Residência RP Pediátrica
Publicação Oficial da Sociedade Brasileira de Pediatria
ISSN-Online: 2236-6814

Submitted on: 01/16/2024
Approved on: 05/06/2024

REVIEW ARTICLE

Sleep disorders in adolescents: a critical evaluation of the influence of electronic devices - literature review

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Keywords:
Sleep wake disorders,
Circadian rhythm,
Adolescent,
Smartphone
Light pollution.

Abstract

Objective: To present a scoping review of the literature concerning the impact of excessive use of electronic devices by teenagers on sleep quality. **Data sources:** Articles listed in the repositories of PubMed and the National Library of Medicine, using the search terms sleep, adolescence, smartphones, eletronic midia, books and other references were analyzed. **Synthesis of data:** Adolescence is a phase characterized by profound changes that impact the well-being of young individuals. Sleep is crucial but has been affected by the extensive use of social media and electronics, leading to challenges in learning, emotional balance, and both physical and mental health. **Conclusion:** Electronic devices have a negative impact on teenagers sleep in various ways, be it through the emission of blue light, the influence of social media or external factors. It is therefore crucial to adopt comprehensive strategies to promote healthy sleep habits and thus improve the quality and duration of adolescents sleep.

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Resid Pediatr. 2025;15(1). DOI: 10.25060/residpediatr-2025.v15n1-1220

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INTRODUCTION

Adolescence is a period of significant transformation. The resulting physical and emotional changes frequently impact the well-being of young people and signify a vital transition in their lives[1], second only to early childhood[2].

Among the essential elements for healthy development in this stage of life, often overlooked, sleep[3] stands out. Undeniably, sleep plays a crucial role in consolidating learning[4], regulating emotional balance[5], and maintaining physical and psychological integrity[6]. However, the quality and quantity of sleep adolescents experience has become a growing concern, partly due to the rapid spread of social media [7] and excessive use of electronic devices[8].

Adolescents encounter distinct challenges regarding sleep, as the shift towards social independence[9], academic pressure[10], and the prevalence of electronic devices[8] threaten the quality of essential sleep.

This idea is supported by Dornbusch's work, highlighting that sleep arises from a complex interplay of various processes, including maturation and evolution, specific behaviors, internal sleep mechanisms, and circadian rhythm. Each factor likely plays a critical role during the transition from childhood to adulthood[11].

This article provides a narrative review of the literature. It aims to discuss and critically assess the current understanding of adolescent sleep characteristics, mainly focusing on the effects of excessive electronic device use on sleep quality.

Articles listed in the PubMed and National Library of Medicine repositories, books, book chapters, and various references were reviewed in a broad search using the terms sleep, adolescence, cell phones, and electronic media.

SLEEP ORGANIZATION AND CICARDIAN CYCLE: NEUROBIOLOGICAL ASPECTS

Sleep unfolds in multiple intricate stages. This biological phenomenon comprehensively influences all aspects of human physical and mental functions, including hormone regulation[12], muscle tone[13], respiratory rate[14], and cognitive processes[15].

These striking behavioral changes are evident in the brain's electrical activity during sleep. Brain parameters, including bioelectrical activity, extracerebral parameters, rapid eye movements monitored by electrooculogram (EOG), and muscle tone assessed by electromyogram (EMG), are commonly used to identify the different stages of sleep[16].

Based on these measurements, the sleep phenomenon can be divided into two stages that alternate throughout a night: REM sleep and NREM sleep[17]. Rapid eye movements occur in the first stage, while they do not in the second.

NREM sleep has three phases: N1, N2, and N3[18,19]. Stage N1 represents the transition from wakefulness to sleep, marked by a moment when sleep feels imminent but is not yet fully established[18]. Stage N2 is characterized by a relaxation of muscle tone, slow side-to-side eye movements, a gradual regularization and slowing of breathing, and a gradual drop in body temperature[20]. Stage N3 is identified through electroencephalogram (EEG) analysis, which shows a significant presence of delta oscillations, indicating slow brain frequency (below 5 Hz), often called deep slow-wave sleep[16]. Delta oscillations indicate a substantial reduction in excitatory brain activity, alongside increased synchrony in cortical and thalamic activity[21]. During stage N3, breathing becomes slow and regular, heart rate decreases, muscles relax, and body temperature diminishes again[18].

