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Authors

Coleman, Anne L
Stone, Katie L
Kodjebacheva, Gergana
et al.

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Glaucoma Risk and the Consumption of Fruits and Vegetables Among Older Women in the Study of Osteoporotic Fractures

ANNE L. COLEMAN, KATIE L. STONE, GERGANA KODJEBACHEVA, FEI YU, KATHRYN L. PEDULA, KRIS E. ENSRUD, JANE A. CAULEY, MARC C. HOCHBERG, FOTIS TOPOUZIS, FEDERICO BADALA, AND CAROL M. MANGIONE, ON BEHALF OF THE STUDY OF OSTEOPOROTIC FRACTURES RESEARCH GROUP

• PURPOSE: **To explore the association between the consumption of fruits and vegetables and the presence of glaucoma.**

• DESIGN: **Cross-sectional cohort study.**

• METHODS: **In a sample of 1,155 women located in multiple centers in the United States, glaucoma specialists diagnosed glaucoma in at least one eye by assessing optic nerve head photographs and 76-point suprathreshold screening visual fields. Consumption of fruits and vegetables was assessed using the Block Food Frequency Questionnaire. The relationship between selected fruit and vegetable consumption and glaucoma was investigated using adjusted logistic regression models.**

• RESULTS: **Among 1,155 women, 95 (8.2%) were diagnosed with glaucoma. In adjusted analysis, the odds of glaucoma risk were decreased by 69% (odds ratio [OR], 0.31; 95% confidence interval [CI], 0.11 to 0.91) in women who consumed at least one serving per month of green collards and kale compared with those who consumed fewer than one serving per month, by 64% (OR, 0.36; 95% CI, 0.17 to 0.77) in women who consumed more than two servings per week of carrots compared with those who consumed fewer than one serving per week, and by 47% (OR, 0.53; 95% CI, 0.29 to 0.97) in women who consumed at least one serving per week of canned or dried peaches compared with those who consumed fewer than one serving per month.**

• CONCLUSIONS: **A higher intake of certain fruits and vegetables may be associated with a decreased risk of glaucoma. More studies are needed to investigate this relationship.** (Am J Ophthalmol 2008;145:1081–1089.

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From the Department of Ophthalmology and Jules Stein Eye Institute (A.L.C., G.K., F.Y., F.B.); the School of Public Health (A.L.C., G.K., F.Y.); and the Department of Medicine, UCLA, Los Angeles, California (C.M.M.); the San Francisco Coordinating Center, California Pacific Medical Center Research Institute, San Francisco, California (K.L.S.); the Kaiser Permanente Center for Health Research, Northwest/Hawaii, Portland, Oregon (K.L.P.); the Veterans Affairs Medical Center and Departments of Medicine and Epidemiology, University of Minnesota, Minneapolis, Minnesota (K.E.E.); the Department of Epidemiology, University of Pittsburgh, Pittsburgh, Pennsylvania (J.A.C.); the Division of Rheumatology, Departments of Medicine and Epidemiology and Preventive Medicine, University of Maryland, Baltimore, Maryland (M.C.H.); and the Department of Ophthalmology, Aristotle University, Thessaloniki, Greece (F.T.).

Inquiries to Anne L. Coleman, Jules Stein Eye Institute, 100 Stein Plaza, Los Angeles, CA 90095; e-mail: colemana@ucla.edu

THE PREVALENCE OF GLAUCOMA, DEFINED AS THE deterioration of the optic nerve that may cause the loss of all vision, is increasing because of the aging of the population.[1] It is the second leading cause of blindness worldwide, whereas cataracts are the first.[2] This disease presents a greater public health concern than cataract, however, because the blindness it causes is irreversible. In 2002, more than 2.2 million Americans aged 40 years and older had primary open-angle glaucoma (POAG),[3] the most common type of glaucoma. Blacks are more likely to have glaucoma than Whites; the disease is one of the leading causes of blindness in this group.[4,5] Given the significant individual and economic consequences of glaucoma, prevention strategies are essential if we hope to decrease the burden of this eye condition.

Intraocular pressure (IOP) is an identified modifiable risk factor associated with glaucoma.[6–9] Lowering IOP is accomplished through the use of medications, laser, and surgery. Nutritional factors may be important in the development of eye diseases, and antioxidants may protect retinal ganglion cells.[10–14] Fruits and vegetables are rich sources of antioxidant nutrients, but to our knowledge only one manuscript has reported the findings on their consumption in relation to glaucoma risk. A combined manuscript on the results from the Nurses' Health Study and the Health Professionals Follow-up Study reported no association between fruit and vegetable consumption and the risk of glaucoma in individuals older than 40 years of age.[15]

We investigated the association between glaucoma and the consumption of specific fruits and vegetables in a cohort of women aged 65 and older participating in the Study of Osteoporotic Fractures (SOF). To examine whether specific nutrients accounted for the association between glaucoma risk and fruit and vegetable consumption, the associations among glaucoma risk and antioxidants, calories, fat, protein, and carbohydrates obtained from natural food sources also were evaluated.

