Diet, vegetarianism, and cataract risk[1–3]

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ABSTRACT

Background: Age-related cataract is a major cause of morbidity. Previous studies of diet and cataract risk have focused on specific nutrients or healthy eating indexes but not on identifiable dietary groups such as vegetarians.

Objective: We investigated the association between diet and cataract risk in a population that has a wide range of diets and includes a high proportion of vegetarians.

Design: We used Cox proportional hazards regression to study cataract risk in relation to baseline dietary and lifestyle characteristics of 27,670 self-reported nondiabetic participants aged ≥40 y at recruitment in the Oxford (United Kingdom) arm of the European Prospective Investigation into Cancer and Nutrition (EPIC-Oxford) by using data from the Hospital Episode Statistics in England and Scottish Morbidity Records.

Results: There was a strong relation between cataract risk and diet group, with a progressive decrease in risk of cataract in high meat eaters to low meat eaters, fish eaters (participants who ate fish but not meat), vegetarians, and vegans. After multivariable adjustment, incidence rate ratios (95% CIs) for moderate meat eaters (50–99 g meat/d), low meat eaters (<50 g meat/d), fish eaters, vegetarians, and vegans compared with high-meat eaters (≥100 g meat/d) were 0.96 (0.84, 1.11), 0.85 (0.72, 0.99), 0.79 (0.65, 0.97), 0.70 (0.58, 0.84), and 0.60 (0.38, 0.96), respectively ($P < 0.001$ for heterogeneity). Associations between cataract risk and intakes of selected nutrients and foods generally reflected the strong association with diet group.

Conclusion: Vegetarians were at lower risk of cataract than were meat eaters in this cohort of health-conscious British residents. *Am J Clin Nutr* 2011;93:1128–35.

INTRODUCTION

Cataract is a clouding of the lens of the eye, which obstructs the passage of light and leads to vision loss if left untreated. Age-related cataract is responsible for 48% of world blindness, which represents ≈18 million people, and cataract is an important cause of low vision in both developed and developing countries (1). Annual rates of admission for cataract surgery in England (United Kingdom) rose 10-fold from 1968 to 2003 and reached 637 episodes per 100,000 people in 2004, which made cataract surgery the most commonly performed elective operation in the National Health Service (NHS) and a phenomenon attributed to changes in practice and government initiatives that led to the widespread use of phacoemulsification, local anesthesia, and day case surgery (2).

Diabetes, smoking, and exposure to ultraviolet B light have been identified as risk factors for cataract development (3–6). Many studies have investigated possible associations between cataract and diet, and reviewers have suggested that eating foods rich in a variety of vitamins and minerals (7), especially antioxidants such as vitamins C and E (8, 9) and the carotenoid xanthophylls lutein and zeaxanthin (10–13), may protect against cataract.

The objective of this study was to assess the incidence of cataract in relation to diet in the Oxford (United Kingdom) arm of the European Prospective Investigation into Cancer and Nutrition (EPIC-Oxford), which consists of a cohort with a large proportion of vegetarian participants, by focusing on diet group and nutrients hypothesized to be associated with cataract risk.

SUBJECTS AND METHODS

Recruitment of participants

Between 1993 and 1999, 65,414 men and women aged ≥20 y were recruited into EPIC-Oxford, of whom 57,446 subjects completed a detailed dietary questionnaire. A description of the recruitment and characteristics of participants in the EPIC-Oxford cohort has been published elsewhere (14). Briefly, 11% of participants were recruited through general practices in Oxfordshire, Buckinghamshire, and Greater Manchester (United Kingdom), and the remaining 89% of participants were recruited by using postal methods that aimed to recruit health-conscious people who were living throughout the United Kingdom through advertisements in health-food magazines, direct mailing to members of vegetarian and vegan societies, or friends and relatives of other participants. The protocol was approved by a Multicenter Research Ethics Committee, and all participants provided written informed consent.

At recruitment, participants completed a lifestyle questionnaire, which included information on smoking and exercise habits, alcohol consumption, socioeconomic status, weight and height, and reproductive factors in women, and a validated semiquantitative food-frequency questionnaire that estimated

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their intakes of 130 different food items over the previous 12 mo (15, 16).

Follow-up

The incidence of cataract was ascertained by linking the participant NHS number, which is a unique personal identifier of NHS records, and other personal information, such as the subject name and date of birth, to computerized records of NHS hospital admissions, procedures, and operations from Hospital Episode Statistics in England and from the Information Services Division of Scottish Morbidity Records. The reasons for hospital admission were provided by these agencies by using ≤14 (England) or 6 (Scotland, United Kingdom) diagnoses coded from either the ninth or 10th (from 1 April 1996) revisions of the World Health Organization International Classification of Diseases (ICD-9 and ICD-10). Cataract incidence was taken as the earliest hospital episode with any diagnosis code of 366 (ICD-9) or H25, H26, or H28 (ICD-10). Participants were also followed up until 30 September 2009 by record linkage with the UK's NHS Central Register, which provides information on cancer diagnoses and deaths.

