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Relation of Smoking, Drinking and Physical Activity to Changes in Vision Over a 20-Year Period: The Beaver Dam Eye Study

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Abstract

Objective—To describe relationships of lifestyle characteristics to changes in vision and incidence of visual impairment (VI) over a 20-year period in the Beaver Dam Eye Study (BDES).

Design—Longitudinal population-based cohort study.

Participants—A cohort of 4926 persons aged 43–86 years participated at the baseline examinations in 1988–1990, and 3721, 2962, 2375, and 1913 participated in follow-up examinations in 1993–1995, 1998–2000, 2003–2005, and 2008–2010, respectively.

Methods—Best corrected visual acuity measured by a modified Early Treatment Diabetic Retinopathy Study protocol.

Main Outcome Measure—Change in number of letters read correctly and incidence of VI based on best-corrected visual acuity in the better eye assessed at each examination over 20-year period.

Results—The 20-year cumulative incidence of VI was 5.4%. There was a mean loss of 1.6 letters between exams with a 20-year loss of 6.6 letters. While adjusting for age, income, and age-related macular degeneration (AMD) severity, being a current or past smoker was related to greater change in the numbers of letters lost. Persons who had not consumed alcoholic beverages over the past year and sedentary persons had higher odds of incident VI than persons who drank occasionally or who were physically active. For example, in women with early AMD and annual household income less than \$10,000, the estimated 20-year cumulative incidence of VI in those

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who drank occasionally and were physically active was 5.9% compared to 25.8% in women who had not consumed alcoholic beverages over the past year and were sedentary.

Conclusions—Three modifiable behaviors, smoking, drinking alcohol, and physical activity were associated with changes in vision. Further evidence that changes in these behaviors will result in less loss of vision is needed because of the expected increase in the burden of VI due to the aging of the population.

The number of people with visual impairment (VI) in the year 2000 was estimated to be 2.4 million and was projected to increase by 70% to reach 4.0 million by the year 2020.¹ This increase was thought to be due, in part, to the growing number of people expected to live longer and develop age-related eye conditions, e.g., age-related macular degeneration (AMD), age-related cataracts, and glaucoma. Visual impairment is associated with poorer quality of life, and, when severe, it may result in a loss of independence.² Therefore, it is important to identify modifiable risk factors that can be intervened upon to decrease the burden of VI (defined by the best-corrected visual acuity (VA) in the better-seeing eye of worse than 20/40).

There is growing evidence of a relationship of smoking to the long-term incidence of AMD, cataract, and glaucoma and less consistent evidence of a deleterious relationship of heavy drinking and sedentary lifestyle to the incidence of age-related eye diseases.^{3–14} However, there are few population-based data on the relationship of these modifiable behaviors to the prevalence and incidence of VI.^{15–17} In this report, we examine the relationships of these behaviors to changes in vision and the incidence of VI over a 20-year period in the population-based Beaver Dam Eye Study (BDES) cohort.

METHODS

Population

The population has been described in detail. In brief, there were 5924 eligible individuals aged 43–84 years at the time a private census of the population of Beaver Dam, Wisconsin was performed from September 15, 1987 to May 4, 1988. Of those, 4926 participated in the baseline examination (1988–1990 (BDES1)); 3721 participated in the 5-year follow-up (1993–1995 (BDES2)); 2962 participated in the 10-year follow-up (1998–2000 (BDES3)); 2375 participated in the 15-year follow-up (2003–2005 (BDES4)); and 1913 participated in the 20-year follow-up (2008–2010 (BDES5)).¹⁸ Ninety-nine percent of the cohort was Caucasian. Information regarding participation rates and reasons for nonparticipation are presented elsewhere.¹⁸ Those who participated in the follow-up were more likely than nonparticipants who were alive at follow-up to be older and, while adjusting for age, more likely to have a higher annual household income, to have more education, not to be institutionalized, not to be visually impaired, not to have a central cataract, and not to have AMD.

Approval was granted by the Institutional Review Board at the University of Wisconsin. Written informed consent for the use and disclosure of protected health information was obtained from all subjects before being enrolled in the study and before each examination.

The study was performed in accordance with the Health Insurance Portability and Accountability Act and the tenets of the Declaration of Helsinki.

At each examination, the visual acuity (VA) measurements from the better-seeing eye were used for the analyses. Visits with unreliable (or unmeasured) VA in one of the eyes were not used for analyses. At each visit, approximately 95% of participants had reliable VA.¹⁸ Over the 20 years of follow-up there were a total of 9648 (3481 from BDES1 to BDES2, 2532 from BDES2 to BDES3, 2017 from BDES3 to BDES4 and 1618 from BDES4 to BDES5) person-visits with reliable VA data available for the analyses of change in the number of letters read correctly.