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METHODS

• **SETTING AND SUBJECTS:** The SOF is a multicenter longitudinal cohort study. A total of 9,704 ambulatory White female volunteers aged 65 years or older, with no history of osteoporosis or bilateral hip replacement, were enrolled in the study between 1986 and 1988. Participants were recruited from several United States clinic centers located in Baltimore, Maryland; Minneapolis, Minnesota; Portland, Oregon; and the Monongahela Valley, Pennsylvania. Between 1997 and 1998, all surviving participants were invited to take part in a year 10 follow-up clinical examination (sixth clinic visit, or V6), which included an eye evaluation. A total of 662 Black women also were recruited using population listings at the four study locations. The resulting participants in the V6 included 5,482 women (4,820 Whites and 662 Blacks), representing 63% of the surviving cohort. Participants identified their race or ethnicity. They provided informed consent to participate. The characteristics of the study population have been described in earlier reports.[16,17]

• **GLAUCOMA (OUTCOME MEASUREMENT) ASCERTAINMENT:** At the eye examination, 5,482 women had optic nerve images obtained with a Canon nonmydriatic camera (Canon CR 45UAF 45-degree autofocus noncamera; Canon, Inc, Kanagawaken, Japan) through a dilated pupil. In addition, these women had undergone visual field (VF) testing of each eye using the 76-point suprathreshold VF test. A random sample of 1,274 (of 5,482) women was selected for photograph grading by the University of California San Francisco Coordinating Center using a random numbers generator program. A random sample of subjects was chosen for glaucoma photography grading instead of grading all available photographs because of the associated costs. Average vertical cup and disk diameters of the optic nerves of these women were obtained from the measurements made by two masked, trained graders using a reticule (peak scale lupe, ×10). VFs and photographs of all women with at least one eye with a cup-to-disk ratio of 0.6 or more (n = 208), asymmetry of the vertical cup-to-disk ratios between two eyes of a subject of 0.2 or more (n = 4), or both, along with a 5% random sample of the women with cup-to-disk ratios less than 0.6 (n = 89) were evaluated by two masked, trained glaucoma specialists. Independently, the two glaucoma specialists diagnosed glaucoma based on the appearance of the optic nerve head and the presence of VF loss using results from the Humphrey Field Analyzer (Carl Zeiss Meditec, Dublin, California, USA) suprathreshold 76-point 30-degree VF tests. The optic nerves were diagnosed as glaucomatous based on diffuse and localized thinning of the neuroretinal rim and loss of retinal fiber layer. VF loss was defined as the presence of at least one missing point on the suprathreshold test. Discrepancies in the diagnoses by the two glaucoma specialists and all questionable diagnoses by either glaucoma specialist were adjudicated by a third, masked glaucoma specialist.

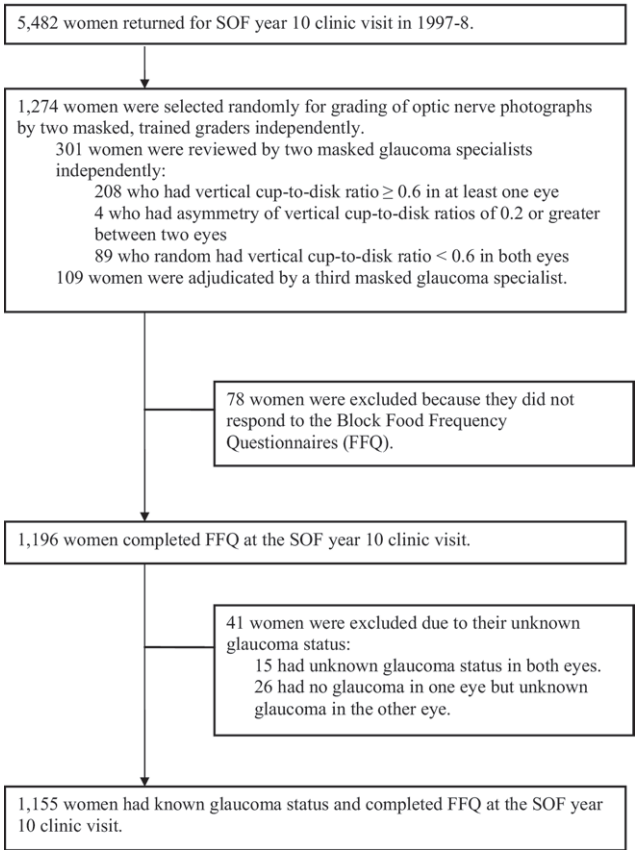

FIGURE . Algorithm showing study progression. SOF = Study of Osteoporotic Fractures.

