

# Sunlight and Age-Related Macular Degeneration

## The Beaver Dam Eye Study

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• **Objective.**—To investigate the relationship of sunlight exposure with age-related maculopathy. This was investigated in the population-based Beaver Dam Eye Study.

**Design.**—In this cross-sectional population-based study, questionnaire data about sunlight exposure were obtained. Stereoscopic color fundus photographs were graded to determine the presence of age-related maculopathy.

**Participants.**—People aged 43 through 84 years who resided in Beaver Dam, Wis, between 1987 and 1988 were examined between 1988 and 1990.

**Results.**—Light exposure was not associated with early age-related maculopathy in women. In men, after adjusting for age, the amount of time spent outdoors in summer was associated with increased retinal pigment (odds ratio [OR], 1.44; 95% con-

fidence interval [CI], 1.01 to 2.04). Wearing eyeglasses was inversely associated with increased retinal pigment (OR, 0.75; 95% CI, 0.58 to 0.97), and the use of hats and sunglasses was inversely associated with soft indistinct drusen (OR, 0.61; 95% CI, 0.38 to 0.98). The amount of leisure time spent outdoors in summer was significantly associated with exudative macular degeneration (OR, 2.26; 95% CI, 1.06 to 4.81) and late maculopathy (OR, 2.19; 95% CI, 1.12 to 4.25). There were no associations between estimated ambient UV-B exposure and age-related maculopathy.

**Conclusions.**—These data suggest that exposure to sunlight may be associated with age-related maculopathy. However, longitudinal studies of these associations are needed.

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### SUBJECTS AND METHODS

The Beaver Dam Eye Study is a population-based study of age-related ocular disorders. Details of the methods have been published previously.<sup>11-14</sup> A private census was conducted to identify all persons aged 43 through 84 years residing in the city or township of Beaver Dam, Wis. Of the 5925 eligible persons identified, 4926 (83.1%) were examined between 1988 and 1990, 225 (3.8%) died before examination, 91 (1.5%) had moved out of the area, 23 (0.4%) could not be located, 269 (4.5%) completed a questionnaire only, and 391 (6.6%) refused to participate. Mean age of nonparticipants was older than that of participants.

During the examination, a medical history questionnaire was administered. Participants were asked about residential history, time spent outdoors during leisure and work, and use of eyeglasses for distance vision, hats with brims, and sunglasses.

Information regarding residential history was used to construct a measure of the average annual ambient UV-B exposure using an adaptation of the technique employed by the Maryland Watermen Study.<sup>9,10,15</sup> Each year spent in another region was weighted by the ratio of the total ambient UV-B light present in that area to the level for 1 year in Wisconsin (Wisconsin sun year [WISY]).<sup>16</sup> One Wisconsin sun year is equivalent to the total ambient UV-B irradiance of a horizontal surface in Wisconsin in 1 year. A person would have to spend every hour of sunlight in a year outdoors to accumulate a personal exposure of 1.0 WISY. We do not have the information about time spent outdoors on an annual basis needed to compute the exact personal exposure, but have used this measure of maximum ambient exposure as an exposure index.

The cumulative ambient UV-B exposure was computed and divided by age to compute the average annual ambient UV-B exposure. Because most participants had spent most of their lives in Wisconsin, this variable was

Age-related macular degeneration (AMD) is a leading cause of blindness in older persons, yet few epidemiologic studies have investigated risk factors for this disorder.<sup>1,2</sup> Animal studies and case reports in humans have suggested that exposure to intense bright sunlight or UV radiation may cause changes in the retinal pigment

epithelium (RPE) similar to those seen in age-related maculopathy (ARM).<sup>3-7</sup> However, epidemiologic evidence of an association between light exposure and ARM is lacking. In a case-control study by Hyman et al,<sup>8</sup> there was no association between recreational or occupational exposure to sunlight and AMD.<sup>8</sup> Ocular exposures to UV-A and UV-B light were not related to maculopathy in the Maryland Watermen Study,<sup>9,10</sup> but cumulative ocular exposure to blue light in the 20 years before examination was associated with an increased prevalence of severe macular degeneration.<sup>10</sup> This report describes the relationship between exposure to sunlight and the prevalence of ARM in the population-based Beaver Dam Eye Study.