Measurements

Similar procedures were used at all examinations. Participants underwent a standardized interview and examination at each visit. Information on demographic characteristics and smoking, drinking and physical activity was obtained from a questionnaire. Photographs of the ocular fundus¹⁹ and the lens²⁰ were taken after pharmacological dilation of the pupil according to protocol and were graded in masked fashion by experienced graders. The protocols for photography and the grading procedures have been previously described.²⁰ History of cataract surgery was obtained by grading of red reflex photographs corroborated by clinical assessment during the slit lamp examination.

The Wisconsin Age-Related Maculopathy Grading System^{19,21,22} was used to assess the presence and severity of lesions associated with AMD from the fundus photographs. Grading procedures, lesion descriptions, and detailed definitions for their presence and severity appear elsewhere.¹⁹ Early AMD was defined as the presence of soft drusen and/or any drusen with retinal pigmentary abnormalities (increased retinal pigment and/or retinal pigment epithelium depigmentation) in the absence of signs of late AMD. Late AMD was defined as the presence of exudative macular degeneration and/or pure geographic atrophy.

At all examinations, the refraction from a Humphrey 530 refractor (Carl Zeiss Inc., Oberkochen, Germany) was placed in a trial lens frame and the best-corrected VA was measured for each eye by means of the Early Treatment Diabetic Retinopathy Study protocol with charts R 1 and 2 modified for a 2 meter distance.^{23,24} If the best-corrected VA was 20/40 or worse in either eye, an Early Treatment Diabetic Retinopathy Study refraction was performed for that eye and the VA was measured. The inter-observer difference among the examiners for the refraction or the best-corrected VA was low and not clinically appreciable (data not shown). Visual impairment (VI) was defined by the best-corrected VA in the better-seeing eye: no impairment (20/40 or better), any VI (worse than 20/40).

Changes were calculated for each 5-year interval between examinations. The number of letters lost (or gained) between examinations was calculated by subtracting the number of letters read correctly at the start from the number of letters read correctly at the end of the interval. Incidence of any VI was calculated for persons with VA of 20/40 or better in one or both eyes at the beginning of a 5-year examination. The 5-year intervals were modeled together as described in the statistical methods section.

Age and other characteristics were defined at the beginning of an interval. Because all analyses use one VA measure (from the better-seeing eye) for a person, the corresponding AMD and central cataract status from this eye were used for analyses. When the VA was the same in both eyes the AMD and central cataract status from the worse eye were used. For persons in which the AMD and central cataract status for the analysis eye was not gradable, if the VA in the other eye was similar (<10 letters different), the AMD/central cataract status from the other eye was used.

At the beginning of each examination interval, subjects were classified as nonsmokers if they had smoked fewer than 100 cigarettes in their lifetime; as past smokers if they had smoked more than 100 cigarettes in their lifetime but had stopped smoking before the examination; and as current smokers if they had not stopped smoking. In the questionnaire, one serving of alcoholic beverage was defined as 12 fluid oz. (0.355 liters) of beer, 4 fluid oz. (0.118 liters) of wine, or 1.5 fluid oz. (0.044 liters) of liquor or distilled spirits. For each type of alcohol, persons were asked whether they had consumed any in the past year and how many servings they consumed in an average week. The amounts of alcohol from beer, wine, and liquor were summed to obtain average alcohol consumed from any source in a week. Persons reporting no consumption in the past year were considered "nondrinkers". Those who had consumed alcohol in the past year but reported zero servings in an average week were considered "occasional" drinkers. Those reporting 1 or more servings in an average week were labeled as "regular" drinkers. A current heavy drinker was defined as a person who self-reported consumption of 4 or more servings of alcoholic beverages daily; a former heavy drinker had consumed 4 or more servings of alcoholic beverages daily in the past but not in the previous year; a non-heavy drinker had never consumed 4 or more servings of alcoholic beverages on a regular, daily basis.

Household income was asked in categories and based on prior analyses; income categories were combined. Analyses are based on annual household income $<\$10,000$ or $\$10,000$. Participants were asked the following questions regarding physical activity: "On average, how many flights of stairs do you climb each day?"; "On average, how many city blocks do you walk each day?"; "At least once a week, do you engage in a regular activity long enough to work up a sweat?" and if so, "How many times per week do you do this?" For the purpose of analyses, stair climbing was categorized as 0, 1 to 3 flights, 4 to 6 flights, and >6 flights per day; walking was categorized as 0, 1 to 4 blocks, 5 to 12 blocks, and >12 blocks per day. An active lifestyle was defined as engaging in regular activity with or without sweating 3 or more times per week; sedentary lifestyle was defined as engaging in regular activity less than 3 times per week.