Participants were excluded from the analysis if they were aged <40 y at recruitment (n = 20,812), had no follow-up information (n = 410), had a registered or self-reported prevalent malignant cancer (excluding nonmelanoma skin cancer; n = 1806), were of unknown smoking status (n = 233) or diet group (n = 199), had incomplete or inconsistent dietary data (n = 730), or had a self-reported prior history of diabetes at recruitment (n = 4334). After excluding an additional 1235 participants whose place of residence was not in England or Scotland (the 2 UK countries for which hospital admissions data were available), data were available for 27,687 participants of whom 15,461 participants had at least one hospital admission between 1 January 1981 and 31 December 2008 (Scotland) or between 1 April 1997 and 31 March 2009 (England), including 1501 participants with a diagnosis of cataract. An additional 17 participants whose date of cataract diagnosis preceded their date of recruitment were excluded from the analysis, which left a total of 1484 incident cases in 27,670 participants available for analysis.

Assessment of diet and lifestyle variables

The mean daily food and nutrient intakes were estimated by multiplying the frequency of consumption of each food listed on the recruitment food-frequency questionnaire by the size and nutrient content of a standard portion of the food obtained from food-composition tables, as described elsewhere (14). Participants were categorized into 1 of 4 diet groups on the basis of their replies to questions that asked whether participants ate any *1*) meat *2*), fish *3*), eggs, and *4*) dairy products as follows: meat eaters (participants who ate meat), fish eaters (participants who did not eat meat but ate fish), vegetarians (participants who did not eat meat or fish but ate either or both dairy products and eggs) and vegans (participants who did not eat meat, fish, eggs, or dairy products). For 900 women recruited in the pilot phase of the study and the first 1300 general practice–recruited participants, these 4 dietary categorization questions were not asked, and the diet group was assigned according to responses provided on the food-frequency questionnaire.

Participants were asked to report their heights and weights in the recruitment questionnaire. Heights and weights were also measured in a subset of participants (n = 4808), and results showed good agreement between the self-reported and measured values ($r > 0.9$) (17). Weights and heights were used to calculate body mass index [weight in kilograms divided by the square of height in meters], which was divided into 5 categories as follows: <20.0, 20.0–22.4, 22.5–24.9, 25.0–27.4, or ≥27.5. A lifetime history of cigarette smoking was categorized as never, former, light smoker (currently smoking <15 cigarettes/d), or heavy smoker (currently smoking ≥15 cigarettes/d), and alcohol consumption was categorized as <1, 1–7, 8–15, or ≥16 g alcohol/d. Participants were categorized by their level of education (basic secondary education, higher secondary education, and "degree" indicating a university degree or equivalent qualification) and by their socioeconomic status categorized by approximate quartiles of the Townsend Deprivation Index (18). The average number of hours per week spent cycling and engaging in other energetic physical exercise combined with the level of physical activity at work was used to categorize the physical activity level as either inactive or active. A current or past use of exogenous hormones [oral contraceptives or hormone replacement therapy (HRT)] was assessed in women and categorized as yes or no. Participants were asked to report if they had been diagnosed with a range of conditions, including high blood pressure (hypertension) and high blood cholesterol (hyperlipidemia), and to report the use of any long-term medication that they were taking for any illness or condition. An unknown category was added for each variable when data were missing or incomplete.

Statistical analysis

Person-years were calculated from the date of recruitment to the study to the earliest date of a cataract diagnosis, death, emigration, or other loss to follow-up or the last date of hospital admission data (31 March 2009 for participants who resided in England or 31 December 2008 for participants who resided in Scotland). For participants who resided in England whose date of recruitment preceded the earliest date of hospital admission data for England (1 April 1997), the date of recruitment to the study was taken to be the latter date.

Incidence rate ratios (IRRs) and 95% CIs for cataract were calculated by using Cox proportional hazards regression with age as the underlying time variable. All analyses were stratified by sex, method of recruitment, and region of residence and adjusted for smoking. Analyses for dietary variables were further adjusted for ethnicity, self-reported high blood pressure at recruitment, receipt of long-term medical treatment at recruitment, and use of HRT, with food- and nutrient-intake analyses further adjusted for sex-specific fifths of energy intake. All statistical analyses were performed with STATA statistical software, release 10 (StataCorp, College Station, TX). A 2-sided $P < 0.05$ was considered statistically significant.

RESULTS

Of the 27,670 participants included in the analysis, 1484 (5.4%) subjects had an incident cataract during 315,558 person-years of follow-up. Of the 1484 cases, 481 (32%) subjects were diagnosed with senile cataract (ICD-10 H25), and the remaining 1003 (68%) subjects were diagnosed with an unspecified or other cataract (ICD-9 366.9, ICD-10 H26).

