The Benefits of Early Ocular UV Protection in Children: *An Overview*

Steven J. Lichtenstein, MD

Introduction

Numerous epidemiologic studies have documented the harmful effects of sunlight on the skin and the need for regular ultraviolet (UV) skin protection, particularly in children.[1] No less compelling, but less broadly communicated, are the ocular risks associated with sun exposure and the need for eye protection starting from childhood. This article reviews the literature on the damaging effects of sunlight on the eyes and examines the evidence for the use of protective lenses at an early age. Current protective lens options and selection guidelines are also presented.

Children and Sunlight

Investigations conducted over the last 30 years have established that many of the serious ocular diseases associated with aging are at least partially a result of cumulative exposure of the eyes to the sun over a lifetime, and in particular to UV and higher-energy visible light.[2-8] Vision experts agree that children are especially vulnerable to eye damage from UV radiation and have long recommended the use of protective lenses for all children whenever they are exposed to the sun.[4,7,9-12] Some experts suggest that the use of polycarbonate photochromic lenses provide more protection than traditional fixed-tint polycarbonate lenses against higher energy visible light.

Several factors contribute to this increased ocular vulnerability in children. First, under normal circumstances, children spend more time outdoors than adults, particularly during the summer. As a result, the average child receives approximately three times the annual UV dose of the average adult and up to 80% of lifetime UV exposure before age 20.[1,10] Second, the crystalline lens of children transmits more visible and UV radiation to the retina than does the lens of adults. As a result, over 75% of UV radiation is transmitted by lenses in subjects under 10 years of age, compared with 10% in those older than 25 years.[11,13]

UV Radiation and Sunlight

Energy particles known as photons travel through space in the form of visible and invisible light waves.[2,10] As the energy content of the light waves increases, so does the potential for ocular injury.[3] Ultraviolet light ranges in wavelength from 100 to 380 nm; visible light ranges from 380 to 700 nm; and infrared light ranges from 700 to 1400 nm (International Standards Organization).[16] The amount of energy light contains is inversely proportional to its wavelength.[10] The hazardous effects of sunlight on the eye are strictly correlated with its energy content.[3] UV light has more energy than visible or infrared light and thus has greater potential for biological damage.[10]

The ultraviolet spectrum consists of UVV waves (100 to 190 nm), UVC (190 to 280 nm), UVB (280 to 315 nm), and UVA (315 to 380 nm). UVC waves are toxic to human tissue but are almost completely absorbed by the ozone layer and do not reach the earth's surface.[2,5,10] However, as the earth's protective ozone layer decreases, health risks from exposure to UVC waves may become a concern.[2] The UV light waves that cause eye damage are UVA and UVB, although the actual dose that causes injury is not known.[2,12,15] Higher-energy visible blue light can also have harmful effects, although less is known about blue light and the damage it causes.[11]

Ocular Damage and UV Radiation

Ultraviolet radiation comes from direct (ambient) sunlight or from reflected (incidental) light.[2] The amount and quality of ambient light we receive depends on several factors including time of day, time of year, geographic location and the actual physical surroundings. Ambient UV light is most intense between 9 am and 3 pm and during the summer, when the sun is directly above us. It is considerably more intense at higher altitudes and at latitudes closer to the equator. More time spent outdoors increases exposure to ambient UV radiation.[2,10]

Sunlight reflected off environmental surfaces is a far more important source of eye damage from UV radiation than ambient sunlight.[2,16] In fact, 50% of the UV radiation the average person receives is from reflected or scattered UV radiation.[14] Environmental surfaces such as snow, water, and sand are major sources of reflected UV light. Fresh snow reflects 85% of UV radiation, almost three times as much as any other environmental surface and can cause "snow blindness."[2,16] Conversely, grass reflects only 1% or 2% of UV radiation.[16] Thus, the presence of green foliage in the environment significantly reduces the amount of reflected UV radiation the eye receives.[14,16] (See table 1).