Statistical Analysis

For both the continuous measure of change (i.e., change in the number of letters read) and the binary measure of change (i.e., incidence of VI), models were fit that use information from each interval with time-updating covariates (all covariates were updated). Generalized estimating equation was used to account for correlation from multiple visits using an unstructured correlation matrix (fit with PROC GENMOD in SAS). For the change in the number of letters read, a linear function was used. For incidence of impairment, a logit link

function was used. Model selection began with examination of the age, period, and sex relationships, including possible interactions. Change in number of letters was best fit with a quadratic term for age, and incidence of impairment with a linear term for age. Based on previous findings, we then added total household income, cataract status, AMD severity, and any possible age, gender, and period interactions with those factors.¹⁸ Education was also considered instead of total household income, however models with income fit significantly better. Some factors were not always significant, or were of borderline significance ($P < 0.10$), but we chose to include the same set of factors for all models. From these two "base" models, we considered other factors (smoking, alcohol, and physical activity measures) separately, and interactions between each factor and age, sex, or period were evaluated. Statistically significant ($P < 0.05$) "univariate" relationships were entered into a multivariate model. Where total alcohol consumption was significant, as well as consumption specifically for wine and distilled liquor, we chose to include the more inclusive factor (total alcohol). For discussion purposes, we also examined the relationship of specific types of alcohol to VA.

There are several reasonable descriptive statistics that aid in the interpretation of the model results and the understanding of the relationships among factors. The underlying data setup for the models (change in number of letters as well as incidence of VI) is to treat each observed interval as a separate record. While the rates are changing as the population ages and the error terms need to account for the multiple measures for a single individual, the mean change across all examination intervals is a reasonable estimate of the unadjusted expected outcome for each level of the risk factors. We present the number of person-visits and the mean 5-year change, or incidence accumulated over all the intervals, without reporting the standard error (and confidence intervals for this estimate).

In addition to the change in an interval, the 20-year change is of more interest. We chose to calculate the 20-year change using the estimates from the unadjusted models. For example, the 20-year change in the number of letters is simply the sum of the change expected in the first interval, the second interval, the third interval, and the fourth interval. Similarly the 20-year cumulative incidence is $1 - (1 - \text{rate in first interval}) * (1 - \text{rate in second interval}) * (1 - \text{rate in third interval}) * (1 - \text{rate in fourth interval})$. We use the appropriate change for an interval based on the ages for that interval. A person age 50 for the first interval would be 55 for the second, and so on. While there are other ways of calculating the 20-year rates, this smooths aging issues as it is difficult to acquire 20 years of follow-up data for 80-year-old participants, and it allows us to account for updates to the risk profiles over the course of the study.

SAS version 9 (SAS Institute, Cary, NC) was used for all analyses.

RESULTS

Change in Number of Letters

On average 1.6 letters were lost between visits approximately 5 years apart which results in a loss of 6.6 letters over the 20 years of the study. The number of letters lost increased with age, from 0.1 letters over each interval in persons 45–54 years of age at the start of the

interval to 6.7 letters in persons 85-years-old and older. The 20-year change similarly increases from 3.2 letters lost for persons 45–54 years at BDES1 to almost 35 letters lost for persons 75–84 years at BDES1. We are unable to estimate the 20-year change for persons 85+ at baseline because there are no estimates for the 5-year changes in the fourth interval (when the person would be 100 years of age at the start of the interval). While adjusting for age and examination interval, women lost fewer letters than men (5.7 vs. 7.0 letters over 20-years, $P=0.001$). Age-specific relationships of change in number of letters to smoking status, history of drinking status, amount and type of alcohol consumed per week, physical activity level, and number of flights of stairs climbed and blocks walked are presented in Figure 1 and in Table 1. While adjusting for age, period and sex, both smoking and the number of flights of stairs climbed were statistically significantly associated with the change in number of letters read correctly. A history of past and current smoking was associated with an average β estimate of -0.24 and -0.44 , respectively, when compared with never smokers after adjusting for age, gender, and examination. Thus, within each 5-year interval, current smokers lost 0.44 more letters than the number of letters lost by never smokers. Notably, the mean change and 20-year change (Table 1) appear to go in opposite directions suggested from the β estimate because of the importance of age adjustment for this factor. Persons who had a history of climbing more stairs lost fewer letters than persons who had a history of not climbing stairs. Inclusion of income, cataract status, AMD severity, and age interaction into the model attenuated the relationships (Table 1). In multivariate models where both smoking status and physical activity are considered, only smoking status remained statistically significantly associated with decrease in number of letters read correctly (Table 2).