Baseline characteristics of participants subdivided by sex and cataract status are shown in **Table 1**. The median age at recruitment was 66 y for male and female cases and 52 and 51 y, respectively, for male and female control subjects. A lower percentage of cases than of control subjects had never smoked, but a higher percentage of control subjects than of case subjects were current smokers. The mean alcohol consumption was lower in cases than in control subjects, and cases were also more likely to be overweight than were control subjects. Cases were less likely to be physically active, educated to a degree level, or in the poorest quartile of socioeconomic status than were control subjects, but cases were more likely to have reported prior high blood pressure or hyperlipidemia or to be receiving long-term

TABLE 1
Baseline characteristics of 27,670 participants subdivided by sex and cataract status

	Men		Women	
Characteristic	Cases	Control subjects	Cases	Control subjects
n	387	7106	1097	19,080
Age at entry [*n* (%)]				
40–49 y	27 (7.0)	2860 (40.2)	81 (7.4)	8590 (45.0)
50–59 y	64 (16.5)	2123 (29.9)	202 (18.4)	6245 (32.7)
60–69 y	175 (45.2)	1462 (20.6)	468 (42.7)	3066 (16.1)
70–79 y	99 (25.6)	523 (7.4)	292 (26.6)	943 (4.9)
≥80 y	22 (5.7)	138 (1.9)	54 (4.9)	236 (1.2)
Age at entry (y)[1]	65.4 ± 9.6	54.3 ± 10.5	64.9 ± 9.5	52.6 ± 9.6
Smoking[2]				
Never smoker	144 (37.2)	3436 (48.4)	626 (57.1)	11,184 (58.6)
Former smoker	205 (53.0)	2801 (39.4)	401 (36.6)	6256 (32.8)
Light smoker	28 (7.2)	580 (8.2)	32 (2.9)	943 (4.9)
Heavy smoker	10 (2.6)	289 (4.1)	38 (3.5)	697 (3.7)
Alcohol consumption [*n* (%)]				
<1 g/d	65 (16.8)	1012 (14.2)	319 (29.1)	3941 (20.7)
1–7 g/d	104 (26.9)	2225 (31.3)	485 (44.2)	8747 (45.8)
8–15 g/d	109 (28.2)	1735 (24.4)	190 (17.3)	4174 (21.9)
≥16 g/d	109 (28.2)	2134 (30.0)	103 (9.4)	2218 (11.6)
Alcohol consumption (g/d)[1]	13.3 ± 14.9	15.3 ± 18.2	6.1 ± 8.6	7.5 ± 9.6
BMI [*n* (%)][3]				
<20.0 kg/m^2	15 (4.0)	361 (5.3)	97 (9.2)	1925 (10.4)
20.0–22.4 kg/m^2	74 (19.7)	1533 (22.4)	260 (24.6)	5626 (30.5)
22.5–24.9 kg/m^2	127 (33.9)	2341 (34.1)	309 (29.3)	5250 (28.5)
25.0–27.4 kg/m^2	97 (25.9)	1583 (23.1)	214 (20.3)	2946 (16.0)
≥27.5 kg/m^2	62 (16.5)	1040 (15.2)	175 (16.6)	2681 (14.5)
BMI (kg/m^2)[1]	24.7 ± 3.1	24.5 ± 3.3	24.3 ± 4.0	24.0 ± 3.9
Physically active [*n* (%)][3]	214 (62.0)	4710 (72.4)	534 (56.8)	11,712 (70.2)
Educated to degree level [*n* (%)][3]	117 (34.8)	2712 (41.7)	162 (17.8)	4872 (27.9)
Poorest quartile of socioeconomic status[3]	62 (17.9)	1294 (20.3)	195 (19.5)	3338 (19.8)
Nonwhite race [*n* (%)][3]	10 (2.6)	130 (1.9)	11 (1.0)	193 (1.0)
Self-reported prior high blood pressure [*n* (%)][3]	87 (22.5)	932 (13.1)	258 (23.6)	2406 (12.7)
Self-reported prior hyperlipidemia [*n* (%)][3]	54 (14.1)	712 (10.1)	127 (11.6)	1213 (6.4)
Receiving long-term medical treatment [*n* (%)][3]	159 (41.3)	1887 (26.8)	507 (46.9)	5757 (30.6)
Ever used oral contraceptives [*n* (%)][3]	—	—	405 (37.5)	13,172 (69.5)
Ever used hormone replacement therapy [*n* (%)][3]	—	—	351 (32.4)	5295 (28.1)
Regular user of dietary supplements [*n* (%)][3]	193 (51.1)	3139 (45.0)	729 (67.4)	11,767 (63.2)
Diet group and meat intake [*n* (%)]				
Meat eater				
≥100 g/d	111 (28.7)	1557 (21.9)	218 (19.9)	3066 (16.1)
50–99 g/d	135 (34.9)	1780 (25.0)	354 (32.3)	4979 (26.1)
<50 g/d	61 (15.8)	1145 (16.1)	240 (21.9)	3870 (20.3)
Fish eater	25 (6.5)	736 (10.4)	123 (11.2)	2767 (14.5)
Vegetarian	50 (12.9)	1623 (22.8)	148 (13.5)	4038 (21.2)
Vegan	5 (1.3)	265 (3.7)	14 (1.3)	360 (1.9)

[1] Values are means ± SDs.

[2] Heavy smokers smoked ≥15 cigarettes/d; light smokers included all other current smokers, including pipe and cigar smokers; and never smokers were participants who never smoked ≥1 cigarette/d for ≥1 y.

[3] Categories or values are unknown for some participants for these variables (percentages are calculated with the unknown values excluded).