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categorized into two groups. The amounts of time persons reported using hats and sunglasses were combined in a weighted fashion into levels of increasing protection from UV-B light (none, low, moderate, and high). A high protection level represents wearing hats and/or glasses at least half of the time spent outdoors.

During the examination, refractive error was measured using a modification of the Early Treatment Diabetic Retinopathy Study protocol.<sup>17</sup> Pupils were dilated, and stereoscopic 30° color fundus photographs were taken of the disc (Diabetic Retinopathy Study standard field 1) and macula (Diabetic Retinopathy Study standard field 2) of each eye, and a nonstereoscopic color fundus photograph of each eye was taken temporal to but including the fovea.<sup>18,19</sup>

Grading of the photographs for maculopathy was conducted in a masked fashion using a standardized protocol.<sup>20,21</sup> The presence of soft indistinct drusen was determined based on size ( $\geq 63 \mu\text{m}$ ), decreasing density from the center to the periphery, and lack of sharpness of the edges. Areas of depigmentation of the retinal pigment and/or grayish yellow or pinkish yellow areas of varying density and configuration in the plane of the RPE were classified as RPE degeneration. Increased retinal pigment was defined as the presence of granules or clumps of gray or black pigment in or beneath the retina.

In this study, we use the term *age-related maculopathy* rather than *age-related macular degeneration* to describe the spectrum of lesions being examined. The grading system scores the presence and severity of drusen and pigmentary abnormalities as well as the late stages of exudative macular degeneration and geographic atrophy. Because some early lesions are unlikely to reflect a degenerative process and the natural history of early lesions is unknown, we think ARM is a more appropriate term.

Early ARM was defined as the absence of late maculopathy, but the presence of either (1) soft indistinct or reticular drusen (soft drusen forming networks of interlacing ribbons) or (2) any drusen type with RPE degeneration or increased retinal pigment in the macular area.

Late ARM was defined as the presence of signs of exudative AMD or pure geographic atrophy. Exudative macular degeneration was the presence of an RPE detachment or serous detachment of the sensory retina, subretinal or sub-RPE hemorrhages and/or subretinal fibrous scars. Pure geographic atrophy was the presence of geographic atrophy and the absence of exudative macular degeneration.

The grade for the eye with more severe involvement was used for analysis. Data from the 4771 people (96.9%) with gradable fundus photographs of at least one eye and without a lesion unrelated to ARM are included in this report. Statistical software (SAS, SAS Institute Inc, Cary NC) was used to calculate the  $\chi^2$  statistic to test for overall associations, tests for trends in proportions, and results of logistic regression models.<sup>22</sup> Binary logistic regression models were used to examine the relationships of light exposure variables with the prevalence of ARM,

Table 1.—Distribution of ARM by Gender in the Beaver Dam Eye Study (1988-1990)\*

	Women, No. (%) (n=2649)	Men, No. (%) (n=2122)	P
Soft indistinct drusen†	234 (8.8)	171 (8.1)	.34
Retinal pigment epithelial degeneration‡	218 (8.2)	177 (8.4)	.89
Increased retinal pigment‡	306 (11.6)	275 (13.0)	.14
Early ARM	402 (15.5)	342 (16.3)	.42
Exudative macular degeneration	41 (1.6)	17 (0.8)	.02
Pure geographic atrophy	19 (0.7)	10 (0.5)	.28
Late ARM	50 (1.9)	27 (1.3)	.09

\*ARM indicates age-related maculopathy.

†Two women and two men were excluded because soft indistinct drusen could not be graded in either eye.

‡Three people were excluded because retinal pigment epithelial degeneration or increased retinal pigment could not be graded in either eye.

controlling for the effects of age and other covariates. Light exposure variables were also entered into logistic regression models in combinations to test for associations while controlling for the potentially important modifying effects of other exposure measures. For example, the association of ambient UV-B exposure to maculopathy was tested with the index of protection, eyeglasses use, and variables about time spent outdoors included in the model.

## RESULTS

Table 1 presents the prevalence of ARM by gender. Women were older and more likely to have exudative AMD than men.

As shown in Table 2, women were more likely to report wearing eyeglasses for distance vision; men were more likely to have worn them at an earlier age. Women were less likely to spend time outdoors or to have been exposed to higher ambient UV-B than men. There was no gender difference in the level of protection from sunlight by the reported use of sunglasses and hats with brims.