Due to the differing frequency and patterns of behavior between men and women, we also stratified our analyses by sex (Table 2). There were some differences in the strength of association, but the direction was similar (Table 2). For example, while adjusting for age, period, total annual household income, cataract, and AMD status and age with AMD interactions, current smoking was statistically significantly associated with fewer number of letters read correctly (β estimate -0.37 ; 95% confidence interval [CI]: -0.61 , -0.13) in the whole cohort and in men (β estimate -0.45 ; 95% CI: -0.79 , -0.12) but not women (β estimate -0.27 ; 95% CI: -0.61 , 0.07). There were no interactions with sex.

Incidence of VI

Among the 9648 person-visits with VA at the start and end of an interval, 100 were already impaired in both eyes at their first visit and were not eligible for incidence analyses. Incidence of VI occurred in 38 (1.1%) of the 3439 persons at risk from BDES1 to BDES2, 37 (1.5%) of the 2511 persons at risk from BDES2 to BDES3, 28 (1.4%) of the 1999 persons at risk from BDES3 to BDES4, and 28 (1.8%) of the 1599 persons at risk from BDES4 to BDES5. On average, the incidence rate between examination is 1.4%. The 20-year cumulative incidence of VI was 5.4%. Incident VI increased with age from 0.1% in an interval for those aged 43–54 years at the start of the interval to 14.6% for those 85-years-old or older. The 20-year cumulative incidence increased from 1% in those 43–54 at baseline to 60% in those 75–84 at baseline. While adjusting for age and examination, incidence of VI was not statistically significantly different between men and women (4.6% vs. 6.3% 20-year cumulative incidence, $P=0.70$). Relationships of smoking, history of

drinking alcohol (by amount and type of beverage), and physical activity (active vs. sedentary, flights of stairs climbed, number of blocks walked) to the incidence of VI are presented in Table 3. While adjusting only for age and period, current smokers had 65% increased odds, heavy drinkers 166% increased odds and non-drinkers 95% increased odds, and physically active persons 58% decreased odds of incident VI compared to never smokers, to occasional drinkers over the past year, and to those who were sedentary, respectively (Table 3). No interactions were present for age, sex and smoking status, alcohol consumption, and sedentary behavior with incident VI. Only the number of alcoholic beverages (overall consumption as well as specifically for wine and liquor) and physical activity (both sedentary and blocks walked) were statistically significantly related to incident VI. These associations remained after further adjusting for annual household income and AMD severity (Table 3). In the final multivariate model, while adjusting for age, period, sex, annual household income, and AMD severity, alcohol consumption and physical activity level remained statistically significantly associated with the incidence of VI (odds ratio [OR]=2.12 for nondrinkers vs. occasional drinkers; OR=0.41 for active vs. sedentary, Table 4). The number of blocks walked was not statistically significantly associated with VI when physical activity was included in the model. There were some differences in the strength of associations between men and women, but the directions were similar (Table 4). For example, for incidence of VI, history of alcohol consumed was significant in the whole cohort (OR=2.12 for nondrinkers vs. occasional drinkers, 95% confidence interval [CI]: 1.25, 3.60). While the odds were in the same direction, this was statistically significant among women (OR=2.27, 95% CI: 1.22, 4.24) but not men (OR=1.77, 95% CI: 0.63, 4.93). There were no interactions with sex.

From the model, we estimated the cumulative incidence of VI for different ages based on sex, smoking status, alcohol consumption, presence or absence of early AMD, and total annual household income (Table 5). For example, the estimated 20-year cumulative incidence of VI in women aged 55 years varied from 0.2% in those with total annual household income of \$10,000 or more, had no signs of early AMD, drank occasionally, and who were physically active to 7.4% in those whose annual household income was less than \$10,000 per year, had signs of early AMD, did not drink alcohol in the past year, and who were sedentary. For women aged 75 years or older with the same characteristics, the 20-year cumulative incidence of VI varied from 3.6% to 65.2%. Similar relationships were present for men.

DISCUSSION

While adjusting for age, income, and AMD severity, compared to a sedentary lifestyle, a physically active lifestyle was associated with an approximately 60% reduction in the odds for incidence of VI over a 20-year period in the BDES cohort. Alcohol consumption was also associated with incidence of VI, such that persons that did not drink in the past year had higher odds of incident VI compared to occasional drinkers. The incidence of VI by amount of alcohol consumed did not differ otherwise (i.e., risk was similar among persons drinking <1/week and persons drinking 1–2 alcoholic beverages daily; Klein R., unpublished data August 31, 2012). Current and past smokers were more likely to have a larger decrease in the number of letters correctly read compared to never smokers.