• **MEASUREMENT OF FRUIT AND VEGETABLE CONSUMPTION AND ANTIOXIDANT INTAKE:** Consumption of fruits and vegetables was assessed using the 1995 Block Food Frequency Questionnaire (FFQ).[18,19] Participants completed the FFQ just before their clinical visit. Questions about fruit and vegetable consumption referred to respondents' usual eating habits over the past year. Women indicated how often, on average, they consumed specific fruits and vegetables during the past year. The following items were analyzed in this study: canned or dried peaches, raw or cooked spinach, orange juice, green salad, fresh apples, bananas, oranges, green collards and kale, and carrots. These items were chosen based on past research about the relationship between eye diseases and the intake of fruits and vegetables. Response options for frequency of consumption were the same for all fruits and vegetables and included several categories for monthly, weekly, and daily consumption.

Block Dietary Data Systems (Berkeley, California, USA) calculated nutrition summary variables, including daily intake of antioxidants from food, and fat, protein, carbohydrates, and nutrients obtained from all natural food

TABLE 1. Characteristics of Women Who Had Known Glaucoma Status and Completed the Block Food Frequency Questionnaire in the Study of Osteoporotic Fractures Year 10 Clinic Visit

Characteristic	Total (n =1,155)	White (n =1,011)	Black (n =144)
Study sites			
Baltimore	245 (21.2%)	206 (20.4%)	39 (27.1%)
Minneapolis	367 (31.8%)	328 (32.4%)	39 (27.1%)
Pittsburgh	322 (27.9%)	281 (27.8%)	41 (28.5%)
Portland	221 (19.1%)	196 (19.4%)	25 (17.4%)
Age (yrs)			
Mean ± SD (range)	79.4 ± 4.5 (67 to 97)	79.9 ± 4.0 (74 to 97)	75.7 ± 5.5 (67 to 94)
65 to 74	84 (7.3%)	11 (1.1%)	73 (50.7%)
75 to 79	573 (49.6%)	534 (52.8%)	39 (27.1%)
80 to 84	348 (30.1%)	328 (32.4%)	20 (13.9%)
85 and older	150 (13.0%)	138 (13.7%)	12 (8.3%)
Education (yrs)			
Mean ± SD (range)	12.8 ± 2.7 (2 to 19)	12.9 ± 2.6 (2 to 19)	11.9 ± 3.1 (3 to 19)
< 12 years	208 (18.0%)	165 (16.3%)	43 (30.1%)
12 years	492 (42.6%)	438 (43.3%)	54 (37.8%)
> 12 years	454 (39.3%)	408 (40.4%)	46 (32.2%)
Current smoker	54 (4.7%)	38 (3.8%)	16 (11.1%)
At least one alcoholic drink in past 30 days	511 (44.2%)	468 (46.3%)	43 (29.9%)
Walking for exercise	465 (40.4%)	413 (40.9%)	52 (36.4%)
Body mass index (kg/m^2)			
Mean ± SD (range)	26.9 ± 5.1 (15.4 to 53.8)	26.4 ± 4.8 (15.5 to 53.8)	29.7 ± 6.4 (15.4 to 48.5)
Self-rated health status			
Good or excellent	925 (80.1%)	818 (80.9%)	107 (74.3%)
Fair or poor	230 (19.9%)	193 (19.1%)	37 (25.7%)
Self-report of diabetes	72 (6.2%)	44 (4.4%)	28 (19.4%)
Self-report of hypertension	424 (36.7%)	324 (32.1%)	100 (69.4%)
Presence of clinical diagnosed late AMD	36 (3.3%)	35 (3.6%)	1 (0.8%)
Presence of clinical diagnosed glaucoma	95 (8.2%)	83 (8.2%)	12 (8.3%)

AMD = age-related macular degeneration; SD = standard deviation; yrs = years.

sources (not only fruits and vegetables) based on responses about consumption to the FFQ.[20]

• **STATISTICAL ANALYSIS:** Women who did not complete the FFQ or had unknown glaucoma status, because of ungradable photographs or lack of photographs, were excluded from the analysis. The distribution of each selected fruit or vegetable item was examined in the total study population and by race. In the analysis, most items were categorized into four groups: fewer than one serving per week, one serving per week, two servings per week, and more than two servings per week. Some items, however, were categorized into different groups to reflect their distributions. For example, 950 women (82%) consumed green collards and kale fewer than one serving per month, so the consumption of green collards and kale was categorized into two groups: fewer than one serving per month and at least one serving per month. The number of participants consuming a certain item may not add up to the total number of the study population because of incomplete responses for the item. The relationship between the consumption of each item of fruits and vegetables and the risk of glaucoma was evaluated individually using logistic regression models, adjusted for potential confounders. The potential confounders were chosen based on the clinical relevance and evidence from the literature[15] and included study site, age, race or ethnicity, education, smoking status, alcohol consumption, walking for exercise, body mass index (BMI), self-rated health status, presence of self-reported diabetes, presence of self-reported hypertension, and presence of clinical diagnosed late age-related macular degeneration (AMD).

