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Review Article

Overview of solar radiation exposure to the human health particularly to the eye: a review article facts and figures till today

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ABSTRACT

Exposure to solar radiation (SR) induces photochemical and thermal damage to ocular tissues, primarily via ultraviolet radiation (UVR), affecting outdoor workers and recreational users globally. Short-term effects include photokeratitis (corneal inflammation, akin to "snow blindness") and photoretinitis, while chronic exposure leads to cataracts, pterygium, corneal degeneration, and eyelid cancers. High-altitude and snowy areas intensify UVR by up to 85% reflection from fresh snow, exacerbating risks for unprotected eyes in both children and adults. This review synthesizes evidence from epidemiological studies, clinical case series, and photobiology research up to 2025, including world health organization (WHO) global burden estimates and occupational exposure data. Key sources encompass PubMed/PMC articles on UVR mechanisms (e. g., Bunsen-Roscoe reciprocity law for cumulative damage) and field measurements of ultraviolet (UV) reflectance in elevated/snowy terrains. Analysis focuses on human health impacts, prioritizing eye-specific outcomes via qualitative synthesis without meta-analysis. Acute UVR exposure causes painful photokeratitis and conjunctivitis, with snow reflection increasing retinal stress and erythropsia (temporary red vision). Chronic effects show outdoor workers with 4-fold higher pterygium odds and substantial cataract burden (e.g., 529,242 DALYs globally per WHO). Skin and immune impacts include immunosuppression and higher skin cancer rates, with solar retinopathy from direct gazing causing permanent macular damage; 100% UV-protective sunglasses mitigate nearly all risks. SR endangers eyes and skin profoundly in reflective environments, urging optometrists and ophthalmologists to recommend 100% UVA/UVB-blocking sunglasses for patients visiting high altitudes or snowy areas. Prioritizing protection prevents acute injuries and chronic diseases, promoting public health education on evidence-based eyewear selection.

Keywords: Ultraviolet radiation, Solar radiation, UV-A, UV-B, Sunglasses, Immune system, Skin health

INTRODUCTION

The primary purpose of this review article is to analyze the SR exposure risk to the individuals and children to use the sunglasses when go to the high-altitude snowfall areas, and expose to the sun light so how to protect the UVR with sunglasses. And SR affects the skin but also immune system of human life. When sunlight enters eye and reaches the retina, we can observe process, where it is transformed into signals by specialized cells known as photoreceptors. These signals are then jointly processed by eye and brain to form our vision. Light is a segment of electromagnetic spectrum, exhibiting characteristics of both waves and particles. For human vision, crucial elements of this spectrum are termed optical radiation. This encompasses UV light (100-400 nm), visible light (400-760 nm), and infrared (above 760 nm). UVR is classified into 3 subcategories: UVA (315-400 nm), UVB (280-315 nm), and UVC (100-280 nm), while infrared is divided into IRA (700-1400 nm), IRB (1400-3000 nm),

and IRC (3000-10,000 nm). UVR can negatively affect various parts of eye, including cornea and retina etc. Although UVB poses a greater risk, UVA can also lead to damage when its effects accumulate over time.