Figure 1. The Spectrum of Light Waves

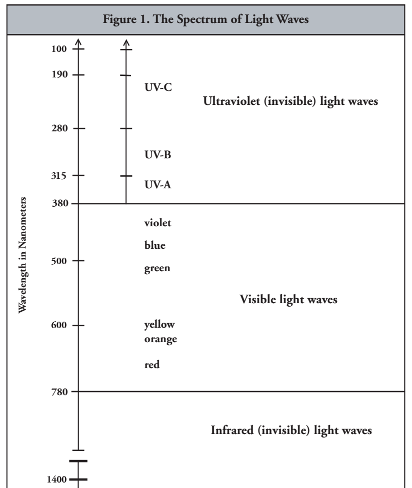


Table 1. The Amount of Ultraviolet Reflected from Some Environmental Surfaces into the Eye*

Highest amount of reflected ultraviolet light	Snow sea with white foam white house paint light, dry beach sand aluminum water without foam concrete pavement asphalt
Lowest amount of reflected ultraviolet light	unpainted wood soil green lawn, trees, flowers

*Adapted from Sliney DH, 1986; 27:781-790.

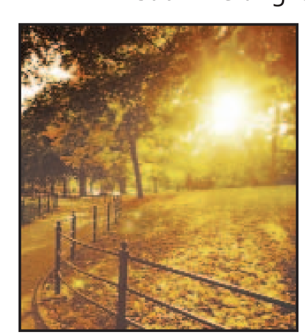
Much of the UV radiation that reaches the eye is absorbed by its structures.[10,17] In general, the cornea absorbs wavelengths <300 nm, while the crystalline lens absorbs light <400 nm. Importantly, while the light absorption properties of the cornea remain constant throughout life, the lens' properties change significantly between infancy and adulthood.[10] The natural crystalline lens of a young child transmits light at 300 nm, whereas that of an older adult begins at 400 nm and peaks at 575 nm.[10] Thus, as noted earlier, because both the lens and the retina in children receive many hours of exposure to large amounts of short wavelength radiation, they are at increased risk of long-term injury from sunlight.[1,12,18]

Photosensitivity or Photophobia

Most children do not experience photophobia or photosensitivity, although it may be an occasional problem for fair-haired, blue-eyed children especially during the infant and toddler stages. In general, however, unless a child requires prescription spectacle correction, the use of good, over-the-counter UV-blocking lenses provides sufficient protection. However, if a child becomes acutely photophobic, this usually indicates a serious condition of inflammation inside the eye. Thus, photophobia should be considered a symptom that requires prompt evaluation and not masked with dark glasses or tinted lenses. For children who do require a prescription, a lens with 100% blocking of UVA/UVB should be prescribed. Variable tint or photochromic lenses should also be considered. Importantly, however, the use of photochromic lenses does not cause or contribute to photophobia in any way. If photophobia occurs in a child wearing spectacles with photochromic lenses, then an inflammatory condition may be present or the lens prescription or spectacle fit is at fault.

Glare

Glare is the loss of visibility or annoyance or discomfort produced by a luminance in the visual field greater than the illuminance to which the eyes are adapted. Glare can come directly from a light source, i.e., when facing the sun, or glare can be reflected off surfaces, for example, sand or snow. Glare does not usually pose a problem in young children, and most do not experience difficulties with contrast fatigue. Glare presents much more of a problem for young adolescents and teenagers when they are reading and for teenagers when they start driving.



