

Frequency of a diagnosis of glaucoma in individuals who consume coffee, tea and/or soft drinks

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ABSTRACT

Aims To evaluate the association between consumption of coffee, tea or soft drinks, and glaucoma in the participants of the 2005–2006 National Health and Nutrition Examination Survey (NHANES).

Methods The exposures of interest of this retrospective cross-sectional study were caffeinated and decaffeinated coffee, iced tea, hot tea and soft drinks. The outcome of interest was a clinical diagnosis of glaucoma based on the Rotterdam criteria. Analysis of the correlation between the frequency of consumption of each type of beverage and glaucoma was performed using logistic regression modelling while controlling for age, body mass index, gender, ethnicity, smoking status and diabetes. Data were weighted using the multistage NHANES sampling design.

Results Among a total of 1678 survey participants, the overall prevalence of glaucoma was 5.1% (n=84). Most participants were non-Hispanic white (n=892; 53.2%). There were no statistically significant associations between consumption of caffeinated and decaffeinated coffee, iced tea and soft drinks, and glaucoma. Participants who consumed at least one cup of hot tea daily had a 74% decreased odds of having glaucoma compared with those who did not consume hot tea (adjusted OR=0.26, 95% CI 0.09 to 0.72, P=0.004 for trend); however, no statistically significant association existed for decaffeinated hot tea and glaucoma.

Conclusion In NHANES, participants who consumed hot tea daily were less likely to have glaucoma than those who did not consume hot tea. No significant associations were found between the consumption of coffee, iced tea, decaffeinated tea and soft drinks, and glaucoma risk. This study is limited by its cross-sectional design and use of multiple statistical testing, and larger prospective studies are needed to investigate the proposed association between tea consumption and decreased glaucoma risk.

BACKGROUND

Glaucoma is one of the leading causes of vision loss worldwide, with an estimated prevalence of 57.5 million projected to reach 65.5 million by year 2020.¹ Various aetiologies for the development of glaucoma have been proposed besides increased intraocular pressure (IOP), including blood flow abnormalities, oxidative stress and autoimmune processes, which contribute to optic nerve and retinal ganglion cell damage resulting in visual field loss.²

Caffeine has been postulated to increase glaucoma risk by promoting increases in IOP and homocysteine. A large prospective cohort study

demonstrated no association between daily caffeinated coffee consumption and glaucoma overall, but a significant correlation among those with consumption of five or more cups daily or a family history of glaucoma.³ However, a recent review found equivocal associations between caffeine, antioxidants and oxidants, and the development of glaucoma.⁴ In a number of studies, caffeine has been reported to transiently increase IOP ranging from 1 to 2 mm Hg within 1 hour of ingestion.⁵ However, studies have found that coffee consumption is not associated with IOP increases among individuals without glaucoma.⁶ Furthermore, ingestion of non-caffeinated fluids ranging from 250 mL to 1000 mL has also been associated with transient increases in IOP, suggesting that the observed ocular hypertensive effect may not be unique to caffeine.⁷ Aside from potential effects on IOP, coffee consumption has been associated with increases in homocysteine and oxidative stress, which may underlie the correlation between coffee consumption and pseudoexfoliation glaucoma.⁸

Currently, most of these studies are limited by small sample sizes and lack of consistency in methodology. It is important to note that caffeine is not analogous to coffee, as the latter contains additional compounds that may modulate glaucoma risk.⁹ No study to date has compared the effects of caffeinated and decaffeinated coffee, tea and soft drinks on glaucoma. The objective of this study is to examine the association between consumption of various caffeinated and decaffeinated beverages and glaucoma in the participants of the 2005–2006 National Health and Nutrition Examination Survey (NHANES).

METHODS

Study design and description of database

This was a retrospective cross-sectional study using data from the 2005–2006 NHANES database. The NHANES programme was founded in the early 1960s as a means for assessing the health and nutritional status of adults and children in the USA.¹⁰ The survey examines a nationally representative sample of about 10 000 persons per iteration and produces weighted estimates targeted to represent the US population. It includes interviews, physical examinations and blood samples.