The gender-specific relationships of the light exposure measures to the lesions and end points of ARM are shown in Tables 3 and 4. Because both the signs of early maculopathy and the light exposure variables were highly related to age (data not shown), logistic regression models were used to examine the relationship of each measure of sunlight or UV-B exposure and each ARM end point, adjusting for the effects of age. There were no significant associations between any of the measures of light exposure and the prevalence of any of the signs of early maculopathy in women.

In men, there were no significant associations between ambient UV-B exposure, work time outdoors, or leisure time outdoors in winter and any of the signs of early maculopathy. Use of sun-

glasses and hats with brims was inversely associated with the prevalence of soft indistinct drusen in men. Men who wore these items at least half of the time when outdoors rated high on the protection scale and were 40% less likely to have soft indistinct drusen than those who rarely wore hats or sunglasses (odds ratio [OR], 0.61; 95% confidence interval [CI], 0.38 to 0.98).

Time spent outdoors in summer (75% of time vs 25% of time) was significantly associated with the prevalence of increased retinal pigment in men (OR, 1.44; 95% CI, 1.01 to 2.04; 75% and 25% for men vs women, respectively). The prevalence of increased retinal pigment was lower in men who reported ever wearing eyeglasses for distance vision (OR, 0.75; 95% CI, 0.58 to 0.97). The age at which eyeglasses were first worn was not significantly associated with the presence of increased retinal pigment (data not shown). In a logistic regression model with age, time outdoors in summer, and use of eyeglasses, all three covariates remained significant predictors of the prevalence of increased retinal pigment in men.

Because few persons had late maculopathy, data for men and women were combined in analyses of the late stages (Table 4). Sex-specific patterns were similar to those reported below, but did not reach statistical significance.

Leisure time outdoors in summer was significantly associated with the presence of exudative macular degeneration (OR, 2.26; 95% CI, 1.06 to 4.81). A similar relationship was observed with pure geographic atrophy, but was not statistically significant. When late maculopathy, a combination of one or both late forms, was used as the end point, a significant odds ratio of 2.19 was obtained.

The relationships of these markers of exposure to sunlight and early signs of maculopathy, exudative macular de-

**Table 2.—Distribution of Light Exposure Variables by Gender in the Beaver Dam Eye Study (1988-1990)**

	Women, No. (%) (n=2649)	Men, No. (%) (n=2122)	P
Ever wore eyeglasses for distance vision*	1878 (71.2)	1254 (59.3)	<.001
Age first wore eyeglasses, y†			
<21	1434 (55.3)	1434 (68.6)	<.001‡
21-39	367 (14.1)	266 (12.7)	
≥40 or never	794 (30.6)	392 (18.7)	
Leisure time outside in summer§			
<¼	1643 (62.3)	571 (27.0)	<.001‡
Half	755 (28.6)	821 (38.8)	
>¾	240 (9.1)	724 (34.2)	
Leisure time outside in winter			
Mostly indoors	2170 (82.0)	1224 (57.8)	<.001‡
Half inside, half outside	458 (17.3)	757 (35.8)	
Mostly outdoors	20 (0.8)	136 (6.4)	
Job time outside¶			
<¼	2245 (84.8)	847 (39.9)	<.011‡
¼-½	162 (6.1)	527 (24.9)	
≥½	240 (9.1)	747 (35.2)	
Protection from UV-B by use of sunglasses and hats with brims#			
None	752 (28.5)	398 (18.8)	.21‡
Low	649 (24.6)	722 (34.1)	
Moderate	369 (14.0)	419 (19.8)	
High	871 (33.0)	579 (27.3)	
Average annual ambient UV-B exposure**			
<1.01 WISY	2188 (85.4)	1319 (62.4)	<.001‡
≥1.01 WISY	374 (14.6)	796 (37.6)	

\*Sixteen people were excluded because of missing data.

†Eighty-three people were excluded because age when glasses were first worn for distance vision was unknown.

‡By a test of trend.

§Twenty-three people were excluded because of missing information.

||Sixty people were excluded because of missing information.

¶Three people were excluded because of missing information.

#Twelve people were excluded because of missing information.

\*\*Ninety-four people were excluded because of missing information. WISY indicates Wisconsin sun year. See "Subjects and Methods" section for definition of WISY.

generation, pure geographic atrophy, and late maculopathy were further explored, adjusting for the potential confounders of diabetes, smoking, heavy alcohol consumption, and refractive error and the potential modifying effects of the other exposure variables. None of these factors altered either the magnitude of the associations reported or the statistical significance of the ORs.