TABLE 2
Number of cataract cases (*n*) and incidence rate ratios [IRRs (95% CIs)] by selected demographic factors[1]

Factor and category	*n*	IRR (95% CI)
Smoking[2]		
Never smoker	770	1.00 (ref)
Former smoker	606	1.16 (1.04, 1.29)
Light smoker	60	1.06 (0.81, 1.38)
Heavy smoker	48	1.50 (1.12, 2.01)
P for heterogeneity	—	0.008
Alcohol consumption[3]		
<1 g/d	384	1.05 (0.92, 1.20)
1–7 g/d	589	1.00 (ref)
8–15 g/d	299	1.03 (0.90, 1.19)
≥16 g/d	212	1.08 (0.92, 1.27)
P for heterogeneity (trend)[4]	—	0.779 (0.745)
BMI[3]		
<20 kg/m^2	112	1.02 (0.82, 1.26)
20.0–22.4 kg/m^2	334	1.00 (ref)
22.5–24.9 kg/m^2	436	1.04 (0.91, 1.21)
25.0–27.4 kg/m^2	311	1.16 (0.99, 1.36)
≥27.5 kg/m^2	237	1.09 (0.92, 1.29)
P for heterogeneity (trend)[4]	—	0.398 (0.125)
Physical activity[3]		
Inactive	537	1.00 (ref)
Active	748	0.94 (0.84, 1.05)
P for heterogeneity	—	0.279
Highest educational level attained[3]		
Basic secondary	699	1.00 (ref)
Higher secondary	269	0.93 (0.81, 1.08)
Degree	279	0.91 (0.79, 1.05)
P for heterogeneity	—	0.338
Socioeconomic status[3]		
Richest quartile	357	1.00 (ref)
Less rich	398	1.04 (0.90, 1.21)
Less poor	332	1.05 (0.91, 1.22)
Poorest quartile	257	1.06 (0.90, 1.24)
P for heterogeneity (trend)[4]	—	0.886 (0.490)
Ethnicity[3]		
White	1424	1.00 (ref)
Nonwhite	21	1.84 (1.19, 2.83)
P for heterogeneity	—	0.012
Self-reported prior high blood pressure[3]		
No	1136	1.00 (ref)
Yes	345	1.18 (1.05, 1.33)
P for heterogeneity	—	0.008
Self-reported prior hyperlipidemia[3]		
No	1296	1.00 (ref)
Yes	181	1.10 (0.94, 1.29)
P for heterogeneity	—	0.236
Receiving long-term medical treatment[3]		
No	801	1.00 (ref)
Yes	666	1.23 (1.10, 1.36)
P for heterogeneity	—	<0.001
Ever used oral contraceptives[3]		
No	674	1.00 (ref)
Yes	405	1.09 (0.95, 1.26)
P for heterogeneity	—	0.214
Ever used hormone replacement therapy[3]		
No	731	1.00 (ref)
Yes	351	1.25 (1.09, 1.43)
P for heterogeneity	—	0.002
Regular user of dietary supplements[3]		
No	538	1.00 (ref)
Yes	922	1.04 (0.94, 1.16)
P for heterogeneity	—	0.437

[1] ref, reference. IRRs were calculated by using Cox proportional hazards regression and by using separate models for the different exposures.

[2] Adjusted for age (as the underlying time variable) and stratified by sex, method of recruitment, and region of residence. Heavy smokers smoked ≥15 cigarettes/d; light smokers included all other current smokers, including pipe and cigar smokers; and never smokers were participants who never smoked ≥1 cigarette/d for ≥1 y.

[3] Adjusted for age and smoking and stratified by sex, method of recruitment, and region of residence. Except for alcohol consumption, all of these factors were unknown for some subjects. In particular, the previous exogenous hormone use factors were coded as unknown for all male participants. The addition of an unknown category ensured that all observations contributed to the analysis, but results for this category are not shown, and tests for heterogeneity and trend relate to known categories.

[4] Tests of trend were performed by scoring the categories 1, 2, 3, 4, or 5 as required.

medical treatment than were control subjects; these characteristics reflected the large difference in average age at recruitment between cases and control subjects. Female cases were less likely to have used oral contraceptives but were more likely to have used HRT than were female control subjects, which again reflected the difference in average age between cases and control subjects. Cases were more likely to be regular users of dietary supplements and more likely to be meat eaters than were control subjects. Overall, 75% of cases and 63% of control subjects ate meat, whereas 15% of cases and 24% of control subjects ate either a vegetarian or vegan diet.

Cataract IRRs for selected demographic variables are shown in **Table 2**. There was a significant association between smoking and cataract with a 50% greater risk of cataract in participants who smoked ≥15 cigarettes/d compared with the risk in never smokers ($P = 0.008$ for heterogeneity). Alcohol intake, body mass index, physical activity, education, socioeconomic status, and dietary supplement use were not associated with cataract risk, but there was evidence of an increased risk in nonwhite participants and in subjects who reported prior high blood pressure, subjects who were receiving long-term medical treatment, and in past or current users of HRT (*P* for heterogeneity: 0.012, 0.008, <0.001, and 0.002, respectively).