The NHANES Food Frequency Questionnaire (FFQ) developed by the National Institutes of Health, National Cancer Institute (NCI) was based on the NCI Diet History Questionnaire, with cognitive theory-based questioning that has improved validity of food frequency estimates, and has been



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applied extensively in nutritional epidemiology research.¹¹ Subar *et al*¹² described the research used to develop the NHANES FFQ, noting strong concordance between reported frequency of consumption using the FFQ and probability of consumption on 24-hour recall, validating the FFQ for its intended purpose as a covariate in estimating food consumption patterns.

In 2005–2006, the NHANES performed additional examination and testing that included Humphrey matrix frequency doubling technology (N30-5 FDT) perimetry and optic disc photographs. Data collection was performed by the National Center for Health Statistics.

Study population

Participants were selected based on availability of optic disc photographs and FDT visual fields in the 2005–2006 NHANES sample. Exclusion criteria included (1) absent optic disc photographs or FDT visual fields; (2) age <40 years (given that optic disc photographs and FDT visual fields were not obtained for individuals under the age of 40); and (3) presence of documented alternative reason for cup-to-disc ratio (CDR) findings (eg, dysplastic disc or marked anisometropia) or for a visual field deficit (macular degeneration, retinal vascular disease or cerebrovascular disease).¹³ Fundus photographs taken as part of the NHANES 2005–2006 study were used to assess for presence of retinal vascular disease, dysplastic disc and macular degeneration. Objective refraction conducted as part of the NHANES 2005–2006 study was used to assess for anisometropia. Self-report from the NHANES interview was used to determine presence of cerebrovascular disease. Age, gender and ethnicity were included in basic demographics for analysis.

Exposures

The exposures of interest were the frequencies of consumption of various caffeinated and decaffeinated beverages including coffee, iced tea, hot tea and soft drinks. The NHANES asked participants to provide responses based on beverage consumption over the past 12 months. Discrepant responses were not edited, and the raw data were presented in daily frequency covariates. Actual survey questions were ‘Did you drink coffee?’ and if yes then a follow-up question was asked regarding frequency of consumption: ‘How many cups of coffee, caffeinated or decaffeinated, did you drink?’ Response options included none, less than 1 cup per month, 1–3 cups per month, 1 cup per week, 2–4 cups per week, 5–6 cups per week, 1 cup per day, 2–3 cups per day, 4–5 cups per day, and 6 or more cups per day. A follow-up question was then asked ‘Did you drink decaffeinated?’ and ‘How often was the coffee you drank decaffeinated?’ with choices of almost never or never, about a quarter of the time, about half of the time, about three-quarters of the time, and almost always or always. The same question structure including frequency and decaffeinated versus caffeinated types applied to iced tea, hot tea and soft drinks.

Outcome

The primary outcome of interest was the prevalence of glaucoma as defined by the Rotterdam criteria (using optic nerve appearance and visual field defects).¹⁴ The Rotterdam criteria were selected to produce an objective clinical definition of glaucoma using the data available within the NHANES as previously described (incidence and subtype of glaucoma were not available in the database).^{15 16} Per NHANES available data, optic nerve appearance was assessed per optic nerve photographs, and visual field defects were assessed by FDT visual fields.

A clinical diagnosis of glaucoma was defined as both (1) having two or more abnormal points in at least one eye on the N30-5 FDT on two tests in the same eye, and (2) CDR in one eye or CDR asymmetry between eyes $\geq 97.5\%$ of the normal NHANES population.

The FDT was performed by trained health technicians. All tests were conducted in a dark room. A practice test was conducted before the actual test to assess each participant’s understanding of the procedure. The right eye was tested first and the left eye second. A repeat test was then performed for each eye. The test comprised 19 visual field locations; each was tested until a participant response was recorded. Reliability checks for each test included three false-positive tests and three blind spot tests conducted at random intervals. Results of the FDT were documented as normal, positive, insufficient or unreliable. Participants with incomplete or unreliable results were excluded from the study population. Retinal images obtained by trained technicians were used to determine the CDR. Each participant had two 45-degree non-mydratic digital images of the retina taken. The first image was centred on the macula and the second image on the optic nerve. The vertical CDR in each eye was assessed by trained graders at the University of Wisconsin immediately as the images appeared in the digital camera. At least two of nine trained graders reviewed each image. In cases of initial disagreement, an additional grader evaluated the image. If a discrepancy persisted after evaluation by three trained graders, an adjudicator performed the final decision.