#### COMMENT

These data are the first from a population-based study to examine the relationships of reported exposure to sunlight with the prevalence of lesions and stages of ARM. We found no evidence of a UV-B association with any of the lesions characteristic of early ARM or with the late stages of exudative macular degeneration or pure geographic atrophy. These results are consistent with previous reports from the Maryland Watermen Study<sup>9,10</sup> and the case-control study by Hyman et al.<sup>8</sup>

Although experimental studies have suggested that the retina may be particularly susceptible to damage by this part of the light spectrum,<sup>3,6</sup> there is no evidence in human populations that UV-B exposure is related to ARM. The lens absorbs UV-B radiation and may protect the retina in phakic individuals from this potentially harmful exposure.<sup>23</sup>

Our measure of UV-B exposure is crude, as it categorizes individuals by their maximum potential ambient exposure to UV-B based on residential history. Clearly, time spent outdoors during each year as well as use of protective devices annually may have significantly altered actual personal and ocular exposures to UV-B. However, it was not feasible to obtain reliable detailed information in this population-based cohort, as individuals would have had to recall habits from 25 to 60 years of life. Prospectively collected information about exposure is needed to accu-

rately measure ocular exposure to UV-B. While our index is a gross measure of exposure, it has been shown to be significantly associated with the prevalence of cortical opacities in men in this population.<sup>16</sup> Nonetheless, it is important to view the negative finding with caution, as it is possible that a relationship between UV-B exposure and ARM would be detectable with precise information about ocular exposure.

The amount of leisure time spent outdoors in summer was related to the prevalence of increased retinal pigment in men and late ARM in men and women. These results, as well as the inverse association found between the level of protection from light through the use of sunglasses and hats with brims and the prevalence of soft indistinct drusen, suggest that exposure to bright sunlight may be associated with late AMD. These findings are consistent with animal studies suggesting that retinal changes occur after exposure to bright light.<sup>3-6</sup> Others<sup>3-7</sup> have reported that sun gazing or prolonged exposure to bright operating room lights can lead to mottling and depigmentation of the RPE in humans. Retinal changes after prolonged exposure to bright ambient light at the beach or in the desert have also been reported.<sup>3</sup> A recent article by Taylor et al<sup>10</sup> reported a weak association between exposure to blue light and late AMD in the Maryland Watermen Study. Thus, exposure to visible light may be a risk factor for ARM.

The inverse association of wearing eyeglasses with the prevalence of increased retinal pigment may be due to the slight attenuating effect glasses have on the transmission of UV-B radiation to the eye.<sup>24</sup> Alternatively, myopia, a leading reason for wearing eyeglasses for distance vision, may have a protective effect.<sup>8,25,26</sup> However, in this population-based study, we did not find an association between current refractive error or the presence of myopia or hyperopia and the prevalence of increased retinal pigment or late ARM (K.J.C., R.K., and B.E.K.K., unpublished data, 1990). The use of eyeglasses for distance vision in men in Beaver Dam may be serving as a surrogate for another characteristic of importance in the etiology of ARM. Further investigations are needed to clarify this association.

In this study, light exposure was associated with early maculopathy only in men. The failure to find an association in women may have been due to the lower frequency of sunlight exposure in women than in men. Alternatively, these results may suggest that light exposure is a minor factor in early ARM, as both men and women are equally likely to have this

**Table 3.—Age-Adjusted ORs for the Associations of Light Exposure Variables and Early Signs of ARM by Gender in the Beaver Dam Eye Study (1988-1990)\***