To understand better the relationship between glaucoma and fruit and vegetable consumption, the major nutrient components of fruits and vegetables were determined.[21] These included vitamins A, C, D, E, B (folate), B1 (thiamin), B2 (riboflavin), B3 (niacin), B6, α- and β-carotenes, cryptoxanthin, lutein and zeaxanthin, and lycopene. The intake of these nutrients, along with the total intake of calories, fats, proteins, and carbohydrates, were then calculated based on the consumption of all food collected in the FFQ. Their relationships with the risk of glaucoma were examined individually using logistic regression models, with the same adjustments described earlier.

TABLE 2. Frequency of Selected Fruit and Vegetable Consumption among a Random Sample of Women Who Participated in the Study of Osteoporotic Fractures Year 10 Clinic Visit and Stratified by Race

Fruits and Vegetables	Food Frequency, No. (%) Total (n =1,155)	White (n =1,011)	Black (n =144)
All fruits and fruit juices			
< 1 serving per day	195 (17%)	165 (16%)	30 (21%)
1 serving per day	423 (37%)	365 (36%)	58 (40%)
2 servings per day	301 (26%)	258 (26%)	43 (30%)
≥ 3 servings per day	236 (20%)	223 (22%)	13 (9%)
All vegetables			
< 1 serving per day	83 (7%)	69 (7%)	14 (10%)
1 serving per day	326 (28%)	273 (27%)	53 (37%)
2 servings per day	373 (32%)	331 (33%)	42 (29%)
≥ 3 servings per day	373 (32%)	338 (33%)	35 (24%)
Fresh apple			
< 1 serving per wk	342 (35%)	302 (35%)	40 (33%)
1 serving per wk	146 (15%)	128 (15%)	18 (15%)
2 servings per wk	210 (21%)	185 (21%)	25 (21%)
> 2 servings per wk	292 (29%)	255 (29%)	37 (31%)
Fresh banana			
< 1 serving per wk	175 (16%)	147 (15%)	28 (21%)
1 to 2 servings per wk	248 (23%)	223 (23%)	25 (19%)
3 to 6 servings per wk	375 (34%)	318 (33%)	57 (43%)
≥ 1 serving per day	291 (27%)	268 (28%)	23 (17%)
Fresh orange			
< 1 serving per wk	296 (36%)	257 (35%)	39 (44%)
1 serving per wk	126 (15%)	116 (16%)	10 (11%)
2 servings per wk	168 (20%)	148 (20%)	20 (23%)
> 2 servings per wk	240 (29%)	221 (30%)	19 (22%)
Orange juice			
≤ 1 serving per wk	398 (35%)	354 (35%)	44 (31%)
2 servings per wk to < 1 serving per day	309 (27%)	265 (26%)	44 (31%)
≥ 1 serving per day	446 (38%)	390 (39%)	56 (39%)
Fresh peach			
< 1 serving per wk	251 (29%)	220 (28%)	31 (32%)
1 serving per wk	126 (14%)	112 (14%)	14 (15%)
2 servings per wk	213 (24%)	190 (25%)	23 (24%)
> 2 servings per wk	280 (32%)	252 (33%)	28 (29%)
Canned/dried peach			
< 1 serving per mo	416 (36%)	362 (36%)	54 (38%)
1 serving per mo to < 1 serving per wk	388 (34%)	345 (34%)	43 (30%)
≥ 1 serving per wk	347 (30%)	302 (30%)	45 (32%)
Fresh carrot			
< 1 serving per wk	315 (29%)	262 (27%)	53 (43%)
1 serving per wk	250 (23%)	226 (23%)	24 (19%)
2 servings per wk	234 (21%)	219 (23%)	15 (12%)
> 2 servings per wk	298 (27%)	266 (27%)	32 (26%)
Spinach (cooked or raw)			
≤ 1 serving per mo	261 (37%)	236 (39%)	25 (24%)
> 1 serving per mo to < 1 serving per wk	203 (29%)	172 (28%)	31 (30%)
1 serving per wk	134 (19%)	109 (18%)	25 (24%)
> 1 serving per wk	112 (16%)	89 (15%)	23 (22%)
Green salad			
< 1 serving per wk	161 (16%)	130 (14%)	31 (25%)
1 serving per wk	137 (13%)	115 (13%)	22 (18%)
2 servings per wk	204 (20%)	182 (20%)	22 (18%)
> 2 servings per wk	533 (51%)	484 (53%)	49 (39%)
Green collards or kale			
< 1 serving per mo	950 (82%)	929 (92%)	21 (15%)
≥ 1 serving per mo	204 (18%)	81 (8%)	123 (85%)

Mo = month; wk = week.

Because of the skewed distribution of antioxidant intake, all antioxidants were categorized by easily interpreted cut-off points close to their corresponding quartiles, except for a few that were categorized by easily interpreted cut-off points close to their corresponding tertiles.

All statistical analyses were performed using SAS statistical software version 9.1 (SAS Institute, Cary, North Carolina, USA). Trend *P* values indicate whether a dose-response effect exists as more fruits and vegetables and antioxidants are consumed. Trend *P* values were used when more than two categories of consumption were present.

