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Blue light and its effects on sleep

George-Alexandru Diaconu[1], Cătălina Maria Iordăchel[2], Cătălin Coca[1], Nicolae Feraru[1], Constantin Gheorghevici[1], Dănuț Zisu[1], Șandru Emilia[1], Beatrice Burdușel[1], Andreea Popa[1], Ioana Munteanu[1,2,]*

[1]"Marius Nasta" Institute of Pneumology, Bucharest, Romania
[2]"Titu Maiorescu" University, Faculty of Medicine, Phisiology Department, C.F.2 Hospital, Bucharest, Romania

Abstract

English:

Short wavelenght light (blue light) contributes to dysregulations of the circadian cycles. In an era where most of the light sources were replaced by Light Emitting Diodes (LEDs), a new problem regarding sleep quality and nictemeral cycle appears. Even though blue light is currently being used a treatment for sleep dysregulations and insomnia (through cycle altering), this stimuli activates the melanopsin secretory mechanism via photoreceptor cells and thus supresses the pineal secretion of melatonin. Melatonin plays a crucial role in provoking pre-sleep symptoms, inducing and maintaining sleep, improving sleep quality and multiple other effects dependant to the organ, such as being an antioxidant or its protective atribute against diabetes. This paper is a general review of the literature and brings to a single place multiple studies about the importance of sleep, physiology of melatonin secretion and the effect of light exposure on those aforementioned.

Keywords

Sleep • Circadian • Blue light • LED • Melatonin • Melanopsin

Lumina albastra si efectele ei asupra somnului

Rezumat

Romanian:

Lumina cu lungime de undă scurtă (lumina albastră) contribuie la dereglarea ciclurilor circadiene. Într-o eră în care majoritatea surselor de lumină au fost înlocuite cu diode emițătoare de lumină (LED), apare o nouă problemă în ceea ce privește calitatea somnului și ciclul nictemeral. Cu toate că lumina albastră este utilizată în prezent ca tratament pentru dereglările somnului și insomnie (prin modificarea ciclurilor), acest stimul activează mecanismul de secreție a melanopsinei prin intermediul celulelor fotoreceptoare și astfel suprimă secreția epifizară de melatonină. Melatonina joacă un rol esențial în provocarea simptomelor de pre-somn, în inducerea și menținerea somnului, în îmbunătățirea calității somnului și în multiple alte efecte care depind de organ, cum ar fi calitatea de antioxidant sau caracterul său protector împotriva diabetului. Această lucrare reprezintă o trecere în revistă a literaturii de specialitate și aduce într-un singur loc date din mai multe studii despre importanța somnului, fiziologia secreției de melatonină și efectul expunerii la lumină asupra celor menționate mai sus.

Cuvinte-cheie

Somn • circadian • lumină albastră • LED • Melatonină • Melanopsină

Introduction

In recent years, the lighting industry has undergone major changes comparable to a revolution. Whereas 10 years ago, incandescent light bulbs were almost ubiquitous in people's homes, today we are witnessing an increase in the use of LED sources [1,2].

In most cases, legislation has forced manufacturers to shift the production of incandescent light bulbs towards CFLs (Compact fluorescent lamps), traditionally "energy saving bulbs", citing their undeniable energy advantage. However, for the household user, the need for a more efficient light

*Corresponding author: Ioana Munteanu
E-mail: ioana.munteanu2015@yahoo.ro

source has emerged. LEDs (Light Emitting Diodes) are a cheap and efficient way of lighting, which is why research in this field has been growing and the technology has been evolving at a rapid pace [2].

Inevitably, LED panels have quickly climbed to the top of the smartphone display industry, and will slowly take over the podium for TV displays (currently reigned by Liquid Crystal Displays – LCD) [3].

Today, white light LEDs (the most common type of LED technology) manage to combine the emission of blue LED light with yellow phosphor, which creates for the human eye the “illusion” of white light when viewed directly [4,5].

The body’s need for sleep decreases with age. From 14-17 hours/day in a newborn, to 7 hours/day in an adult, and less after the age of 65, fragmented, shortened during the night, and requiring periods of sleep during the day.

This requirement is regulated by the epiphyseal gland which is responsible for regulating circadian rhythms through the secretion of melatonin [6].

Physiologically, melatonin secretion begins at dusk, after 8pm, peaks at midnight and decreases towards morning.

The epiphyseal gland involutes over time and calcifies around the age of 60-70 and as a result melatonin secretion decreases. This explains the more frequent insomnia in patients in this age group [7,8].

