health.

3.2 Smoking Prevalence among Adolescents

Youth smoking is a major public health issue. Despite the decrease in tobacco consumption, the majority of adolescents still smoke due to peer pressure, marketing, or autonomy. Studies proved that Japanese youth smoking prevalence decreased significantly from 5.2% in 2008 to 1.8% in 2017, indicating a positive trend towards tobacco control. SHS exposure was still common, however, with 36.3% ever exposed to SHS anywhere, 23.8% ever exposed at home, and 27.0% ever exposed away from home in public places in 2017. SHS exposure was also, in this study, strongly associated with smoking behavior since adolescents who were exposed to SHS had higher odds of smoking, and the risk was higher with higher frequency of exposure. It means that limiting the exposure to SHS, especially indoors and out of the home, is paramount to further reduce the incidence of smoking among youths and to support the protection of their health (Kuwabara et al. 2023). Smoking causes immediate nicotine intake into the body, a stimulant that can destroy the quality of sleep. Nicotine withdrawal during nighttime sleeping can cause disturbed sleeping as well as waking up earlier than usual in the daytime. Adolescent smokers are also prone to risk of sleep onset latency, decrease in total sleeping time, and prevalence of chronic sleeping disorders. The habit of smoking not only affects immediate sleep quality but also has long-term health implications, including increased risks of

respiratory diseases, cardiovascular issues, and compromised lung function. Addressing the smoking prevalence among adolescents is essential to mitigate both short-term sleep disturbances and long-term health risks.

4 OVERUSE OF ELECTRONIC DEVICES

4.1 Blue Light Interference

The blue light emitted from electronic devices disrupts the secretion of melatonin, a hormone crucial for regulating sleep-wake cycles (Minich et al. 2022). Melatonin is a hormone secreted by the pineal gland that plays a crucial role in regulating the body's circadian rhythm (biological clock). Its secretion is influenced by light exposure, with blue light in the visible spectrum (wavelengths around 460-480 nm) having the most significant impact. When the retina detects blue light, it transmits signals via the optic nerve to the suprachiasmatic nucleus (SCN) in the brain, which then inhibits the synthesis and release of melatonin by the pineal gland. This means that exposure to blue light at night (such as from electronic device screens and LED lighting) reduces melatonin secretion, making it more difficult to feel sleepy, thus affecting sleep onset and quality. Studies have shown that using electronic screens for more than an hour can significantly lower melatonin levels. In particular, using electronic devices before bedtime delays the melatonin secretion peak, leading to difficulty falling asleep (Minich et al. 2022). In contrast, avoiding blue light or using dim, warm-colored lighting can effectively reduce melatonin suppression, helping the body naturally transition into sleep.

4.2 Increased Cognitive Stimulation

Stimulating content from electronic devices, such as engaging videos, interactive games, or social media, can increase brain activity and excitement. This heightened state of alertness makes it harder to relax and transition into sleep, further contributing to sleep disturbances. Since the stimulatory contents of electronic devices can significantly stir the brain activity and excitement, using electronic screens for more than an hour happens frequently in adolescents, leading to a lower melatonin level. Studies show a strong negative correlation between screen time and sleep, with computer use having the most significant impact (94% of studies), followed by unspecified screen time (91%) and video gaming (86%), both linked to sleep disturbances. Mobile device use (83%) also strongly disrupts sleep, likely due to its accessibility and interactive nature. While television use (76%) had the least impact, it still contributed to shorter sleep duration and delayed bedtime. These findings highlight the pervasive role of screen exposure in reducing sleep quality among adolescents (Hale & Guan 2015).

The study, based on a survey of 776 adolescents in grades 6 to 9, found that widespread use of social media and electronic devices is significantly associated with reduced sleep duration, particularly among teens who use phones and computers in their bedrooms. Sleep-deprived teens (≤6 hours) were more likely to experience difficulties falling asleep, waking up in the morning, daytime drowsiness, and reduced energy compared to those with adequate sleep (≥9 hours), and they also reported more emotional issues such as irritability and sadness. The study also revealed that sleep duration gradually decreased with age, with 6th graders sleeping significantly more than 9th graders. The research indicates the high level of association between sleep deprivation among teenagers and social media usage and device use, which calls for early learning regarding healthy sleep and screen time and parental involvement in enforcing proper bed times to enhance the quality of sleep among teenagers (Hale & Guan 2015). Overuse of electronic devices is most likely to result in late bedtimes. Exposure to screens prior to sleeping will most probably extend the wakefulness period, decreasing the overall sleeping time and interrupting the normal sleep pattern.

5 CONCLUSION

Circadian rhythm sleep disorders (CRSD) among teenagers are mainly brought about by three reasons: irregular meal times, exposure to nicotine, and overuse of electronic media. Irregular meal times, like eating late at night and skipping breakfast, interfere with the internal clock of the body, causing delayed sleep-wake phase disorder (DSWPD) and metabolic dysregulation. Caffeine consumption, primarily in coffee and energy drinks, also increases sleep disturbance by prolonging sleep latency and decreasing sleep. Secondhand smoking and smoking introduce nicotine, a drug that affects the circadian

rhythm by generating drug-entrained anticipatory activity, resulting in disrupted sleep patterns and non-restorative sleep. Also, overreliance on the use of electronic devices, particularly during late-night hours, affects the production of melatonin with exposure to blue light, thus delaying sleep initiation and lowering sleep quality. Besides, psychological arousal resulting from watching such content on electronic media also increases alertness and prevents adolescents from sleeping. In most cases, they induce generalized circadian desynchronization and sleep loss in adolescents, which requires focused interventions towards improved sleep practices and prevention of the long-term health effects of CRSD.

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