Diet group was strongly related to cataract risk, with a progressive decrease in risk of cataract in high-meat eaters to low-meat eaters, fish eaters, vegetarians, and vegans after adjustment for age, smoking, ethnicity, self-reported prior high blood pressure, receipt of long-term medical treatment, and HRT use, as shown in **Table 3**. Compared with meat eaters, IRRs (95% CIs) were 0.85 (0.72, 1.02) for fish eaters and 0.74 (0.63, 0.86) for vegetarians and vegans combined ($P < 0.001$ for heterogeneity). When the number of diet groups was increased to 6 by the division of meat eaters into 3 categories and the separation of vegetarians and vegans, IRRs (95% CIs) for moderate meat eaters (50–99 g meat/d), low meat eaters (<50 g meat/d), fish eaters, vegetarians, and vegans compared with high meat eaters

TABLE 3
Numbers of cataract cases (n) and incidence rate ratios [IRRs (95% CIs)] by diet group[1]

	All participants		Men		Women		<65 y of age		≥65 y of age	
Factor and category	n	IRR (95% CI)	n	IRR (95% CI)	n	IRR (95% CI)	n	IRR (95% CI)	n	IRR (95% CI)
Diet group										
Meat eater	1119	1.00 (ref)	307	1.00 (ref)	812	1.00 (ref)	468	1.00 (ref)	651	1.00 (ref)
Fish eater	148	0.85 (0.72, 1.02)	25	0.73 (0.48, 1.12)	123	0.89 (0.73, 1.07)	71	0.99 (0.76, 1.28)	77	0.77 (0.61, 0.98)
Vegetarian or vegan	217	0.74 (0.63, 0.86)	55	0.60 (0.44, 0.82)	162	0.79 (0.66, 0.94)	110	0.98 (0.79, 1.23)	107	0.58 (0.47, 0.72)
P for heterogeneity	—	<0.001	—	0.003	—	0.022	—	0.987	—	<0.001
P for interaction[2]	—	—	—	—	0.268	—	—	—	0.004	—
Diet group and meat intake										
Meat eater										
≥100 g/d	329	1.00 (ref)	111	1.00 (ref)	218	1.00 (ref)	145	1.00 (ref)	184	1.00 (ref)
50–99 g/d	489	0.96 (0.84, 1.11)	135	0.97 (0.75, 1.26)	354	0.96 (0.81, 1.14)	199	0.96 (0.77, 1.19)	290	0.98 (0.81, 1.18)
<50 g/d	301	0.85 (0.72, 0.99)	61	0.72 (0.52, 1.00)	240	0.89 (0.74, 1.07)	124	0.90 (0.70, 1.15)	177	0.81 (0.66, 1.00)
Fish eater	148	0.79 (0.65, 0.97)	25	0.66 (0.42, 1.04)	123	0.84 (0.67, 1.05)	71	0.94 (0.69, 1.26)	77	0.71 (0.54, 0.94)
Vegetarian	198	0.70 (0.58, 0.84)	50	0.56 (0.39, 0.81)	148	0.75 (0.60, 0.93)	102	0.96 (0.73, 1.27)	96	0.54 (0.42, 0.69)
Vegan	19	0.60 (0.38, 0.96)	5	0.39 (0.16, 0.96)	14	0.73 (0.42, 1.26)	8	0.66 (0.32, 1.37)	11	0.57 (0.31, 1.06)
P for heterogeneity	—	<0.001	—	0.004	—	0.098	—	0.870	—	<0.001
P for interaction[2]	—	—	—	—	0.465	—	—	—	0.027	—

[1] ref, reference. IRRs were calculated by using Cox proportional hazards regression adjusted for age (as the underlying time variable), smoking, ethnicity, self-reported prior high blood pressure, receipt of long-term medical treatment, and, when applicable, hormone replacement therapy use and stratified by sex, method of recruitment, and region of residence by using separate models for each subset.

[2] Tests of interaction were performed by using data for all participants by adding a diet group × sex or a diet group × age group interaction term to the model as appropriate.

(≥100 g meat/d) were 0.96 (0.84, 1.11), 0.85 (0.72, 0.99), 0.79 (0.65, 0.97), 0.70 (0.58, 0.84), and 0.60 (0.38, 0.96), respectively ($P < 0.001$ for heterogeneity).

Cataract IRRs (95% CIs) by diet group subdivided by sex and age at recruitment are shown in Table 3. The progressive decrease in risk of cataract in high-meat eaters to vegans was seen for men and women and for subjects aged ≥65 y at recruitment but not for younger participants (P for heterogeneity: 0.004, 0.098, <0.001, and 0.870, respectively). Tests for interactions showed that there were no significant differences in risk by sex but a significant interaction with age at recruitment. Compared with meat eaters, IRRs (95% CIs) for fish eaters and for vegetarians and vegans combined were 0.99 (0.76, 1.28) and 0.98 (0.79, 1.23), respectively, in participants aged <65 y at recruitment (P = 0.987 for heterogeneity) and 0.77 (0.61, 0.98) and 0.58 (0.47, 0.72), respectively, in participants aged ≥65 y at recruitment ($P < 0.001$ for heterogeneity; P = 0.004 for interaction).