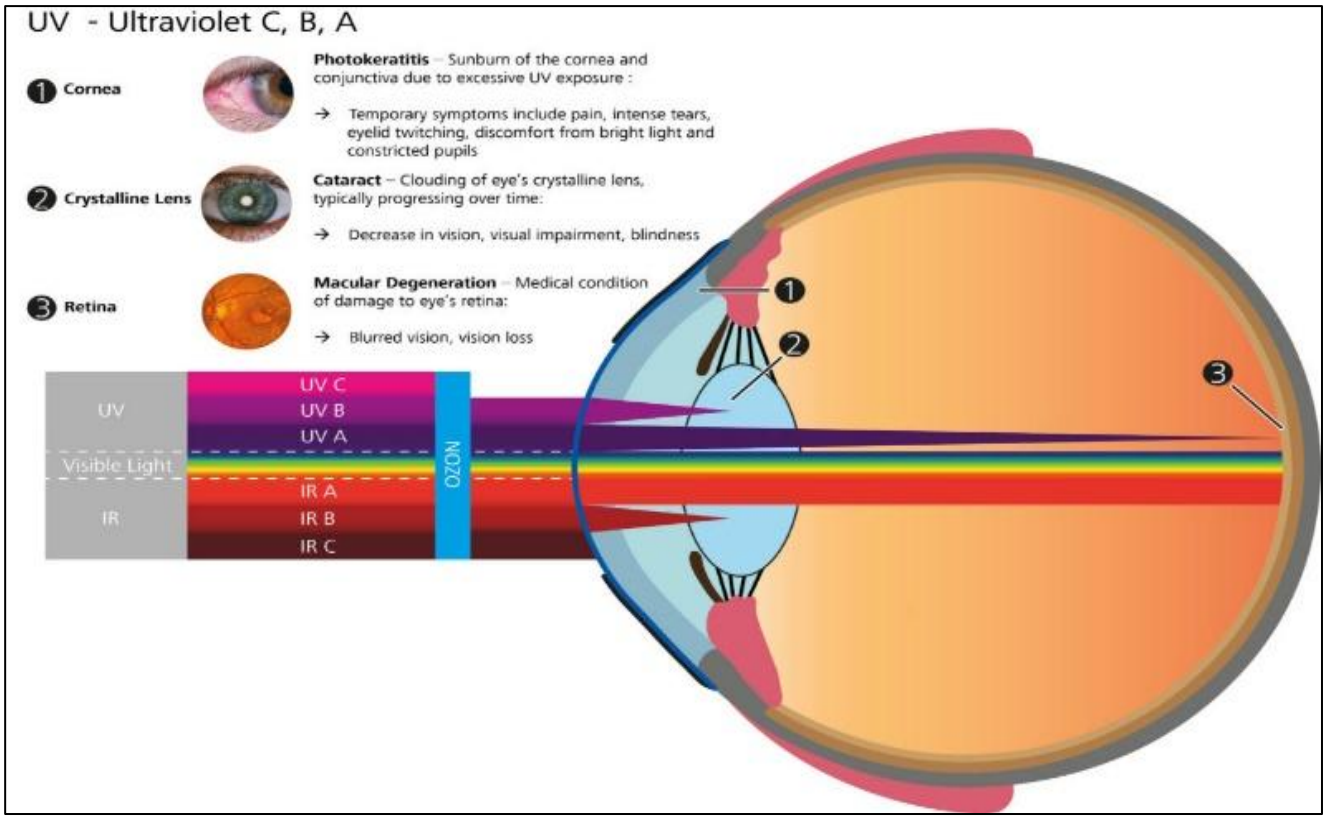

Figure 1: UV-C, B and A.

