# Sun Exposure as a Risk Factor for Nuclear Cataract

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**Background:** Cataracts are the leading cause of blindness and visual impairment throughout the world. An association of sun exposure with cortical cataract has been well established, but the association with nuclear cataract remains unclear.

**Methods:** This case-control study was nested within the Nambour (Australia) Trial of Skin Cancer Prevention conducted between 1992 and 1996. We compared 195 cases who had a nuclear opacity of grade 2.0 or greater with 159 controls. Structured questionnaires were used to ascertain lifetime sun exposure history, eyeglasses and sunglasses use, and potentially confounding variables such as education and smoking.

**Results:** There was a strong positive association of occupational sun exposure between the ages of 20 and 29 years with nuclear cataract (odds ratio = 5.9; 95% confidence interval = 2.1–17.1). Exposure later in life resulted in weaker associations. Wearing sunglasses, particularly during these early years, afforded some protective effect.

**Conclusions:** This study provides new evidence to support a link between sun exposure and nuclear cataract. Risk was highest among those with high sun exposure at younger ages.

**Key Words:** cataract, ultraviolet radiation

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Cataracts are the leading cause of blindness and visual impairment throughout the world.[1–5] Of the world's 40 to 45 million blind people,[6] approximately half are blind from cataracts.[7] As populations age, the number of people who are blind is expected to double by the year 2025.[7] Age-related cataracts account for >80% of all cataracts,[4] and nuclear lens opacities are the most common of these.

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The causes of nuclear cataracts are not understood. Although it is likely that the normal processes of aging lead to some degree of lens opacification, a complex interplay of sociodemographic, environmental, and genetic factors probably also plays a role.[8] In 1926, Duke-Elder[9] proposed that the fundamental cause of cataract in all its forms may be traced to the incidence of radiant energy directly on the lens, which absorbs substantial amounts of ultraviolet radiation. Although an association has been established between lifetime exposure to sunlight and cortical and posterior subcapsular cataracts,[10–15] the association between sunlight exposure and nuclear opacities remains controversial.[16] We report here the results of a case-control study designed to assess whether excessive sunlight exposure (overall or during specific decades of life) increases the risk of developing nuclear cataract.

## METHODS

This study was approved by the Ethics Committee of the Queensland Institute of Medical Research and written consent was obtained from all participants. This case-control study was conducted in conjunction with a large intervention trial, the Nambour Trial, designed to evaluate the daily use of sunscreen and/or beta-carotene for the prevention of skin cancer; the methods have been reported previously.[17,18] Briefly, the Nambour Trial was a 2-by-2 factorial field trial to test the interventions of daily sunscreen application and beta-carotene supplementation over 5 years for the prevention of skin cancer. Participants were residents of Nambour, a subtropical town of around 8000 people lying 100 kilometers north of Brisbane, the capital of Queensland, Australia. In 1986, 3000 residents randomly selected from the electoral roll (for which enrollment is compulsory) were invited to participate in a skin cancer prevalence survey. In 1992, 1621 of the 2095 people who had taken part in this previous survey, were randomly assigned to 1 of 4 groups (beta-carotene tablets and sunscreen; placebo tablets and sunscreen; beta-carotene only; placebo only). Of these, 1555 agreed to receive a baseline eye examination by a qualified ophthalmologist, as described elsewhere.[19] Nuclear opacities were graded using a method developed by West et al[20] and further refined by Bailey et al.[21] Accordingly, slit-lamp photographs of the eyes of study participants were compared with standard photographs of nuclear opacities graded from 1 to 4. A single ophthalmologist determined all gradings. Visual acuity and participants' identities were masked during grading so that diagnosis of nuclear cataracts was based entirely on the color, density, and extent of the opacity. A randomly selected sample of 95 photographs was sent to a second opthalmologist for grading. The agreement between the 2 graders was high (intraclass correlation coefficient = 0.84).