Cataract IRRs (95% CIs) by sex-specific fifths of intake of selected nutrients estimated from the baseline food-frequency questionnaire are shown in **Table 4**. Energy intake was positively associated with cataract risk, with a 16% higher risk in participants in the top fifth compared with participants in the bottom fifth of intake (IRR: 1.16, 95% CI: 0.98, 1.36; P = 0.044 for trend). Dietary cholesterol and protein intakes were also positively associated with cataract risk [IRR (95% CI) in the top fifth compared with the bottom fifth of dietary cholesterol intake: 1.23; 1.01, 1.50; P = 0.001 for trend; IRR (95% CI) in the top fifth compared with the bottom fifth of protein intake, 1.30; 1.10, 1.55; P = 0.004 for trend]. Intakes of saturated and polyunsaturated fatty acids (PUFAs) were not significantly associated with risk, although there was a significantly increased risk in the top fifth of saturated fat intake compared with the bottom fifth of saturated fat intake (IRR: 1.19; 95% CI: 1.01, 1.40; P = 0.068 for trend). Cataract risk was not associated with carbohydrate or dietary fiber intakes. Of the micronutrients studied, retinol and vitamin B-12 intakes were positively associated with cataract risk (P = 0.003 and P = 0.025 for trend, respectively), but intakes of carotene, thiamine, riboflavin, niacin, folate, and vitamins C, D, and E were not associated with risk, although there was a suggestion of a positive association with risk for vitamin D with raised risks in the top two-fifths of intake compared with in the bottom fifth of intake (P = 0.075 for trend).

The associations between nutrient intake and cataract risk were further investigated with the data restricted to meat eaters to determine the extent to which the associations seen for all participants reflected the strong association between diet group and cataract risk. In meat eaters, none of the nutrients were associated with cataract risk according to the trend test (results not shown).

DISCUSSION

In this cohort of predominantly health-conscious British residents, there was a strong association between diet group and cataract with a progressive decrease in cataract risk in high meat eaters to low meat eaters, fish eaters, vegetarians, and vegans. This progressive decrease in cataract risk was seen for both men and women but appeared to be confined to participants aged ≥65 y at recruitment. Overall, compared with meat eaters who consumed ≥100 g meat and meat products/d, fish eaters, vegetarians, and vegans had approximately 20%, 30%, and 40% lower risk of cataract, respectively. Associations between intakes of selected nutrients and cataract risk generally reflected the strong association with diet group with significant positive associations for energy, dietary cholesterol, protein, and vitamins A and B-12.

To our knowledge, this is the first study to describe the risk of cataract in relation to a vegetarian diet in a predominantly white

TABLE 4

Numbers of cataract cases (*n*) and incidence rate ratios [IRRs (95% CIs)] by sex-specific fifths of intake of selected nutrients[1]

