Ocular Ultraviolet B Exposure and Lens Opacities: A Review

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A review of the epidemiological evidence linking cataract and chronic ultraviolet B radiation (UV-B) exposure was carried out. The majority of ecological studies suggest an increased risk of cataract with residence in areas of greater ambient UV-B. Studies which have measured personal ocular exposure to UV-B have found that even low exposures, as encountered in the general populations of developed countries, confer a measurable risk of cortical cataract. There is sufficient evidence of increased risk of cortical lens opacity with ocular exposure to UV-B to warrant public health messages about simple measures to decrease exposure.

Despite advances in cataract surgery, and programs to reduce blindness from cataract, cataract remains the leading cause of visual loss in the world. Efforts to determine factors which are cataractogenic have been a major thrust of epidemiological research for decades, in the hope of finding ways to prevent or delay the progression of cataract. Such factors have the potential to be the basis for preventive strategies. Among the factors studied, ocular exposure to sunlight, particularly Ultraviolet B (UV-B) radiation, has been of considerable interest and especially now in the era of ozone depletion and potential for even greater exposure to UV-B. The purpose of this review is to provide an update of current knowledge of the relationship of exposure to UV-B and risk of cataract in populations, and identify further research priorities.

BIOLOGICAL PLAUSIBILITY

Acute, high dose exposure to UV-B in humans causes unequivocal ocular damage, including retinal damage (solar retinopathy) and corneal damage (arc welders flash burns or "snow blindness"). However, the relationship of chronic, low dose exposure, as typified by sunlight exposure, to ocular damage has been more difficult to assess. Yet, there is biological plausibility to suggest that such exposure can cause lens damage.

The cornea transmits UV-B and UV-A to the lens, which is known to absorb both. In fact, only minute amounts of UV-B, and to a greater extent UV-A, are transmitted to the retina. Thus, the potential for photo toxic reactions with lens constituents is present. Animal studies have documented changes in lens clarity with short term, high intensity exposure and chronic exposure to UV-B. Anterior segment, or cortical, opacities were the most common type observed. Thus, there is reason to believe that UV-B may be cataractogenic, but uncertainty as to whether the doses usually encountered in sunlight by the general population are important.

ECOLOGICAL STUDIES

Early research into the association between cataract and sunlight used an ecological approach. That is, the exposure was defined as some measure of ambient levels of sunlight or UVB in the area of residence. Three examples of this approach are the work of Hollows and Moran in Australia, Brilliant et al, in Nepal, and Hiller et al, in the United States. In Australia, a National Survey was carried out where cataract status was determined clinically in a population of 64,307 Australian aborigines. The whole of Australia was divided into five zones according to the ambient levels of UV-B. Within age categories, the prevalence of cataract increased with increasing...
ambient UV-B. Similarly, a National Blindness survey was carried out throughout Nepal, and average daily sunlight hours determined, accounting for shading by mountainous terrain. The prevalence of cataract was four times as high in areas where sunlight hours were maximal, compared to sites where ambient levels were seven hours or less. In the third study, multiple examiners determined cataract status of over 10,000 participants in the National Health and Nutrition Examination Survey of the United States. Ambient levels of annual sunshine hours were determined in 35 geographic regions, and the prevalence of cataract calculated. Independent of other factors, the risk of cataract was greater in sites with more sunlight, and cortical cataract was the specific type identified.

In all three studies, ambient exposure at place of residence was the surrogate measure of cumulative ocular exposure. For the populations in Australia and Nepal, such a surrogate measure may be reasonable because there are likely to be few personal behaviors that severely modify exposure. In the United States, however, time actually spent outside, use of glasses or hats, and migration are enormous modifiers of personal exposure. Thus, there is significant variations in exposure which is not captured by place of residence, and which must be taken into account when modeling personal exposure.

**MODELING PERSONAL OCULAR EXPOSURE**

Later studies, recognizing the need to bring exposure to a personal level, attempted to develop models of personal exposure in a number of ways. Some studies tried to determine a history of work or leisure time spent outside, or developed residential histories to account for migration; others reported on use of glasses when outside. Results from these studies were mixed, in part due to the imprecision in definition of cataract, and in part due to imprecision in ascertaining exposure (Table 1).

