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Association between composite dietary antioxidant index and stroke among individuals with diabetes

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Abstract

BACKGROUND

Recent research has underscored the potentially protective role of dietary antioxidants against chronic conditions, such as cardiovascular diseases and stroke. The composite dietary antioxidant index (CDAI), which reflects the overall intake of key dietary antioxidants, has been identified as a crucial metric for exploring this relationship. Although previous research has shown a negative correlation between CDAI levels and stroke risk in prediabetic individuals, there remains a substantial gap in understanding this association among individuals with diabetes, who are at an inherently greater risk for cerebrovascular events.

AIM
To investigate the association between CDAI and stroke risk in individuals with diabetes.

METHODS
Using a cross-sectional study design, this investigation analyzed data from the National Health and Nutrition Examination Survey spanning from 2003 to 2018 that included 6735 participants aged over 20 years with diabetes. The CDAI was calculated from 24-h dietary recalls to assess intake of key antioxidants: Vitamins A, C, and E; carotenoids; selenium; and zinc. Multivariate logistic regression and restricted cubic spline analysis were used to rigorously examine the relationship between CDAI and stroke risk.

RESULTS
The participant cohort, with an average age of 59.5 years and a slight male majority, reflected the broader demographic characteristics of individuals with diabetes. The analysis revealed a strong inverse relationship between CDAI levels and stroke risk. Remarkably, those in the highest quintile of CDAI demonstrated a 43% lower prevalence of stroke compared to those in the lowest quintile, even after adjustments for various confounders. This finding not only highlights the negative association between CDAI and stroke risk but also underscores the significant potential of antioxidant-rich diets in reducing stroke prevalence among patients with diabetes.

CONCLUSION
Our findings suggested that CDAI was inversely associated with stroke prevalence among patients with diabetes. These results suggest incorporating antioxidant-rich foods into dietary regimens as a potential strategy for stroke prevention.

Key Words: Stroke; Diabetes; Composite dietary antioxidant index; National Health and Nutrition Examination Survey; Cross-sectional study

Core Tip: Previous research on the composite dietary antioxidant index (CDAI) and its impact on stroke risk among individuals with diabetes is limited. Our study addressed this gap by examining the association between higher CDAI scores and stroke prevalence. Our findings revealed that higher CDAI scores correlated with reduced stroke risk in this population, indicating that a diet rich in diverse antioxidants may play a crucial role in mitigating stroke risk among individuals with diabetes.

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INTRODUCTION

Stroke is the second largest cause of death worldwide and a major contributor to long-term disability[1]. Additionally, the chronic condition of diabetes, which is prevalent globally, has been identified as a significant stroke risk factor[2,3]. Importantly, individuals with diabetes face a 1.5 to 2-fold greater risk of stroke than individuals without diabetes, which intensifies with a longer duration of diabetes[4]. Additionally, patients with diabetes tend to experience worse post-stroke outcomes and a heightened risk of recurrent strokes[5-10]. The 2024 ADA Standards of Care underscore the critical role of dietary management in diabetes to mitigate the risk of associated complications, including stroke[11].

Hyperglycemia, a hallmark of diabetes, is known to induce mitochondrial dysfunction and endoplasmic reticulum stress, leading to increased accumulation of reactive oxygen species (ROS). This buildup is crucial in causing cellular damage, hastening the development of diabetes-related complications like stroke[12-15]. Furthermore, hyperglycemia-induced oxidative stress is implicated in the upregulation of proinflammatory factors, triggering cellular apoptosis and impairing nitric oxide release[16]. This interplay between oxidative stress and inflammation forms a vicious cycle, exacerbating the progression of atherosclerosis, a critical process in stroke pathogenesis[17,18]. Emerging research suggests that increasing daily dietary antioxidant intake can increase plasma antioxidant levels, effectively mitigating oxidative stress-related damage[19,20]. Therefore, dietary modifications aimed at reducing oxidative stress present a promising approach for decreasing stroke risk in individuals with diabetes.

The efficacy of individual antioxidants, such as vitamin E and carotenoids, in reducing cardiovascular disease (CVD) risk remains controversial[21-26]. Measurements based on individual antioxidants, including vitamins A, C, E, zinc, selenium, and total carotenoids, may not accurately capture overall antioxidant intake. In contrast to individual antioxidants, the composite dietary antioxidant index (CDAI) provides a more extensive evaluation of total antioxidant

consumption, which correlates with specific inflammatory biomarkers, including tumor necrosis factor-α and interleukin-1β[27,28]. Although elevated CDAI scores have been inversely associated with the risks of coronary heart disease, stroke, depression, and cancer[17,29-31], its specific impact on stroke risk among individuals with diabetes is yet to be studied. To the best of our knowledge, this study represents the initial investigation into the correlation between the CDAI and stroke risk within a diabetic population. Our cross-sectional analysis examines how CDAI relates to stroke risk among this group, which may inform future preventive and therapeutic approaches.

MATERIALS AND METHODS

Study population

The National Health and Nutrition Examination Survey (NHANES) supplies essential information related to the health and diet specifics of the United States population. Employing a stratified, multistage probability sampling approach, NHANES ensures a demographically representative sample. Data collection encompasses structured personal interviews in participants' homes, comprehensive health assessments at mobile examination centers, and laboratory analysis of collected specimens. Every participant consented to the study by signing an informed consent form.