The association of physical activity with incidence of VI in the BDES is consistent with data from a representative population in Gothenburg, Sweden.¹⁷ In that study, men but not women who were age 70 in 1971 and had a history of physical activity during leisure time were more likely to have VA better than 20/25 at age 82 and age 88 years. While adjusting for age, sex, and other factors, persons in the BDES leading an active lifestyle at baseline had statistically significant 70% lower odds of developing exudative AMD compared with people not leading a physically active lifestyle.¹² The protective association of physical activity with VI we report here remained significant when AMD severity status was included in the multivariate model, suggesting that factors aside from incidence of AMD accounted for this finding. Compared to persons in the BDES who did not have an active lifestyle, those who did were more likely to be younger, and, after adjusting for age, had less education, were less likely to currently smoke or to have a history of heavy drinking (Klein R., unpublished data, August 31, 2012). Persons with an active lifestyle may also be biologically younger than those who are sedentary. We found that when measures of frailty (first collected at BDES3) were added to the model, the association of physical activity and the incidence of VI was no longer statistically significant (Klein R., unpublished data, August 31, 2012). The association may also be a result of uncontrolled confounding, i.e., an active lifestyle may be a marker for a higher likelihood of differences in care for eye conditions that affect vision. For example, while controlling for age and sex, persons leading an active lifestyle were more likely to be seen by an ophthalmologist or optometrist in the past year but not to have had surgery when cataract was present in eyes with VI.

In the BDES, both current and past smoking were related to an increase in the number of letters lost. This was expected, as smoking has been shown to be associated with increased risk of developing AMD and cataract.^{16,25,26} In a blindness registry in New Zealand, nearly one-third of severe VI in persons with late AMD 55-years-old and older and 10% of severe VI in persons with cataract has been attributed to smoking.²⁵ In a Canadian study, the odds of self-reported VI were nearly 3 times as high among smokers compared to nonsmokers.²⁶ Data from the Behavioral Risk Factor Surveillance System showed a cross-sectional association between smoking and self-reported VI among older adults (aged 50 years and older) with age-related eye disease.¹⁶ After adjustment for age, sex, and other factors, persons who were current smokers with AMD or cataract had 16% higher odds of self-reported VI than never smokers with these conditions. In the BDES, while the odds of incident VI were approximately 100% higher in a current smoker compared to a never smoker, the difference was not statistically significant. This may be due to limited power to show this relationship or because smokers who developed VI were more likely to die before being seen at follow-up. This would bias our finding to the null.

In the BDES, those who had not consumed alcoholic beverages in the past year had 100% increased odds of incident VI compared to occasional drinkers. There were no statistically significant protective associations of drinking 1 or more alcoholic beverages or type of beverage drank, and no deleterious associations of heavy drinking with change in the number of letters read correctly or the incidence of VI. Other studies' findings of associations between drinking of alcohol and VI and conditions that may cause it have been inconsistent.^{14,15,27-34} Data from the Behavioral Risk Factor Surveillance System showed that after adjustment for age, sex, history of eye diseases, and other factors, drinking more

than 1 serving of alcohol per day (OR=1.21; 95% CI: 1.09, 1.35) and binge drinking (OR=1.32; 95% CI: 1.14, 1.53) were associated with self-reported VI among current drinkers.¹⁵ The deleterious effect in the BDES may have been found because non-drinkers were more likely to be older and have medical conditions that may have caused them to stop drinking.

Despite the many strengths of the BDES (large population-based cohort followed over a 20-year period using standardized protocols to measure vision and conditions affecting it), there are limitations which may affect the findings. Physical activity was measured using a questionnaire and we have no measurement of how long the participant may have been physically active. Participants with a sedentary lifestyle were less likely than those who were physically active to return for follow-up examinations. We believe that these limitations would only bias the associations with VI towards the null. We cannot rule out the possibility of uncontrolled confounding. Low incidence of VI and low frequency of some of the exposures (e.g., heavy drinking) in the population may also have limited our ability to detect an association. Despite these limitations, this report provides evidence that modifiable behaviors such as regular physical activity may have a protective effect for incident VI and that smoking may have deleterious effects on vision.

In summary, we report that the three modifiable factors of cigarette smoking, drinking of alcoholic beverages, and physical activity are associated with changes in vision in the Beaver Dam Eye Study cohort. It remains to be seen whether changes in these factors will result in fewer incident cases of VI in the aging population.