The Chesapeake Bay Waterman Study was the first investigation to develop a detailed model of personal ocular exposure to UV-B, and correlate it with a detailed, standardized system for assessment of cataract. The watermen, fishermen by trade, are a highly exposed occupational group with strong modifiers of exposure in their use of glasses and hats, and time spent outdoors. Field measurements were carried out on this group to determine the ratio of ocular UV-B to ambient levels, and the degree of modification to ocular exposure when wearing hats and/or glasses. Questionnaire data were collected on job history of time spent outdoors, and use of glasses and hats since age 16. An increased risk of cortical opacity was found with increasing average annual ocular UV-B exposure. No risk was found associated with nuclear opacity. The increased risk was apparent with exposure in all age groups (from age 16 on) suggesting there is no one age which is more vulnerable to lens damage from UV-B. This study provided the strongest evidence to date that cumulative exposure to UV-B in sunlight was associated with cortical opacity.

<table>
<thead>
<tr>
<th>Author</th>
<th>Population</th>
<th>Assessment of Cataract</th>
<th>Exposure Variable</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taylor et al. (14)</td>
<td>838 fisherman</td>
<td>clinical, by type</td>
<td>Personal Exposure</td>
<td>† risk cortical</td>
</tr>
<tr>
<td>West et al. (16)</td>
<td>2520 pop'n age 65-84</td>
<td>photo, by type</td>
<td>Personal Exposure</td>
<td>† risk cortical</td>
</tr>
<tr>
<td>Cruickshanks et al. (15)</td>
<td>771 pop'n age 40+</td>
<td>photo, by type</td>
<td>hxs of residency</td>
<td>† risk cortical for males</td>
</tr>
<tr>
<td>Hiller et al. (8)</td>
<td>NHANES 1971-1972, 2225</td>
<td>clinical, multiple ex-</td>
<td>hxs residency, Amb.</td>
<td>† risk cortical</td>
</tr>
<tr>
<td>Dolezal et al. (10)</td>
<td>160 matched cataract surgery cases and controls (mostly nuclear)</td>
<td>chart review</td>
<td>UV-B</td>
<td></td>
</tr>
<tr>
<td>Coleman et al. (9)</td>
<td>113 cases, 161 controls</td>
<td>chart review</td>
<td>residency plus time spent outdoors</td>
<td>† risk cortical, PSC (but N.S.)</td>
</tr>
<tr>
<td>Hollows, Moran (6)</td>
<td>63,798 Aborigines</td>
<td>Clinical-all</td>
<td>UV-B zones of</td>
<td>† Prevalence of cataract, † UV-B</td>
</tr>
<tr>
<td>Brilliant, et al (17)</td>
<td>27,785 residents of Nepal</td>
<td>Clinical-all</td>
<td>Australia Average daily sunlight hours</td>
<td>† prevalence of cataract, † sunlight</td>
</tr>
<tr>
<td>Leske, et al. (11)</td>
<td>435 controls, 1380 cataract cases</td>
<td>photo (by type)</td>
<td>Questions on working in sunlight</td>
<td>no association</td>
</tr>
<tr>
<td>Ital-Amer Study (12)</td>
<td>1008 cataract cases, 469 controls</td>
<td>photo-by type</td>
<td>activities in sunlight, hat use</td>
<td>† risk cortical with time in sun</td>
</tr>
<tr>
<td>Wong, et al. (13)</td>
<td>367 (54%) age 55-74 in fishing village</td>
<td>Clinical</td>
<td>&quot;Lifetime exposure to sunlight&quot;</td>
<td>† risk cortical, † exposure to sun</td>
</tr>
</tbody>
</table>
However, questions remained about the risk associated with the lower exposure likely to be encountered by the general population. Moreover, the waterman study population was composed of white males, with no data on possible racial or gender differences. Another study, carried out in a white population in Wisconsin, found an increased risk of severe cortical opacities associated with average ambient UV-B at the place of residence; however, no association was found among women\(^{15}\). The exposure among women in this study showed little dispersion and an association may have been difficult to detect with such low levels.

To address the question of ocular exposures likely to be encountered in the general population, and the possible risk of cortical opacities, a population based study of 2520 older Americans was carried out in Salisbury Maryland\(^{16}\). The status of the lens was assessed, using photographic documentation and type of opacity determined using the Wilmer grading scheme\(^{17}\). A model of ocular exposure was developed, similar to the one used in the Chesapeake Bay waterman study, but more generalizable\(^{18-20}\). The model for personal ocular exposure to UV-B was as follows:

\[
H = R_o \left( \sum_i F_i(t_i) H_a(t_i) \right) T_{hat} T_{eye} G
\]