Notably, REM sleep is associated with severe hypotonia while sparing the diaphragm due to inhibiting motor neurons in the spinal cord via descending pathways[20]. Motor neurons in the brainstem, which control eye movements, are not inhibited, as the eyes continue moving during this sleep phase[20,22].

The sleep cycle in children aged six months and older, adolescents, and adults begins in the NREM stage and consists of a sequence of phases from N1 to N3, followed by a brief period of REM sleep. This cycle is repeated throughout the night in a pattern resembling a gently attenuated oscillation[18,19]. As the night progresses, the depth of NREM sleep gradually decreases, while the duration of REM sleep increases[18].

The opportunity for nocturnal rest is understood as sleep, which relates to the circadian rhythms that influence it, characterized by cyclical and corresponding phases[23].

The sleep cycle is governed by the rotational movement of the Earth and by temporal indicators, or synchronizers, which delineate the alternation between daylight and nighttime darkness in all living beings[24]. In this context, the primary temporal marker is, invariably, daily dawn.

Since ancient times, endogenous rhythms, which have a cycle that oscillates around 24 hours and is known as circadian rhythms, have prevailed in all animal and plant life[25]. These rhythms have evolved to optimize the natural cycle of light and darkness, anticipating dawn even without clear luminous signals[24].

However, sleep synchronization with the day-night cadence is related to an intricate interplay involving a handful of ganglion cells in the retina. These cells can react directly to light and forward their signals to the suprachiasmatic nucleus (SCN) of the hypothalamus[20, 26].

To synchronize physiological processes with the day-night cycle in a more sophisticated yet still comprehensible manner, the biological clock must detect decreases in light levels as night approaches[24,27]. This detection occurs through receptors found in the outer layer of the retinal nucleus since removing or concealing the eye eliminates the dragging effect caused by light[27].

However, it is essential to note that the receptors in the retina are not the traditional cones and rods typically associated with vision, which hyperpolarize when exposed to light. These unique ganglion cells contain a specialized photopigment called melanopsin, and when activated by light, they depolarize instead of hyperpolarizing[26]. The primary function of these peculiar photoreceptors is undoubtedly to encode the brightness of the environment and thus make necessary adjustments to the biological clock[23,24,27].

These preganglionic neurons influence neurons in the superior cervical ganglia, from which postganglionic axons extend toward the pineal gland, situated in the middle region of the brain near the dorsal thalamus[24]. The pineal gland, in turn, synthesizes the neurohormone that promotes sleep, known as melatonin (N-acetyl-5-methoxytryptamine), derived from the amino acid tryptophan[28].

The pineal gland then releases melatonin into the bloodstream, which affects brain circuits in the brain stem and is crucial for regulating the sleep-wake cycle[29].

It is important to note that melatonin production increases as the intensity of ambient light decreases, reaching its peak between 2 and 4 a.m.[30]. However, when ganglion cells fail to detect a significant reduction in light due to prolonged exposure to electronic devices, melatonin production is inhibited[31]. This phenomenon significantly affects sleep quality, often resulting in sleep disorders[32].

ADOLESCENCE IN MODERN TIMES AND THE EXCESSIVE USE OF ELECTRONIC DEVICES

Living in a modern era with pervasive digital connectivity presents a challenging and nearly inescapable reality[33]. Adolescents comprise a significant portion of the vast network of individuals interconnected by electronic devices[34].

Electronic devices have transformed the lives of adolescents in many different areas.

According to Jean M. Twenge, an American psychologist specializing in generational disparities, the current generation of teenagers, commonly known as "Generation I" or "iGen," includes individuals born between 2000 and 2009. Technological devices profoundly influence teens' interpersonal, social, and emotional experiences and aspects of their health in a manner never before seen in previous generations[35]. In her 2017 book, iGen, the author introduces the concept right from the opening pages that the prominence of smartphones among young people could significantly affect every facet of Generation I's lives. From social interactions to mental health, this is the first generation with constant access to the internet, and due to these various influences, Generation I may distinguish itself from earlier generations in how its members allocate their time[35].

According to data compiled by the Brazilian Institute of Geography and Statistics (IBGE), in the last quarter of 2021, the percentage of Brazilian individuals aged 10 to 13 who used the internet reached 82.2% of the total number of respondents in this age group, while in the population aged 14 to 17, this figure increased to 90.9%[36].