Covariates

Smoking status was included as a covariate due to its potential to be a confounder as it enhances P450 metabolism of caffeine. Body mass index (BMI) was included given its inverse association with glaucoma, and diabetes was included because of its positive association with glaucoma.^{17 18} Both smoking status and diabetes were ascertained based on participants’ self-report and coded as binary variables (current smoker vs not a current smoker; has diabetes vs does not have diabetes).

Statistical analysis

Sampling within the NHANES occurred in four stages, starting with primary sampling units (PSUs) and followed by segments within PSUs (usually city blocks), households and individuals. Based on this multistage probability sampling design, data were weighted and adjusted for non-response to produce weighted estimates aimed to represent the US population. All data analyses in this study were based on weighted estimates using sample weights provided by the NHANES.

Descriptive statistics were used to describe baseline characteristics for the study population. Age and BMI were analysed as continuous variables, and ethnicity, gender, smoking status and diabetes were analysed as categorical variables. Consumption of caffeinated and decaffeinated coffee, iced tea, hot tea and soft drinks was analysed as categorical variables further broken down by frequency of consumption. Glaucoma was assessed as a binary outcome based on the Rotterdam criteria.¹⁴

Logistic regression modelling was used to examine the association between varying frequencies of consumption of caffeinated and decaffeinated beverages and diagnosis of glaucoma. Separate unadjusted models were created for each beverage type as predictors of glaucoma. Partially adjusted models were then created, including age, gender and ethnicity, and fully adjusted models were created using age, ethnicity, gender, BMI, smoking status and diabetes as

Table 1 Prevalence of covariates by glaucoma status within the National Health and Nutrition Examination Survey, 2005–2006

Weighted estimates			
Characteristics	Total number (%) n=83 308 317	With glaucoma (%) n=2 657 336	Without glaucoma (%) n=80 650 982
Age	Mean=53.7 (SE=0.6)	Mean=62.2 (SE=1.3)	Mean=53.4 (SE=0.6)
BMI	Mean=29.2 (SE=0.3)	Mean=28.6 (SE=1.0)	Mean=29.2 (SE=0.3)
Gender			
Male	39 779 596 (47.7)	1 426 123 (53.7)	38 353 473 (47.6)
Female	43 528 722 (52.2)	1 231 213 (46.3)	42 297 509 (52.4)
Ethnicity			
Non-Hispanic white	63 954 484 (76.7)	1 404 960 (52.9)	62 549 524 (77.6)
Non-Hispanic black	8 131 513 (9.8)	644 521 (24.3)	7 486 992 (9.3)
Mexican American	4 612 275 (5.5)	208 338 (7.8)	4 403 937 (5.5)
Other Hispanic	2 416 147 (2.9)	110 661 (4.3)	2 305 486 (2.9)
Other	4 193 898 (5.0)	288 856 (10.9)	3 905 042 (4.8)
Smoking status			
Current smoker	18 229 456 (21.9)	395 653 (14.9)	17 833 803 (22.1)
Not a current smoker	65 078 862 (78.1)	2 261 683 (85.1)	62 817 179 (77.9)
Diabetes			
Yes	8 219 208 (9.9)	189 029 (23.3)	7 600 060 (9.4)
No	75 089 110 (90.1)	225 114 (76.7)	73 050 921 (90.6)
Actual frequencies			
Characteristics	Total number (%) n=1678	With glaucoma, n (%) n=84	Without glaucoma, n (%) n=1594
Age	Mean=55.8 (SD=11.7)	Mean=62.8 (SD=12.1)	Mean=55.4 (SD=11.6)
BMI	Mean=29.2 (SD=6.9)	Mean=28.6 (SD=5.5)	Mean=29.3 (SD=6.9)
Gender			
Male	851 (50.7)	47 (56.0)	804 (50.4)
Female	827 (49.3)	37 (44.0)	790 (49.6)
Ethnicity			
Non-Hispanic white	892 (53.2)	26 (31.0)	866 (54.3)
Non-Hispanic black	384 (22.9)	34 (40.5)	350 (22.0)
Mexican American	293 (17.5)	16 (19.1)	277 (17.4)
Other Hispanic	44 (2.6)	3 (3.6)	41 (2.6)
Other	65 (3.9)	5 (6.0)	60 (3.8)
Smoking status			
Current smoker	368 (21.9)	13 (15.5)	355 (22.3)
Not a current smoker	1310 (78.1)	71 (84.5)	1239 (77.7)
Diabetes			
Yes	216 (12.9)	20 (23.8)	196 (12.3)
No	1462 (87.1)	64 (76.2)	1398 (87.7)

BMI, body mass index.

potential confounders. All analyses were conducted with SAS V.9.3.