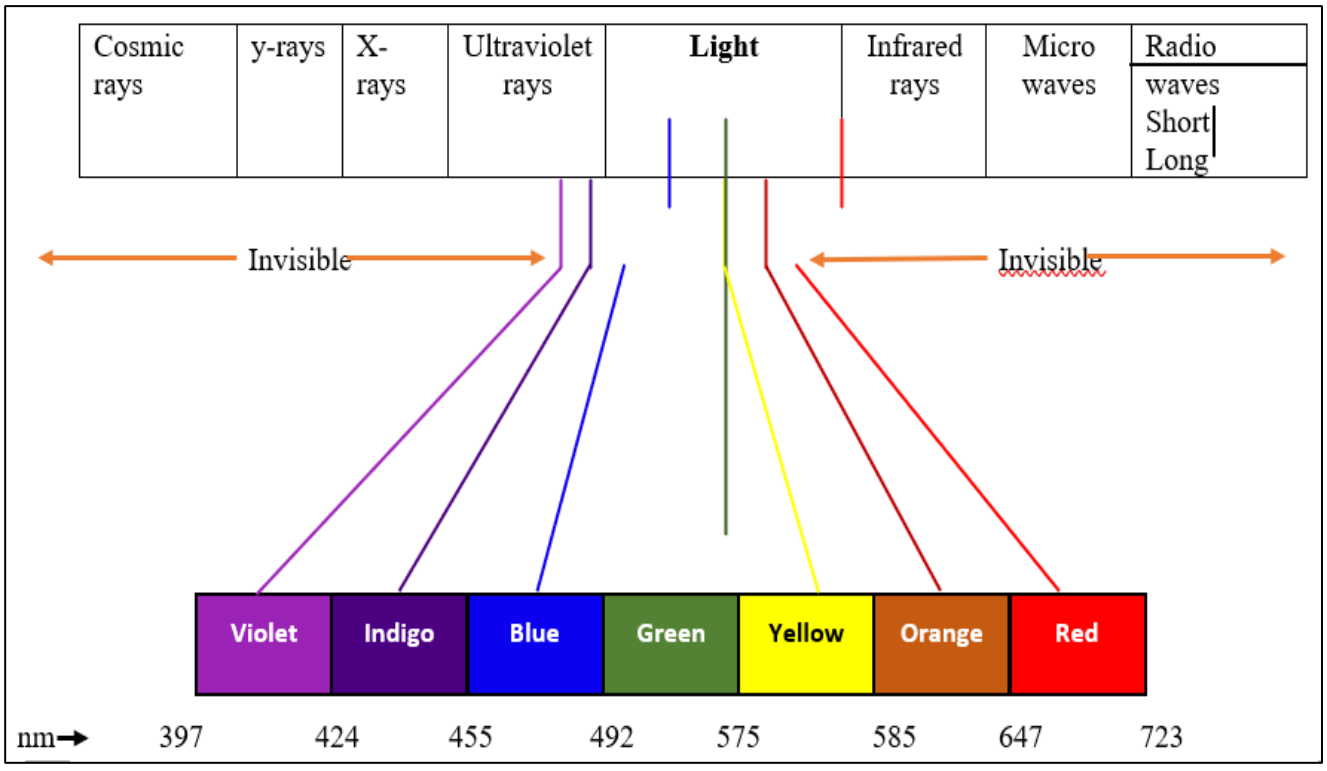

Figure 2: An invisible danger posted on October 13, 2018 spectrum of electromagnetic radiation.

*Note the very small portion occupied by visible light.

WHAT ARE THE BENEFITS OF UVR FOR THE SKIN, AND WHAT EFFECTS DOES IT HAVE ON THE SKIN?

The beneficial effects of human exposure to UVR are relatively few. The best proven is the necessity for UVB radiation to promote the synthesis in the skin of pro-vitamin D obtained in the diet to vitamin D. Human beings eat very little natural vitamin D but mainly ingest it as the pro-vitamin. Daily exposure of face, forearms and hands to normal human beings' sunlight for 10-15 min is required to maintain synthesis of vitamin D from pro-vitamin D and to prevent depletion of vitamin D stores. There is currently concern as to whether or not campaigns to encourage the public to protect their skin at all times of year against potentially damaging UVR may deplete vitamin D stores.[1] The three main types of cutaneous malignancy are basal cell carcinoma, squamous cell carcinoma (SCC) and malignant melanoma. All of these types of malignancy are associated with excess exposure to UVR commonly in the form of natural sunlight. In certain individual how are very sensitive to the sunlight. The case of SCC, the epidemiological evidence available strongly incriminates cumulative lifetime excess sun exposure as a major causative factor. Thus, patients at greatest risk are those who have been born in a high solar exposure environment such as Australia or South Africa, and who have thereafter had an outdoor occupation or a significant outdoor recreation. In the UK individuals at greatest risk are farmers, fishermen and, nowadays, professional outdoor sportsmen.[2]

HOW DOES UVR AFFECT HUMAN HEALTH AND THE IMMUNE SYSTEM?

There is substantial evidence indicating that UV-B radiation exposure impacts the immune system in animals and human beings, often diminishing normal immune functions. The health implications of these changes are evident in certain situations, such as with skin cancer and infectious diseases etc. In other instances, like cell-mediated immunity, this effect may actually provide a protective benefit by preventing harmful immune reactions triggered by skin damaged by UV exposure. In humans, the evidence for similar immune alterations is not as robust, primarily due to a scarcity of studies rather than the absence of these effects. Nonetheless, research demonstrates that UV-B radiation can lead to observable changes in the human immune system, along with indications of functional consequences as well.

HOW DOES UVR AFFECT THE HUMAN EYE?

Certain studies indicate that despite the extensive connection between UV radiation and eye disorders like photokeratitis, age-related macular degeneration (MD), eye cancer, cataracts, and pterygium development, a significant number of individuals remain unaware of the harmful ocular effects caused by UV exposure. Many people in the country resort to the use of sunglasses to shield their eyes from the gross effect of radiation from the sun and other artificial sources. They acquire these sunglasses from the optical shops and or very often, from roadside (street) vendors. What draws the attention of the local ophthalmic community is that, some of these sunglasses may not have the level of protection claimed by manufacturers. But it should be done by the measurement of the lesnometer with the facility (D-903) auto lensometer with an inbuilt UVA meter to determine their level of protection against UVA using the American optometrist association (AOA) UVA-protection standard as our reference. The measured values were then compared with the AOA standard which is set a minimum of 99% of UVA. This is similar to concerns raised in other studies; sunglasses with inferior protection are even thought to enhance transmittance of UVR into the eye because their darker tints cause pupillary dilatation allowing much than less of harmful radiation to enter the eyes.[3-5]

