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European Journal of Medical Research (2025) 30:62
https://doi.org/10.1186/s40001-025-02294-z

European Journal
of Medical Research

RESEARCH

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Association of dietary inflammatory index with ocular diseases: a population-based cross-sectional study

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Abstract

Background Our research was designed to investigate the relationship between dietary inflammatory index (DII) and risk of ocular diseases, including glaucoma, cataract, age-related macular degeneration (ARMD), and diabetic retinopathy.

Methods We used the National Health and Nutrition Examination Survey (NHANES) data from 2005 to 2008 to conduct this study. The correlation between DII and risk of ocular diseases was examined using weighted multivariable logistic regression analysis, restricted cubic spline (RCS) plots, and subgroup analysis.

Results In total, 2885 participants from the NHANES database were included. The DII scores were divided into four group: Q1 (– 4.438–0.386), Q2 (0.387–1.848), Q3 (1.849–3.073), and Q4 (3.074–4.970). RCS shown that there was a U-shaped correlation between DII and prevalence of glaucoma, cataract, ARMD, and diabetic retinopathy. After adjusting for underlying confounding variables, compared to Q1 group, the odd ratios (ORs) with 95 percent confidence intervals (CIs) for glaucoma, cataract, ARMD, and diabetic retinopathy across the quartiles were [0.97 (0.54, 1.75), 1.20 (0.68, 2.11), and 1.29 (0.73, 2.30)], [0.87 (0.56, 1.35), 1.12 (0.73, 1.73), and 1.16 (0.75, 1.80)], [0.85 (0.53, 1.36), 0.66 (0.40, 1.09), and 0.97 (0.61, 1.56)] and [0.86 (0.63, 1.18), 0.89 (0.65, 1.22), and 1.04 (0.75, 1.45)] for DII, respectively.

Conclusions Reducing the intake of pro-inflammatory foods may be an effective measure to prevent the onset of ocular disease, including glaucoma, cataract, ARMD, and diabetic retinopathy. However, eating only anti-inflammatory foods is not the best choice.

Keywords Cross-sectional study, Dietary inflammation index, Ocular diseases, United States

Introduction

The dietary inflammatory index (DII) serves as a valuable instrument for evaluating the impact of dietary choices on the inflammatory response. Through a meticulous analysis of various nutrients and food components within the diet, the DII generates a comprehensive index that elucidates their respective effects on inflammation [1]. A higher DII value signifies a diet that is more prone to inducing inflammation [2]. Empirical investigations pertaining to ocular diseases have consistently demonstrated the pivotal role of inflammation in the pathogenesis of numerous ocular ailments. For example, macular degeneration, glaucoma, dry eyes and conjunctivitis eye disease are closely related to the inflammatory response [3–7]. Inflammation has the potential to induce harm to ocular tissues and prompt the liberation of inflammatory mediators, thereby resulting in ocular symptoms such as eye discomfort, vision loss, and other related manifestations [8]. Age-related macular degeneration, an ocular

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disease affecting the eyeground, stands as a prominent cause of blindness. Vergroesen JE and his research team discovered that the high dietary inflammatory index (DII) is linked to an elevated risk of macular degeneration [9]. Consequently, the adoption of a low-inflammatory diet holds the potential to mitigate the incidence and progression of chronic inflammation, thereby exerting a beneficial influence on the prevention and management of ocular diseases. Low inflammatory diet included increased intake of fruits, vegetables, whole grains and healthy fats (such as olive oil and fish oil), and reduced intake of red meat, processed foods, sugar and saturated fats such as inflammatory food [10, 11]. According to existing research, the association between DII and ocular diseases, including glaucoma, cataract, age-related macular degeneration (ARMD), and diabetic retinopathy in American adults has not been fully examined. Thus, the purpose of this study was to investigate the relationship between DII and ocular diseases, including glaucoma, cataract, ARMD, and diabetic retinopathy by integrating NHANES data from 2005 to 2008 and to provide guidance for clinical decision-making.

Materials and methods

Study population

The current cross-sectional research was based on the NHANES, a survey of nutrition and health in the United States that is representative nationwide [12]. In the total sample of 19,488 participants, there were 13,922 without ocular disease questionnaire and examination data. In addition, those lacking data on DII ($n=117$) were also excluded. Finally, we also removed the patient's missing demographic and biochemical data to ensure the accuracy of the results ($n=3164$). A total of 2,285 participants were included in the final analysis (Fig. 1). The NHANES website (https://www.cdc.gov/nchs/nhanes/) has comprehensive information on the survey's design, methodology, and statistics. The National Center for Health Statistics Research Ethics Review Board approved all protocols, and informed permission was acquired from all the participants included in the investigation [13].

Covariates

The following covariates were considered in the study: age, marital status (having a partner/no partner/