RESULTS

Within the 2005–2006 NHANES sample of 10 348 interviewed, 1678 participants met the inclusion criteria; 8670 were excluded due to lack of optic disc photographs and/or FDT visual fields for evaluating the status of glaucoma. The overall prevalence of glaucoma was 3.2% (n=2 657 336, 95% CI 2.8% to 3.6%) in the weighted sample and 5.1% (n=84, 95% CI 4.0% to 6.1%) in the actual sample (table 1).

In the weighted sample, the mean age was 53.7 years (SE=0.6 years) in the overall population and 62.2 years (SE=1.3 years) in participants with glaucoma. In the actual sample, the mean age was 55.8 years (SD=11.7 years) in the overall population and 62.8 years (SD=12.1 years) in participants with glaucoma. In the weighted sample, most participants in the overall population were female (n=43 528 722; 52.2%), whereas most participants with glaucoma were male (n=1 426 123; 53.7%). In the actual sample, most participants in the overall population were male (n=851; 50.7%) and most participants with glaucoma were male (n=47; 56.0%). In the weighted sample, most individuals were non-Hispanic white (n=63 954 484; 76.7%), including participants with glaucoma (n=1 404 960; 52.9%). In the actual sample, the participants were predominantly non-Hispanic white (n=892; 53.2%), and participants with glaucoma were primarily non-Hispanic black (n=34; 40.5%). About twice the number of participants with glaucoma had diabetes compared with the general population (n=189 029; 23.3% vs n=8 219 208; 9.9%) but fewer were smokers (n=395 653; 14.9% vs n=18 229 456; 21.9%). This finding was supported by the actual sample, with slightly less than twice the number of participants with glaucoma reporting having diabetes compared with the overall population (n=20; 23.8% vs n=216; 12.9%) and fewer smokers (n=13; 15.5% vs n=368; 21.9%).

Among beverages consumed daily, coffee was reported most frequently in the weighted overall population (n=37 549 318; 45.1%). Daily hot tea consumption was least frequent in the weighted overall population (n=6 513 975; 7.8%) (table 2). According to the NHANES data protocol, only subjects who responded 'No' to the question for each main beverage type were not asked for the question regarding the decaffeinated version; however, those with omitted responses to the overall beverage category had the potential to respond to the follow-up question regarding the decaffeinated version of that beverage, causing occasional discrepancies in total respondents.

In estimates based on the weighted sample, no statistically significant associations were noted between consumption of coffee, iced tea, decaffeinated hot tea and soft drinks, and glaucoma in the models both with and without all specific covariates. In unadjusted and adjusted models, there was a statistically significant decreased odds of a diagnosis of glaucoma in participants who consumed daily hot tea (fully adjusted OR=0.26, 95% CI 0.09 to 0.72, P=0.004 for trend). These estimates and additional results from logistic regression modelling are presented in table 3.

DISCUSSION

Individuals who consumed hot tea daily had reduced odds of having a diagnosis of glaucoma in the 2005–2006 NHANES population. Interestingly, this association was not observed with the consumption of iced tea or decaffeinated hot tea. Tea contains phytochemicals and flavonoids, which have been observed to have anti-inflammatory, anticarcinogenic, antioxidant and neuroprotective properties¹⁹ associated with the prevention of cardiovascular disease, cancer and diabetes.²⁰ Prior studies have noted an oxidative and neurodegenerative aetiology in the pathogenesis of glaucoma, suggesting that antioxidants may play a protective role in glaucoma. Additionally, flavonoids have been shown to inhibit the vascular endothelial growth factor receptor, and potentially prevent neovascular glaucoma, fibrotic scar tissue formation after glaucoma surgery and neurodegeneration.²¹ Poor ocular perfusion has been implicated in the development of glaucoma, and flavonoids may play a protective role

Table 2 Prevalence of beverage consumption by glaucoma status within the National Health and Nutrition Examination Survey, 2005–2006