Of the 1555 participants who underwent baseline eye examinations, the following were not eligible for the present case-control study: those who withdrew from the trial or had died prior to 1994; those who were diagnosed with pterygium, cortical cataract, or posterior subcapsular cataract; or those who had previously undergone cataract surgery in either eye. Also, participants who were involved in either of 2 time-intensive substudies running concurrently were excluded, as it was felt that placing more burden on participants would jeopardize their ongoing participation in the prevention trial. Participants had been randomly selected for participation in these studies.

Participants with a pure nuclear cataract grade of 2.0 or higher were classified as "cases". Controls (those with a nuclear grade of <2.0) were randomly sampled from prestratified 10-year age groups to ensure an age distribution similar to that of cases. In 1994, a questionnaire was administered in which participants recorded the age that they started wearing eyeglasses. Participants completed a sun exposure calendar in which they reported main places of residence and details of work and leisure activities during specific age periods. Corresponding amounts of time spent in the sun were reported in 4 categories (never, sometimes, usually, or always) separately for work and leisure time. Use of hats and sunglasses when outside was reported without differentiation between occupational and leisure time.

The 4 possible responses were coded from 1 to 4. We summed the codes recorded in each decade to generate a lifetime exposure score. This score was divided into approximate quartiles for analysis, based on the distribution in both cases and controls. The codes assigned to the frequency of sunglass wearing in each decade were similarly summed and categorized at the median. In the first instance, the wearing of eyeglasses and sunglasses was included in multivariate models, rather than being incorporated into the exposure index. A subsidiary analysis, in which people were classified according to both their exposure and eyeglass/sunglass use, assessed associations between this variable and risk of nuclear cataract.

We considered variables collected at baseline as part of the skin cancer intervention study as possible confounders of the association between sun exposure and cataract. These included country of birth, smoking status, history of diabetes or glaucoma, level of education, use of supplementary vitamins and minerals, and the use of aspirin and steroids. The interventions (daily beta-carotene supplementation and/or sunscreen application) were not associated with nuclear cataract and have not been included in any models.

Crude odds ratios (OR) with 95% confidence intervals (95% CI) were calculated as estimates of the relative risk of nuclear cataract. Adjusted OR were estimated using multiple categorical logistic regression.

## RESULTS

Of the 1555 people who underwent eye examinations, 439 (28%) were found to have a nuclear opacity of grade 2.0 or higher. In comparison, only 8% had cortical cataract and 0.6% had posterior subcapsular cataract. Of those with nuclear opacities, 10 had died or withdrawn from the intervention study, 27 had cortical cataract, 4 had pterygia, and 183 were involved in other substudies, leaving 215 eligible cases. For logistic reasons, 167 eligible, age-matched controls were selected. A total of 195 cases (91%) and 159 controls (95%) completed the study questionnaire. Cases had a mean age of 59.7 years and controls 55.9 years. Women comprised 59% of cases and 53% of controls.

After adjustment for age, education, smoking, history of diabetes, cumulative occupational sun exposure, and use of eyeglasses, women were more likely to have nuclear cataract than men (OR = 1.64; 95% CI = 0.91-2.94) (Table 1). Education beyond school was associated with an 80% decrease in risk (OR = 0.19; CI = 0.06–0.62). Those with diabetes showed a small increase in risk, as did ex- and current smokers (Table 1). Eye color did not affect the risk of nuclear cataracts.

Living in the north compared with living in the south of Australia during specific decades of life appeared to have no effect on the prevalence of nuclear cataract. However, living in Australia as compared with living overseas, particularly during the early years of life, was associated with nuclear opacities. For example, the odds of nuclear cataract for those resident in Australia from 13 to 19 years compared with those who lived overseas was 2.05 (CI = 0.97–4.35).