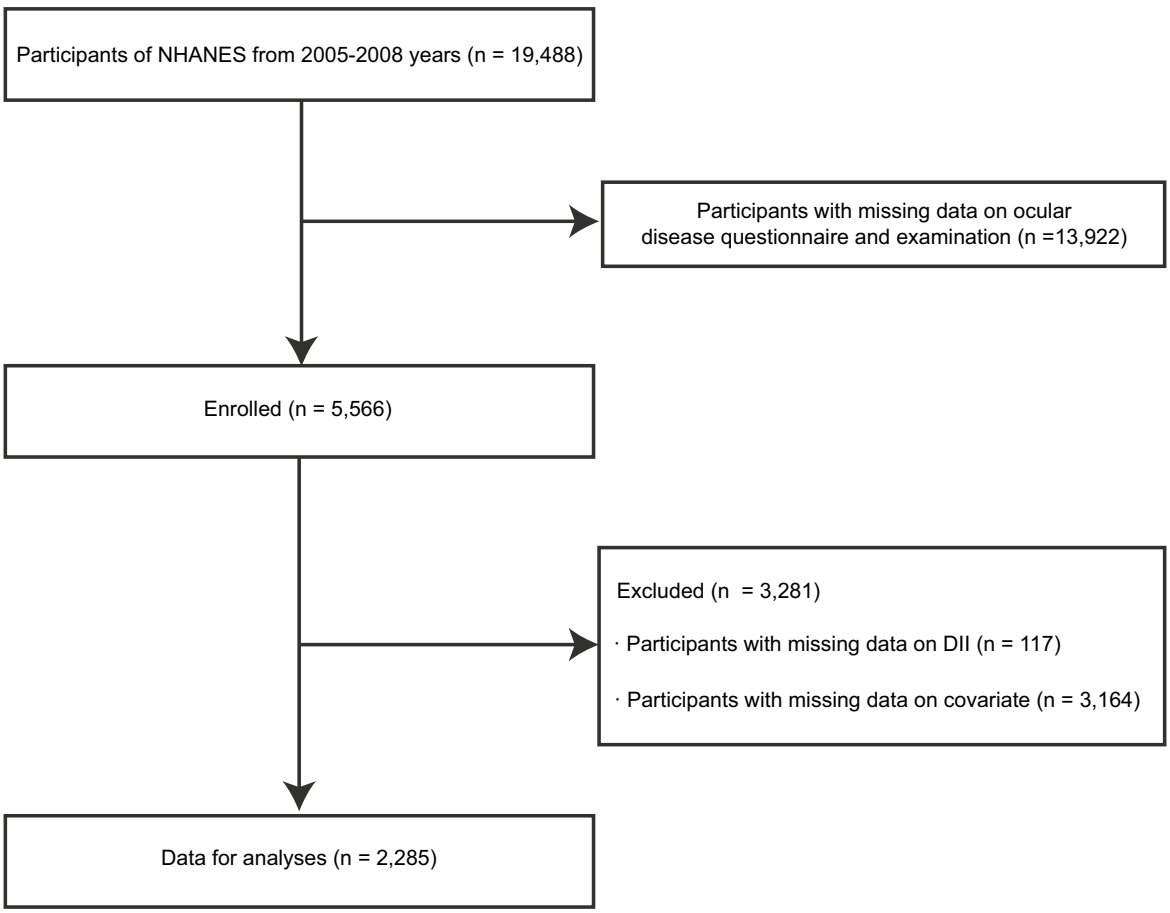

Fig. 1 Study flow chart. *NHANES* National Health and Nutrition Examination Surveys, *DII* dietary inflammation index

unmarried), sex (female/male), race/ethnicity (Other Hispanic/Non-Hispanic Black/Other race/Mexican American/Non-Hispanic White), family poverty income ratio (PIR), the complication of hypertension (no/yes), the complication of diabetes mellitus (DM) (no/yes), smoker (no/former/now), education level (less than high school/more than high school), drinker (never/former/mild/moderate/heavy), waist circumference, estimated glomerular filtration rate (eGFR), high-density lipoprotein cholesterol (HDL-C), total cholesterol (TC), serum creatinine (Scr), triglyceride (TG), blood urea nitrogen (BUN), fast glucose (FBG), uric acid (UA), and body mass index (BMI). More information regarding the variables used in this study is available at https://www.cdc.gov/nchs/nhanes/index.htm.

Calculation of the DII

Based on literature review, Shivappa developed the DII score system to assess the potential inflammatory level of dietary components [14]. Dietary consumption effects on inflammation are calculated from 45 nutrients in DII. However, due to the limitation of the NHANES database, the calculation of DII could only be based on 28 nutrients. It is calculated by adding the scores from each component of the diet consumed in 24 h, including the scores from the pro-inflammatory and anti-inflammatory diets. A Z-score can be calculated by subtracting the Global daily mean intake and dividing by the standard deviation, and then, the result is converted to a percentile score by doubling each percentile score and subtracting "1" to produce a symmetrical distribution. By multiplying the percentile value by the corresponding "overall inflammation effect score," we can produce an individual "overall DII score." Based on diet recall interviews conducted within 24 h, DII scores were calculated as described previously. In our study, the DII was calculated based on 28 nutrients, including carbohydrates, protein, total fat, alcohol, fiber, cholesterol, saturated fat, monounsaturated fatty acids (MUFAs), polyunsaturated fatty acids (PUFAs), n-3 fatty acids, n-6 fatty acids, niacin, vitamin A/B12/C/D/E, thiamin (vitamin B1), riboflavin (vitamin B2), Fe, Mg, zinc, selenium, folic acid, beta-carotene, caffeine, and energy [15].