Weighted estimates			
Beverage	Total number (%) n=83 308 317	With glaucoma (%) n=2 657 336	Without glaucoma (%) n=80 650 982
Coffee consumption			
Never	13 746 587 (16.5)	334 607 (12.6)	13 411 981 (16.6)
<1 cup per week	7 527 422 (9.0)	234 577 (8.8)	7 292 846 (9.0)
1–6 cups per week	6 782 981 (8.1)	318 912 (12.0)	6 464 069 (8.0)
>6 cups per week	37 549 318 (45.1)	1 244 115 (46.8)	36 305 203 (45.0)
Decaf coffee consumption among coffee consumers			
Never	33 711 748 (65.5)	1 304 821 (71.3)	32 406 926 (64.7)
A quarter of the time	3 790 477 (7.4)	57 578 (3.1)	3 732 899 (7.5)
Half of the time	3 745 071 (7.3)	93 147 (5.1)	3 651 923 (7.3)
Three-quarters of the time	1 475 862 (2.9)	52 398 (2.9)	1 423 464 (2.8)
More than three-quarters of the time	8 768 819 (17.0)	323 320 (17.7)	8 445 498 (16.9)
Iced tea consumption			
Never	18 178 785 (21.8)	906 609 (34.1)	17 272 175 (21.4)
<1 cup per week	24 686 019 (29.6)	766 557 (28.9)	23 919 462 (29.7)
1–6 cups per week	12 662 702 (15.2)	288 954 (10.9)	12 373 748 (15.3)
>6 cups per week	9 725 478 (11.7)	161 918 (6.1)	9 563 559 (11.9)
Decaf iced tea consumption among iced tea consumers			
Never	29 116 970 (59.4)	845 405 (64.0)	28 271 566 (59.3)
A quarter of the time	5 195 450 (10.6)	116 918 (8.8)	5 078 532 (10.6)
Half of the time	4 597 152 (9.4)	63 729 (4.8)	4 533 423 (9.5)
Three-quarters of the time	2 169 662 (4.4)	68 597 (5.2)	2 101 066 (4.4)
More than three-quarters of the time	7 930 703 (16.2)	226 697 (17.2)	7 704 007 (16.2)
Hot tea consumption			
Never	26 820 636 (32.2)	1 163 610 (43.8)	25 657 027 (31.8)
<1 cup per week	24 635 870 (29.6)	703 773 (26.5)	23 932 098 (29.7)
1–6 cups per week	7 185 098 (8.6)	155 511 (5.9)	7 029 587 (8.7)
>6 cups per week	6 513 975 (7.8)	109 318 (4.1)	6 404 657 (7.9)
Decaf hot tea consumption among hot tea consumers			
Never	14 777 858 (38.5)	445 860 (44.8)	14 331 999 (38.4)
A quarter of the time	3 232 758 (8.4)	199 051 (20.0)	3 033 707 (8.1)
Half of the time	5 289 727 (13.8)	46 460 (4.7)	5 243 268 (14.0)
Three-quarters of the time	2 559 729 (6.7)	36 936 (3.7)	2 522 793 (6.8)
More than three-quarters of the time	10 437 031 (27.2)	267 586 (26.9)	10 169 445 (27.2)
Soft drinks consumption			
Never	606 548 (0.7)	18 731 (0.7)	587 818 (0.7)
<1 cup per week	13 551 899 (16.3)	368 448 (13.9)	13 183 451 (16.4)
1–6 cups per week	21 319 269 (25.6)	888 984 (33.5)	20 430 285 (25.3)
>6 cups per week	25 864 635 (31.1)	483 119 (18.2)	25 381 516 (31.5)
Decaf soft drinks consumption among soft drinks consumers			
Never	31 789 729 (52.0)	1 008 910 (57.4)	30 780 819 (51.8)
A quarter of the time	7 234 391 (11.8)	144 157 (8.2)	7 090 234 (11.9)
Half of the time	7 310 843 (12.0)	158 559 (9.0)	7 152 284 (12.0)
Three-quarters of the time	3 691 718 (6.0)	89 721 (5.1)	3 601 997 (6.1)
More than three-quarters of the time	11 105 051 (18.2)	357 935 (20.3)	10 747 116 (18.1)
Actual frequencies			
Beverage	Total number (%) n=1678	With glaucoma (%) n=84	Without glaucoma (%) n=1594
Coffee consumption			
Never	258 (15.4)	9 (10.7)	249 (15.6)
<1 cup per week	160 (9.5)	9 (10.7)	151 (9.5)
1–6 cups per week	150 (8.9)	8 (9.5)	142 (8.9)
>6 cups per week	686 (40.9)	36 (42.9)	650 (40.8)
Decaf coffee consumption among coffee consumers			
Never	624 (62.7)	40 (72.7)	584 (61.9)
A quarter of the time	69 (6.9)	2 (3.6)	67 (7.1)