There was a strong association between lifetime occupational sun exposure and cataract, with people in the upper 2 quartiles of occupational sun exposure having 2 to 3 times the risk of nuclear opacity compared with those in the lowest quartile, after adjustment for age, sex, education, smoking, diabetes, wearing eyeglasses and sunglasses, and leisure sun exposure (Table 1). Stratification of the analysis by lifetime sunglass use (high or low use) did not substantially alter the association with lifetime occupational exposure. Classifying people according to both occupational exposure and sunglass use confirmed that the association with high occupational exposure is independent of sunglass use. Compared with those who had both low exposure and low use of sunglasses, there was little difference in the OR between those who had high exposure and low sunglass use and those who had high

**TABLE 1.** Risk Factors for Nuclear Cataract in 354 Residents of Nambour, Queensland, 1993–95

| Factor | Cases (N = 177)* % | Controls (N = 143)* % | Crude OR (95% CI) | Adjusted OR† (95% CI) |
|---|---|---|---|---|
| Sex | | | | |
| Males‡ | 41 | 46 | 1.00 | 1.00 |
| Females | 59 | 55 | 1.22 (0.78–1.91) | 1.68 (0.93–3.02) |
| Education | | | | |
| Primary/high‡ | 75 | 60 | 1.00 | 1.00 |
| Senior high | 23 | 27 | 0.69 (0.41–1.45) | 0.94 (0.53–1.66) |
| Tertiary | 2 | 13 | 0.15 (0.05–0.44) | 0.20 (0.06–0.64) |
| Diabetes‡ | | | | |
| No | 93 | 96 | 1.00 | 1.00 |
| Yes | 7 | 4 | 1.66 (0.61–4.54) | 1.38 (0.46–4.15) |
| Smoking | | | | |
| Never‡ | 56 | 60 | 1.00 | 1.00 |
| Former | 34 | 31 | 1.28 (0.78–2.08) | 1.37 (0.78–2.41) |
| Current | 10 | 9 | 1.07 (0.50–2.29) | 1.21 (0.52–2.83) |
| Eyeglasses | | | | |
| No‡ | 5 | 18 | 1.00 | 1.00 |
| Yes | 95 | 82 | 4.00 (1.78–8.78) | 2.96 (1.23–7.12) |
| Sun exposure§ | | | | |
| Lifetime occupational exposure | | | | |
| Very low‡ | 19 | 29 | 1.00 | 1.00 |
| Low | 27 | 35 | 1.20 (0.65–2.19) | 1.13 (0.53–2.41) |
| Medium | 25 | 14 | 2.80 (1.39–5.63) | 2.94 (1.14–7.60) |
| High | 30 | 22 | 2.18 (1.15–4.11) | 2.11 (0.74–5.98) |
| Lifetime leisure exposure | | | | |
| Very low‡ | 20 | 24 | 1.00 | 1.00 |
| Low | 28 | 27 | 1.25 (0.66–2.34) | 0.75 (0.35–1.63) |
| Medium | 24 | 32 | 0.91 (0.48–1.70) | 0.36 (0.15–0.88) |
| High | 28 | 17 | 1.98 (1.01–3.91) | 0.84 (0.51–1.38) |
| Sunglass use | | | | |
| Rarely/never (low use)‡ | 52 | 46 | 1.00 | 1.00 |
| Almost always (high use) | 48 | 54 | 0.77 (0.50–1.20) | 0.84 (0.51–1.38) |
| Exposure‖/sunglass use | | | | |
| Low/low‡ | 22 | 24 | 1.00 | 1.00 |
| Low/high | 23 | 40 | 0.65 (0.35–1.19) | 0.60 (0.31–1.18) |
| High/low | 30 | 21 | 1.59 (0.84–3.01) | 1.61 (0.70–3.71) |
| High/high | 25 | 15 | 1.88 (0.94–3.76) | 2.05 (0.88–4.80) |

*34 observations were missing data for either diabetes or eyeglass use and have therefore been excluded from this analysis. Including all observations in univariate analysis did not result in > 5% change in the OR.

†OR adjusted for age, sex, education, smoking, diabetes, wearing eyeglasses and sunglasses, and occupational and leisure sun exposure where appropriate.

‡Reference category.

§Defined approximately as quartiles.

‖Low occupational exposure combines very low and low categories; high occupational exposure combines medium and high categories.

exposure and high sunglass use. Reported sun exposure during leisure activities showed no clear association with nuclear cataract.