Mechanisms of Injury

Studies of light exposure have focused on two principal mechanisms of ocular damage: thermal and photochemical.[3,6] Thermal damage occurs when radiant energy is absorbed in the lens or retina and converted to heat sufficient to cause photocoagulation.[3,6] Exposure duration for thermal damage varies between 100 milliseconds and 10 seconds.[6,11] Thermal injury is less common than previously thought. Many injuries such as solar retinitis, once believed to be the result of thermal damage, are now known to be photochemical in origin.[10] Photochemical damage occurs when ocular tissue absorbs radiation at levels well below those needed to produce thermal damage, with exposure durations ranging from >10 seconds to days.[11] Light sources with the greatest potential for causing photochemical damage have a high percentage of UVA.[11] A chief characteristic of photochemical injury is reciprocity. That is, relatively low irradiance (dose rates) can cause injury in several hours, whereas very high irradiances can cause injury in seconds or minutes.[6]

Photochemical damage to ocular structures, such as the lens and retina, is mediated in part through the harmful effects of short-lived molecules known as free radicals, produced by processes that involve light absorption and reduction of oxygen. Free radicals have unpaired electrons in their outer orbital rim, making them reactive with other molecules and toxic to ocular tissues. Singlet oxygen, hydroxyl or superoxide radicals can destroy essential components of biological membranes, such as polyunsaturated fatty acids (concentrated within photoreceptor cell membranes) or inactivate important enzymes leading to cell deterioration. Free radicals can also depolymerize hyaluronic acid and induce degradation of collagen, such as that found in the vitreous humor of the human eye. The retina's light-absorbing ability, together with its oxygen requirements increase the likelihood it will also suffer damage from photochemical effects and associated free radicals.[11]

Eye Pathology Caused by UV Radiation

All of the structures of the eye can be damaged by chronic or high-dose exposure to UV radiation, as described below.[2] As noted earlier, children are especially vulnerable to the damaging effects of UV radiation due to the amount of time they spend outdoors exposed to the sun as well as to the immature nature of the crystalline lens, which transmits over 75% of UV radiation in children under 10 years of age, compared with 10% in those older than 25 years.[11,13]

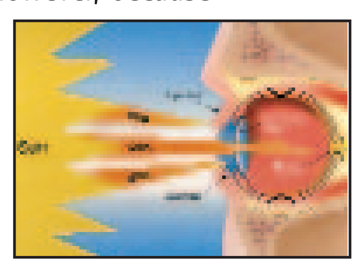
Eyelids, Conjunctiva, and Cornea

UVB radiation is associated with the development of skin cancers of the eyelid.[5,10] Basal cell carcinoma is the most common malignant tumor of the eyelid and represents about 90% of all eyelid malignancies. Squamous cell carcinoma accounts for approximately 9% of periocular skin tumors and appears most frequently in people who have had chronic sun exposure and are fair skinned. Both UVA and UVB radiation have been implicated in the development of squamous cell tumors.[10] Unlike periocular skin cancers, the risk of damage from UV radiation to the eye itself does not correlate with skin pigmentation. Thus, people of all complexions and eye colors, especially children, are at risk for ocular damage from UV radiation and require preventative protection.[19] Chronic exposure to UV radiation is associated with various changes on the surface of the eye such as pinguecula, a triangular patch of mucous membrane growing involving the conjunctiva at the inner canthus of the eye; pterygia, a similar entity found on the cornea; and corneal injuries such as climactic droplet keratopathy and keratitis (an inflammation of the cornea).[2,5,10]

Lens

Perhaps the best known ocular pathology associated with UV radiation is cataracts, which represent decreased transparency of the ocular crystalline lens or its capsule.[3,10] Although many factors may contribute to cataract formation, such as advancing age, heredity, diabetes and trauma, numerous epidemiologic studies support the conclusion that the development of cataracts is positively correlated with cumulative hours of solar exposure.[3, 4, 6, 7, 10, 11, 16, 17]