Nutrient and sex-specific fifths of intake[2]	*n*	IRR (95% CI)
Energy		
First (6015 and 5375 kJ)	258	1.00 (ref)
Second (7514 and 6673 kJ)	263	0.98 (0.82, 1.16)
Third (8701 and 7670 kJ)	288	1.00 (0.85, 1.19)
Fourth (10,018 and 8810 kJ)	305	1.02 (0.87, 1.21)
Fifth (12,204 and 10,635 kJ)	370	1.16 (0.98, 1.36)
P for trend[3]	—	0.044
Saturated fat		
First (7.0% and 6.9% of energy)	252	1.00 (ref)
Second (9.3% and 9.2% of energy)	283	1.07 (0.90, 1.27)
Third (11.0% and 10.7% of energy)	295	1.14 (0.96, 1.35)
Fourth (12.8% and 12.4% of energy)	284	1.04 (0.88, 1.24)
Fifth (15.8% and 15.5% of energy)	370	1.19 (1.01, 1.40)
P for trend[3]	—	0.068
Polyunsaturated fat		
First (4.0% and 4.1% of energy)	322	1.00 (ref)
Second (5.2% and 5.3% of energy)	316	1.13 (0.97, 1.32)
Third (6.2% and 6.3% of energy)	307	1.11 (0.95, 1.30)
Fourth (7.4% and 7.5% of energy)	286	1.01 (0.86, 1.19)
Fifth (9.6% and 9.6% of energy)	253	0.93 (0.79, 1.10)
P for trend[3]	—	0.148
Dietary cholesterol		
First (84 and 83 mg)	205	1.00 (ref)
Second (160 and 147 mg)	186	0.78 (0.64, 0.95)
Third (216 and 196 mg)	319	1.17 (0.98, 1.41)
Fourth (278 and 250 mg)	355	1.19 (0.99, 1.44)
Fifth (385 and 343 mg)	419	1.23 (1.01, 1.50)
P for trend[3]	—	0.001
Protein		
First (11.7% and 12.6% of energy)	233	1.00 (ref)
Second (13.3% and 14.5% of energy)	262	1.13 (0.95, 1.35)
Third (14.7% and 16.0% of energy)	311	1.22 (1.02, 1.45)
Fourth (16.3% and 17.8% of energy)	317	1.21 (1.02, 1.44)
Fifth (18.8% and 20.5% of energy)	361	1.30 (1.10, 1.55)
P for trend[3]	—	0.004
Carbohydrates		
First (39.7% and 41.7% of energy)	291	1.00 (ref)
Second (45.1% and 46.5% of energy)	327	1.08 (0.92, 1.27)
Third (48.7% and 49.8% of energy)	302	0.96 (0.81, 1.13)
Fourth (52.1% and 53.1% of energy)	294	0.92 (0.78, 1.08)
Fifth (57.3% and 58.2% of energy)	270	0.92 (0.78, 1.09)
P for trend[3]	—	0.099
Dietary fiber (nonstarch polysaccharide)		
First (11.6 and 12.2 g)	252	1.00 (ref)
Second (15.7 and 16.2 g)	276	0.97 (0.82, 1.16)
Third (19.2 and 19.5 g)	312	1.05 (0.88, 1.25)
Fourth (22.9 and 23.2 g)	331	1.04 (0.87, 1.25)
Fifth (30.0 and 29.6 g)	313	0.90 (0.74, 1.09)
P for trend[3]	—	0.276
Retinol		
First (163 and 167 μg)	205	1.00 (ref)
Second (298 and 280 μg)	227	1.01 (0.83, 1.22)
Third (418 and 381 μg)	299	1.16 (0.97, 1.40)
Fourth (627 and 538 μg)	348	1.15 (0.95, 1.39)
Fifth (1233 and 1103 μg)	405	1.28 (1.07, 1.54)
P for trend[3]	—	0.003
Carotene		
First (1247 and 1429 μg)	243	1.00 (ref)
Second (2004 and 2445 μg)	304	1.11 (0.93, 1.31)
Third (2824 and 3143 μg)	268	0.95 (0.80, 1.14)
Fourth (3470 and 4005 μg)	342	1.17 (0.99, 1.38)
Fifth (5203 and 5785 μg)	327	0.91 (0.76, 1.08)
P for trend[3]	—	0.157
Thiamine		
First (1.12 and 1.09 mg)	243	1.00 (ref)
Second (1.43 and 1.40 mg)	266	1.02 (0.85, 1.23)
Third (1.68 and 1.63 mg)	313	1.18 (0.98, 1.43)
Fourth (1.95 and 1.89 mg)	331	1.16 (0.95, 1.42)
Fifth (2.43 and 2.33 mg)	331	1.08 (0.87, 1.33)
P for trend[3]	—	0.532
Riboflavin		
First (1.38 and 1.34 mg)	259	1.00 (ref)
Second (1.84 and 1.78 mg)	257	0.90 (0.75, 1.08)
Third (2.18 and 2.11 mg)	307	1.02 (0.85, 1.22)
Fourth (2.53 and 2.46 mg)	316	0.98 (0.81, 1.18)
Fifth (3.17 and 3.06 mg)	345	1.03 (0.85, 1.25)
P for trend[3]	—	0.494
Niacin		
First (14.7 and 13.5 mg)	236	1.00 (ref)
Second (19.2 and 17.9 mg)	265	1.07 (0.90, 1.29)
Third (22.8 and 21.2 mg)	318	1.19 (0.99, 1.42)
Fourth (26.5 and 24.8 mg)	314	1.11 (0.92, 1.34)
Fifth (32.4 and 30.6 mg)	351	1.19 (0.97, 1.45)
P for trend[3]	—	0.127
Vitamin B-12		
First (1.53 and 1.88 μg)	187	1.00 (ref)
Second (3.61 and 3.72 μg)	260	1.24 (1.02, 1.50)
Third (5.19 and 5.13 μg)	306	1.26 (1.04, 1.52)
Fourth (7.12 and 6.88 μg)	366	1.35 (1.12, 1.62)
Fifth (9.98 and 9.85 μg)	365	1.29 (1.06, 1.56)
P for trend[3]	—	0.025
Folate		
First (220 and 216 μg)	248	1.00 (ref)
Second (280 and 276 μg)	255	0.94 (0.79, 1.13)
Third (327 and 324 μg)	288	1.00 (0.84, 1.20)
Fourth (378 and 376 μg)	348	1.12 (0.93, 1.35)
Fifth (475 and 469 μg)	345	1.01 (0.83, 1.22)
P for trend[3]	—	0.559
Vitamin C		
First (62 and 74 mg)	274	1.00 (ref)
Second (90 and 105 mg)	264	0.91 (0.77, 1.08)
Third (113 and 133 mg)	302	0.95 (0.80, 1.12)
Fourth (142 and 165 mg)	314	0.99 (0.84, 1.17)
Fifth (197 and 229 mg)	330	0.95 (0.80, 1.13)
P for trend[3]	—	0.918
Vitamin D		
First (0.79 and 0.86 μg)	203	1.00 (ref)
Second (1.67 and 1.70 μg)	257	1.09 (0.91, 1.32)
Third (2.42 and 2.41 μg)	298	1.17 (0.97, 1.40)
Fourth (3.33 and 3.30 μg)	371	1.26 (1.05, 1.51)
Fifth (5.49 and 5.50 μg)	355	1.20 (1.00, 1.45)
P for trend[3]	—	0.075
Vitamin E		
First (7.5 and 7.3 mg)	299	1.00 (ref)
Second (10.3 and 9.8 mg)	293	0.99 (0.84, 1.17)
Third (12.9 and 12.0 mg)	284	0.95 (0.80, 1.13)
Fourth (17.0 and 15.1 mg)	290	0.86 (0.72, 1.04)
Fifth (24.3 and 21.3 mg)	318	0.89 (0.74, 1.08)
P for trend[3]	—	0.090

[1] ref, reference. IRRs were calculated by using Cox proportional hazards regression adjusted for age (as the underlying time variable), smoking, ethnicity, self-reported prior high blood pressure, receipt of long-term medical treatment, hormone replacement therapy use, and, when applicable, sex-specific fifths of energy intake and stratified by sex, method of recruitment, and region of residence.

