Blue Light Toxicity Isn't Real

Many claims are misleading and overblown, but blue light is not harmless.



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Alarming headlines about blue light toxicity and the dangers of digital screens for eye health are everywhere. Much of this concern is rooted in quality laboratory studies evaluating acute exposure to high-intensity blue light, but there is insufficient evidence to support definitive claims about the long-term effects of blue light in an everyday environment. This caveat has not prevented the science from being used for fearmongering and misleading marketing claims. The misinformation on blue light toxicity has become so extreme that many ophthalmologists now erroneously believe that blue light has no harmful effects at all.

This article separates the myths about blue light exposure from the realities.

MYTH: There is a common belief that concerns about blue light from digital devices are entirely overblown, and some even claim it poses no risk at all to eye health.

REALITY: Although some claims are exaggerated, blue light is not harmless. It plays a vital role in regulating circadian rhythms and enhancing cognitive function. Excessive exposure, however, may contribute to sleep disruptions, eye strain, and damage to ocular tissues, among other issues.

THE BENEFITS OF BLUE LIGHT

Blue light is ubiquitous. Its primary source is the sun. Daytime exposure to blue light helps regulate human behavior and circadian rhythms, which are essential for maintaining sleep-wake cycles and overall well-being. Exposure to natural blue light helps people stay alert, improves their mood, and enhances their cognitive function throughout the day.[1] Blue light therapy has even been used to treat psychiatric disorders, including depression and bipolar disease.[2]

THE HARMFUL EFFECTS OF BLUE LIGHT

Increased Exposure

The use of LEDs as a more sustainable and cost-effective alternative to incandescent bulbs has increased significantly during the past 30 years. LEDs are a richer source of small-point, high-intensity blue light than other artificial light sources.[3] The shift to LEDs combined with people's growing use of digital devices such as computers, televisions, smartphones, and tablets—many of which use LED backlighting—has notably increased their exposure to artificial blue light.

Suppressed Melatonin Secretion

The rise in screen time, particularly in the evening and at night, exposes viewers to higher levels of blue light, compounding their daytime exposure.[4] Excessive nighttime exposure to artificial blue light can disrupt circadian rhythms[5] by suppressing melatonin secretion, leading to sleep disturbances, eye strain, decreased alertness, poor sleep quality, and irregular sleep patterns, all of which can contribute to chronic sleep deprivation.[1,6] Blue light exposure, particularly during evening hours, can also impair cognitive functions such as attention, reaction time, and memory consolidation.[7]

Oxidative Stress

As the first barrier to light, the cornea absorbs almost all radiant energy below 295 nm. The high energy of blue light can trigger the production of reactive oxygen species (ROS), which can lead to oxidative stress damage. Marek et al found that blue light damaged corneal and conjunctival epithelial cells and that hyperosmolar stress—used to simulate dry eye disease (DED)—exacerbated the phototoxic effects.[8] Shorter-wavelength blue light, moreover, can cause cellular damage and stress, leading to chronic ocular surface inflammation and tear film dysfunction and aggravating DED symptoms.

In addition to affecting the cornea and ocular surface, blue light can penetrate deeper into the crystalline lens than other wavelengths. The human lens absorbs short wavelengths of UV-B light and all UV-A wavelengths and effectively filters out some near-infrared wavelengths to protect the retina. Prolonged exposure to UV light is a well-documented risk factor for cataract development.[9] Research has suggested that exposure to blue light may cause photodynamic damage by producing ROS in the mitochondria of lens epithelial cells (LECs).[10] A study that assessed the oxidative stress induced by white LEDs on LECs found increased intracellular ROS and DNA damage that led to cell apoptosis.[11] Over time, increasing oxidative damage to LECs can trigger yellowing and clouding of the lens and contribute to cataract formation.[12,13]

As the crystalline lens absorbs and filters different wavelengths of light, only the visible part of the electromagnetic spectrum (380–780 nm) and a portion of near-infrared wavelengths (780–1,400 nm) can penetrate to the retina. Wavelengths that reach the retina can induce photomechanical, photothermal, and photochemical damage.[14] High-energy blue light accelerates photochemical reactions and cellular damage by producing ROS, leading to photoreceptor death, lipid peroxidation, and cell apoptosis.[15]