LITERATURE RESEARCH

In carrying out this review, Google Scholar was chosen as the main literature source due to its extensive coverage and accessibility to high-quality academic materials. The platform grants access to peer-reviewed journals, original research articles, and review papers, guaranteeing that the evidence gathered is both trustworthy and up to date. Its interdisciplinary database proved particularly useful since UVR spans various fields of science and healthcare. Given that UV exposure impacts not just the eyes but also the skin and immune system, it was crucial to examine literature from ophthalmology, dermatology, immunology, and environmental health sciences. The search strategy utilized relevant keywords such as "UVR and ocular health," "SR and skin damage," "immune effects of UV exposure," and "preventive measures against UV hazards." Advanced filters were deployed to prioritize the most recent studies, ensuring that the latest findings were included. Publications from the past two decades were highlighted, with a specific focus on systematic reviews, meta-analyses, and clinical trials, which offer stronger levels of evidence. Additionally, foundational works that remain pertinent in the field were incorporated to provide a historical perspective. The inclusion criteria centered on studies that specifically examined human health outcomes, whereas those confined to animal models without human relevance were excluded unless they offered valuable mechanistic insights. Google Scholar's citation tracking feature was also utilized to pinpoint significant articles that are frequently referenced within the field. This strategy facilitated the incorporation of a diverse array of viewpoints, merging clinical observations, experimental investigations, and public health information. Ultimately, utilizing Google Scholar as the primary research platform ensured that the review was thorough, dependable, and reflective of the current scientific understanding concerning the dangers and effects of UVR. Types of UVR exposure to the ocular tissues

The following is a list of the elements which influence solar UVR exposure to the eyes, as provided by international commission on non-ionizing radiation protection (ICNIRP):

Pollutants

The presence of pollutants in the air cuts down on UV exposure.

Latitude

The amount of undiscovered UV rays is proportionally reduced with increasing latitude away from the equator.

Altitude

At higher elevations, more of the sun's UV rays are exposed to the atmosphere.

Reflection

The reflection of surfaces in the environment may play an essential role in the amount of solar UV radiation and individual is exposed to. This phenomenon can potentially increase UV radiation exposure in parts of the body that are usually protected from direct sunlight, such as the eyes. A unique aspect of albedo is referred to as the Coroneo effect, and it occurs when light rays coming from the temporal side of the face are refracted by the corneal dome in the nasal corneal limbus as well as in the nasal and inferonasal regions of the lens.[6]

Personal considerations

The execution of outside activity, whether at work/ during leisure time on vacations or for the practice of sports or outdoor pastimes, is one of the personal factors that might influence a person's exposure to sun's UVR. Individual behaviors, such as covering up with protective clothes, sunglasses, and hats, protecting oneself with sunscreen, and seeking out shade, are among the most critical factors determining the amount of solar UV exposure.[7]

Occupational considerations

Work performed outside is particularly significant in cumulative exposure; photochemical damage will likely accumulate in workers' eyes for their employment, ultimately leading to detrimental consequences.