Melatonin manifests specific effects for the organ that binds it: epiphyseal gland (role in controlling circadian (nictemeral) rhythms, thermoregulation, sleep/wake state, cortisol secretion - adaptation to stress), retina (role in local cell proliferation), WBCs (role in regulating immune function). It also produces effects on metabolism and general physiological processes such as:

- Antioxidant and cell protective effect;
- Skin protection from UV radiation and skin pigmentation;
- Dilates and contracts blood vessels;
- Inhibits the release of insulin from pancreatic cells belonging to the Langerhans islets;

Controls the release of hormones involved in sexual maturation and reproduction by inhibiting prolactin, follicle-stimulating hormone (FSH), Luteinizing Hormone (LH) [19].

This paper is a review of the literature and aims to examine the effects of blue light on sleep, considering the physiological mechanisms affected by it.

Materials and Methods

This paper is a Literature Review on the effects of blue light on sleep quality, patterns and physiological mechanisms.

In this study, we used the PubMed, ScienceDirect and Google Scholar databases to perform the literature search for studies. No timeframe was used. Keywords were represented by combinations of “blue light”, “sleep”, “sleep quality”, “LED”, “Light emitting diode”, “melatonin”. We considered any type of article/study as long as the topic was satisfactory to our work. From the total number of studies identified in the databases (PubMed, Google Scholar) based on the search keywords, we excluded papers that did not have the same topic as our search and included 30 papers in the systematic review.

Results and Discussion

Sleep has beneficial effects on concentration, memory and cognition according to literature data. Decision-making, concentration, mood - all are cognitive-behavioural processes on which sleep quality acts. Added to this are effects on immunity, hormonal control that ensure normal development and regeneration of the body [10].

The effects of acute or chronic sleep deprivation have been widely described in the literature. Sudden loss of 4 hours of sleep in 6 days leads to hyperglycaemia with hypoinsulinaemia, thus impaired glucose tolerance and eventually can lead to diabetes and obesity. Looking at the problem on the chronic side, less than 6 hours of sleep per night leads to increased insulin levels in the blood and subsequently to insulin resistance, hepatic steatosis, dysregulation of homeostasis, imbalance of circulating lipids, etc. - in a nutshell - metabolic syndrome) [11].

Melatonin, a hormone produced by the pineal gland, is known to induce sleep in humans and other diurnal species. It also has fatigue-inducing and pre-sleep effects. These effects occur due to its action on the suprachiasmatic nucleus (SCN) and default mode network (DMN) regions in the brain. The DMN is a brain network that becomes active during rest, practically in the absence of a stimulus that requires attention. This includes the posterior cingulate cortex and precuneus, the medial prefrontal cortex, the lateral temporal cortex, the lower parietal lobe, and the hippocampal formation and plays roles in introspection and “mind-wandering” [12].

Through its chronobiotic effects on the SCN, melatonin manages to induce sleep. The hormone also has an effect on thermoregulatory and cardiovascular centres, these being two of the aforementioned pre-sleep effects. The nictemeral cycle is regulated by the suprachismatic nucleus and relatively deppendent to the light-dark cycle, and synchronises other metabolic cycles via melatonin synthesis. When environmental stimuli change, melatonin binds on the SCN receptors, aiding resynchronisation. High melatoninemia signals to tissues and organs that it is night time, thus playing an important role in regulating homeostasis [13].

Easy to deduce, disturbances in melatonin production lead to insomnia. Insomnia is the most common sleep disorder in humans. Adolescents, in particular, suffer from this pathology and, above all, girls in late adolescence, as a study conducted in 2018 shows [14].

If we refer to the adolescent: sleep deprivation deliberately causes appetite disorders, impaired glucose metabolism, leading to obesity and diabetes. On the other hand, information/images that teenagers access 30 minutes before bedtime can lead to insomnia, anxiety and depression [15]. By shortening nighttime sleep and delaying wake-up time, circadian rhythm changes occur with disruptions in growth, development, school performance and decision-making power [16]. These aspects can be explained by the increased use of smartphones among the global population, and especially among young people.

For example, one report shows that in Romania about 97% of the population has a mobile/smartphone capable of 26 million mobile connections. This can be translated into the fact that almost 22 million mobile phones lie unused in Romanians' homes (Romania ranks 9th out of 27 countries surveyed - 24 in Europe plus Canada, the US and New Zealand) [17]. Accessibility, creativity, socialization and especially gaining leisure time are at the top of the list when choosing a technology. The usefulness of devices cannot be denied, but the negative effects they have, especially on sleep and the body in general, must also be taken into account.

Van Maanen et al. conducted in 2017 a study on 84 children suffering from insomnia with late melatonin onset. 26 patients received melatonin, 30 children were treated with bright light to regulate their circadian rhythm, and 28 received placebo pills. The authors conclude that both methods showed superiority over placebo, but melatonin supplementation had stronger effects than light therapy [18].