Ocular diseases measurement

There were two methods for determining ocular diseases: self-report or retinal imaging. A total of two digital images per eye were taken to measure retinal thickness using Canon EOS 10D digital camera (Canon, Tokyo, Japan) and Canon CR6-45NM ophthalmic digital imaging system during the retinal imaging study which was restricted to participants who were 40 years or older. By placing participants in a darkened room for a period of time, participants' pupils were physiologically dilated. Two digital images were taken, the first of which was centered around the macula, and the other of which was centered around the optic nerve. The pictures of the retinas were read at the Ocular Epidemiologic Reading Center, located at the University of Wisconsin in Madison, and they used the worst eye among the two eyes to define ocular diseases. The early treatment diabetic retinopathy study grading standards defined diabetic retinopathy as a condition where one or more of the retina's microaneurysms or retinal hemorrhages were present with or without more severe lesions. In accordance with the modified Wisconsin Age-Related Maculopathy Grading Classification Scheme, age-related macular degeneration (ARMD) was defined. To identify disc-defined glaucoma, cup-to-disc ratios ≥ 0.6 for each eye from photographs of the optic nerve were graded as no, possible, probable, or definite, with the results being adjudicated whenever necessary. A glaucoma diagnosis of probable or definite in at least one eye was defined by us, as in other studies using NHANES data [16]. The following questions were used to determine whether a self-reported history of ocular diseases existed: "Have you ever been told by an eye doctor that you have glaucoma, sometimes called high pressure in your eyes?"; "Have you ever had eye surgery to treat cataracts?"; "Have you been told by an eye doctor that you have age-related macular degeneration?"; and "Has a doctor ever told you that diabetes has affected your eyes or that you had retinopathy?" Not all participants with self-reported ocular diseases also completed the retinal image testing.

Statistical analysis

Mean ± (standard deviation) and quantity (percentage, %) are used to represent continuous and categorical variables, respectively. For continuous variables, the weighted t-test was used. In addition, to compare the constituent ratios between each group, the weighted Chi-square test was performed. Multivariate logistic regression analysis and restricted cubic spline (RCS) plot were performed to explore the potential nonlinearity of the association between DII and ocular disease. First, model 1 was adjusted for age and sex. Second, model 2 was further adjusted for race/ethnicity, marital status, hypertension, education level, smoker, family PIR, DM, and drinker. Finally, model 3 was further adjusted for waist circumference, TG, Scr, BMI, BUN, FBG, HDL-C, UA, TC, and eGFR as our core model. Finally, subgroup analysis stratified by age, sex, hypertension, DM, and obesity was applied to examine the association of DII with ocular disease. All statistical analyses were performed using R version 3.6.4 (R Foundation for Statistical Computing, Vienna, Austria), Stata version 13.0 (Stata Corporation,

College Station, TX, USA), and SPSS version 22.0 (SPSS Inc., Chicago, IL, USA). P value < 0.05 was regarded as statistically significant.

Results

Baseline characteristics

The characteristics of 2885 participants are presented in Table 1. The DII scores were divided into four group: Q1 (− 4.338–0.386), Q2 (0.387–1.848), Q3 (1.849–3.073), and Q4 (3.074–4.970). Sex, race/ethnicity, family PIR, education level, marital status, smoker, alcohol user, and BMI had significant difference among Q1, Q2, Q3 and Q4 group. Participants in Q1 group had the lowest BMI, waist circumference, FBG, TC, and TG and had the highest level of family PIR, BUN, and HDL-C. Q4 group had the highest level of BMI, waist circumference, and TC and had the lowest level of BUN, and UA, and occupied a highest proportion of hypertension, DM. In addition, individuals in Q4 group seem to be the oldest, with 15.6% of them females.

Association between DII and ocular disease

The restricted cubic spline (RCS) plot is shown in Fig. 2A–D, representing U-shaped curve association of DII with glaucoma, cataract, ARMD, and diabetic retinopathy (P for nonlinearity < 0.05). The DII scores were divided into four groups: Q1, Q2, Q3, and Q4, with Q1 serving as the reference group. Results of the multivariate logistic regression analysis of DII and ocular disease (glaucoma, cataract, ARMD, and diabetic retinopathy) are presented in Table 2. After adjusting for underlying confounding variables, compared to Q1 group, the odd ratios (ORs) with 95 percent confidence intervals (CIs) for glaucoma, cataract, ARMD, and diabetic retinopathy across the quartiles were [0.97 (0.54, 1.75), 1.20 (0.68, 2.11), and 1.29 (0.73, 2.30)], [0.87 (0.56, 1.35), 1.12 (0.73, 1.73), and 1.16 (0.75, 1.80)], [0.85 (0.53, 1.36), 0.66 (0.40, 1.09), and 0.97 (0.61, 1.56)], and [0.86 (0.63, 1.18), 0.89 (0.65, 1.22), and 1.04 (0.75, 1.45)] for DII, respectively.

Subgroup analyses

Age, sex, hypertension, DM, and BMI were stratified, and analysis confirmed non-liner association between DII and ocular disease (glaucoma, cataract, ARMD, and diabetic retinopathy) (Supplementary Fig. 1, 2, 3, and 4; Supplementary Table 1, 2, 3, and 4). The U-shaped association was observed between DII and glaucoma among participants who aged < 60 years, were male, with hypertension, without DM, and with BMI < 30 kg/m^2 (Supplementary Fig. 1; Supplementary Table 1). The above U-shaped association between DII and cataract was also presented in individuals aged ≥ 60 years, were female, with hypertension, and with BMI ≥ 30 kg/m^2 (Supplementary Fig. 2; Supplementary Table 2). In addition, the U-shaped relationship between DII and ARMD was also existed among people who aged < 60 years, were female, with hypertension, without DM, and with BMI ≥ 30 kg/m^2 (Supplementary Fig. 3; Supplementary Table 3). Finally, the U-shaped association was observed between DII and glaucoma among participants who aged < 60 and ≥ 60 years, were male, with hypertension, with or without DM, and with BMI ≥ 30 kg/m^2 (Supplementary Fig. 4; Supplementary Table 4).