The presence of nuclear cataracts later in life was strongly associated with the amount of time a person spent in the sun during occupational activities at every age period after the age of 13 years (Table 2). The collinearity between exposure during different decades was low (3 of the 10 correlation coefficients in the matrix were between 0.5 and 0.7, with the remaining 7 <0.5). Thus, we could use multivariate analysis to determine the independent effects of decade-specific exposure. Occupational exposure to the sun "always" during the 20- to 29-year age period was associated with a 6-fold increase in risk (OR = 5.94; 95% CI = 2.07–17.10), after adjusting for sun exposure during teenage years. The strength of the associations between sun exposure during the fourth and subsequent decades and cataracts were greatly reduced by adjusting for sun exposure between 20 and 29 years (Table 2). In contrast, the strong association between exposure during the third decade of life and nuclear cataracts was not modified by adjustment for exposure later in life (data not shown).

The association with early life exposure was confirmed by categorizing people according to whether their occupational sun exposure in later decades was different from that between age 20 and 29 years. People who had high sun exposure in their twenties but low in subsequent decades had consistently higher risks than those with low exposure between 20 and 29, but increased exposure subsequently (Table 3).

Wearing eyeglasses conferred approximately a 3-fold increase in risk compared with people who did not wear glasses (OR = 3.00; CI = 1.23–7.12) (Table 1). The risks were not different among people who started to wear their eyeglasses before age 20 or among those who always wore their eyeglasses when outside. Conversely, wearing sunglasses during both work and leisure activities during specific age decades was associated with a reduced risk of nuclear cataract (Table 4). Wearing sunglasses in the early decades of life appeared to confer a greater protective effect than wearing them at older ages (Table 4).

Investigation of hat wearing for both work and leisure activities yielded no consistent results (data not shown). During the 6- to 19-year age period, wearing a hat appeared to be protective for nuclear cataracts. During later years, wearing a hat seemed to be associated with a slightly increased risk of developing nuclear opacity after adjusting for sun exposure.

## DISCUSSION

Nuclear opacities were the most prevalent type of cataract diagnosed in Nambour,[22] in agreement with 2 large prevalence studies in the United States.[23,24] The prevalence

**TABLE 2.** Occupational Sun Exposure for Each Age Period Throughout Life and Nuclear Cataract Risk

| Age Group (years) | Occupational Sun Exposure | Cases (N = 195) % | Controls (N = 159) % | OR* (95% CI) | OR† (95% CI) |
|---|---|---|---|---|---|
| 13–19 | Never/sometimes‡ | 56 | 62 | 1.00 | |
| | Usually | 30 | 32 | 1.07 (0.60–1.91) | |
| | Always | 14 | 7 | 2.12 (0.84–5.41) | |
| 20–29 | Never/sometimes‡ | 53 | 69 | 1.00 | 1.00 |
| | Usually | 27 | 22 | 1.65 (0.90–2.99) | 1.71 (0.91–3.23) |
| | Always | 20 | 9 | 5.24 (2.19–12.6) | 5.94 (2.07–17.10) |
| 30–39 | Never/sometimes‡ | 62 | 71 | 1.00 | 1.00 |
| | Usually | 21 | 22 | 1.17 (0.64–2.12) | 0.89 (0.43–1.81) |
| | Always | 17 | 7 | 3.34 (1.34–8.33) | 1.15 (0.33–3.96) |
| 40–49 | Never/sometimes‡ | 64 | 73 | 1.00 | 1.00 |
| | Usually | 20 | 20 | 0.99 (0.53–1.83) | 0.72 (0.35–1.48) |
| | Always | 15 | 7 | 2.43 (1.00–5.91) | 0.86 (0.28–2.62) |
| 50–59 | Never/sometimes‡ | 54 | 59 | 1.00 | 1.00 |
| | Usually | 22 | 20 | 1.49 (0.79–2.82) | 1.13 (0.56–2.28) |
| | Always | 11 | 3 | 5.15 (1.55–17.1) | 2.17 (0.55–8.53) |
| 60 or over | Never/sometimes‡ | 35 | 27 | 1.00 | 1.00 |
| | Usually | 19 | 14 | 1.98 (0.84–4.65) | 1.77 (0.72–4.38) |
| | Always | 8 | 4 | 3.45 (0.86–13.8) | 1.38 (0.19–10.2) |

*OR adjusted for age, sex, education, smoking, diabetes, and wearing spectacles.
†OR for sun exposure during the 20–29 years of age period adjusted for sun exposure during the 13–19 years of age period; all remaining OR adjusted for sun exposure during the 20–29 years of age period.
‡Reference category.