[2] Median daily intakes for men and women, respectively.

[3] Tests of trend were performed by replacing the categorical food or nutrient intake variable in the model by a continuous variable equal to the sex-specific median intake within each category.

population. One previous study examined cataract risk in relation to a vegetarian diet in 86 members of the British Asian community and showed that a strict vegetarian diet was positively associated with age-related cataract (19). However, the authors of this study acknowledge that rates of vegetarianism showed considerable variation within the Asian community and that a vegetarian diet might have acted as a marker for some underlying risk factor. Most Asians in this study were of Indian descent, and a low consumption of protein foods including meat, milk, eggs and curd, which are characteristic of a strict vegetarian diet, had also been identified as a risk factor for cataract in the Punjab (20). In contrast, a recent case-control study in India showed that the intake of animal foods was significantly higher in 140 cataract patients compared with that in 100 age- and sex-matched control subjects (21), which was a result in agreement with our finding of a markedly reduced risk of cataract in vegetarians compared with meat eaters. However, only a small percentage of participants in our study were of nonwhite race, which made it difficult to compare our findings with those of studies conducted either in subjects in India or in British Asians, which are communities with a high prevalence of cataract compared with the indigenous British population (19, 22).

The progressive decrease in cataract risk in meat eaters to vegans shown in our study might have been mediated by differences in nutrient intake between diet groups. Several nutrients, including antioxidants (3, 8, 9) and the carotenoid xanthophylls lutein and zeaxanthin (10–13), have been postulated to reduce cataract risk. Of the antioxidants included in our study, carotene and vitamins C and E were not associated with cataract risk, which was a finding that was in contrast to the inverse association generally shown in previous studies (3, 23–28), although a field-based clinical trial in South India failed to show a benefit of antioxidant supplementation in slowing cataract progression (29).

The nutrients that were positively associated with cataract risk in our study (energy, protein, dietary cholesterol, retinol, and vitamin B-12) may have been acting as markers of diet group, rather than being directly related to cataract risk, because these associations were no longer significant when the analysis was restricted to meat eaters. Indeed, our finding of a positive association between intakes of protein and retinol and cataract risk contrasted with the inverse associations showed in some (20, 24, 30, 31), but not all (32, 33), previous studies. Intakes of various B vitamins including thiamin, riboflavin, niacin, and folate have been associated with lower cataract risk or a reduced progression of age-related lens opacification (3, 34, 35), but of the B vitamins, only vitamin B-12 was associated with cataract risk in our study. Intake of PUFAs was not associated with cataract risk in our study. Previous studies have reported a decreased risk of nuclear cataract with higher intake of $n-3$ PUFAs (30), significant positive associations between linoleic and linolenic acid intakes and nuclear opacity (35), and a reduced prevalence of cortical cataract with increased PUFA intake (31). There was no association of cataract risk with carbohydrate intake, whereas positive associations between cataract and carbohydrate intake and between lens opacity and dietary glycemic index have been reported elsewhere (36, 37), although a high dietary glycemic load was not associated with cataract risk in a large prospective study (38). Finally, studies of cataract risk or lens opacity in relation to the use of vitamin supplements have generally (3, 24, 27, 34), but not always (7), shown an inverse association, but we found no difference in cataract risk between regular dietary supplement users and other participants.

It is possible that the differences in cataract risk between diet groups were caused by other dietary or nondietary factors. However, our results were adjusted for several nondietary factors with effects in accordance with results from other studies, including smoking (5), ethnicity (3, 19, 22), and HRT use (39), and our analysis was restricted to participants with no self-reported diabetes at recruitment. It is possible that the diet group is simply a better marker of a healthy diet than the intake of any given nutrient; previous studies have shown measures of a healthy diet, such as the US Dietary Guidelines Healthy Eating Index, to be associated with a reduced risk of nuclear cataract or nuclear opacity in women (7, 40). Confounding by other unmeasured factors was also possible, although their effects would have to have been considerable to explain the large difference in risk between diet groups seen in our data.

The strengths of our study were the prospective nature of the investigation, large number of incident cataract cases, and wide variation in diets of participants, who ranged from meat eaters to vegans. Weaknesses include the single measure of diet at recruitment, which might have been insufficient to accurately reflect long-term food and nutrient intakes, our inability to estimate intakes of the carotenoids lutein and zeaxanthin, and the lack of information on the type of cataract other than that provided by the ICD code. Nevertheless, we showed that vegetarians and vegans had a significantly lower risk of cataract than did meat eaters, predominantly in the elderly, with a progressive decrease in risk in parallel with the amount of meat and other animal products in the diet. Additional research is needed to substantiate these findings and to determine the specific aspects of a vegetarian diet that might give rise to a reduced risk of cataract.

The authors' responsibilities were as follows—PNA and TJK: conceived and designed the study; PNA: performed the statistical analysis and drafted the manuscript; and all authors: interpreted the findings and critically reviewed and contributed to the final version of the manuscript. None of the authors had a personal or financial conflict of interest.

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