where

- \(H\) = personal ocular UVB exposure
- \(R_o\) = the ocular-ambient exposure ratio (fixed for the day but variable with season); The ocular ambient exposure ratio was derived from field studies using persons in a variety of jobs with hats and glasses, and in different seasons. Data suggested the ratio varied across seasons, from about 10% to 19%, but not across gender or occupations. Hat use decreased exposure about 30%, and published data were used on the diminution with glasses (both sunglasses and regular eyewear)\(^{21,22}\).
- \(F_i(t_i)\) = the fraction of time spent outdoors in the \(i^{th}\) period of the day (can be variable by month);
- \(H_a(t_i)\) = the global ambient exposure during this day
- \(T_{hat}\) = fixed factor (between 0 and 1) that reflects the diminution conferred by the use of hats (for UVB =30%);
- \(T_{eye}\) = fixed factor (between 0 and 1) that reflects the diminution conferred by the use of eyewear (for UVB, 96% for plastic and 80% for glass); and,
- \(G\) = a geographic correction factor that relates the total yearly ambient exposures seen in the Maryland area to those observed elsewhere in the world.

Exposure for each month was summed over the months, then summed over each year of life since age 30. To determine the exposures for each person in the study, questions about time spent outside in connection with employment and leisure time were asked, as well as use of hats and glasses. The results showed much lower average annual ocular UVB exposures for this population compared to the Chesapeake Bay Watermen, with exposures ranging from 0 to 0.11 Maryland Sun Year (MSY) (see figure 1).

African Americans and Caucasians had similar exposures, but men had higher exposures than women. Adjusting for age, race, gender, and diabetes, the risk of cortical opacity increased

![Figure 1](image-url)
significantly with increasing dose of UVB. An increase in 0.01MSY was associated with a 10% increase risk of cortical opacity (Table 2).

There was no evidence for a threshold dose, and the same risk was observed among women and among African Americans. This study provided very conclusive evidence of an association between cortical opacity and chronic ocular UVB exposure, even with low exposures likely to be encountered by the general population.

**RESEARCH QUESTIONS**

It is unlikely that more data are needed to establish the association of cataract and exposure to sunlight. Further work in this area should advance our understanding of this association, and the following are suggestions for research:

1. **Exposure in Children.** The detailed studies carried out so far have not been able to quantify the contribution of exposure in childhood to the risk of cortical opacity later in life. There is no reason to suspect that any age group is immune from the potential photo toxic effect of exposure to the lens. However, extrapolation to exposure in childhood is not warranted at this time. The problem has been reliance on recall of exposure, which is prone to significant measurement error when recalling events in childhood. On approach may be to study populations in which childhood was spent in areas with high levels of UVB but adult life was spent in areas of low UVB, compared to those whose entire life was spent in areas of low UVB, providing other factors associated with migration can also be accounted for.

2. **The role of Ultraviolet A (UVA) in contributing to lens damage.** Animal studies have not implicated UVA in contributing to lens damage, primarily because the lenses of the animal models appear not to contain chromophores that absorb in the UVA range. The cornea transmits radiation in the UVA wavelength to the lens, but it has been felt to be less biologically active compared to UVB. Nevertheless, there may be an additive effect or synergy between the two in producing a cataractogenic effect. This issue is important because eyewear typically transmits more UVA, especially in wavelengths close to the visible range. Because of the high correlation between exposure to UVA and UVB (both occur in sunlight) it will be very difficult to tease apart the effect of the two wavelength bands.

**IMPORTANCE FOR PUBLIC HEALTH**

The weight of the evidence from epidemiological studies now implicates UVB exposure from sunlight as a risk factor for cortical cataract. No age group, nor gender or racial group, appears to be immune from the lens damage associated with ocular UVB exposure. However, there are simple, inexpensive steps that can be taken to reduce ocular exposure to UVB in sunlight, which includes wearing a hat with a brim and wearing glasses made of plastic. Plastic eye wear is a very good UVB shield, blocking up to 98%-100% of UVB, regardless of the cost or the degree of darkness. Thus recommendations on the avoidance of adverse health effects from sun exposure should include protection against ocular exposure as well.

**ACKNOWLEDGMENTS**

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**LITERATURE**


**Table 2.** Average Annual UV-B Exposure and Odds of Cortical Opacity in SEE Project Sample Populations.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds Ratio</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UV-B</strong>(1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UV-B (Total population)</td>
<td>1.10</td>
<td>(1.02-1.20)</td>
</tr>
<tr>
<td>UV-B (Females)</td>
<td>1.14</td>
<td>(1.01-1.30)</td>
</tr>
<tr>
<td>UV-B (African-Americans)</td>
<td>1.18</td>
<td>(1.04-1.33)</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>1.09</td>
<td>(1.07-1.12)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1.26</td>
<td>(0.93-1.70)</td>
</tr>
</tbody>
</table>

(1) Separate models were run for each population group. Co-variates on age and diabetes obtained from total population model.