Continued

Table 2 Continued

Actual frequencies			
Beverage	Total number (%) n=1678	With glaucoma (%) n=84	Without glaucoma (%) n=1594
Half of the time	65 (6.5)	1 (1.8)	64 (6.8)
Three-quarters of the time	41 (4.1)	2 (3.6)	39 (4.1)
More than three-quarters of the time	197 (19.8)	10 (18.2)	187 (19.8)
Iced tea consumption			
Never	379 (22.6)	26 (31.0)	353 (22.1)
<1 cup per week	487 (29.0)	25 (29.8)	462 (29.0)
1–6 cups per week	218 (13.0)	6 (7.1)	212 (13.3)
>6 cups per week	163 (9.7)	5 (6.0)	158 (9.9)
Decaf iced tea consumption among iced tea consumers			
Never	540 (58.0)	27 (65.9)	513 (57.6)
A quarter of the time	97 (10.4)	2 (4.9)	95 (10.7)
Half of the time	85 (9.1)	3 (7.3)	82 (9.2)
Three-quarters of the time	45 (4.8)	2 (4.9)	43 (4.8)
More than three-quarters of the time	164 (17.6)	7 (17.1)	157 (17.6)
Hot tea consumption			
Never	488 (29.1)	31 (36.9)	457 (28.7)
<1 cup per week	459 (27.4)	22 (26.2)	437 (27.4)
1–6 cups per week	155 (9.2)	4 (4.8)	151 (9.5)
>6 cups per week	141 (8.4)	5 (6.0)	136 (8.5)
Decaf hot tea consumption among hot tea consumers			
Never	285 (37.7)	13 (40.6)	272 (37.6)
A quarter of the time	68 (9.0)	4 (12.5)	64 (8.8)
Half of the time	93 (12.3)	3 (9.4)	90 (12.4)
Three-quarters of the time	49 (6.5)	2 (6.3)	47 (6.5)
More than three-quarters of the time	225 (29.8)	10 (31.3)	215 (29.7)
Soft drinks consumption			
Never	16 (1.0)	1 (1.2)	15 (0.9)
<1 cup per week	274 (16.3)	13 (15.5)	261 (16.4)
1–6 cups per week	422 (25.1)	22 (26.2)	400 (25.1)
>6 cups per week	468 (27.9)	16 (19.0)	452 (28.4)
Decaf soft drinks consumption among soft drinks consumers			
Never	596 (50.7)	29 (55.8)	567 (50.5)
A quarter of the time	150 (12.8)	6 (11.5)	144 (12.8)
Half of the time	136 (11.6)	5 (9.6)	131 (11.7)
Three-quarters of the time	64 (5.4)	1 (1.9)	63 (5.6)
More than three-quarters of the time	229 (19.5)	11 (21.2)	218 (19.4)

by promoting vasodilation in individuals without glaucoma.²² Caffeinated teas have been found to have greater antioxidant capacity compared with decaffeinated teas,²³ which may explain why decaffeinated tea consumption was not correlated with decreased glaucoma risk. The fact that no protective effect was observed with iced tea may be due to the limited sample size, and the lack of data regarding whether the iced tea was instant or brewed. Prior studies have noted instant iced tea to have significantly less flavonoids compared with brewed iced and hot tea.²⁴

In contrast to the protective association between hot tea and glaucoma, our study found no positive or negative association between coffee consumption and glaucomatous optic neuropathy. Compared with tea, coffee contains more caffeine and a different profile of polyphenols comprising less flavonoids but more hydroxycinnamic acids,²⁵ which may underlie the observed differences in glaucoma risk modulation. Prior studies have suggested that coffee may play a detrimental role by increasing IOP,^{5,6} whereas others noted no clear association between coffee and increased IOP.⁷ The proposed mechanism of caffeine-induced increase in IOP based on animal models is

increased aqueous humour production and transport via the non-pigmented ciliary epithelium.²⁶ Aside from possible effects on increasing IOP, coffee may increase plasma and aqueous homocysteine levels, which have been linked to the development of pseudoexfoliation glaucoma but not normal-tension glaucoma.⁸ By contrast, other studies suggest that chlorogenic acid in coffee may play a protective role by preventing hypoxia-related retinal degeneration and glutamate neurotoxicity.⁹ Caffeine's beneficial effect is further supported by a well-established animal model of glaucoma that showed decreased neuroinflammation, diminished retinal ganglion cell loss and lower IOP in ocular hypertensive animals with ingestion of caffeine²⁷ attributed to its antagonism of adenosine receptors.²⁸