The retina's high metabolic activity and oxygen consumption make retinal pigment epithelium (RPE) cells particularly susceptible to oxidative damage. Recent animal studies indicated that prolonged exposure to blue light can cause oxidative stress in the retina and severely damage retinal tissue, especially in RPE cells.[16-18] Wang et al showed that blue light irradiation in mice induced mitochondrial fragmentation, which led to further oxidative stress and eventual cell death.[16] Oxidative stress may cause ROS overproduction in mitochondria and thus disrupt the dynamic balance between mitochondrial fusion and fission. This can propagate the cycle of ROS production and oxidative stress. A study of human RPE cells found that exposure to blue light increased cellular and mitochondrial ROS and that blue light–filtering IOLs attenuated these effects.[19]

Understanding the sensitivity of RPE cells to blue light could provide insight into the pathogenesis of age-related macular degeneration. Studies on sunlight's possible role in the disease have reported conflicting results.[20,21] Complicating matters is that sunlight contains both blue light and other wavelengths. Long-term studies are needed to assess the impact of different light sources under normal living conditions.

Pediatric Eyes

Because they have larger pupils and clearer lenses than adults, children may be particularly vulnerable to the harmful effects of extended exposure to blue light. Twenty-five times more 400-nm light passes through the crystalline lens of an infant versus an average 70-year-old adult.[22] Multiple studies, moreover, have found a significant correlation between increased screen time and reduced outdoor activity (trends exacerbated during the COVID-19 pandemic) and the development of myopia and greater refractive error in children.[23-25]

Both LED screens and sunlight expose viewers to blue light, but the quality of the light differs. Compared to artificial sources, natural light is much richer in shorter-wavelength blue light,[26] which promotes the release of dopamine in the retina and may help reduce the rate of axial length progression during visual development.[27] Some animal studies have indicated that blue-violet light (360–400 nm) can slow myopia progression in children.[28-30] For instance, Torii et al reported slower progression in myopic children fitted with corrective contact lenses that allowed the passage of violet light.[29]

The potentially harmful effects of exposure to blue light from digital devices and the protective effects of exposure to blue-violet light from the sun require further study.

BLUE LIGHT–BLOCKING GLASSES

Increased public awareness of the deleterious effects of blue light on ocular health and circadian rhythms has fueled the popularity of blue light–blocking (BB; ie, amber) glasses that filter the UV radiation portions of short-wavelength visible light.[31] Commercially available BB glasses are marketed as improving wearers' sleep quality and reducing the symptoms of digital eye strain, including sore eyes, headache, blurred vision, and DED. BB glasses are available in various styles for both daytime and nighttime use; prices range from $10 to $500.[32]

To date, studies have reported conflicting results on the efficacy of BB glasses. In a study by the American Optometric Association, a filter that eliminated 99% of emitted blue light was no more effective at reducing symptoms of digital eye strain than a neutral-density filter.[33] A systematic review of randomized controlled trials found that, over a short-term follow-up period, BB glasses may not improve the symptoms of digital eye strain compared to non-BB glasses.[31] There was also no statistical difference in critical flicker-fusion frequency (used as a measure of visual fatigue) with BB versus non-BB glasses.[31,34] It should be noted that this review included only 17 randomized controlled trials with sample sizes ranging from five to 156 participants and follow-up periods no longer than 5 weeks.[31] Another study found that BB glasses did not significantly improve objective measures of total sleep time or quality in a randomized controlled trial of 20 healthy adults.[35]

Additional studies with larger, more diverse sample sizes are required to elucidate the effects of BB glasses on ocular health and sleep. For now, the AAO recommends reducing digital eye strain through conservative measures such as sitting about an arm's length from the screen, following the 20-20-20 rule (ie, looking at something 20 feet away for 20 seconds for every 20 minutes spent looking at a screen), and using a matte screen filter if needed.[36]

CONCLUSION

There is insufficient human clinical evidence to support many current claims about blue light toxicity and ocular health. A large body of laboratory evidence, however, suggests that level-headed caution and a reasonable reduction in exposure to blue light are warranted. Adults' and children's use of LEDs and digital devices continues to rise. Further research on the long-term effects of blue light exposure is needed to identify and mitigate its harmful effects. ■

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