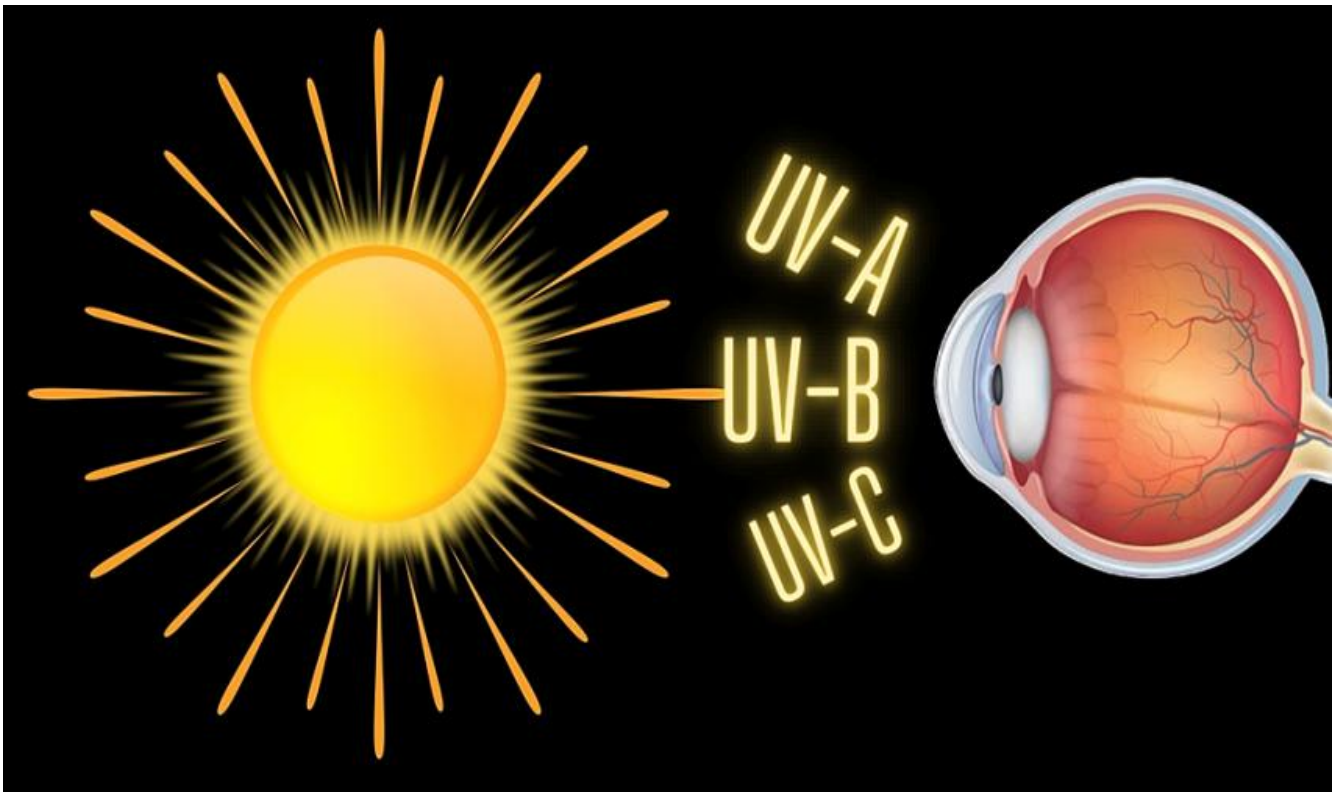

Figure 3: Effects of SR on the eyes.[27]

PTERYGIUM

It is a wing-shaped growth of the conjunctiva onto cornea that can cause ocular discomfort, aesthetic consequences, and, in late stages of corneal tissue invasion, vision impairment. Pathogenesis is still not known. A fourfold risk has been seen in regions where solar rays are elevated. Occupational exposure was positively linked with illness severity. Sunglasses and hats are found to be influential factors in preventing pterygium.

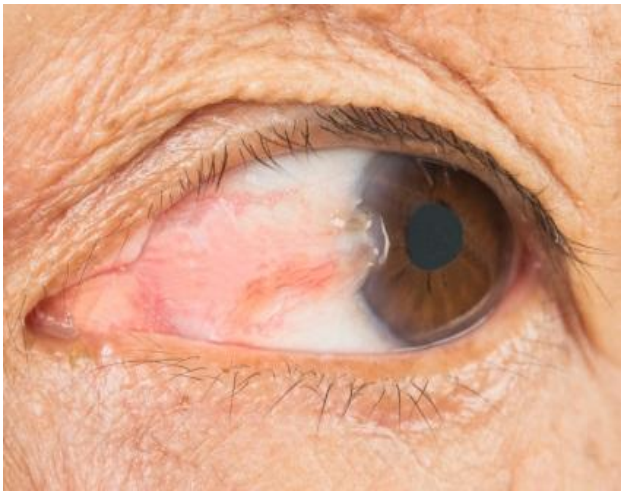

Figure 4: Effects of UVR on eye or ocular tissues.

CATARACTS

In every region of the world, cataracts are the leading cause of blindness. Exposure to UV light over an extended period is one of the most critical risk factors.[8] The incidence of cataracts has decreased as a direct result of the lessening of the Sun's direct beams.[7] The most recent evidence for a causal relationship between occupational SR exposure and cataracts came from research on the nuclear subtype of the condition.[8]

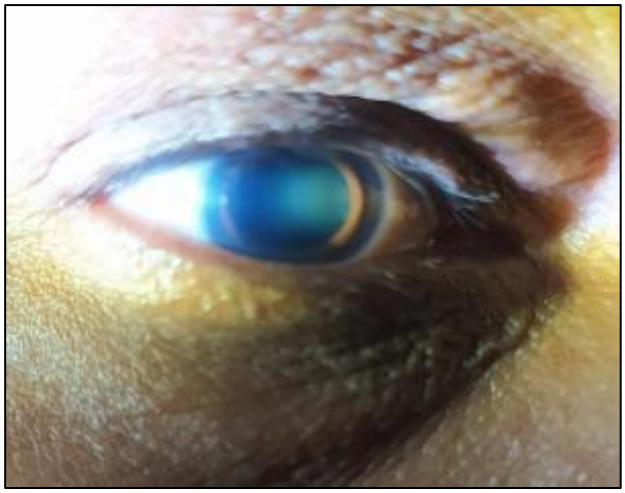

Figure 5: Cataracts.

