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Screen Time, Blue Light, and Sleep Disturbances: Consequences for Children's Health

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ABSTRACT

Due to ease of access and availability, the use of electronic devices by children has become increasingly common worldwide, raising concerns about potential health effects, particularly as the age of initial exposure continues to drop. Beyond the time spent on these activities and the impact on emotional well-being and stress levels, the blue light emitted by screens - and its consequences for the human body - emerges as a significant factor to consider. Studies indicate that screen time is a major environmental factor contributing to sleep disturbances in children, as blue light interferes with the circadian rhythm by increasing alertness. This narrative review outlines the characteristics of blue light emitted by electronic device screens and its relationship with circadian rhythms and melatonin release, highlighting the impact on sleep duration and quality among children.

Keywords: *Blue light - Sleep - Circadian Rhythm - Sleep hygiene - Screen time*

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Introduction

Light is electromagnetic radiation visible to the human eye that propagates as waves and also behaves as particles (photons), a phenomenon known as wave-particle duality. The visible spectrum corresponds to wavelengths between 380 and 700 nanometers and is essential for humans, as it affects various physiological systems and helps regulate vital body functions, supporting physical and mental health. In addition to enabling vision, light provides several benefits to the body through its action as a synchronizer of the circadian rhythm and as an essential factor in the synthesis of vitamin D and mood regulation by stimulating serotonin production. Natural sources include sunlight (about 25 % of which is blue light) and artificial sources (light-emitting diodes [LEDs]). LEDs - used for general lighting, smartphone screens, tablets, computers, and televisions, whose backlight brightness emits peaks between ~ 440-460 nm and are essential for modern life [1-3]. Although artificial light provides illumination when natural light is unavailable, improving visual performance, increasing visibility in indoor and outdoor environments, safety, and comfort, growing evidence points to adverse impacts on humans, the environment, and the balance of the ecosystem. Studies suggest that exposure to light at inappropriate times alters the circadian rhythm in humans, potentially causing various health impairments [4,5].

Blue light is the part of the visible spectrum with a wavelength between 400–500 nm, characterized as the visible light with the shortest wavelength and the highest photonic energy. It is a natural and physiological component of solar radiation and is also present in artificial sources of white light such as LEDs, fluorescent lamps, and screens. In the last 30 years, there has been a rapid evolution in lighting technology, with the emergence of the high-brightness light-emitting diode (LED), which, in addition to general lighting, has also been used in mobile devices such as smartphones, tablets, and notebooks [6]. During the day, blue light is physiological and beneficial [1].

At night, blue light from cool LEDs, electronic device screens, or residential lighting rich in blue light suppresses melatonin, delays the circadian phase, and delays the onset of sleep [7-9].

Melatonin and circadian rhythm

Melatonin (N-acetyl-5-methoxytryptamine) is a hormone secreted by the pineal gland (a small neuroendocrine gland located in the center of the brain, in the epithalamus region, associated with the regulation of biological rhythms), whose highest plasma levels are reached during the night (40-100 pg/mL), while daytime levels are low (up to 20 pg/mL). Nighttime release is controlled by light through the retinohypothalamic pathway, and its main function is the regulation of the sleep-wake rhythm and circadian synchronization of the organism, although it exerts several other effects (antioxidant and cell protection action, protection of the skin against ultraviolet radiation, contractility of blood vessels, inhibition of insulin release by pancreatic cells of the islets of Langerhans, control of the release of hormones involved in sexual maturation and reproduction, cortisol secretion, adaptation to stress, and regulation of immune function) [10,11]. In humans, melatonin secretion begins after 8 p.m., peaks between 2 a.m. and 4 a.m., and decreases as morning approaches. Exposure to intense light, especially light rich in short wavelengths (460 nm), transiently suppresses this release through the activation of intrinsically photosensitive retinal ganglion cells and the suprachiasmatic nucleus. Under physiological conditions, this suppression is reversible and adaptive, allowing the biological clock to adjust to the light-dark cycles of the environment [5,12].

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Effects of blue light on the body

Exposure to light is the main synchronizer of the human circadian rhythm, since one of its most frequent effects is related to the interaction between melanopsin (a photopigment of the retina responsible for regulating the circadian rhythm and the sleep- wake cycle) and blue light that penetrates the eye and reaches the retina [13,14]. During the day, intense light rich in short wavelengths promotes alertness and suppresses melatonin. At night, the absence of this stimulus allows melatonin secretion and the onset of sleep. Exposure to blue light at night can also suppress melatonin production, delaying the onset of sleep and reducing its quality, as well as contributing to visual fatigue [12,15-17].

Controlled trials with electronic devices have shown that nighttime reading on backlit screens is associated with delayed sleep onset and reduced morning alertness compared to the use of printed materials. This phenomenon has motivated the widespread use of amber or red lenses to "block blue light" before bed [12,15,16,18]. Electronic devices such as televisions, computers, and smartphones have become permanent elements of our daily lives, and the repercussions of using screens with blue light emission on the circadian rhythm have sparked the interest of researchers in understanding the effects on the human organism [19].