Another relevant piece of data exemplifying this panorama is the "TIC Kids Online Brasil 2023" survey conducted by the Regional Center for Studies for the Development of the Information Society (Cetic.br). The survey revealed that 83% of adolescents between 9 and 17 used the Internet "more than once a day"[37].

The constant use of electronic devices is an undeniable reality. While there are positive consequences, such as access to information and instant communication, the negative effects often outweigh the positives, particularly when considering the implications of mobile phone use on young people's physical, mental, cognitive, and social health[38,39].

Smartphones, tablets, computers, and similar devices have become integral to adolescents' daily lives[40]. However, they negatively impact young people's health, particularly by disrupting the nocturnal circadian cycle, as they extend waking hours beyond 9 p.m. This has various detrimental effects on the sleep quality of pre-adolescents and adolescents, affecting them both physically and mentally[41].

Adolescents are actively participating in the social digital revolution. While technological advances offer undeniable benefits in the contemporary era[42], it is crucial to recognize the potential drawbacks associated with excessive use of electronic devices, particularly regarding health[43]. In addition to issues like sleep deprivation, adolescents may face a range of risks linked to sleep disorders, as numerous studies have predicted[2,8,38,41].

CHALLENGES RELATED TO SLEEP QUALITY DURING ADOLESCENCE

Research indicates that individuals spend about a third of their lives resting[44]. Sleep is crucial for ensuring a revitalized awakening the next day. It is comforting and essential for cognitive function[15] and survival[45].

Sleep quality is influenced by an individual's satisfaction with various aspects of rest. It encompasses four fundamental elements: sleep efficiency, the time needed to fall asleep, sleep duration, and the time awake after the start of sleep. This last variable can vary between individuals, resulting in different patterns, such as short— or long-duration sleep, which are influenced by genetics, age, and lifestyle factors[46].

The determinants of sleep quality include physical factors such as age, biological rhythm, body weight, and sleep stages (NREM and REM), as well as psychological factors like stress, anxiety, and depression. In addition, environmental influences such as room temperature and the use of electronic devices are taken into account, along with family and social obligations that can affect the rest period.

Although it is not possible to determine a precise duration of nocturnal sleep that guarantees complete revitalization upon awakening, researchers from various geographic locations participated in a consensus study led by the National Sleep Foundation. The study established a guideline for total sleep duration across different age groups throughout life. For adolescents, the recommendation is 8 to 10 hours of sleep per night, with a variation of 7 to 11 hours[47].

A recent study in Brazil revealed that 54.7% of the adolescents assessed—11,525 students of both genders aged 14 to 17 who attend public schools in Fortaleza—did not achieve the minimum recommended eight hours of sleep[48]. This indicates that many adolescents do not receive an adequate quantity and quality of sleep, thereby compromising their well-being.

A study conducted with adolescents (10-18 years old) from three schools in São Paulo found that 39% of the population experienced sleep deprivation. The study also found a correlation between age (older teens) and hyperhidrosis during sleep as a risk factor[49].

A population study conducted via an online questionnaire completed by parents and guardians of children and adolescents across all regions of Brazil found a prevalence of 33.4% for sleep disorders among adolescents according to the Pittsburgh Scale[50].

During the COVID-19 pandemic, a study employing a method similar to the previously mentioned found that the proportion increased to 56.6% in 2020 and decreased to 54.2% in 2021. This study also posed an additional question, asking respondents to indicate whether their sleep had remained the same, improved, or worsened during the pandemic. For those who indicated it worsened, a qualitative follow-up question prompted them to describe the reason for the deterioration in one or two words. Among adolescents, the most common responses were anxiety, increased use of electronics, and sleeping later[51,52].

Sleep quality is a crucial factor during adolescence. Teenagers who get adequate sleep experience numerous positive effects on their lives, including physical, psychological, and cognitive enhancements[6]. This phenomenon stems from the bidirectional relationship between sleep and brain development, which influences aspects such as learning, memory, attention, cognition[15], and emotional processing at this stage of life[15,53,54].

Sleep is an extremely important factor in determining physical health. Evidence points to a direct relationship between sleep deprivation and excess sleep, which significantly increases the risk of developing cardiometabolic problems, cardiovascular diseases, and even mortality from all causes[55-59].

While sleep quality is linked to health benefits, insufficient sleep significantly contributes to sleep deprivation issues and sleep disorders, which are prevalent and treatable conditions among adolescents[60].