MACULAR DEGENERATION

It is a disorder that damages the macula and causes progressive vision loss. This vision loss often starts in the center of the visual field and progresses outward.[9] The advancement is slow, taking many years to produce considerable visual impairment, and the severity of the condition varies from the early to the late stages of the illness. The disease progresses in phases. It is also the primary cause of vision impairment in nations such as the India, United Kingdom and the United States.[8] A shift in the metabolic sustainment of photoreceptor cells (rods and cones) and the retinal pigment epithelium (RPE) as a consequence of inflammatory processes and vascular abnormalities is suggested to be the source of long-lasting retinal damage in MD. According to the WHO, prolonged exposure to SR, in particular its blue light component is a risk factor for MD. Other risk factors include smoking, diabetes, genetics, and alcohol abuse.[9,10]

Figure 6: Macular degeneration.

PHOTOKERATITIS

Photokeratitis is induced by sudden exposure to UVR, and the symptoms typically go away between 8 and 12 hours after the exposure. Symptoms such as significant vision loss, sensitivity to light, and severe eye pain are brought on by irritation and destruction to the cells that make up the superficial layer of the epithelium that lines the cornea.[11] Photosensitivity may be caused by prolonged exposure to bright light, whether it comes from the Sun or a fluorescent light bulb. Snow blindness is induced by natural UVB exposure and happens when the light is substantially reflected, such as while skiing or in high mountains. Even momentary exposure to UVB and UVC rays may result in a painful condition known as the welder's eye, which is a form of photokeratitis.[12]

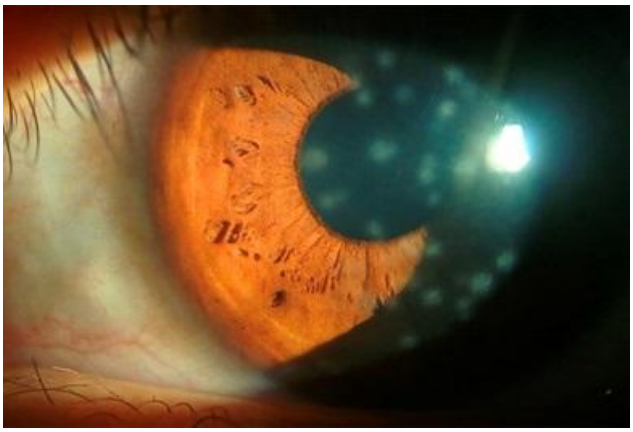

Figure 7: Photokeratitis.

SCC OF THE CONJUNCTIVA

UVB radiation is believed to be the primary cause of SCC of the conjunctiva and cornea; viruses human papillomavirus (HPV) and HIV are also likely to be related to the disorder. SCC of the conjunctiva was seen with a high frequency in the Ugandan population that is close to the equator. Studies on populations suggest that there is a connection between the geographic distribution of conjunctival and corneal SCC incidence and the amounts of ambient SR in the environment.[13]

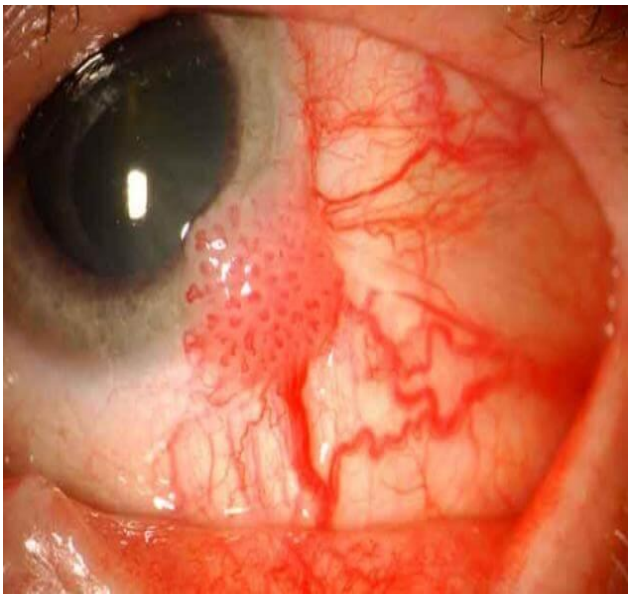

Figure 8: SCC of the conjunctiva.

UNDERSTANDING THE FACTS ABOUT SOLAR RADIATION EXPOSURE TO THE HUMAN EYES

To understand the inside facts about the review article questions and answers are done for below clarity for the readers.

Why is it important for children to wear UV-protective sunglasses compared to adults?

Kids' eyes are more susceptible to UV damage compared to adults because their lenses are more transparent, which permits a larger amount of harmful rays to reach the retina. As children typically spend more time outside, their overall exposure to UVR is greater, heightening the chance of developing early cataracts and MD in the future. Using UV-blocking sunglasses from an early age helps protect their growing eyes and minimizes the risk of vision issues later on.