Discussion

The eye, being our most vital sensory organ, possesses intricate and delicate characteristics. Numerous ocular disorders can significantly impair our visual perception and yield severe implications on our interpretation of the surrounding environment. These encompass a range of detrimental eye diseases, such as glaucoma, cataracts, age-related macular degeneration (ARMD), and diabetic retinopathy. Our findings revealed a U-shaped correlation between DII scores and the prevalence of these ocular diseases, suggesting that both low and high DII scores may be associated with increased risk. Specifically, after adjusting for confounding variables, the odds ratios indicated varying levels of risk across different quartiles of DII.

Glaucoma is commonly present in the majority of patients as elevated intraocular pressure or as a vascular dysfunction impacting the optic nerve. However, it is noteworthy that in exceptional instances, glaucoma can induce reduced intraocular pressure. Various risk factors, such as diabetes, cardiovascular disease, ocular infections, and individuals aged 65 years and above, can contribute to heightened eye pressure and potentially precipitate the onset of glaucoma. Anti-inflammatory medications are potentially essential in the management of glaucoma, whether for therapeutic or preventive purposes. Sebbag et al. conducted clinical observations on canines afflicted with primary glaucoma, revealing that inflammation exacerbates intraocular pressure (IOP) by impeding the outflow of aqueous humor at the iridocorneal angle. In addition, inflammation contributes to the degeneration of neurons, thereby hastening the deterioration of vision [17]. In a study, Valdecoxib is a commonly employed selective cyclooxygenase (COX)−2 inhibitor for the treatment of osteoarthritis and rheumatoid arthritis, and the ATF4-CHOP axis can be effectively blocked by Valdecoxib, thereby inhibiting apoptosis of ischemia/reperfusion-induced glaucoma-like damaged cells in rats [18], thereby preventing CHOP-induced ROS-formation [19]. Various bioactive components in the diet can affect the inflammatory response process in the human body [20]. In the context of glaucoma progression, it has been

Table 1 Characteristics of the study population based on DII index quartiles

DII	Total ($n=2885$)	Q1 ($n=572$)	Q2 ($n=571$)	Q3 ($n=570$)	Q4 ($n=572$)	*P*-value
Age, years	56.04 ± 0.45	56.18 ± 0.79	55.72 ± 0.67	56.01 ± 0.59	56.25 ± 0.65	0.905
Sex, %						
Male	1176 (51.5%)	348 (15.2%)	339 (14.8%)	274 (12.0%)	215 (9.4%)	< 0.001
Female	1109 (48.5%)	224 (9.8%)	232 (10.2%)	296 (13.0%)	357 (15.6%)	
Race/ethnicity, %						
Mexican American	340 (14.9%)	90 (3.9%)	92 (4.0%)	77 (3.4%)	81 (3.5%)	0.032
Other Hispanic	151 (6.6%)	32 (1.4%)	43 (1.9%)	41 (1.8%)	35 (1.5%)	
Non-Hispanic Black	425 (18.6%)	73 (3.2%)	98 (4.3%)	131 (5.7%)	123 (5.4%)	
Non-Hispanic White	1294 (56.6%)	355 (15.5%)	311 (13.6%)	308 (13.5%)	320 (14.0%)	
Other race						
Family PIR	3.34 ± 0.07	3.71 ± 0.08	3.51 ± 0.09	3.18 ± 0.10	2.88 ± 0.12	< 0.001
Education level, %						
Less than high school	633 (27.7%)	115 (5.0%)	142 (6.2%)	159 (7.0%)	217 (9.5%)	0.007
More than high school	1652 (72.3%)	457 (20.0%)	429 (18.8%)	411 (18.0%)	355 (15.5%)	
Marital status, %						
Having a partner	1485 (65.0%)	406 (17.8%)	397 (17.4%)	355 (15.5%)	327 (14.3%)	0.002
No partner	653 (28.6%)	133 (5.8%)	143 (6.3%)	170 (7.4%)	207 (9.1%)	
Unmarried	147 (6.4%)	33 (1.4%)	31 (1.4%)	45 (2.0%)	38 (1.7%)	
Hypertension, %						
No	1054 (46.1%)	290 (12.7%)	273 (11.9%)	257 (11.2%)	234 (10.2%)	0.089
Yes	1231 (53.9%)	282 (12.3%)	298 (13.0%)	313 (13.7%)	338 (14.8%)	
DM, %						
No	1687 (73.8%)	451 (19.7%)	422 (18.5%)	410 (17.9%)	404 (17.7%)	0.431
Yes	598 (26.2%)	121 (5.3%)	149 (6.5%)	160 (7.0%)	168 (7.4%)	
Smoker, %						
No	1050 (46.0%)	263 (11.5%)	276 (12.1%)	260 (11.4%)	251 (11.0%)	< 0.001
Former	759 (33.2%)	217 (9.5%)	193 (8.4%)	186 (8.1%)	163 (7.1%)	
Now	476 (20.8%)	92 (4.0%)	102 (4.5%)	124 (5.4%)	158 (6.9%)	
Alcohol user, %						
Never	282 (12.3%)	57 (2.5%)	60 (2.6%)	67 (2.9%)	98 (4.3%)	< 0.001
Former	601 (26.3%)	113 (4.9%)	124 (5.4%)	164 (7.2%)	200 (8.8%)	
Mild	821 (35.9%)	259 (11.3%)	225 (9.8%)	192 (8.4%)	145 (25.3%)	
Moderate	300 (13.1%)	71 (3.1%)	84 (3.7%)	78 (3.4%)	67 (2.9%)	
Heavy	281 (12.3%)	72 (3.2%)	78 (3.4%)	69 (3.0%)	62 (2.7%)	
BMI, kg/m^2	29.08 ± 0.17	28.38 ± 0.29	28.72 ± 0.33	29.56 ± 0.35	29.82 ± 0.28	0.013
Waist circumference, cm	100.55 ± 0.46	99.35 ± 0.75	100.33 ± 0.91	101.43 ± 0.85	101.34 ± 0.61	0.160
FBG, mg/mL	109.01 ± 0.87	107.67 ± 2.02	110.49 ± 1.51	108.86 ± 1.59	109.21 ± 1.31	0.558
BUN, mg/dL	13.48 ± 0.15	13.90 ± 0.28	13.61 ± 0.24	13.27 ± 0.25	13.06 ± 0.27	0.218
UA, mg/dL	5.62 ± 0.04	5.64 ± 0.07	5.72 ± 0.07	5.59 ± 0.07	5.50 ± 0.07	0.235
Scr, mg/dL	0.92 ± 0.01	0.93 ± 0.01	0.91 ± 0.01	0.93 ± 0.02	0.91 ± 0.02	0.361
eGFR, ml/min/1.73 m^2	86.21 ± 0.62	86.16 ± 1.08	87.49 ± 0.77	85.44 ± 0.95	85.70 ± 0.99	0.229
TC, mg/dL	203.46 ± 0.93	200.55 ± 1.95	203.90 ± 2.10	202.94 ± 1.90	207.07 ± 2.07	0.086
TG, mg/dL	147.22 ± 2.98	141.67 ± 6.36	149.47 ± 5.86	150.37 ± 5.55	148.24 ± 4.82	0.759
HDL-C, mg/dL	54.93 ± 0.38	56.52 ± 0.82	53.84 ± 0.87	54.05 ± 0.70	55.12 ± 0.73	0.149
Glaucoma, %						
No	2164 (94.7%)	548 (24.0%)	545 (23.9%)	536 (23.5%)	535 (23.4%)	0.466
Yes	121 (5.3%)	24 (1.1%)	26 (1.1%)	34 (1.5%)	37 (1.6%)	