This issue is critical because this age group is experiencing rapid changes in physical development and emotional regulation[61], which makes them more vulnerable to various adverse effects.

Sleep disorders in adolescents often arise from various causes, including socioeconomic and cultural factors[62-64]. Research indicates that sleep deprivation correlates with decreased sleep duration and quality. However, it is crucial to recognize that findings may differ based on each study's focus and specific objectives[64-66].

Furthermore, as previously mentioned in this article and widely observed among most adolescents[36,37,40], excessive use of electronic devices also significantly affects sleep quality[8,38,41].

THE EFFECTS OF ELECTRONIC DEVICE USE ON ADOLESCENT HEALTH

Sleep deprivation and daytime sleepiness are highly relevant issues concerning adolescents' health, carrying significant implications. Sleep disorders arise as a major complication in this context[32,60].

New technologies, digital platforms, and behaviors associated with social networks are continuously evolving, sometimes exceeding our understanding of their impact on sleep and health[43]. This phenomenon arises from the stimulating nature of social network content[7] and exposure to artificial light emitted by electronic devices[69], which can lead to increased agitation and difficulty falling asleep.

Similarly, the extensive and prolonged use of social media platforms from early childhood through adolescence, including the transition into preadolescence, raises important questions about their complex impact on the developmental process[7,38], encompassing not only physical and mental well-being but also, in particular, the quality of nighttime rest[41].

Multiple studies have examined how screen and digital media usage affects adolescents' sleep[67-75]; the main findings are summarized below.

Amra et al.[67], in an investigative study involving 2,400 Iranian adolescents (12-18 years old), observed that using mobile devices at night was associated with decreased sleep quality. They also found that participants who maintained a higher level of physical activity enjoyed better quality sleep and longer sleep duration.

Adelantado-Renau et al.[68] found in a study of 269 Spanish adolescents that the time spent online mediates the relationship between sleep quality and academic performance. They concluded that reducing Internet usage could be a viable intervention to enhance sleep quality and improve academic performance.

Shimoga et al.[69] conducted a population study in the United States involving 43,994 students in the 8th, 10th, and 12th grades who used digital platforms. They identified a correlation between social media use, physical activity, and the likelihood

of sleeping at least seven hours per night. They noted that daily users of electronic media had a mistaken belief about getting adequate sleep and experienced sleep deprivation.

Bruni et al.[41] evaluated the use of electronic media on sleep and chronotype in 850 adolescents and pre-adolescents. They observed that both groups had a tendency towards a nocturnal chronotype, which was related to different media uses. After 9 p.m., adolescents demonstrated greater engagement in online activities and mobile devices, while pre-adolescents showed a preference for game consoles.

In a cross-sectional study conducted in Norway involving 9,846 adolescents aged 16 to 19 years, Hysing et al. [8] observed that the use of electronic devices during the day and before the nighttime rest period showed a significant correlation with multiple aspects of the sleep cycle. This correlation led to an increased likelihood of shorter sleep periods, longer delays in falling asleep, and a greater tendency toward sleep deprivation. Additionally, an association was found between the use of personal computers and the risk of sleeping less than five hours, while the chances of achieving a sleep duration of seven hours were significantly reduced.

Parent et al.[70] evaluated a community of children (n = 401) and adolescents (13-17 years, n = 210) in Vermont, USA, and observed an association between greater screen time and more sleep disorders, which in turn were also correlated with more behavioral problems in all age groups.

Schweizer et al.[71] conducted a longitudinal study involving 591 Swiss adolescents and found that those who purchased or received a cell phone slept fewer hours than their peers in the control group who did not have a cell phone.

Chung et al.[72] evaluated 1,796 Korean adolescents in terms of their risk for cell phone addiction. They found that the risk factors included being female, consuming alcohol, achieving low academic performance, feeling unrested in the morning, and sleeping after midnight. This group also scored higher on assessments of excessive daytime sleepiness.

Maurya et al.[73] evaluated the sleep patterns of 16,292 Indian adolescents and young adults, discovering that 15.6% of male adolescents and 23.5% of female adolescents experienced sleep problems. Adolescents who used their cell phones for more than two hours a day were more likely to have sleep disorders than their peers who had not used a cell phone in the past 24 hours.