 

**TABLE 3.** Associations Between Change in Sun Exposure From 3rd to Subsequent Decades and Nuclear Cataract

| Sun Exposure Between Age 20 and 29/Sun Exposure During Comparison Decade | Cases N (%) | Controls N (%) | Crude OR (95% CI) |
|---|---|---|---|
| 20–29/13–19 | | | |
| Low/low* | 82 (42) | 84 (53) | 1.00 |
| Low/high | 22 (11) | 26 (16) | 0.88 (0.46–1.65) |
| High/low | 27 (14) | 14 (9) | 1.98 (0.99–4.03) |
| High/high | 64 (33) | 35 (22) | 1.87 (1.12–3.13) |
| 20–29/30–39 | | | |
| Low/low* | 94 (48) | 99 (62) | 1.00 |
| Low/high | 10 (5) | 11 (7) | 0.96 (0.39–2.36) |
| High/low | 27 (14) | 14 (9) | 2.03 (1.00–4.11) |
| High/high | 64 (33) | 35 (22) | 1.93 (1.17–3.17) |
| 20–29/40–49 | | | |
| Low/low* | 93 (48) | 96 (61) | 1.00 |
| Low/high | 10 (5) | 13 (8) | 0.79 (0.33–1.90) |
| High/low | 32 (16) | 20 (13) | 1.65 (0.88–3.09) |
| High/high | 59 (30) | 29 (18) | 2.10 (1.24–3.56) |
| 20–29/50–59 | | | |
| Low/low* | 72 (42) | 75 (58) | 1.00 |
| Low/high | 15 (9) | 11 (9) | 1.42 (0.61–3.30) |
| High/low | 34 (20) | 18 (14) | 1.97 (1.02–3.79) |
| High/high | 50 (29) | 25 (19) | 2.08 (1.17–3.72) |
| 20–29/60+ | | | |
| Low/low* | 46 (38) | 33 (46) | 1.00 |
| Low/high | 14 (12) | 10 (14) | 1.00 (0.40–2.54) |
| High/low | 23 (19) | 10 (14) | 1.65 (0.69–3.93) |
| High/high | 38 (31) | 18 (26) | 1.51 (0.74–3.10) |

*Reference category.

**TABLE 4.** Association Between Wearing Sunglasses During Different Decades of Life and Nuclear Cataract

| Age | Frequency of Wearing Sunglasses | Cases | Controls | OR* (95% CI) |
|---|---|---|---|---|
| 13–19 | Never† | 173 (89) | 127 (80) | 1.00 |
| | Sometimes | 11 (6) | 21 (13) | 0.48 (0.20–1.11) |
| | Usually/always | 11 (6) | 11 (7) | 0.72 (0.28–1.87) |
| 20–20 | Never† | 132 (68) | 88 (55) | 1.00 |
| | Sometimes | 30 (15) | 43 (27) | 0.48 (0.26–0.87) |
| | Usually/always | 33 (17) | 28 (18) | 0.89 (0.46–1.71) |
| 30–39 | Never† | 111 (57) | 76 (48) | 1.00 |
| | Sometimes | 28 (14) | 42 (26) | 0.56 (0.30–1.03) |
| | Usually/always | 55 (28) | 41 (26) | 1.11 (0.62–1.97) |
| 40–49 | Never† | 95 (49) | 68 (43) | 1.00 |
| | Sometimes | 35 (18) | 42 (27) | 0.77 (0.42–1.43) |
| | Usually/always | 64 (33) | 48 (30) | 1.21 (0.67–2.15) |
| 50–59 | Never† | 81 (47) | 52 (40) | 1.00 |
| | Sometimes | 27 (16) | 33 (26) | 0.59 (0.30–1.18) |
| | Usually/always | 63 (37) | 44 (34) | 0.92 (0.51–1.67) |
| Over 60 | Never† | 58 (48) | 30 (42) | 1.00 |
| | Sometimes | 28 (23) | 17 (24) | 0.71 (0.31–1.61) |
| | Usually/always | 35 (29) | 24 (34) | 0.76 (0.35–1.65) |

