EYE COMPLICATIONS OF EXPOSURE TO ULTRAVIOLET AND BLUE-VIOLET LIGHT

Harmful effects of ultraviolet (UV) and blue-violet light manifest differently in the human eye. Cumulative exposure to blue-violet light has been linked with the development of age-related macular degeneration (AMD). This article highlights the potential hazards of exposure to UV and blue-violet light, and summarizes some of the commonly prescribed protective/preventative measures.

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KEYWORDS

UV, blue-violet light hazard, eye damage, age-related macular degeneration, cataract, harmful light, electronic devices, climatic droplet keratopathy, population at risk, prevention, protection, risk factors, IOL.

Light is part of the electromagnetic spectrum, which ranges from radio waves to gamma rays. Visible light is not inherently different from the other parts of the electromagnetic spectrum with the exception that the human eye can detect visible waves. Light can be classified into different categories depending upon its wavelength, not all of which are visible to the human eye. The human eye can see light of wavelengths ranging from 380-780 nm (also known as the visible spectrum). [1] Shorter wavelengths than 380 nm are classified as ultraviolet (UV) light while wavelengths longer than 780 nm are classified as infrared light.

1. UV radiations: definition and transmission

Ultraviolet light is categorized into UV-C (100-280nm, short wavelength), UV-B (280-315nm, medium wavelength) and UV-A (315-380nm, long wavelength). [1,2] The sun is the single largest source of UV light. UV-C is effectively filtered out by the earth's ozone layer and atmosphere. UV-A and UV-B penetrate the earth's atmosphere to reach its surface. Some of the common factors affecting the transmission of UV radiation from the sun to the earth's surface include:

1. Sun elevation: The more vertical the sun is in the sky, the more intense the UV radiation. UV radiation levels are therefore highest around noon and in summer. [3,4] However, it is postulated that as our eyes are set deep in the orbital bone structure, the level of UV entering the eye at noon may be lower than at other times of the day. [5]
2. Latitude: Regions that are closer to the equator receive higher UV radiation levels. [6]
3. Cloud cover: UV-A and UV-B radiation can penetrate through light cloud cover. Different thicknesses of cloud

cover have variable effects on levels of transmission of UV radiation. [7]
4. Altitude: At higher altitudes the atmosphere is thinner and absorbs less UV radiation, allowing more UV light to reach the earth. [8]
5. Ozone: Ozone absorbs UV-C radiation. [9] The filtering mechanism is becoming less efficient as the layer is increasingly depleted.
6. Ground reflection: While grass, soil and water reflect less than 10% of UV radiation reaching the earth, fresh snow reflects as much as 80% while dry beach sand reflects around 15% and sea foam about 25%. [5]

2. The beneficial and harmful components of blue light
The wavelength adjacent to UV-A is called blue light. Blue light (also known as high energy visible, HEV) has wavelengths of approximately 380-500 nm. Most blue light, together with other visible light, is transmitted through the cornea and the crystalline lens to reach the retina. Blue light is vital for performing a number of visual functions including perceiving objects of different color and contrast in our surroundings. Blue-turquoise light, whose wavelength lies close to the green light, helps regulate our circadian cycle, which in turn maintains and regulates non-visual functions such as memory, mood and hormonal balance. [10] Blue-violet wavelengths lie close to UV light and therefore have higher energy (being inversely proportional to the wavelength). An excess of blue-violet is considered to be hazardous to the human retina if exposed for a long period of time as it radiates more energy than blue-turquoise and other visible light.