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C.

Figure 1. Relationships of various lifestyle factors to change in number of letters read correctly on the visual acuity chart within an interval. A. Smoking; B. Alcohol consumption; C. Physical activity.

Table 1

Relationship of Smoking, Alcohol, and Physical Activity to Change in Visual Acuity in the Beaver Dam Eye Study, 1988–2010.

Risk Factor	Change in Visual Acuity					
	Base Model [§]			Fully Adjusted Model		
	N*	Mean change in interval [†] (# letters)	20-year change [‡] (# letters)	β (95% CI)	P value	β (95% CI) P value
Smoking status					0.003	0.004
Never	4510	-1.59	-6.38	Referent		Referent
Past	3775	-1.82	-7.27	-0.24 (-0.46, -0.02)		-0.23 (-0.42, -0.04)
Current	1358	-1.32	-5.27	-0.44 (-0.71, -0.17)		-0.36 (-0.60, -0.12)
Heavy drinking status					0.71	0.95
Never	8163	-1.66	-6.63	Referent		Referent
Past	1306	-1.57	-6.28	-0.07 (-0.34, 0.20)		-0.02 (-0.27, 0.22)
Current	171	-1.51	-6.06	-0.21 (-0.83, 0.41)		0.08 (-0.52, 0.69)
Any alcohol in past year					0.87	0.83
None	1703	-2.07	-8.28	-0.04 (-0.39, 0.32)		0.03 (-0.29, 0.36)
<1 serving/week	3464	-1.61	-6.45	Referent		Referent
1 serving/week	4478	-1.51	-6.04	-0.06 (-0.29, 0.17)		-0.05 (-0.26, 0.16)
Any beer in past year					0.91	0.81
None	3808	-1.86	-7.43	0.05 (-0.23, 0.32)		0.07 (-0.17, 0.31)
<1 serving/week	3175	-1.59	-6.37	Referent		Referent
1 serving/week	2663	-1.40	-5.61	-0.01 (-0.25, 0.24)		0.06 (-0.17, 0.30)
Any wine in past year					0.13	0.26
None	3813	-1.98	-7.91	-0.25 (-0.49, -0.01)		-0.17 (-0.39, 0.06)
<1 serving/week	4629	-1.38	-5.50	Referent		Referent
1 serving/week	1205	-1.63	-6.51	-0.14 (-0.44, 0.15)		-0.18 (-0.45, 0.10)
Any liquor in past year					0.88	0.88
None	3419	-1.95	-7.81	-0.05 (-0.31, 0.21)		0.01 (-0.22, 0.25)
<1 serving/week	3539	-1.45	-5.79	Referent		Referent

Risk Factor	Change in Visual Acuity					
	Base Model [§]			Fully Adjusted Model ^{//}		
	N*	Mean change in interval [†] (# letters)	20-year change [‡] (# letters)	β (95% CI)	P value	P value
1 serving/week	2688	-1.51	-6.05	-0.06 (-0.31, 0.19)	-0.05 (-0.28, 0.18)	
Physical activity level						
Sedentary	6860	-1.73	-6.93	Referent	Referent	0.60
Active	2783	-1.42	-5.69	0.11 (-0.11, 0.32)	0.06 (-0.15, 0.26)	
Blocks walked						
0 per day	3536	-1.79	-7.18	Referent	Referent	0.99
1-4 per day	2300	-1.59	-6.37	0.17 (-0.15, 0.48)	0.05 (-0.24, 0.34)	
5-12 per day	2280	-1.62	-6.49	0.12 (-0.19, 0.42)	0.03 (-0.26, 0.31)	
> 12 per day	1450	-1.36	-5.43	0.10 (-0.21, 0.42)	0.05 (-0.26, 0.36)	
Flights of stairs climbed						
0 per day	1946	-2.43	-9.71	Referent	Referent	0.18
1-3 flights per day	2931	-1.67	-6.68	0.43 (0.06, 0.79)	0.24 (-0.10, 0.58)	
4-6 flights per day	2517	-1.33	-5.33	0.57 (0.21, 0.93)	0.38 (0.04, 0.71)	
> 6 flights per day	2226	-1.27	-5.09	0.42 (0.09, 0.76)	0.24 (-0.07, 0.56)	

AMD, age-related macular degeneration; β , beta estimate; CI, confidence interval; VA, visual acuity.

* Person-visits with VA at start and end of interval.

[†] Unadjusted change in number of letters within an interval.

[‡] Calculated by summing the changes in each interval.

[§] Adjusts for age (linear), age², sex, and examination interval.