As noted earlier, UV exposure during childhood, when the crystalline lens of the eye is virtually transparent and offers no protection, appears to account for much of the cumulative damage. One study, for example, showed that a doubling of the cumulative UVB exposure increases the risk of cortical cataract by 60%; and another found a dramatic increase in brunescent cataracts with decreasing latitude.[5,11] However, because we do not know the intensity, duration, or rate of UV exposure needed to produce a cataract in humans, protection is always needed, especially during childhood when the crystalline lens provides no protection against retinal damage.[15,17] The lens is exposed to UVA radiation in the central or nuclear region, where light waves converge.[2] Elements in the lens proteins, such as tryptophan particles, absorb this intense UV radiation and undergo a series of gradual photo-oxidative changes that cause the lens to become more opaque and yellowish brown in color. This commonly results in a brunescent cataract.[2,11] Ironically, studies suggest that lens discoloration may help protect adult retinas from cumulative photochemical damage, since it effectively blocks 90% of UVA radiation that enters the eye.[11]



Retina

The relationship between exposure to UV radiation and retinal damage is less clear.[5] Recent research suggests that cumulative exposure to the sun's higher energy visible light may contribute to the development of age-related macular degeneration (AMD), the leading cause of legal blindness in the US in people over the age of 65.[5,10] In AMD, blood vessels gradually encroach into the macula, resulting in a devastating loss of central vision.[2,10] Reports of a decreased incidence of AMD among patients with nuclear cataracts, which prevent light from reaching the retina, lend some support to this theory.[10] Studies also suggest that blue-light retinal injury (photoretinitis) can result from viewing either an extremely bright light for a short time or a less bright light for longer periods.[11,16]

Benefits of Protective Lenses

Today, most vision experts agree that one of the simplest and efficient ways to prevent or delay the onset or progression of various eye diseases is the use of appropriate fixed-tint, or photochromic protective lenses designed to prevent UV radiation and higher energy visible light from reaching the eyes, beginning in childhood.[2-7, 9, 10, 13-16, 17, 20] According to one investigator, use of tinted lenses or sunglasses that block all UV radiation and severely attenuate high-energy visible radiation will slow the pace of ocular deterioration and delay the onset of age-related disease. A 20-year delay would practically eliminate these diseases as significant causes of visual impairment in the United States.[3] Not all fixed-tint lenses block 100% UV radiation. The attenuation of visible light that occurs when a fixed-tint lens is worn may dilate the pupil relative to wearing no lens. This may result in more UV entering the eye with a fixed-tint lens than without it. In contrast, photochromic polycarbonate lenses such as those produced by Transitions Optical, Inc. block 100% UV radiation and reduce visible blue light.[21]

Sunglass Concerns

A review of the literature on sunglasses and protective lenses and its impact on children, reveals significant variance in the quality of over-the-counter sunglasses over the last three decades. There has also been an ongoing concern among eye care professionals that necessary standards do not yet exist or are not strictly adhered to, especially with regard to protective lenses designed for children.[6, 7, 10, 13-16, 17, 20]

Several investigators have questioned whether the use of some over-the-counter sunglasses may actually be harmful, either by depriving the wearer of theoretical "health benefits" of UV exposure, such as increased vitamin D synthesis; affecting color perception; or by increasing the amount of UV light that actually enters the eye. Some have also expressed concern that ocular damage may result if using polarized lenses which reduce glare, can also reduce the associated instinct that causes one's gaze to be averted from a brilliant light source such as the sun.[8,12,16, 22] As Sliney points out in his recent review, however, "it is frankly difficult to understand some of the arguments." He observes, for example, that concerns about tinted lenses and color perception "ignore the fact that the solar spectrum constantly changes, and our eyes adapt selectively to a significant change in the visible spectrum."[16] Other claims, such as the impact on vitamin D synthesis are largely "red herrings," since the amount of vitamin D the body needs can be synthesized after less than 10 minutes of an individual's skin exposure to daylight. Vitamin D is also readily available in the foods we eat and in dietary supplements, which can safely and easily correct a deficiency without posing any ocular risk.