Table 1 (continued)

DII	Total ($n=2885$)	Q1 ($n=572$)	Q2 ($n=571$)	Q3 ($n=570$)	Q4 ($n=572$)	*P*-value
Cataract, %						
No	2008 (87.9%)	507 (22.2%)	504 (22.1%)	507 (22.2%)	490 (21.4%)	0.151
Yes	277 (12.1%)	65 (2.8%)	67 (11.7%)	63 (2.8%)	82 (3.6%)	
ARMD, %						
No	2110 (92.3%)	521 (22.8%)	531 (23.2%)	536 (23.5%)	522 (22.8%)	0.228
Yes	175 (7.7%)	51 (2.2%)	40 (1.8%)	34 (1.5%)	50 (2.2%)	
Diabetic retinopathy, %						
No	1829 (80.3%)	476 (20.9%)	449 (19.7%)	447 (19.6%)	457 (20.1%)	0.971
Yes	449 (19.7%)	96 (4.2%)	121 (5.3%)	118 (5.2%)	114 (5.0%)	

Dietary inflammation index, DII; Q1, − 4.438–0.386; Q2, 0.387–1.848; Q3, 1.849–3.073; Q4, 3.074–4.970; family PIR, family poverty income ratio; DM, diabetes mellitus; BMI, body mass index; FBG, fast glucose; BUN, blood urea nitrogen; UA, uric acid; Scr, serum creatinine; eGFR, estimated glomerular filtration rate; TC, total cholesterol; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; ARMD, age-related macular degeneration