RESULTS

• **SAMPLE SIZE:** Among 1,274 women whose photographs were chosen randomly to be graded, glaucoma status could not be determined for 44 women (3.5%) because of ungradable photographs or lack of photographs. An additional 75 women did not complete the FFQ. Thus, a total of 119 women were excluded from the analysis, and the final study population consisted of 1,155 women (Figure). There were no statistically significant differences in baseline characteristics among those 119 women who were excluded, except that they were slightly older ($P = .008$) and less likely to be Black ($P = .036$).

• **SAMPLE CHARACTERISTICS:** The sample consisted of older and predominantly White women. One thousand and eleven of the 1,155 (87.5%) women were White and 144 (12.5%) were Black. Participants' ages ranged from 67 to 97 years, with a mean of 79.4 years (± standard deviation, 4.5 years). The overwhelming majority (95.3%) were not current smokers. A total of 72 (6.2%) women had diabetes. Black women tended to be younger, with a higher percentage reporting to be current smokers and to have

TABLE 3. Adjusted Effects of Selected Fruit and Vegetable Consumption on Glaucoma among a Random Sample of Women Who Participated in the Study of Osteoporotic Fractures Year 10 Clinic Visit*

Average Intake of Fruits and Vegetables	Odds Ratio	95% Confidence Interval	*P* value
All fruits and fruit juices			
< 1 serving per day	Referent (1)	—	—
1 serving per day	1.06	(0.52 to 2.15)	.883
2 servings per day	1.19	(0.57 to 2.49)	.637
≥ 3 servings per day	0.98	(0.44 to 2.19)	.963
All vegetables			
< 1 serving per day	Referent (1)	—	—
1 serving per day	1.64	(0.54 to 4.96)	.381
2 servings per day	1.65	(0.55 to 4.96)	.371
≥ 3 servings per day	1.44	(0.47 to 4.36)	.524
Fresh apple			
< 1 serving per wk	Referent (1)	—	—
1 serving per wk	0.67	(0.30 to 1.53)	.344
2 servings per wk	0.70	(0.34 to 1.42)	.317
> 2 servings per wk	0.86	(0.47 to 1.57)	.628
Fresh banana			
< 1 serving per wk	Referent (1)	—	—
1 to 2 servings per wk	0.75	(0.36 to 1.56)	.445
3 to 6 servings per wk	0.61	(0.30 to 1.23)	.164
≥ 1 serving per day	0.86	(0.42 to 1.73)	.663
Fresh orange			
< 1 serving per wk	Referent (1)	—	—
1 serving per wk	1.19	(0.53 to 2.66)	.676
2 servings per wk	1.11	(0.51 to 2.45)	.792
> 2 servings per wk	0.99	(0.49 to 1.98)	.969
Orange juice			
≤ 1 serving per wk	Referent (1)	—	—
2 servings per wk to < 1 serving per day	1.13	(0.59 to 2.15)	.718
≥ 1 serving per day	1.73	(0.99 to 3.00)	.053
Fresh peach			
< 1 serving per wk	Referent (1)	—	—
1 serving per wk	0.53	(0.21 to 1.36)	.187
2 servings per wk	0.69	(0.34 to 1.41)	.311
> 2 servings per wk	0.74	(0.38 to 1.45)	.382
Canned/dried peach			
< 1 serving per mo	Referent (1)	—	—
1 serving per mo to < 1 serving per wk	0.74	(0.43 to 1.27)	.276
≥ 1 serving per wk	0.53	(0.29 to 0.97)	.040
Fresh carrot			
< 1 serving per wk	Referent (1)	—	—
1 serving per wk	1.57	(0.87 to 2.84)	.133
2 servings per wk	0.90	(0.46 to 1.76)	.762
> 2 servings per wk	0.36	(0.17 to 0.77)	.009
Spinach (cooked or raw)			
≤ 1 serving per mo	Referent (1)	—	—
> 1 serving per mo to < 1 serving per wk	1.16	(0.53 to 2.56)	.713
1 serving per wk	1.12	(0.45 to 2.83)	.806
> 1 serving per wk	2.19	(0.94 to 5.10)	.070
Green salad			
< 1 serving per wk	Referent (1)	—	—
1 serving per wk	1.95	(0.74 to 5.14)	.179
2 servings per wk	1.07	(0.41 to 2.80)	.889
> 2 servings per wk	1.49	(0.66 to 3.36)	.334
Green collards/kale			
< 1 serving per mo	Referent (1)	—	—
≥ 1 serving per mo	0.31	(0.11 to 0.91)	.034

Mo = month; wk = week.

*Based on multiple logistic regression models of the prevalence of glaucoma adjusting for potential confounders including study sites, age, race and ethnicity, education, smoking status, alcohol consumption, walking for exercise, body mass index, self-rated health status, presence of self-reported diabetes, presence of self-reported hypertension, and presence of clinical diagnosed late age-related macular degeneration.

diabetes compared with Whites. The characteristics of the study population are described in Table 1.