The more serious concern is that the use of tinted lenses disables the naturally protective squint reflex and causes pupil dilation, allowing larger amounts of UV light to enter the eye than if the person wore no sunglasses at all.[16] This seems to occur only with tinted lenses that have non–UV-blocking capabilities.[2]

Protective Eyewear Standards and Guidelines

The American National Standards Institute (ANSI) has issued a consensus standard for sunglasses and "fashion eyewear," which requires <1% transmission at wavelengths <310 nm. Different shades are recommended for the beach and boating. The most recent Sunglass Association of America (SAA) standards are less strict and recommend that all sunglasses block at least 70% of UVB and at least 60% of UVA to be adequately protective.[23]

Significantly, however, both the ANSI and SAA standards are voluntary and fall short of the American Academy of Ophthalmology recommendation that protective lenses should block 99% of all UV radiation.[10,16] As Sliney observes, "the dominant view in ANSI has been that sunglasses are for fashion and really not needed for eye protection..."[15] This philosophy differs from that of countries such as Australia or Israel, where formal guidelines have been developed and communicated to the public.[5,16,18]

Recent studies demonstrate a significant improvement in the quality of over-the-counter protective lenses over the last 20 years, although there is very little specific attention given to protective lenses for children. Figure 1 summarizes the most recent selection guidelines and recommendations for use of appropriate protective lenses. Essentially all protective fixed and variable tint lenses manufactured today block at least 95% of UVB radiation and all those with plastic lenses and most with glass lenses block at least 90% of UVA.[2] As noted previously, some photochromic lenses block 100% of both UVA and UVB radiation.[7,23] Young children are advised to wear shatter-resistant protective lenses with sturdy frames. The use of a wide-brimmed hat that effectively shields the face can offer additional protection from UV radiation.[2,23]

Benefits of Photochromic Lenses for Children

From a practical point of view, some consideration must also be given to issues of convenience when encouraging the use of protective eyewear in children. Since proper protection from UV radiation must often extend from the early morning hours until dusk, it would appear that polycarbonate photochromic lenses may provide a good option for many active children.

For the ametropic child who must wear corrective spectacles, for example, polycarbonate photochromic lenses allow him or her to use one pair of spectacles for many purposes. There is no need to change spectacles to play in outdoor sports, for example. And, as noted earlier, properly fitted photochromic lenses carry no risk of photophobia or photosensitivity.

The full-time UV radiation and impact protection these lenses provide also accommodate the indoors-outdoors life of many active children with normal vision.

Improved Awareness Needed

Perhaps the most important message coming from the literature is the need for improved awareness about the ocular risks associated with sun exposure. This was evident from the results of a recent Australian study of adolescents aged 13 to 17 years, nearly three-quarters (71%) of whom admitted owning sunglasses. Although most subjects said they knew that sun was harmful to their eyes, the majority (81%) said they wore sunglasses only occasionally, or not at all.[4] Another recent industry-sponsored study, in the United States, found that although 92% of those surveyed knew that the UV radiation causes skin damage and 79% knew that it leads to skin cancer, only 6% knew that UV radiation could cause eye disease.[24]

Educating Parents

Parents have the primary responsibility for the health and well being of their children. We have seen that encouraging parents to practice early protective behaviors in areas such as UV skin protection and many aspects of vision care are effective and can positively impact the outcome of many serious diseases.[14, 25] However, the same conscientious parents who would not consider allowing their children to spend time at the beach without a generous application of sunblock to protect their skin, may allow their children's eyes to go unprotected from the sun because of their lack of awareness.

Thus, we must now focus our attention on educating parents on the ocular hazards of UV radiation and the need to protect young eyes from its cumulative effects. Increased parental awareness and education can begin even before the birth of their child — as part of the plan for a healthy life. Parents should also be encouraged to talk to their young children and teenagers about sun safety on a regular basis and lead by example by wearing protective lenses whenever they are exposed to the sun.[14]

Conclusions

Substantial amounts of evidence demonstrate that a significant portion of serious ocular diseases, principally those connected with older age, are at least partially a result of cumulative exposure of the eyes to the sun's UV radiation over a lifetime, beginning in childhood. Evidence also suggests that the use of fixed or variable tint protective lenses that block UV radiation and reduce higher-energy visible light from reaching the eyes can help to prevent or delay the development of these diseases. The appropriate age to begin using protective lenses is during childhood, and they should be used every time an individual is exposed to the sun. Although a variety of options exist, the best option would be fixed-tint or photochromic protective lenses that block 100% UVA/UVB radiation.