No studies to date have assessed the effect of soft drink consumption on glaucoma risk, and our study found no correlation between the two. Prior research has shown that soft drinks contain about a tenth of the polyphenol content of coffee.²⁹

This study has several limitations mainly related to its observational and cross-sectional design. The incidence of glaucoma was not available owing to the cross-sectional nature of the

Table 3 Association between beverage consumption and glaucoma in the National Health and Nutrition Examination Survey, 2005–2006

Beverage type	Unadjusted OR (95% CI)	OR (95% CI) adjusted for age, gender and ethnicity	OR (95% CI) adjusted for age, BMI, gender, ethnicity, smoking status and diabetes	P value for fully adjusted models
Coffee consumption				
None	1.00 (ref)	1.00 (ref)	1.00 (ref)	
<1 cup per week	1.29 (0.50 to 3.30)	1.09 (0.40 to 2.95)	1.07 (0.40 to 2.87)	0.90
1–6 cups per week	1.98 (0.76 to 5.17)	1.44 (0.46 to 4.52)	1.38 (0.42 to 4.50)	0.60
>6 cups per week	1.37 (0.82 to 2.31)	1.18 (0.64 to 2.16)	1.24 (0.67 to 2.32)	0.49
				P=0.43 for trend
Decaf coffee consumption among coffee consumers				
Almost never or never	1.00 (ref)	1.00 (ref)	1.00 (ref)	
A quarter of the time	0.38 (0.08 to 1.87)	0.34 (0.07 to 1.60)	0.33 (0.07 to 1.53)	0.16
Half of the time	0.63 (0.09 to 4.45)	0.59 (0.08 to 4.45)	0.57 (0.08 to 4.26)	0.58
Three-quarters of the time	0.91 (0.21 to 4.03)	0.61 (0.14 to 2.69)	0.60 (0.13 to 2.72)	0.51
More than three-quarters of the time	0.95 (0.43 to 2.11)	0.66 (0.24 to 1.81)	0.63 (0.23 to 1.74)	0.37
				P=0.31 for trend
Iced tea consumption				
None	1.00 (ref)	1.00 (ref)	1.00 (ref)	
<1 cup per week	0.61 (0.35 to 1.06)	0.72 (0.39 to 1.33)	0.73 (0.40 to 1.33)	0.30
1–6 cups per week	0.45 (0.16 to 1.23)	0.59 (0.18 to 1.94)	0.59 (0.19 to 1.85)	0.36
>6 cups per week	0.32 (0.09 to 1.17)	0.40 (0.11 to 1.49)	0.39 (0.10 to 1.47)	0.16
				P=0.11 for trend
Decaf iced tea consumption among iced tea consumers				
Almost never or never	1.00 (ref)	1.00 (ref)	1.00 (ref)	
A quarter of the time	0.77 (0.14 to 4.30)	0.92 (0.13 to 6.31)	0.90 (0.13 to 6.19)	0.92
Half of the time	0.47 (0.12 to 1.83)	0.52 (0.13 to 2.09)	0.52 (0.14 to 1.97)	0.34
Three-quarters of the time	1.09 (0.25 to 4.84)	0.90 (0.24 to 3.39)	0.91 (0.24 to 3.52)	0.89
More than three-quarters of the time	0.98 (0.37 to 2.66)	0.83 (0.26 to 2.59)	0.82 (0.27 to 2.46)	0.73
				P=0.64 for trend
Hot tea consumption				
None	1.00 (ref)	1.00 (ref)	1.00 (ref)	
<1 cup per week	0.65 (0.31 to 1.34)	0.57 (0.28 to 1.17)	0.55 (0.26 to 1.17)	0.12
1–6 cups per week	0.49 (0.13 to 1.77)	0.37 (0.11 to 1.23)	0.35 (0.10 to 1.19)	0.093
>6 cups per week	0.38 (0.15 to 0.93)	0.26 (0.09 to 0.70)	0.26 (0.09 to 0.72)	0.010
				P=0.004 for trend
Decaf hot tea consumption among hot tea consumers				
Almost never or never	1.00 (ref)	1.00 (ref)	1.00 (ref)	
A quarter of the time	2.11 (0.56 to 7.92)	2.29 (0.59 to 8.89)	2.44 (0.66 to 9.08)	0.18
Half of the time	0.29 (0.07 to 1.20)	0.38 (0.08 to 1.74)	0.38 (0.08 to 1.71)	0.21
Three-quarters of the time	0.47 (0.08 to 2.74)	0.54 (0.08 to 3.92)	0.56 (0.08 to 4.04)	0.56
More than three-quarters of the time	0.85 (0.25 to 2.86)	0.86 (0.25 to 2.95)	0.85 (0.23 to 3.23)	0.82
				P=0.59 for trend
Soft drinks consumption				
None	1.00 (ref)	1.00 (ref)	1.00 (ref)	
<1 cup per week	0.88 (0.11 to 7.04)	1.42 (0.13 to 15.51)	1.14 (0.13 to 10.35)	0.91
1–6 cups per week	1.37 (0.17 to 11.28)	2.25 (0.24 to 21.16)	1.85 (0.22 to 15.55)	0.57
>6 cups per week	0.60 (0.08 to 4.34)	1.19 (0.12 to 11.74)	0.93 (0.11 to 7.73)	0.95
				P=0.48 for trend
Decaf soft drinks consumption among soft drinks consumers				
Almost never or never	1.00 (ref)	1.00 (ref)	1.00 (ref)	
A quarter of the time	0.62 (0.25 to 1.54)	0.53 (0.22 to 1.31)	0.49 (0.18 to 1.33)	0.16
Half of the time	0.68 (0.24 to 1.88)	0.69 (0.23 to 2.09)	0.65 (0.20 to 2.12)	0.48
Three-quarters of the time	0.76 (0.11 to 5.32)	0.85 (0.09 to 8.12)	0.81 (0.08 to 8.02)	0.86
More than three-quarters of the time	1.02 (0.45 to 2.28)	0.83 (0.33 to 2.11)	0.79 (0.32 to 1.93)	0.60
				P=0.64 for trend