	Soft Indistinct Drusen		Retinal Pigment Epithelial Degeneration		Increased Retinal Pigment		Early ARM	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
<b>Women</b>								
Leisure time outdoors in summer, >¾ vs <¼	1.22	0.79-1.90	1.18	0.75-1.85	0.93	0.63-1.38	0.91	0.64-1.29
Leisure time outdoors in winter, mostly outdoors vs mostly indoors	1.04	0.53-2.04	1.05	0.52-2.11	0.91	0.50-1.67	0.79	0.46-1.37
Time outside at work, ≥½ vs <¼	1.20	0.79-1.18	1.25	0.82-1.91	1.17	0.81-1.71	1.04	0.73-1.46
Level of protection from UV-B by use of sunglasses and hats with brims, high vs none	0.99	0.69-1.42	1.00	0.69-1.45	1.03	0.75-1.41	0.99	0.75-1.31
Level of exposure to ambient UV-B, ≥1.01 WISY vs <1.01 WISY	1.0	0.67-1.48	1.12	0.75-1.67	1.04	0.73-1.47	0.99	0.72-1.35
Ever wore eyeglasses for distance vision, yes vs no	1.15	0.82-1.61	0.95	0.68-1.33	1.09	0.82-1.46	1.21	0.93-1.57
<b>Men</b>								
Leisure time outdoors in summer, >¾ vs <¼	1.34	0.88-2.05	1.06	0.71-1.59	1.44†	1.01-2.04	1.23	0.91-1.67
Leisure time outdoors in winter, mostly outdoors vs mostly indoors	1.10	0.65-1.86	0.95	0.57-1.57	1.04	0.85-1.28	1.08	0.74-1.58
Time outside at work, ≥½ vs <¼	1.40	0.96-2.04	1.03	0.72-1.47	0.95	0.71-1.28	1.28	0.97-1.68
Level of protection from UV-B by use of sunglasses and hats with brims, high vs none	0.61†	0.38-0.98	1.30	0.84-2.01	1.31	0.91-1.87	1.08	0.78-1.51
Level of exposure to ambient UV-B, ≥1.01 WISY vs <1.01 WISY	0.71	0.50-1.00	0.89	0.64-1.23	1.09	0.84-1.42	0.94	0.74-1.19
Ever wore eyeglasses for distance vision, yes vs no	0.93	0.66-1.32	0.78	0.56-1.07	0.75†	0.58-0.97	0.81	0.64-1.04

\*OR indicates odds ratio; CI, confidence interval; ARM, age-related maculopathy; WISY, Wisconsin sun year. See "Subjects and Methods" section for definition of WISY.

†P<.05.

stage of the disorder despite the lower exposures reported by women.

There are inherent limitations in the cross-sectional nature of the study design. Participants were asked about the amount of time they were currently spending outdoors and about time during which hats and sunglasses were used. Answers to such queries may not accurately classify their exposures during earlier years when the initial damage may have occurred. Gender differences in how well reported current exposure reflects past habits may partially explain the discrepant patterns between men and women for early maculopathy. Longitudinal data are needed to investigate the associations between light exposure and the incidence and progression of ARM.

Odds ratios for the associations between time spent outdoors in summer and late stages in ARM were similar for men and women (data not shown). Although many of the other measures of exposure were not significantly related to the late stages of ARM, the overall pattern was consistent. Our data support the hypothesis that exposure to

**Table 4.—Age-Adjusted ORs for the Associations Between Light Exposure Variables and Exudative Macular Degeneration, Pure Geographic Atrophy, and Late ARM in the Beaver Dam Eye Study (1988-1990)\***

	Exudative Macular Degeneration		Pure Geographic Atrophy		Late ARM	
	OR	95% CI	OR	95% CI	OR	95% CI
Leisure time outdoors in summer, >¾ vs <¼	2.26†	1.06-4.81	2.38	0.80-7.08	2.19†	1.12-4.25
Leisure time outdoors in winter, mostly outdoors vs mostly indoors	1.82	0.65-5.06	1.51	0.34-6.58	1.72	0.71-4.15
Time outside at work, ≥½ vs <¼	1.05	0.52-2.11	1.70	0.69-4.23	1.10	0.60-2.00
Level of protection from UV-B by use of sunglasses and hats with brims, high vs none	1.89	0.94-3.83	1.03	0.36-2.91	1.44	0.77-2.69
Level of exposure to ambient UV-B, ≥1.01 WISY vs <1.01 WISY	1.74	0.84-3.59	1.72	0.72-4.12	1.30	0.74-2.28
Ever wore eyeglasses for distance vision, yes vs no	0.96	0.48-1.93	0.93	0.39-2.21	1.46	0.80-2.64

\*OR indicates odds ratio; ARM, age-related maculopathy; CI, confidence interval; and WISY, Wisconsin sun year. See "Subjects and Methods" section for definition of WISY.

†P<.05.

bright visible light may be associated with ARM.



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