The synthesis of melatonin release from the epiphysis gland is directly related to exposure to light and the nickel rhythm is dependent on the light/dark variations to which the body is exposed [19]. Several studies show a decrease in melatonin production when there is exposure to light [20–22].

It appears that melatonin secretion increases sharply a few hours before sleep, in direct relation to the weakening of external light. This is called Dim Light Melatonin Onset (DLMO). On the contrary, when the stimulus associated with an illumination in crescendo appears, the secretion of melatonin is suddenly extinguished. This DLMO is considered to be a reliable, easy-to-obtain and non-invasive circadian phase marker [19].

Several papers address the subject of luminous stimulation of cells with cones and sticks and intrinsically photosensitive retinal ganglion cells (IPRGCs) and the effects on melatonin secretion. The role played by these cells was isolated in experiments where they were stimulated by light with wavelengths specific to the colors blue, green and red. Short wavelength light (blue light) is the most potent for acute suppression of melatonin secretion. Apparently, the red and green light wavelenghts produce effects following the same principle, only that their intensity is lower [23–26].

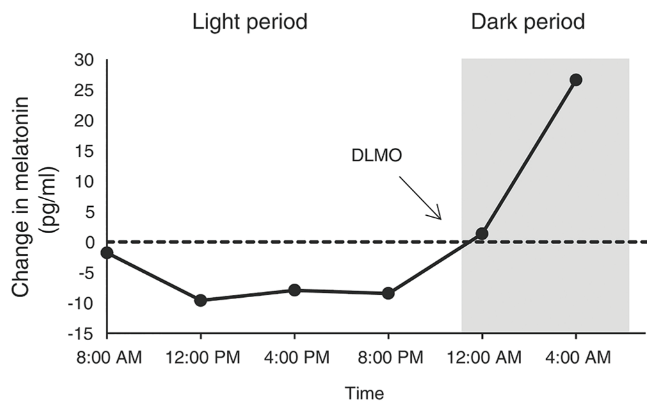

Figure 1. Blood melatonin levels during the day and Dim Light Melatonin Onset effect.

This phenomenon of suspension of melatonin secretion is explained by the mechanism of activation of melanopsin-containing IPRGCs. IPRGCs and its photoreceptor, melanopsin, are considered to be environmental irradiance detectors. Melanopsin is light-activated in a direct way and has a maximum sensitivity to short wavelenghts at around 482nm. As a result of the triggering of an action potential in IPRGCs, the secretion of melanopsin happens which produces myosis and direct inhibition of the melatonin genesis in the pineal gland [27]. Another paper analyses the blood levels of melatonin following exposure of human subjects to bright light. Low melatonin levels were in all subjects, including completely blind patients [28]. This is of particular importance in understanding day-night rhythms because it supports the theory of luminous stimulation of cells with cones, stickers and IPRGCs and, implicitly, the effects of melanopsin suppression of melatonin-genesis. It also explains why blind pleople manifest physiological day/night behaviour and proves that the melatonin secretion functions properly despite the unfunctioning optic nerve.

Nowadays, the effect of light on nictemeral cycles is being used as treatment for insomnia and irregular sleep patterns. Light therapy is a non-pharmacological therapy that is involves watching artificially-produced light through a visor or a lightbox [29]. Its mechanism of action includes altering the circadian rhythm through processes explained above.

Shechter et al. publish a randomized controlled trial in which they test amber-tinted blue light-blocking lenses or clear placebo lenses on 14 subjects before bedtime for 2 hours. After 7 consecutive nights, subjects who wore amber-tinted lenses had better insomnia-questionnaire scores than subjects wearing placebo lenses. Also, the reported wake-up-time was delayed, quality of sleep and total sleep time (TST) was significally higher in the blue light blocking group [30]. This study brings relevance to the subject because it introduces a new therapy option for a problem that we did not even know it existed until recently – display usage. Amber lenses are a non-expensive way of blocking short wavelenght light and, therefore, not damaging the circadian cycle.

Conclusion

Exposure to blue light in the day-time is imperious to suppress the secretion of melatonin, a hormone that is produced in the pineal gland and plays a vital role in the nictemeral rhythm entrainment. There are even therapies which include blue light exposure to treat dysregulations of the day-night cycles, which often translates as insomnia. While the exposure to short wavelength light is important for maintaining metabolism, alertness, and neurocognitive performance during the day, long-time exposure to blue light before bedtime has serious implications on circadian phase regulation and sleep quality. Nevertheless, this problem needs to be adressed as the number of domestic displays rises and the age at which children start to use smartphones and tablets decreases.

Progresses are yet to be done in this display-industry, as few smartphones and TVs already have blue light dimming options but the majority of them do not or the user cannot activate it.

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Institutional Review Board Statement

Not applicable.

Informed Consent Statement

No informed consent was necessary.

Data Availability Statement

Data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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