• **PREVALENCE OF GLAUCOMA:** Among 1,155 women, 95 (8.2%) were diagnosed with glaucoma in at least one eye. The prevalence of glaucoma increased with advancing age. Specifically, five (6%) of the 84 women aged 65 to 74 years had glaucoma compared with 35 (6.1%) of the 573 women aged 75 to 79 years, 30 (8.6%) of the 348 women aged 80 to 84 years, and 25 (16.7%) of the 150 women aged 85 years and older ($P < .001$ for trend of glaucoma with age). The overall prevalence of glaucoma was 8.2%, which was similar in Whites (83 of 1011) and Blacks (12 of 144; $P < .001$ for trend of glaucoma with age in Whites and $P = .215$ in Blacks).

• **OVERALL CONSUMPTION OF FRUITS AND VEGETABLES:** The fruit and vegetable consumption varied among study participants. For example, 298 (27%) women consumed two or more servings of carrots per week, whereas 553 (51%) consumed the same amount of green salad (Table 2). Differences in consumption between Whites and Blacks are notable. Whereas only 81 (8%) White respondents consumed at least one serving of green collards or kale per month, 123 (85%) Black participants consumed this amount.

• **ADJUSTED ANALYSES OF THE RELATIONSHIP BETWEEN FRUIT AND VEGETABLE INTAKE AND GLAUCOMA:** In analyses adjusted for potential confounders including study site, age, race or ethnicity, education,

TABLE 4. Adjusted Effects of Selected Nutrients on Glaucoma among a Random Sample of Women Who Participated in the Study of Osteoporotic Fractures Year 10 Clinic Visit*

Average Daily Intake of Nutrients from Food	Odds Ratio	95% Confidence Interval	*P* value
Vitamin A (retinal equivalent)			
< 800	Referent (1)	—	—
800 to 1099	1.25	(0.71 to 2.22)	.438
1100 to 1399	0.71	(0.36 to 1.41)	.331
≥ 1400	0.50	(0.24 to 1.03)	.061
Vitamin B (folate; mg)			
< 200	Referent (1)	—	—
200 to 249	1.27	(0.67 to 2.41)	.462
250 to 299	1.13	(0.58 to 2.18)	.727
≥ 300	0.98	(0.53 to 1.83)	.948
Vitamin B1 (thiamin; mg)			
< 1	Referent (1)	—	—
1 to 1.4	1.06	(0.63 to 1.78)	.827
≥ 1.5	1.38	(0.72 to 2.66)	.331
Vitamin B2 (riboflavin; mg)			
< 1	Referent (1)	—	—
1 to 1.4	0.53	(0.26 to 1.05)	.068
1.5 to 1.9	0.92	(0.48 to 1.78)	.814
≥ 2	0.39	(0.17 to 0.86)	.019
Vitamin B3 (niacin; mg)			
< 10	Referent (1)	—	—
10 to 14	1.41	(0.62 to 3.19)	.417
15 to 19	1.25	(0.54 to 3.90)	.605
≥ 20	1.35	(0.54 to 3.41)	.525
Vitamin B6 (mg)			
< 1	Referent (1)	—	—
1 to 1.4	1.38	(0.66 to 2.90)	.389
1.5 to 1.9	1.37	(0.63 to 2.98)	.424
≥ 2	1.09	(0.44 to 2.70)	.850
Vitamin C (mg)			
< 70	Referent (1)	—	—
70 to 99	1.30	(0.63 to 2.70)	.475
100 to 129	1.84	(0.93 to 3.66)	.082
≥ 130	1.58	(0.80 to 3.12)	.186
Vitamin E (A-TE)			
< 5	Referent (1)	—	—
5 to 6.9	1.17	(0.62 to 2.19)	.634
7 to 8.9	1.19	(0.61 to 2.32)	.606
≥ 9	0.85	(0.42 to 1.71)	.650
α -carotene (μg)			
< 250	Referent (1)	—	—
250 to 399	0.79	(0.44 to 1.42)	.429
≥ 400	0.61	(0.36 to 1.05)	.073
β-carotene (μg)			
< 1500	Referent (1)	—	—
1500 to 2499	1.11	(0.60 to 2.03)	.743
2500 to 3499	1.02	(0.52 to 1.99)	.950
≥ 3500	0.67	(0.33 to 1.39)	.282
Cryptoxanthin (μg)			
< 50	Referent (1)	—	—
50 to 99	2.11	(1.03 to 4.32)	.042
100 to 149	1.77	(0.84 to 3.73)	.132
≥ 150	2.19	(0.97 to 4.93)	.060
Lutein/zeaxanthin (μg)			
< 500	Referent (1)	—	—
500 to 999	1.23	(0.62 to 2.46)	.553
1000 to 1999	1.36	(0.67 to 2.74)	.395
≥ 2000	1.27	(0.58 to 2.75)	.549
Lycopene (μg)			
< 500	Referent (1)	—	—
500 to 999	1.57	(0.85 to 2.90)	.155
1000 to 1499	0.79	(0.36 to 1.70)	.542
≥ 1500	1.35	(0.67 to 2.72)	.399
Potassium (mg)			
< 2000	Referent (1)	—	—
2000 to 2499	1.13	(0.62 to 2.08)	.686
2500 to 2999	1.49	(0.83 to 2.69)	.184
≥ 3000	0.52	(0.24 to 1.13)	.098
Total calories (Kcal)			
< 1000	Referent (1)	—	—
1000 to 1499	1.47	(0.70 to 3.07)	.306
1500 to 1999	1.40	(0.66 to 3.01)	.384
≥ 2000	0.57	(0.17 to 1.91)	.364
Total fat (g)			
< 40	Referent (1)	—	—
40 to 59	1.47	(0.80 to 2.70)	.219
60 to 79	1.39	(0.72 to 2.69)	.325
≥ 80	0.86	(0.37 to 2.00)	.725
Total protein (g)			
< 50	Referent (1)	—	—
50 to 59	1.67	(0.91 to 3.10)	.101
60 to 69	1.25	(0.64 to 2.42)	.513
≥ 70	0.90	(0.47 to 1.70)	.734
Total carbohydrate (g)			
< 150	Referent (1)	—	—
150 to 179	0.89	(0.49 to 1.63)	.710
180 to 209	0.65	(0.31 to 1.33)	.234
≥ 210	0.89	(0.49 to 1.61)	.697