*OR adjusted for age, sex, occupational exposure, and wearing of eyeglasses.
†Reference category.

of 28% in Nambour was higher than the 16%[24] and 19%[23] reported in the US studies. Although this may be attributable to differences in the definition or diagnosis of cataract or in the age structure of the population, it might also be the result of the very high levels of ultraviolet radiation in Queensland. In support of this, an occupational group from the United States with very high levels of sun exposure had a prevalence (27%)[14] similar to that in Nambour.

We found that regular exposure to sunlight during occupational activities increased the risk of nuclear cataract, consistent with a causal association between chronic ultraviolet exposure and cataract. Leisure exposure, usually thought to be more intermittent, was not associated with cataract risk. Furthermore, our results suggest that the majority of ultraviolet-induced lens damage occurs before 30 years of age. This is consistent with the known physiological changes of the lens with age. During the aging process, cortical lens fibers are pushed to the center of the nucleus as newer lens fibers are created around them.[26] Thus, for nuclear opacities, ultraviolet-induced damage to the outer cortical lens fibers in early years would contribute to the nuclear opacification manifest later in life.

Our finding that sunglasses reduce the risk of cataract was hypothesized a priori. Rosenthal et al[27] in the United States and Gies et al[28] in Australia have clearly demonstrated that sunglasses protect the eyes from the harmful effects of sunlight. The greater beneficial effect we found at earlier ages again supports our hypothesis that it is during these years that solar ultraviolet exposure is most harmful.

In contrast, those who wore eyeglasses were at a significantly higher risk of having nuclear cataracts than those who did not. Confounding by myopia could possibly explain this result. A recent study[29] found an association between risk of nuclear opalescence and early use of eyeglasses, which they took to be an indicator of myopia. Seidman-Ripley and Huang[1] cite 4 studies in which an association between myopia and cataract was detected; Leske and Sperduto[3] cite 2 additional studies, 1 of which specifically found an association between myopia and nuclear cataract.

There was no association between hat use and prevalence of nuclear cataracts; if there was any relation, wearing a hat after age 20 was associated with a slightly increased risk of cataract. One other study[12] has also reported that wearing a hat was associated with an increased risk of cataract, with the explanation that hat wearing was indicative of high sun exposure. Although adjustment was made for sun exposure in this study, residual confounding is likely to be present.

The findings that a higher education has a protective effect on the development of cataract have been reported previously.[1,12,23,24] Differences in nutritional status might contribute to this association.

Our findings are not consistent with other studies that found no association between ocular ultraviolet exposure and nuclear cataract.[11,14,15] Thus, the potential limitations of this study need to be carefully considered. Recall of lifetime sun exposure habits and details such as sunglasses and hat use may be prone to error, and no validity studies of the questions were conducted. However, such errors in recall were unlikely to occur differentially between cases and controls because most participants were not aware of the research question when they completed the questionnaire. Thus, recall errors would bias any observed effect towards the null. In addition, our indices of exposure and of sunglasses use were relatively crude compared with those of others who have gone to extensive lengths to model the intensity of ocular exposure and its attenuation by hats and glasses. Again, it is probable that the misclassification resulting from the imprecision of our indices would have biased the results towards the null.

Misclassification of disease status was also possible. The eye examinations were conducted in 1992 and most of the data for this study were not collected until 1994. It is possible that lenses of people with lower gradings of nuclear cataract (grades below 2) could have deteriorated to higher grades of nuclear opacity and some controls may have become cases, thereby diluting results.

Notwithstanding these limitations, the findings of this study provide new evidence to support a link between sun exposure and nuclear cataracts. It is plausible that previous studies have failed to identify this link because they did not specifically analyze exposure in the early years of life, or that early exposure was lower than is seen in Queensland, Australia. Nuclear cataracts have a large public health impact. Identification of a common preventable causal factor would have far-reaching implications. Future exploration of the role of sun exposure in the early years of life is warranted.

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