How does altitude and geographical location influence the level of UV exposure to the eyes?

Exposure to UVR in the eyes elevates with increased altitude due to the less dense atmosphere absorbing a reduced amount of radiation, resulting in approximately 10-12% additional UV for every 1,000 meters ascended. The geographic location plays a role as well-areas nearer to the equator experience stronger and more intense UV rays throughout the year. Furthermore, surfaces that reflect light, such as snow, water, and sand, can amplify exposure, highlighting the importance of adequate UV protection for the eyes in these settings.

Figure 9: Level of UV exposure to the eyes.

What materials are commonly used in sunglass lenses to block UV rays (e.g., polycarbonate, CR-39)?

Sunglass lenses are constructed from various materials, each possessing distinct UV-blocking abilities and optical characteristics:

Polycarbonate

This material is lightweight and resistant to impact, naturally filtering out 100% of UV rays without needing extra coatings. It is frequently utilized in eyewear for children and sports sunglasses for enhanced safety.

CR-39 (Columbia resin 39)

A lightweight plastic lens material that provides excellent optical clarity. Although it doesn't naturally block all UV rays, it is typically treated with special coatings that absorb UV rays.

Glass (Crown glass)

Offers superior optical clarity and is highly scratch-resistant, but it tends to be heavier and can break easily, making it less suitable for children's eyewear. UV protection is incorporated by adding chemical filters during the manufacturing process.

Trivex

This material is comparable to polycarbonate, being lightweight and impact-resistant while offering built-in 100% UV protection alongside excellent optical clarity.

These materials, particularly when used in combination with UV-blocking coatings or treatments, ensure effective defense against harmful UVA and UVB radiation.

What is photochromic lens technology and how does it protect against UVR?

Photochromic lens technology incorporates unique molecules within the lens that automatically darken when they come into contact with UV rays and revert to a clear state indoors. This changing tint helps safeguard the eyes by blocking harmful UVA and UVB radiation while minimizing glare in bright conditions. Because the lenses adapt according to UV exposure, they offer ongoing protection and comfort, eliminating the need to alternate between regular eyewear and sunglasses.

Why is UV protection important even on cloudy days?

It's crucial to have UV protection even on overcast days since as much as 80% of UV rays can still pass through clouds. This indicates that the eyes remain susceptible to damaging radiation even when the sun is obscured. Extended exposure without adequate protection can elevate the risk of eye injuries like cataracts and photokeratitis, which is why wearing sunglasses with UV protection, is essential throughout the year.

How can improper sunglasses (without certified UV protection) actually increase the risk of UV damage?

Wearing sunglasses with dark lenses that lack certified UV protection can lead to increased UV-related harm. The deep tint causes the pupils to open wider, letting in a higher amount of UV rays. If there is no adequate UV filtering, this added exposure heightens the chances of developing cataracts, retinal damage, and other long-term eye issues. Lenses with certified UV protection mitigate this risk by blocking dangerous radiation while effectively reducing glare.

How does the refractive index of sunglass lens materials influence both UV filtration and optical clarity?

The refractive index of materials used for sunglass lenses plays a crucial role in how light is bent as it travels through the lens, affecting both visibility and protection from UV rays. Materials with a higher refractive index can be designed to be thinner and lighter while still providing effective UV filtration when treated with compounds that absorb UVR. However, excessively high refractive indices may lead to distortions or compromise optical clarity if not designed properly. The right choice of materials and coatings ensures a balance between blocking UV rays and providing clear, comfortable vision.

Polarized and UV protection lens which company manufacturing these lases and where?

Several companies manufacture polarized and UV protection lenses. Some popular brands include Essilor, and Luxottica, which owns brands like Ray-Ban and Oakley. These companies have manufacturing locations across the globe, including Italy, India, and other countries. Additionally, companies like Yash Optics and Lens Limited (India) specialize in manufacturing various types of optical lenses, including those with UV protection.