*Based on multiple logistic regression models of the prevalence of glaucoma adjusting for potential confounders including study sites, age, race and ethnicity, education, smoking status, alcohol consumption, walking for exercise, body mass index, self-rated health status, presence of self-reported diabetes, presence of self-reported hypertension, and presence of clinical diagnosed late age-related macular degeneration.

smoking status, alcohol consumption, walks for exercise, BMI, self-rated health status, presence of self-reported diabetes and hypertension, and presence of clinical diagnosed late AMD, the odds of having glaucoma were decreased by 64% (odds ratio [OR], 0.36; 95% confidence interval [CI], 0.17 to 0.77) in women who consumed fresh

carrots more than two servings per week compared with those who consumed fewer than one serving per week (P = .009; trend P = .002; Table 3). Women who consumed one or more servings per month of fresh green collards or kale were 69% less likely (OR, 0.31; 95% CI, 0.11 to 0.91) to have glaucoma compared with those who consumed fewer than one serving per month (P = .034). The odds of having glaucoma were decreased by 47% (OR, 0.53; 95% CI, 0.29 to 0.97) in women who consumed one or more servings per month of canned or dried peaches compared with those who consumed fewer than one serving per month (P = .040; trend P = .057). The trend results related to the consumption of canned or dried peaches had borderline significance.

The odds of having glaucoma increased by approximately 70% (OR, 1.73; 95% CI, 0.99 to 3.00) in women who drank orange juice at least one serving per day compared with those who drank one serving or less per week (P = .053; trend P = .008; Table 3). Women who consumed more than one serving of spinach per week tended to have a greater odds of glaucoma diagnosis (OR, 2.19; 95% CI, 0.94 to 5.10) compared with those who consumed one or fewer than one serving per month (P = .070; trend P = .256).

Because of the difference in the consumption of fresh green collards or kale between Whites and Blacks, we further examined the effect of fresh green collards or kale on the risk of glaucoma by race. Because of the small sample size of Blacks, only study site- and age-adjusted models were performed. Compared with those who consumed fewer than one serving per month of fresh green collards or kale, the odds of having glaucoma were decreased by 46% (OR, 0.54; 95% CI, 0.19 to 1.53; P = .243) and 85% (OR, 0.15; 95% CI, 0.04 to 0.56; P = .005) in White and Black women who consumed one or more servings per month, respectively.

• **RELATIONSHIP BETWEEN INDIVIDUAL NUTRIENT INTAKE AND GLAUCOMA:** After adjusting for study sites, age, race or ethnicity, education, smoking status, alcohol consumption, walks for exercise, BMI, self-rated health status, presence of self-reported diabetes and hypertension, and presence of clinical diagnosed late AMD, women who consumed at least 2 mg vitamin B2 (riboflavin) from natural food sources tended to be less likely to be diagnosed with glaucoma (OR, 0.39; 95% CI, 0.17 to 0.86; P = .019; trend P = .136) compared with those consuming less than 1 mg (Table 4). Women with a daily intake of at least 1400 retinol equivalents (RE) of vitamin A from food tended to have reduced odds of glaucoma (OR, 0.50; 95% CI, 0.24 to 1.03; P = .061; trend P = .044) compared with those who consumed less than 800 RE daily. Compared with women consuming less than 50 μg cryptoxanthin from food, those consuming 50 to 99 μg tended to have an increased likelihood of glaucoma (OR, 2.11; 95% CI, 1.03 to 4.32; P = .042; trend P = .056).