ORs are based on weighted frequencies using the reference level of non-consumers of each type of beverage. BMI, body mass index; ref, reference level.

study, so a temporal association between beverage consumption and glaucoma could not be established. Further, we were limited by the survey questions, which did not probe into the types of tea consumed (black vs green, instant vs brewed, duration of brewing), possible overlapping consumption patterns of different beverages and total energy intake. As with all survey data, the results are subject to response bias and limited precision, including lack of data on beverage cup sizes. The effect of certain beverage consumptions on the various subtypes of glaucoma could not be determined based on optic nerve images and FDT visual fields alone. Additionally, the FDT visual fields and optic nerve diagnostic criteria used in this study were subject to misclassification bias with a 9% false-positive rate and a 6% false-negative rate.³⁰ Finally, with multiple comparisons, there exists the possibility of a chance statistical association.

Unmeasured or residual confounding factors may contribute to additional analytical bias. Finally, there were no additional data available within the NHANES to validate glaucoma diagnoses in participants who met the Rotterdam criteria for glaucoma based on FDT visual fields and optic nerve images.

CONCLUSION

In summary, individuals who consumed hot tea were less likely to have a diagnosis of glaucoma compared with those who did not consume hot tea. This study is limited by its cross-sectional design and use of multiple statistical testing, and further research is needed to establish the importance of these findings and whether hot tea consumption may play a role in the prevention of glaucomatous optic neuropathy.

Contributors All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing or revision of the manuscript. Conception and design of study: CMW, AMW, VLT, FY, ALC. Acquisition of data: VLT, FY. Analysis and/or interpretation of data: CMW, AMW, VLT, FY, ALC. Drafting the manuscript: CMW, AMW. Revising the manuscript critically for important intellectual content: MCW, AMW, VLT, FY, ALC. Approval of the version of the manuscript to be published: CMW, AMW, VLT, FY, ALC.

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