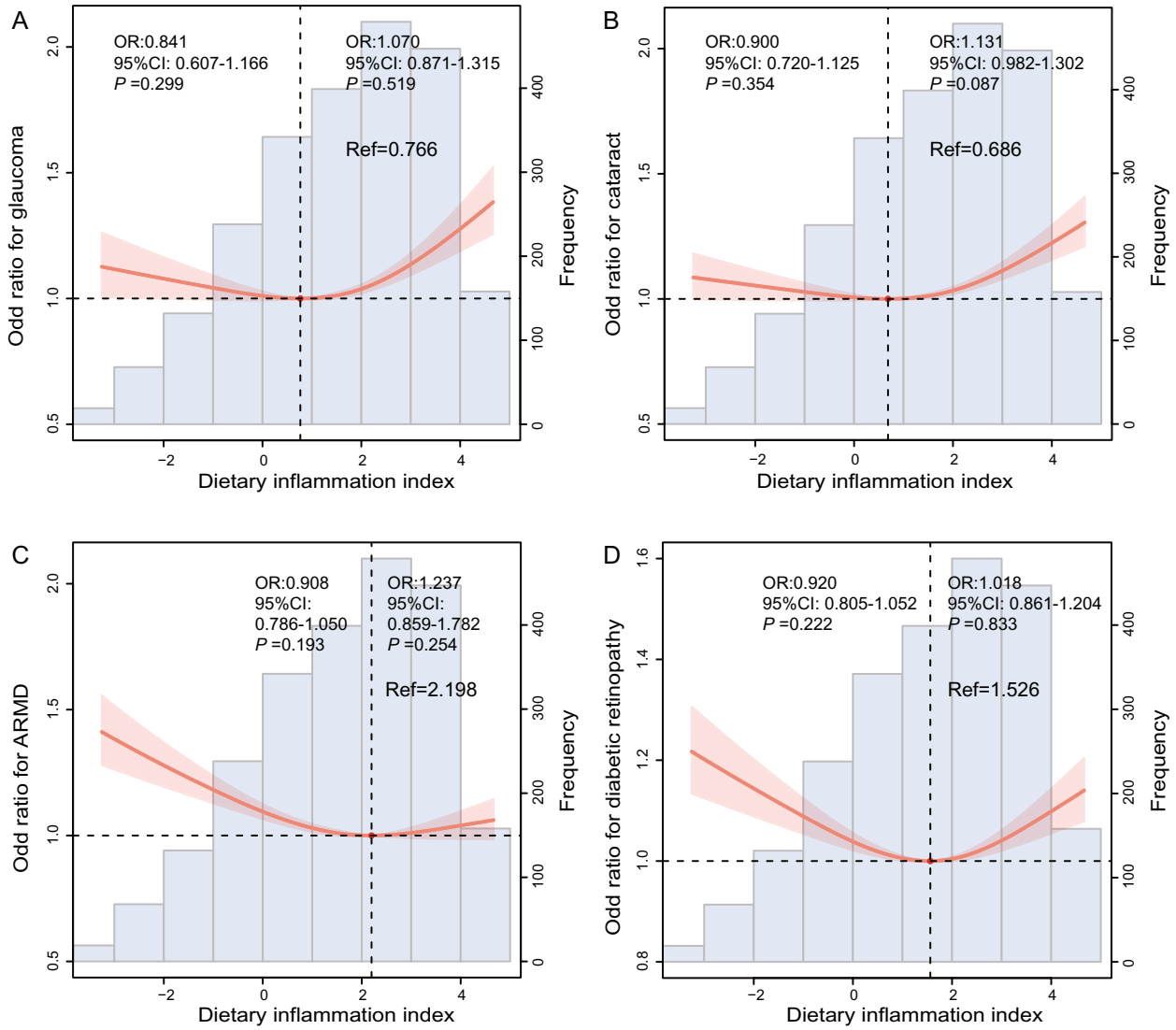

Fig. 2 RCS curve for the association of DII with prevalence of ocular diseases, including (**A**) glaucoma, (**B**) cataract, (**C**) ARMD, and (**D**) diabetic retinopathy. *DII* systemic immune-inflammation index, *ARMD* age-related macular degeneration, *RCS* restricted cubic spline

Table 2 Adjusted ORs for correlation between DII and prevalence of ocular disease

	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
Glaucoma			
Q1 (– 4.438–0.386)	Ref.	Ref.	Ref.
Q2 (0.387–1.848)	0.99 (0.62, 1.96)	0.98 (0.55, 1.76)	0.97 (0.54, 1.75)
Q3 (1.849–3.073)	1.45 (0.84, 2.50)	1.23 (0.71, 2.16)	1.20 (0.68, 2.11)
Q4 (3.074–4.970)	1.54 (0.89, 2.64)	1.35 (0.77, 2.39)	1.29 (0.73, 2.30)
P for trend	0.074	0.207	0.281
Cataract			
Q1 (– 4.438–0.386)	Ref.	Ref.	Ref.
Q2 (0.387–1.848)	0.93 (0.61, 1.42)	0.89 (0.57, 1.38)	0.87 (0.56, 1.35)
Q3 (1.849–3.073)	1.10 (0.72, 1.69)	1.10 (0.72, 1.70)	1.12 (0.73, 1.73)
Q4 (3.074–4.970)	1.25 (0.83, 1.89)	1.18 (0.76, 1.82)	1.16 (0.75, 1.80)
P for trend	0.429	0.669	0.765
ARMD			
Q1 (– 4.438–0.386)	Ref.	Ref.	Ref.
Q2 (0.387–1.848)	0.76 (0.48, 1.20)	0.82 (0.51, 1.30)	0.85 (0.53, 1.36)
Q3 (1.849–3.073)	0.60 (0.37, 0.97) *	0.63 (0.39, 1.03)	0.66 (0.40, 1.09)
Q4 (3.074–4.970)	0.89 (0.57, 1.37)	0.94 (0.59, 1.49)	0.97 (0.61, 1.56)
P for trend	0.433	0.558	0.694
Diabetic retinopathy			
Q1 (– 4.438–0.386)	Ref.	Ref.	Ref.
Q2 (0.387–1.848)	0.74 (0.54, 1.00)	0.83 (0.61, 1.13)	0.86 (0.63, 1.18)
Q3 (1.849–3.073)	0.75 (0.55, 1.01)	0.89 (0.65, 1.21)	0.89 (0.65, 1.22)
Q4 (3.074–4.970)	0.76 (0.56, 1.03)	1.01 (0.73, 1.39)	1.04 (0.75, 1.45)
P for trend	0.095	0.857	0.773

Dietary inflammation index, DII; ARMD, age-related macular degeneration; Q1, – 4.438–0.386; Q2, 0.387–1.848; Q3, 1.849–3.073; Q4, 3.074–4.970; OR, odd ratio; CI, confidence interval; *$P < 0.05$; Model 1 was adjusted for age and sex. Model 2 was further adjusted for race/ethnicity, education level, marital status, family poverty income ratio, hypertension, diabetes mellitus, smoker, and drinker. Model 3 was further adjusted for body mass index, waist circumference, fast glucose, blood urea nitrogen, uric acid, serum creatinine, estimated glomerular filtration rate, total cholesterol, triglyceride, and high-density lipoprotein cholesterol

established that inflammation plays a significant role. However, it is important to note that the limited number of studies investigating the relationship between dietary intake with inflammatory properties and the incidence of glaucoma. However, our study reveals a U-shaped correlation between the DII and the occurrence of glaucoma. This finding further strengthens the evidence supporting the pathogenic role of inflammatory in the development of glaucoma.