Sleep and blue light

Sleep is an essential, reversible neurobiological state organized in cycles (rapid eye movement = REM and non-rapid eye movement = NREM) that alternate during the night, characterized by decreased motor activity and metabolism, reduced responsiveness to external stimuli, and partial disconnection from the environment [20]. The importance of sleep for the body is related to physical recovery (muscle repair, tissue regeneration, hormone release), neurological (elimination of toxins accumulated during the day), strengthening of the immune system, metabolic and cardiovascular regulation, memory consolidation, emotional balance, and mood regulation [21].

From the intrauterine period - when the fetus is subject to hormonal variations from the mother - until adolescence, the circadian rhythm undergoes important modifications. Babies exhibit polyphasic sleep throughout the day and night (several periods of 3 to 4 hours), while the consolidation of predominantly nocturnal sleep begins to develop after the third month of life, as the biological clock matures and responds better to light and darkness signals. The monophasic sleep pattern usually establishes itself around 4 years of age, and while children tend to be more morning-oriented (feel sleepy earlier and wake up earlier), in adolescence a physiological phase delay is observed, in which sleep hormones are released later, temporarily transforming adolescents into more nocturnal beings [22-24].

Since sleep occupies a large part of a child's day and about 1/3 of an adolescent's, being closely linked to growth, neurological development and emotional state, changes in quality or duration can lead to health consequences such as: reduced alertness, attention and reaction time, cognitive and learning impairments, low academic performance and motivation, difficulties in planning tasks and solving problems, mood and behavior dysregulation, difficulty controlling impulses, impaired memory, organization, judgment, self-monitoring - as well as compromised physical health [25-28].

The use of electronic devices at night has become increasingly common among children, raising concerns about the potential health effects [29]. Blue light wavelengths activate intrinsically photosensitive retinal ganglion cells that project directly to the suprachiasmatic nucleus, whose stimulation suppresses melatonin secretion by the pineal gland and delays the circadian phase, shifting the internal clock to a later time. Because children appear to be more sensitive to nighttime light-induced melatonin suppression than adults, and because their circadian systems are still maturing, even relatively brief exposure to blue light from electronic devices at night can cause circadian misalignment [28]. In addition to the time spent on activities, emotional excitement, and stress caused by the use of electronic devices [30], the blue light emitted by the screen of these devices is responsible for several sleep disturbances [5,31-33]. These disturbances result from the stimulation of brain activity caused by blue light, which induces the body to interpret these stimuli as signals similar to those that occur during the day [34].

The digitalization of modern society has a direct impact on children's lives, modifying their social interactions as they grow up in an environment where screen-based technology is a central and practically indispensable element of daily life. Although these technologies offer educational and social opportunities, there is growing evidence linking prolonged screen time to negative effects on children's health, particularly on cognitive, social, and emotional development since, up to the age of two, the still immature central nervous system is subject to environmental influences that directly interfere with learning and emotions [35,36].

In recent years, thanks to ease of access and availability, the use of digital devices among children has increased sharply worldwide as a form of entertainment and interaction, with the age of first exposure becoming increasingly earlier, occurring in early childhood, when they take the place of what was once intended for toys [37-39]. Studies reveal that screen time is a significant environmental factor contributing to sleep disturbances in children. The increased accessibility and use of electronic devices - such as cell phones, tablets, laptops, and televisions - have been associated with both quantitative and qualitative reductions in sleep in children and adolescents. Screen use negatively compromises sleep in several ways, including disruption of circadian rhythms, increased alertness, and reduced sleep duration [28,37-39], as confirmed by systematic reviews and studies with diverse population samples, which can be seen in Table 1.

Table 1. Sleep disruption caused by screen use

Type of sleep impairment	References
Worst overall quality	31, 40, 41, 44, 45, 46, 47, 48, 49, 50, 51, 53, 54, 56, 57, 58, 59
Shorter time	28, 29, 31, 40, 41, 52, 54, 55, 57
Increased latency time	30, 31, 40, 41, 42, 43, 52, 53, 54, 55
Delay in bedtime	28, 31, 40, 57
Daytime sleepiness	28, 40

Conclusion

In recent years, due to the rapid increase in the use of electronic devices by children, there has also been growing concern about the impact of blue light on sleep health. Thanks to technological advancements, these devices have become easy to transport and offer the possibility of watching videos, accessing the internet, and interacting online, resulting in exposure to both light and content - often stimulating -, impacting the duration and quality of sleep when used at night before falling asleep.

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Given this reality and the importance of sleep for the complete well-being and development of children, the use of electronic devices under these conditions is becoming a public health problem worldwide and requires urgent action to reduce its impact on children.

In this sense, setting limits and reducing exposure to blue light at night is fundamental to preserving sleep quality in childhood. Practical measures such as limiting screen use in the hours leading up to sleep and removing devices from the bedroom at night represent reasonable recommendations for pediatricians and families, reinforcing the importance of sleep hygiene as an essential component of healthy child development. Educational campaigns aimed at parents, educators, and healthcare professionals can promote guidance on healthier habits in the use of electronic devices, especially among children, in order to ensure adequate nights of rest to protect well-being and full physical and mental development during the most crucial stages of childhood.

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