References

1. Truhan AP. Sun protection in childhood. *Clin Pediatr.* 1991; 30:676-681.

2. Memmer MK. Preventing eye damage from the sun's ultraviolet light: what health educators should teach. *Health Education.* 1989;20(7):42-47.

3. Young RW. Sunlight and age-related eye disease. *J Natl Med Assoc.* 1992;84:353-358.

4. Lee GA, Hirst LW, Sheehan M. Knowledge of sunlight effects on the eyes and protective behaviors in adolescents. *Ophthal Epidemiol.* 1999;6:171-180.

5. Cains SE. Royal Australian College of Ophthalmologists policy statement on sunglasses. *Med J Australia.* 1992;157:343-344.

6. Sliney DH. Eye protective techniques for bright light. *Ophthalmology.* 1983;90:937-944.

7. Garber N. Ocular risks from sunlight exposure. *J Ophthal Nursing & Technol.* 2000;19:13-25
.

8. Weale RA. Sunglasses–an ocular hazard? *Br J Ophthalmol.* 1986;70:769-771.

9. Silverstein MW. UV protection [Letter to the Editor]. *Optometry.* 2002;73:466.

10. Young S, Sands J. Sun and the eye: prevention and detection of light-induced disease. *Clin Dermatol.* 1998;16:477-485
.

11. Fishman GA. Ocular phototoxicity: guidelines for selecting sunglasses. In: Perspectives in refraction. Rubin ML, ed. *Surv Ophthalmol.* 1986;31:119-124.

12. Diddie KR. Do sunglasses protect the retina from light damage? *WJM.* 1994;161:594.

13. Werner JS. Children's sunglasses: caveat emptor. *Opt Vision Sci.* 1991;68:318-320.

14. Baldy C, Greenstein V, Holopigian K, Seiple W, Stenson S. *Light, Sight, and Photochromics.* Pinellas Park, Florida: Transitions Optical Inc. 2002.

15. Rosenthal FS, Safran M, Taylor HR. The ocular dose of ultraviolet radiation from sunlight exposure. *Photochem Photobiol.* 1985;42:163-171.

16. Sliney DH. Photoprotection of the eye - UV radiation and sunglasses. *J Photochem Photobiol.* 2001;64:166-175.

17. Magnante DBO, Miller D. Ultraviolet absorption of commonly used clip-on sunglasses. *Ann Ophthalmol.* 1985;17:614-616.

18. Belkin M. Sunglasses for children as a preventive health measure [in Hebrew]. *The Goldschlager Institute for Ophthalmic Research.* 1993;124:367-370.

19. The World Health Organization. The Intersun Global UV Project. Available at: http://www.who.int/docstore/peh-uv/IntersunPresentation/sld010.htm. Accessed April 5, 2004.

20. Evans PY. What to tell your patients about sunglasses. *Medical Times.* 1973;106:103-106.

21. Data on file. Transitions Optical, Inc.

22. Clark BAJ. Polarizing sunglasses and possible eye hazards of transmitted radiation. *Am J Optom Arch Am Acad Optom.* 1969;46:499-509.

23. Danger: ultraviolet light! *Insight: Journal of the American Society of Ophthalmic Registered Nurses.* 2002;27:80-81.

24. International Communications Research Survey. From April 10 to April 14, 2002.

25. The American Association for Pediatric Ophthalmology and Strabismus Committee (AAPOS). Eye care for the children of America: The American Association for Pediatric Ophthalmology and Strabismus. *J Pediatric Ophthalmol Strabismus.*1991;28:64-67.

Transitions®

Sponsored by Transitions Optical, Inc.