DISCUSSION

HIGHER INTAKE OF CERTAIN FRUITS AND VEGETABLES MAY be associated with a decreased risk of glaucoma in older women. Women with greater consumption of carrots, which are rich in vitamin A, and alpha- and beta-carotenes[21]; of green collards or kale, which are rich in vitamins A, C, B2, and β-carotene; and of canned or dried peaches, which are rich in vitamin A, had a reduced odds of glaucoma diagnosis. The results indicate that green collards or kale may be more protective in Blacks than in Whites. A greater intake of vitamin B2 (riboflavin) also was associated with lower odds of having glaucoma, although the results did not indicate a linear dose-response effect. The exact mechanism in which fruits and vegetables and antioxidants may affect glaucoma presence is unknown.

Interestingly, some antioxidants such as vitamin C were not associated with a reduction in the risk of glaucoma, although green collards or kale are rich in vitamin C and were associated with lower odds of having glaucoma. Other factors in green collards or kale besides vitamin C may contribute to the reduced risk of glaucoma. Constituents of fruits and vegetables, including flavonoids, isothiocyanates, fiber, and potassium, benefit the health of individuals.[22] Antioxidants also may act synergistically with other constituents of food including components of fruits and vegetables.[23]

In the study by Kang and associates,[15] the authors did not find an association between the risk of POAG and six food groups, specifically citrus foods, cruciferous vegetables, yellow vegetables, green leafy vegetables, all fruits combined, and all vegetables combined, with the use of a food-frequency questionnaire. The authors showed a 32% decreased risk of POAG after four years in subjects in the highest quintiles of lutein and vitamin E intake. In the pooled four-year data, there was a 32% reduction in the risk of glaucoma in all subjects in the third quintile of vitamin C intake. Although a strength of the study by Kang and associates is that it was a large 10-year prospective study, the authors used self-report to identify cases of POAG. In their population of nurses and physicians, only 11.0% to 14.8% of subjects who reported glaucoma were considered actually to have glaucoma by the investigators. In addition, the investigators did not evaluate the records of a random sample of subjects who did not report a diagnosis of glaucoma; this could result in an additional measurement bias because 50% or more of subjects with glaucoma are unaware of the diagnosis.[6,24] An additional difference between the study by Kang and associates and this investigation is the age of the populations. The mean age of females was 48 to 50 years and of males was 53 to 57 years in their study. Additionally, the median consumption of antioxidants among women in the SOF falls within the first two quintiles of the Nurses' Health Study and Health Professionals Follow-up Study populations.

Certain fruits and vegetables and antioxidants tended to increase the likelihood of having glaucoma. Greater intake of orange juice was found to be associated with higher risk of having glaucoma. Higher daily intake of cryptoxanthin, one major nutrient component of orange juice, also was related to an increased risk of having glaucoma. Although not statistically significant, higher consumption of fresh oranges and higher intake of vitamin C and lutein and zeaxanthin, components of oranges and orange juice, also were associated with an increased risk of having glaucoma. The consumption of spinach also tended to increase the likelihood of glaucoma. Although these results may be confounded by other factors including the intake of medication and having chronic diseases, which we tried to control for by using self-rated health status in our analyses, they are worth further investigation.

Past studies have found that Blacks have higher rates of glaucoma than Whites. In this study, we found that the rates were the same in White and Black participants. Because the rates of glaucoma increase as individuals age, the similar rates of glaucoma in Whites and Blacks could be the result of the older age of Whites compared with Blacks in this study. A total of 73 (50.7%) Black women in this study were between the ages of 65 and 74 years, whereas only 11 (1.1%) White females were in this age category. In addition, the rates of glaucoma in this study for both White and Black women are within the prevalence confidence intervals of a recent study[25] summarizing results from 46 studies investigating the prevalence of POAG by age, gender, and race.

Several limitations should be considered when interpreting the results of this cross-sectional study. The findings may not be generalizable to men, to individuals other than Whites and Blacks, or to women younger than 65 years. The sample of Blacks in this study was significantly smaller and younger than Whites. Information on both fruit and vegetable consumption and the presence of glaucoma was obtained during the same visit; therefore, the causal relationship could not be assessed. The multiple comparison of fruits and vegetables and antioxidants is a general limitation of similar studies. The results also may be confounded by other risk factors associated with women's lifestyle because higher fruit and vegetable intake may be related to a healthier lifestyle.

A higher intake of certain fruits and vegetables may be associated with a decreased risk of glaucoma in older women. Although this study provides a cross-sectional analysis, the findings are intriguing because very few environmental and dietary influences have been reported to affect glaucoma. Further investigations are needed of the relationship between glaucoma and the consumption of fruits and vegetables.

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THE STUDY OF OSTEOPOROTIC FRACTURES RESEARCH GROUP

A complete list of the members of the Study of Osteoporotic Fractures Research Group is available at the SOF website: http://sof.ucsf.edu/beta.

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