Cataract refers to the opacity of the lens caused by various reasons and is still the most common blinding eye disease in the world [21]. There are a number of mechanisms involved in the pathogenesis of cataracts, with oxidative stress, lens protein degeneration, and genetic mutations, among others, being important factors in the formation and development of cataracts [22–24]. At present, surgery is still the most effective treatment for cataracts, but some postoperative complications may seriously impair the quality of life in some patients [22]. In recent years, researchers have identified diet as a key non-surgical and behavioral factor influencing the risk of developing cataracts. Ziyan Yu et al. found that daily intake of higher levels of selenium helped prevent cataracts by studying the diets of 7525 subjects [25]. This may be attributed to the antioxidant capacity of selenium. Paul J. Donaldson et al. summarized previous trials in humans and animal models and discovered that moderate vitamin C intake prevents the development of cataracts, whereas excessive vitamin C intake increases the likelihood of cataract occurrence [26]. This is mainly due to the fact that different doses of vitamin C allow it to act as both an antioxidant and a pro-oxidant in its own right. All the above studies are based on the effects of single foods on cataracts, and the essence is the anti-inflammatory and pro-inflammatory effects behind the food. Based on the above research, the present study investigated the relationship between the level of inflammation represented by the combined 45 nutrients and cataract genesis by directly using the DII index as the study variable. Adjusting for confounders found that higher DII levels were associated with an increased risk of cataracts, which is consistent with previous studies.

ARMD is the predominant cause of irreversible vision loss or even loss of vision in the senior population [27]. Abraham D. Flaxman et al. stated that 19.83 million (12.58%) people aged greater than or equal to 40 years old in the United States suffered from ARMD in 2019, and the number is still growing in recent years [28, 29]. ARMD is classified into two pathological types, neovascular and non-neovascular (the main type), and the mechanisms include retinal neovascularization, oxidative stress, inflammation, and immune response, among others [30–32]. Intravitreal injection of anti-VEGF therapy is the primary regimen for neovascularization ARMD, while non-neovascularization ARMD therapy is currently dominated by antioxidant supplementation [33]. Supplementation with vitamins A, B, C, and E, trace-element selenium, lutein, and minerals has been reported to have beneficial protective effects against ARMD [34, 35]. There is no clear explanation mechanism for this association, but it is mostly related to the characteristics of anti-inflammatory response and anti-oxidative stress. Currently, there is still not enough research on food interventions and the risk of ARMD. A systematic review that included 18 studies found that the Mediterranean

dietary pattern was negatively associated with the development of ARMD and that the Mediterranean diet provided significant anti-inflammatory properties [35]. Trudy Voortman et al. found that 972 of a population of 7436 people without ocular disease in Rotterdam progressively developed ARMD through dynamic follow-up [9]. Higher levels of DII were observed to accelerate the onset and progression of ARMD by adjusting for confounders. This study, based on a population in the United States, further confirms these findings.

Diabetic retinopathy is one of the common complications of diabetes and can eventually lead to blindness. It is caused by chronically elevated blood sugar that damages the blood vessels at the back of the eye (retina). It is well known that dietary adjustments can regulate blood sugar in diabetic patients. What is more, dietary modification is also an important factor in controlling obesity-induced hyperglycemia in type 2 diabetes and in losing weight [36]. Previous research has shown that an anti-inflammatory diet can alleviate retinopathy in older or diabetic participants [37]. Consistent with previous research, in this study, when DII was treated as a categorical variable, it was associated with a higher risk of diabetic retinopathy in obese participants. Therefore, DII, as a comprehensive indicator for evaluating dietary inflammatory potential, can comprehensively reflect consumption lifestyle and provide guidance for obese patients at high risk of developing retinopathy.

The subgroup analysis in this study focused on age, sex, hypertension, DM, and BMI to explore potential effect modifications and interactions in the relationship between DII and ocular diseases. This stratification is crucial because these factors can significantly influence both dietary patterns and ocular health. Age is particularly important as the risk of many ocular diseases increases with age, and older adults may have different dietary habits and inflammatory responses [38]. Sex-based analysis is valuable due to hormonal differences that can affect inflammation and disease susceptibility [39]. Hypertension and diabetes are included as they are known risk factors for several ocular diseases and may interact with dietary inflammation [40, 41]. BMI stratification is relevant because obesity is associated with chronic low-grade inflammation, which could modify the effect of dietary inflammation on ocular health [42]. The potential interactions between these variables and DII in relation to ocular diseases are noteworthy. For instance, the impact of DII on ocular diseases might be more pronounced in older adults due to age-related changes in inflammatory responses. The effect of DII on diabetic retinopathy risk could be stronger in individuals with both diabetes and hypertension, given their combined impact on vascular health. In addition, the relationship between DII and ocular diseases might be modified by BMI, with potentially stronger associations in obese individuals due to their existing pro-inflammatory state. By examining these subgroups and potential interactions, the study provides a more nuanced understanding of how dietary inflammation relates to ocular health across different population segments, offering valuable insights for targeted prevention and intervention strategies.