PROTECTION FROM HARMFUL SOLAR RADIATION AND UVR

Ski goggles, hats with wide brims, contact lenses with UV filters, glasses with coatings that block UV rays, sunglasses with UV filters, and skiing goggles are just some of the many options available for shielding one's eyes from the potentially damaging effects of the Sun's rays.[14] Other options include wearing glasses with coatings that block UV rays. It is to the user's advantage to link as many of these various channels all at once as possible. Nevertheless, the tactic that has shown to be the most effective is to avoid being in the Sun at those periods of the day when the Sun's intensity is at its

highest.[15] Eye protection needs to be significant in mountainous locations with high elevations and in situations with powerful light reflections, such as when there is snow or sand present. This includes any environment where there is a combination of these two factors [16]. These requirements were established by the American national standards institute. Contact lenses provide an extra layer of protection since they cover not only the cornea but also its limbus. This complete coverage of the cornea helps prevent infections. When a person wears dark sunglasses, their pupils do not contract, which stops the eyes natural defense system from working.[17,18-25] The vast majority of sunglasses let sunlight that has been reflected into the eye from three distinct directions: from the top, from the bottom, and from the sides. It is essential to pay close attention to the shape of the sunglasses that you choose. Because they provide the highest level of all-around protection for the eyes, the ones that have a body that extends toward the temples are the ones that should be used. Experiments and studies have shown that wearing a hat with a wide brim may reduce the quantity of UV light that reaches a person's eyes by a factor of four.[6,26]

OBSERVATIONS

The reviewed studies indicate that prolonged exposure to solar UVR has significant effects on ocular health. Evidence consistently links UV exposure with increased risks of photokeratitis, pterygium, and cortical cataract, particularly among outdoor workers and travellers. The cornea and lens were identified as the most vulnerable structures due to their direct exposure to UVB rays. In contrast, macular damage was more associated with cumulative exposure and aging. Studies also highlight that consistent use of UV-blocking sunglasses and wide-brimmed hats provides effective protection, yet public awareness and compliance remain low in many regions. Moreover, variations in latitude, occupation, and behavior influence exposure levels, emphasizing the need for region-specific prevention strategies.

DISCUSSION

The findings from this review show that SR, particularly UV light, has both beneficial and harmful effects on human health. While limited sun exposure is essential for vitamin D synthesis and overall well-being, excessive or unprotected exposure can cause serious damage to ocular tissues. Studies consistently report a strong link between chronic UV exposure and conditions such as photokeratitis, pterygium, and cataract formation. The evidence also suggests that the cornea and lens act as the primary filters for UVR, which protects the retina but increases the risk of anterior segment damage. Despite the availability of protective eyewear and public health guidelines, awareness and compliance remain low, especially among outdoor workers in tropical and high-altitude regions. Furthermore, variations in lifestyle, environmental conditions, and occupational exposure make it difficult to establish uniform global prevention strategies. Future research should focus on standardizing UV exposure measurements, improving protective device design, and increasing public education to minimize long-term ocular damage due to SR. There are a variety of eye conditions that have been connected to UVR exposure. Short-term exposure to UVR has been shown to cause photokeratitis and photo retinitis. In contrast, long-term exposure to UVR has been shown to cause CDK, cataracts, pterygium.[27]

Limitations

This review is based on the current information and research available. The studies we examined were conducted in various ways, across different regions, and involved varying sample sizes, which may influence the comparability of the results. A significant number of these studies were observational in nature, meaning they cannot establish a direct causal link between sunlight exposure and specific ocular issues. Additionally, the levels of UVR and the methods used to assess them were inconsistent across the studies. Some recent or localized research may not have been taken into account, and lifestyle changes, such as increased screen time or improved protective eyewear, may also impact the outcomes. Thus, while this article provides a comprehensive overview of the existing knowledge, further long-term and experimental studies are necessary to validate the conclusions.

CONCLUSION

UVR can harm the eyes in many ways. Short-term exposure can cause problems like photokeratitis (sunburn of the eye) and photoretinitis. Long-term exposure may lead to serious conditions such as cataracts, pterygium, corneal diseases, skin cancers on the eyelids, and sometimes age-related MD. Since the damage from UVR adds up over time, protecting children’s eyes is especially important because they are more sensitive and spend more time outdoor and snow area. Even on cloudy days, UV rays still reach the eyes. Protection can be done by wearing hats, proper clothing, sunglasses, or contact lenses that block UVR. To reduce the detrimental effects of UVR, it is highly advisable to implement protective actions. Extended exposure to SR can adversely impact not only eye health but also the skin and the immune system.

Recommendations

According to the results of this review, it is advisable to increase awareness regarding the detrimental effects of excessive SR on eye health. Public health initiatives should promote protective practices like wearing UV-blocking sunglasses, using wide-brimmed hats, and minimizing direct sun exposure during peak hours. Eye care professionals ought to inform patients about the dangers of prolonged UV exposure and emphasize the

necessity of routine eye examinations for the early identification of damage. Future research should aim at conducting long-term studies using standardized approaches to gain a deeper insight into the relationship between SR and ocular diseases. Additionally, governments and health organizations should advocate for policies that support public education, establish standards for protective eyewear, and ensure occupational safety for workers who spend considerable time outdoors.

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