^{//} Adjusts for everything in base model plus income, AMD, cataract status, and interactions between AMD and age.

Multivariate Model Results for Change in Number of Letters Read Correctly in the Beaver Dam Eye Study, 1988–2010.

Table 2

Factor in Model**	All Participants			Women Only			Men Only		
	β estimate* (95% CI)	P value		β estimate* (95% CI)	P value		β estimate* (95% CI)	P value	
Smoking status									
Past vs. never	-0.23 (-0.43, -0.04)	0.004		-0.16 (-0.46, 0.14)	0.23		-0.27 (-0.52, -0.01)	0.02	
Current vs. never	-0.37 (-0.61, -0.13)			-0.27 (-0.61, 0.07)			-0.45 (-0.79, -0.12)		
Flights of stairs climbed per day									
1–3 vs. none	0.20 (-0.13, 0.54)	0.23		-0.03 (-0.48, 0.42)	0.91		0.60 (0.12, 1.09)	0.02	
4–6 vs. none	0.35 (0.02, 0.68)			0.08 (-0.35, 0.51)			0.81 (0.30, 1.31)		
>6 vs. none	0.21 (-0.11, 0.52)			-0.06 (-0.49, 0.37)			0.64 (0.18, 1.10)		

CI, confidence interval.

* β estimate is the model estimate and represents the difference in amount of change in number of letters within each interval for the comparisons shown.

** Model includes all terms shown as well as adjustment for age (linear), age², gender, examination interval, household income, age-related macular degeneration status, cataract status, and interactions between AMD status and age (linear and quadratic terms).

Table 3

Relationship of Smoking, Alcohol, and Physical Activity to Incidence of Visual Impairment in the Beaver Dam Eye Study, 1988–2010.

Risk Factor	N*	% Incident in interval [†]	% 20-year cumulative incidence [‡]	Base Model [§]		Fully Adjusted Model	
				OR (95% CI)	P value	OR (95% CI)	P value
Smoking status					0.51		0.41
Never	4448	1.6	6.4	Referent		Referent	
Past	3746	1.3	4.9	1.03 (0.68, 1.54)		1.07 (0.66, 1.75)	
Current	1349	0.8	3.2	1.65 (0.81, 3.39)		2.01 (0.87, 4.61)	
Heavy drinking status					0.06		0.56
Never	8070	1.5	5.9	Referent		Referent	
Past	1301	0.5	1.8	0.48 (0.20, 1.13)		0.64 (0.25, 1.66)	
Current	169	1.8	6.9	2.66 (0.83, 8.54)		1.31 (0.24, 7.08)	
Any alcohol in past year					0.02		0.02
None	1669	2.9	11.0	1.95 (1.26, 3.03)		2.17 (1.28, 3.67)	
<1 serving/week	3430	1.2	4.8	Referent		Referent	
1 serving/week	4446	0.9	3.6	1.10 (0.70, 1.72)		1.06 (0.61, 1.84)	
Any beer in past year					0.37		0.50
None	3749	1.9	7.4	1.20 (0.77, 1.87)		1.36 (0.80, 2.31)	
<1 serving/week	3147	1.0	4.1	Referent		Referent	
1 serving/week	2650	1.0	4.0	1.46 (0.87, 2.46)		1.18 (0.62, 2.23)	
Any wine in past year					0.008		0.13
None	3762	2.0	7.8	1.57 (1.07, 2.30)		1.30 (0.82, 2.03)	
<1 serving/week	4591	1.0	4.0	Referent		Referent	
1 serving/week	1194	0.7	2.7	0.67 (0.31, 1.44)		0.61 (0.24, 1.56)	
Any liquor in past year					0.03		0.21
None	3365	2.2	8.6	1.76 (1.14, 2.72)		1.55 (0.94, 2.57)	
<1 serving/week	3514	0.9	3.5	Referent		Referent	
1 serving/week	2667	0.9	3.7	1.30 (0.75, 2.25)		1.09 (0.58, 2.07)	