The mechanisms underlying the association between DII and ocular diseases are multifaceted and interconnected, which supported our findings. First, a diet high in pro-inflammatory foods (high DII) can increase oxidative stress and chronic low-grade inflammation throughout the body, including ocular tissues [43]. This chronic inflammation can damage retinal cells, optic nerve fibers, and other ocular structures over time. Second, the DII also influences vascular health, which is crucial for ocular diseases such as diabetic retinopathy and ARMD [44]. A pro-inflammatory diet may impair endothelial function and promote atherosclerosis, affecting blood flow to the eyes. Third, high DII diets are often associated with increased insulin resistance, a key factor in the development of diabetic retinopathy, leading to microvascular damage in the retina [45]. In addition, diets with a low DII are typically rich in antioxidants from fruits and vegetables, which play a crucial role in protecting ocular tissues from oxidative damage [46]. The DII can also affect lipid metabolism, which is relevant to ocular health, potentially contributing to the formation of drusen in ARMD or affecting the composition of the tear film in dry eye disease [47]. Emerging research suggests that the gut microbiome, influenced by diet, may play a role in ocular health through the gut-eye axis [48]. Lastly, high DII diets often contain more advanced glycation end-products (AGEs), which can accumulate in ocular tissues over time and are implicated in the pathogenesis of diabetic retinopathy [49]. These interconnected mechanisms highlight the complex relationship between dietary choices, inflammation, and ocular health.

The advantages and limitations of this study are as follows. First, this study is the first to investigate the relationship between DII and ocular diseases using a large, nationally representative sample. However, due to the cross-sectional design of this study, a causal relationship between DII and ocular diseases cannot be inferred. Second, selection bias may arise from the complex, multistage probability sampling design of the NHANES data, as those with severe ocular diseases might be less likely to participate, potentially underestimating disease prevalence. Recall bias is a concern due to the reliance on 24-h dietary recalls, which may not accurately reflect typical food intake. Misclassification bias could occur from the use of self-reported ocular disease diagnoses, as

participants may misunderstand or inaccurately report their condition. Despite adjusting for many confounders, residual confounding bias from unmeasured factors such as genetic predisposition or detailed medication use remains possible. Third, due to the limitation of the NHANES database, the calculation of DII could only be based on 28 nutrients. In addition, the calculation of DII was based on 28 nutrients, but this calculation method had the potential limitations or assumptions inherent, such as reliance on self-reported dietary recall. Fourth, the weighted multivariable logistic regression analysis was used to explore the relationship between DII and ocular disease. However, there are potential limitations to our chosen models (Model 1, Model 2, and Model 3) and adjustments, such as residual confounding or multicollinearity. Finally, there are still potential confounding factors that have not been adjusted for in the regression analysis.

Conclusion

In summary, the association of DII with risk of glaucoma, cataract, ARMD and diabetic retinopathy presented a U-shaped curve in the American population. A turning point for DII was observed and prevalence of glaucoma, cataract, and ARMD was lowest when the DII index was 0.766, 0.686, 2.198, and 1.526, respectively. Reducing the intake of pro-inflammatory foods may be an effective measure to prevent the onset of ocular disease, including glaucoma, cataract, ARMD, and diabetic retinopathy. However, eating only anti-inflammatory foods is not the best choice. Finally, the potential mechanisms of DII in ocular disease need further exploration.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40001-025-02294-z.

Additional file 1: Figure S1. RCS curve for the link between DII with prevalence of glaucomastratified by age;stratified by sex;stratified by hypertension;stratified by DM;stratified by BMI. Abbreviations: DII, dietary inflammation index; RCS, restricted cubic spline; DM, diabetes mellitus; BMI, body mass index.

Additional file 2: Figure S2. RCS curve for the link between DII with prevalence of cataractstratified by age;stratified by sex;stratified by hypertension;stratified by DM;stratified by BMI. Abbreviations: DII, dietary inflammation index; RCS, restricted cubic spline; DM, diabetes mellitus; BMI, body mass index.

Additional file 3: Figure S3. RCS curve for the link between DII with prevalence of ARMDstratified by age;stratified by sex;stratified by hypertension;stratified by DM;stratified by BMI. Abbreviations: DII, dietary inflammation index; ARMD, age-related macular degeneration; RCS, restricted cubic spline; DM, diabetes mellitus; BMI, body mass index.

Additional file 4: Figure S4. RCS curve for the link between DII with prevalence of diabetic retinopathystratified by age;stratified by sex;stratified by hypertension;stratified by DM;stratified by BMI. Abbreviations: DII, dietary inflammation index; RCS, restricted cubic spline; DM, diabetes mellitus; BMI, body mass index.

Additional file 5: Table S1. Subgroup analysis for associations of DII with prevalence of glaucoma.

Additional file 6: Table S2. Subgroup analysis for associations of DII with prevalence of cataract.

Additional file 7: Table S3. Subgroup analysis for associations of DII with prevalence of ARMD.

Additional file 8: Table S4. Subgroup analysis for associations of DII with prevalence of diabetic retinopathy.

Acknowledgements
We would like to express our gratitude to all the volunteers who participated in the NHANES.

Author contributions
Xue Wang contributed to the hypothesis development and to the drafting of the manuscript; Can Zhang, and Haitao Jiang were responsibility for the data analysis. Xue Wang contributed to the data interpretation and revision of the manuscript. The final manuscript was read and approved by all authors.

Funding
This study was not supported by any project.

Availability of data and materials
No datasets were generated or analyzed during the current study.

Declarations

Ethics approval and consent to participate
The National Center for Health Statistics obtained institutional review board approval before collecting data from NHANES participants. Considering that the NHANES data are de-identified and publicly available, Institutional Review Board approval was not required for the analysis presented here.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 13 February 2024 Accepted: 13 January 2025
Published online: 31 January 2025

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