Yuan et al.[74] assessed problematic cell phone use among 921 Chinese students at the start of college and found that sleep quality and cognitive flexibility mediated the relationship between cell phone abuse and issues with time management, which were linked to individual motivation and psychological well-being.

Garret et al.[75] assessed the sleep of 59 North American adolescents aged 15 to 18 from diverse ethnic and racial groups over a span of 14 days, using the Fitbit Inspire 2 device. They found that adolescents who used their cell phones during sleep, whether to check messages or receive alerts, experienced a greater number and duration of awakenings and exhibited lower sleep efficiency.

Although the impact of social media use on sleep can be attributed to the alert nature of the content on these platforms [7,76], light emitted by electronic devices also significantly contributes to hyperarousal and reduces sleepiness at bedtime [30,66].

As previously discussed in this article, the mechanism regulating sensitivity to light throughout the diurnal cycle, which influences the inhibition of melatonin production, shows a spectral affinity consistent with that observed for melanopsin[26,29]. The primary consequence of prolonged exposure to blue light is the disruption of the circadian rhythm, primarily resulting in a disorder in the functioning of the biological clock. This leads to imbalances in various areas, from interference in molecular rhythms to discrepancies in behavioral cycles, such as sleep and wakefulness, in relation to environmental changes[76-80,] and even the suppression of melatonin production during the night[81]. When exposed to nighttime light that stimulates melanopsin more intensely, with the same energy/photon flux/photopic illumination level, there is an amplified suppression of melatonin. This is evident, for example, with more intense blue light compared to traditional polychromatic light, leading to changes in the phase of melatonin circadian rhythms[82,83]. Another aspect to consider is the decline in sleep quality observed during the COVID-19 pandemic. Review and meta-analysis studies have indicated a tendency towards reduced sleep efficiency and delayed sleep phase (sleeping later) associated with increased electronic device use[84,85].

GLOBAL INITIATIVES AIMED AT ENHANCING THE RELATIONSHIP BETWEEN EXCESSIVE MEDIA USE AND SLEEP

The relationship between excessive social media use, sleep quality, and mental health is well established among adolescents[86]. This also applies to the connection between risky lifestyles—such as poor diet, physical inactivity, smoking, alcohol use, excessive screen time, and sleep disorders—and chronic diseases[87]. All this evidence demonstrates the role of good sleep quality as a mediating factor between these variables. It is undeniable that cell phones and digital media are integral to adolescents' lives, making it impossible to eliminate their use. Therefore, it is worth proposing regulations for their use. The "SMART Schools" study is currently underway in the United Kingdom, aiming to assess the impact of restricting daily cell phone use on adolescents. This study will compare schools that limit cell phone use with those that do not. Data will be collected on students' mental health, physical activity, behavior, and sleep patterns. The results of this study will help guide new policies and engage teachers and family members in this control[88].

Studies developing proposals for apps that help adolescents control their lifestyles and avoid bad habits (such as Health4Life) that can lead to chronic diseases could increase engagement with this cause[87].

Recommendations from medical societies should emphasize, based on scientific evidence and various approaches (to parents, adolescents, and pediatricians and geriatricians), both the negative and positive effects of using cell phones and digital media. These recommendations should foster better communication between parents and adolescents, address issues such as online bullying and other threats, highlight the importance of privacy, and establish usage rules (permitted and restricted times). The attending physician should also work on creating a support network for the adolescent and, during routine consultations, discuss with the family and the adolescent the risks of addiction, distraction, academic decline, and neuropsychological consequences. Furthermore, they should inquire about sleep quality and offer guidance on maintaining good sleep hygiene routines[89].

CONCLUSION

Based on the analysis of the data presented in this literature review, the relationship between sleep during adolescence and the use of electronic devices reveals an intrinsic complexity with multifaceted effects. These devices have shown a significant impact on the quality of sleep in adolescents, interfering with the organization of the sleep cycle and the circadian rhythm. This interference affects natural sleep patterns, compromising the quality and quantity of rest that is essential at this crucial stage of development.

Prolonged exposure to blue light, commonly emitted by electronic device screens, can lead to sleep disorders. Prolonged exposure to social networks, with their not always positive content, can also have unfavorable consequences for general health.

This debate highlights the urgent need to adopt integrated approaches (family, school, health team) that take into account the interrelationship between biological, behavioral, and environmental elements. These approaches aim to mitigate the adverse effects of electronic devices and promote a healthy sleep pattern during this significant phase of life.

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