3. Anterior segment lesions due to UV exposure
Ultraviolet light (mainly UV-B) is absorbed by the cornea and ocular adnexa (lids, conjunctiva). The chronic absorption of UV-B light by the cornea can lead to photo-keratitis.[11] If the cornea is also exposed to sand and dust then climatic droplet keratopathy can occur, which is a degenerative process characterized by golden-brown translucent material in the anterior corneal stroma, Bowman's layer, and sub-epithelium. Initially, deposits are found near the limbus, which then progress to large nodules in the central cornea, thereby blurring vision. Deposits may also infiltrate the epithelium and the conjunctiva causing painful eyes. [12]

Absorption of UV light by the conjunctiva can causes conditions such as pterygium and pinguecula. [13] (Fig. 1 & 2)

FIG. 1 & 2| Patients with Pterygium

In the eyelids, prolonged exposure to UV light is also a risk factor for cancers such as basal cell carcinomas, squamous cell carcinomas and melanomas. These usually occur in the lower eyelids which are exposed to most sunlight. [14] The longer wavelength UV light (UV-A) which lies adjacent to the blue end of the visible spectrum is transmitted through the cornea to reach the crystalline lens. The lens absorbs most of the UV-A. Hence, chronic exposure of the eye to UV-A can promote cataract formation. [15]

Cataracts are typically treated by removing the crystalline natural lens and replacing it with an artificial intra-ocular lens (IOL). However, the artificially implanted lens is typically less efficient at filtering UV light compared to the natural lens, thereby making the retina vulnerable to the hazardous effects of UV light. This can lead to photo retinitis and also increase the rate of progression of macular degeneration. The damage is even more acute and severe

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when no IOL is implanted (aphakia). It has been suggested that yellow-tinted IOLs may protect the retina more effectively against hazardous effects of UV and blue-violet light than clear IOLs. [16]

Other visual discomforts such as glare, fatigue, and reduced contrast sensitivity, may occur when light entering the eyes becomes scattered due to photo-keratitis and/or the presence of cataract.

4. Retinal damage due to blue-violet light exposure
Unlike UV light, blue light is not as readily absorbed by the anterior eye structures and the lens, and can thus reach the posterior part of the eye potentially causing retinal damage, especially as the filtering mechanisms of the human eye for blue light become weaker. [17,18] Macular degeneration is the most serious form of retinal damage due to the cumulative effect of blue light exposure.[17,18] The severity of the damage may be even greater when the crystalline lens is removed following cataract surgery, allowing both UV-A and blue-violet light to reach the retina. Albino patients are at an increased risk of developing retinal damage since the melanin pigment that blocks most of the UV-A and harmful blue-violet light from entering the iris is deficient (or absent) in these patients.

Retinal damage associated with blue light is primarily of a photochemical nature, unless acute exposure to extreme bright blue light is experienced, in which case the damage may also be induced by mechanical or thermal changes.[19] In addition, the thinning of macular pigment (i.e. carotenoids: lutein, zeaxanthin) with advancing age makes the central retina more vulnerable to harmful effects of blue-violet light. It is more susceptible that UV and/or blue light is even more toxic once retinal damage (even if minimal) has occurred A population-based study with a 10-year follow-up found that exposure to the summer sun for more than 5 hours a day led to a higher risk of retinal pigment damage and early age-related macular degeneration compared to exposure of less than 2 hours. [20]

In 2008, researchers at the Paris Vision Institute split the visible light spectrum into multiple bands of 10 nm and examined the effect of several hours exposure of each band on porcine retinal pigment epithelial cells. Their data showed that specific bands of blue-violet light of wavelengths ranging from 415-455 nm were most harmful to these retinal cells. [1,21]

It is also known that digital screens (TVs, computers, laptops, smart phones and tablets), fluorescent lights, welders' flashes, and LED backlit screens emit blue light. It is possible therefore, that excessive exposure to these devices over a period of time may increase the risk of damage to the eyes. However it has also been suggested that, while LED backlit screens are rich in blue-violet light, they have low levels of irradiance so their main effect may be short-term (e.g., eyestrain) rather than permanent retinal damage.

Okuno and co-workers examined the blue light hazard of various light sources. [22] They found that arc welding was among the most hazardous sources, with an exposure time of 0.6-40s being acutely hazardous to the retina. Viewing very bright sunlight and its reflection on the ocean or desert with unprotected eyes can acutely damage the macula due to blue light.