Risk Factor	N*	% Incident in interval[†]	% 20-year cumulative incidence[‡]	Base Model[§]		Fully Adjusted Model	
				OR (95% CI)	P value	OR (95% CI)	P value
Physical activity level					<.001		0.002
Sedentary	6775	1.7	6.7	Referent		Referent	
Active	2768	0.5	2.0	0.42 (0.23, 0.74)		0.40 (0.20, 0.79)	
Blocks walked per day					0.03		0.57
None	3483	2.2	8.3	Referent		Referent	
1–4	2282	1.1	4.3	0.61 (0.38, 0.98)		0.78 (0.44, 1.37)	
5–12	2256	1.0	3.8	0.63 (0.38, 1.02)		0.79 (0.45, 1.39)	
> 12	1446	0.6	2.2	0.48 (0.23, 1.01)		0.62 (0.26, 1.45)	
Flights of stairs climbed					0.59		0.98
None	1903	2.6	9.9	Referent		Referent	
1–3 flights per day	2907	1.4	5.7	0.84 (0.54, 1.30)		0.95 (0.55, 1.65)	
4–6 flights per day	2494	1.0	4.1	0.77 (0.46, 1.29)		1.01 (0.54, 1.88)	
> 6 flights per day	2217	0.6	2.5	0.67 (0.35, 1.28)		0.89 (0.44, 1.77)	

CI, confidence interval; OR, odds ratio.

* Person-visits at risk.

[†] Unadjusted incident rate within an interval.[‡] Calculated from the rates in each interval.[§] Adjusts for age (continuous), gender, and examination interval.^{||} Adjusts for everything in base model plus annual household income and age-related macular degeneration status.

Table 4
Multivariate Model Results for Incidence of Visual Impairment in the Beaver Dam Eye Study, 1988–2010.

Factor in Model*	All Participants			Women			Men		
	OR (95% CI)	P value		OR (95% CI)	P value		OR (95% CI)	P value	
Amount of alcohol consumed		0.03			0.05			0.56	
None vs. <1 serving/week	2.12 (1.25, 3.60)			2.27 (1.22, 4.24)			1.77 (0.63, 4.93)		
1 vs. <1 serving/week	1.07 (0.62, 1.86)			0.99 (0.46, 2.12)			1.08 (0.45, 2.57)		
Physical activity level, active vs. sedentary	0.41 (0.21, 0.82)	0.002		0.17 (0.04, 0.75)	<.001		0.69 (0.29, 1.66)	0.38	

CI, confidence interval; OR, odds ratio.
* Model includes all terms shown as well as adjustment for age (linear), gender, examination interval, household income, and AMD status.

Table 5

Estimated 20-Year Cumulative Incidence of Visual Impairment by Annual Household Income, Age-Related Macular Degeneration Status, Physical Activity Status, and Drinking Status Starting at Various Ages (Without Impairment) for Men and Women in the Beaver Dam Eye Study.

Age	Annual		Sedentary			Physically Active	
	Household Income (USD)	AMD Status	Nondrinker	Occasional drinker	Regular drinker	Occasional drinker	
Women							
55 y	\$10,000	None	1.1%	0.5%	0.6%		0.2%
	\$10,000	Early	3.5%	1.7%	1.8%		0.7%
	<\$10,000	None	2.4%	1.2%	1.2%		0.5%
	<\$10,000	Early	7.4%	3.6%	3.8%		1.5%
65 y	\$10,000	None	4.5%	2.2%	2.3%		0.9%
	\$10,000	Early	13.4%	6.6%	7.1%		2.8%
	<\$10,000	None	9.4%	4.6%	4.9%		1.9%
	<\$10,000	Early	25.8%	13.5%	14.4%		5.9%
75 y	\$10,000	None	16.8%	8.5%	9.0%		3.6%
	\$10,000	Early	41.8%	23.5%	24.9%		10.7%
	<\$10,000	None	31.6%	17.0%	18.0%		7.5%
	<\$10,000	Early	65.2%	42.1%	44.1%		21.1%
Men							
55 y	\$10,000	None	1.9%	0.9%	1.0%		0.4%
	\$10,000	Early	5.9%	2.8%	3.0%		1.2%
	<\$10,000	None	4.0%	1.9%	2.1%		0.8%
	<\$10,000	Early	12.0%	5.9%	6.3%		2.5%
65 y	\$10,000	None	7.5%	3.6%	3.9%		1.5%
	\$10,000	Early	21.1%	10.8%	11.5%		4.6%

Age	Annual Household Income (USD)	AMD Status	Sedentary			Physically Active	
			Nondrinker	Occasional drinker	Regular drinker	Occasional drinker	Regular drinker
75 y	<\$10,000	None	15.1%	7.6%	8.1%	3.2%	
	<\$10,000	Early	38.5%	21.3%	22.6%	9.6%	
	\$10,000	None	26.2%	13.7%	14.6%	5.9%	
	\$10,000	Early	57.7%	35.5%	37.3%	17.1%	
	<\$10,000	None	45.8%	26.4%	27.9%	12.2%	
	<\$10,000	Early	80.0%	58.0%	60.2%	32.2%	

AMD, age-related macular degeneration; USD, United States dollars.