5. Populations at risk and preventative requirements
The human eye has inbuilt mechanisms to filter UV and harmful blue-violet light; the cornea, the crystalline lens, and macular pigments. However, experience shows that these mechanisms do not always provide adequate protection from the harmful effects of UV and blue-violet light. It has been reported that by the age of 65, the ability of the human eye to protect itself against UV and blue light is reduced by half. [20] Various populations are at increased risk of being prone to ocular damage.

Outdoor workers who are exposed to sunlight for prolonged

« Outdoor workers who are exposed to sunlight for prolonged periods of time are more prone to the harmful effects of UV and blue-violet light »

periods of time are more prone to the harmful effects of UV and blue-violet light. These include various occupations such as construction workers, farmers and truck drivers. Engaging in activities such as arc welding, curing of paints/inks, working in environments that are brightly lit with fluorescent lights/cool indoor white light and also where blue light is used to disinfect equipment in hospitals and laboratories may lead to retinal damage due to the cumulative effect of blue-violet light. Furthermore, with the increased use of compact fluorescent bulbs in the home, [23, 24] exposure to blue light has risen even more significantly in recent years.

In addition, adult eyes are at increased risk simply because of the aging process and the reduced efficiency in filtering out blue light as melanin levels are reduced. [25] Melanin is the natural substance that determines hair and skin color and is responsible for protecting skin and eyes from the damaging rays of sunlight. Given the combined effects of ever increasing amounts of blue light in our surroundings and daily activities, along with increasing life expectancy[26] interest has grown amongst researchers to study the harmful effects of blue-violet light on the human eye. However more research is needed to establish precisely what kinds of preventive measures are required for people living in different geographical regions and for those involved with different types of jobs/activities.

Below, we list some of the commonly prescribed preventive measures:

Indoor activities:
1. Reduce blue light exposure by keeping digital devices out of the bedroom to protect the circadian rhythm.
2. Limit the use of electronic devices: take frequent breaks from their use to reduce visual fatigue and to minimize the cumulative effect of blue light reaching the retina. Studies suggest that 60% of people spend more than 6 hours a day in front of a digital device.[3]
3. Use filters in spectacles that filter out harmful blue-violet and UV light.
4. Use halogen lights to reduce cool indoor white lighting.

Outdoor activities:
1. Limit extended sun exposure whenever possible.
2. Wear wide-brimmed hats while in the sun.
3. Consider a melanin pigmented polarized lens. Although it may cause changes in color perception, it cuts down outdoor blue-violet light exposure. To have unchanged color perception, however, one may use Transitions® lenses that can block up to 88% of blue-violet light.
4. For welders adequate protection is vital as the pupillary constriction in response to striking the arc is too slow to block the initial surge of radiation.

Conclusion

Blue light has both beneficial and harmful effects. Whereas blue-turquoise light regulates the circadian rhythm, blue-violet light cumulatively affects the retina and thus may have a link with macular degeneration. It is vital that the eye is adequately protected against harmful effects of UV and blue-violet light. Proper eyewear when working in the sun and avoiding excessive use of devices that are rich sources of blue-violet can help reduce hazardous effects of blue-violet light in the eye. •

Acknowledgements
We are thankful to Dr Indira Paudel, Consultant Ophthalmologist, Tilganga Institute of Ophthalmology, Nepal for providing clinical pictures used in this article.

> « It is vital that the eye is adequately protected against harmful effects of UV and blue-violet light »

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KEY TAKEAWAYS

- UV and blue-violet light are potentially hazardous to the eye.
- Prolonged exposure to UV increases the risk of various forms of eye damage such as cataract, pterygium, pinguecula, climatic droplet keratopathy, and eyelid cancers.
- Several factors affect UV radiation: Sun elevation, altitude, cloud cover, latitude, ozone layer and ground reflection.
- The blue-violet light wavelengths from 415-455 nm are the most harmful to retinal pigment epithelial cells.
- Adult eyes and specific populations are at increased risk from blue-violet light hazards and of developing macular degeneration.