Our study focused on adults aged 20 years or older with hyperglycemia, participating in NHANES from 2003 to 2018. Diagnosis of diabetes mellitus in participants was established in accordance with the Standards of Medical Care in Diabetes. Criteria included a fasting plasma glucose level of at least 126 mg/dL (7.0 mmol/L), a hemoglobin A1c level of 6.5% or higher (48 mmol/mol), a self-reported diagnosis, or prior use of antidiabetic drugs. Exclusion criteria included being under 20 years of age, pregnancy at study onset, lack of dietary information, or absence of stroke condition data. After rigorous screening, 6735 individuals diagnosed with diabetes from the 2003-2018 NHANES cohorts were selected for analysis. Figure 1 illustrates the detailed screening process and the participant breakdown.

Dietary assessment

Dietary data were collected through structured interviews at the NHANES. Dietary intake data from the subjects was gathered *via* recall interviews conducted by experienced technicians, with participants asked to specify the food and beverages they consumed in the 24 h prior to the interview. This information facilitated the estimation of energy consumption, various nutrients, and other dietary components. The assessment of dietary antioxidants focused on six key antioxidants: Vitamin A; vitamin C; vitamin E; zinc; selenium; and total carotenoids. Total carotenoids were quantified as the sum of five distinct carotenoids: α-carotene; β-carotene; β-cryptoxanthin; lutein/zeaxanthin; and lycopene. To evaluate the cumulative impact of dietary antioxidants on stroke risk in patients with diabetes, we utilized a modified CDAI[32]. This index was derived from the six mentioned antioxidants and is calculated through the following steps. First, we stratify each antioxidant intake by sex, calculating the mean and standard deviation for males and females separately. Next, we standardize each individual's antioxidant intake. For each individual, we subtract the sex-specific mean from their intake and then divide by the sex-specific standard deviation. In this way, we obtain the standardized intake of dietary antioxidants. Finally, we aggregate the standardized intakes of the six antioxidants to calculate each individual's overall standardized intake of dietary antioxidants. The following formula is used for the calculation:

$$CDAI = \sum_{i=1}^{6} \frac{xi - \mu i}{Si}$$

In this formula, xi represents the daily intake of antioxidant i; μi represents the sex-specific mean value of xi for the antioxidants i; Si represents the standard deviation for μi.

Diagnosis of stroke

Stroke diagnosis in this research was determined based on participants' self-reported medical history of stroke[33]. During the NHANES interview process, participants were directly asked, "Have you ever been informed by a doctor or other health professional that you experienced a stroke?" A positive response to this question was considered indicative of a prior stroke occurrence. Conversely, a negative response was interpreted as an indication that the participant had no history of stroke. This method aligns with standard practices in epidemiological research, where self-reported medical histories are commonly used to identify previous health events.

Covariates

Informed by clinical expertise and prior research, this study carefully considered various potential confounders that might influence the association between the CDAI and stroke risk, integrating them as covariates in our analysis. These included demographic data such as age, sex, and race/ethnicity, educational levels spanning from below high school to college education and above, marital status categories, economic indicators like the family poverty-income ratio (PIR), lifestyle aspects like smoking habits and alcohol consumption, and health-related metrics like body mass index (BMI), daily energy intake, and histories of hypertension and hypercholesterolemia. This thorough selection of covariates ensured a robust analysis by accounting for potential confounders in the association under investigation.

Statistical analysis

This study utilized data from the NHANES, a complex, multistage, cluster research survey conducted by the National Center for Health Statistics in the United States. To ensure representativeness of the United States population, the analysis

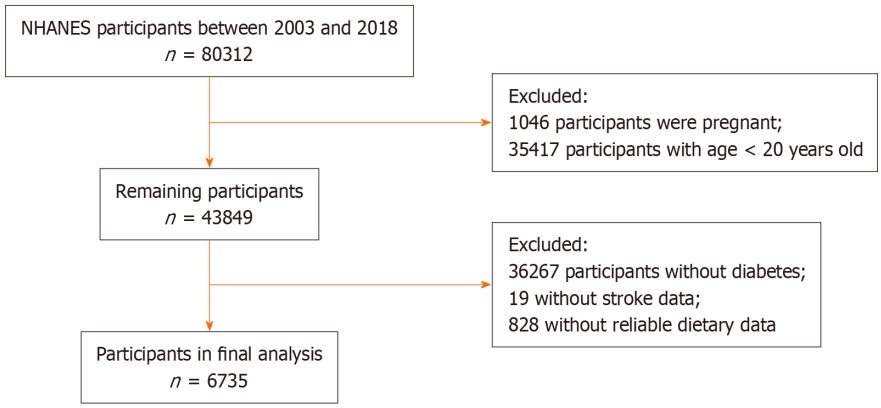

Figure 1 Overview of the study design.

was weighted according to NHANES-specific sample weights. The study population was divided into two groups for analysis: Those with a history of stroke and those without. Continuous variables with a normal distribution were presented as means ± standard deviation, while those with skewed distributions were expressed as medians with interquartile range and subjected to log transformation to approximate normality prior to analysis. Categorical variables were shown as percentages (%).

To assess differences between groups, independent sample *t*-tests or non-parametric Mann-Whitney *U* tests were employed for continuous variables, and χ^2 tests were utilized for categorical variables. Multivariate logistic regression analyses were performed to explore the relationship between CDAI and stroke. Three distinct models were employed: An unadjusted model 1; model 2 adjusted for demographic variables such as age, sex, race, education level, marital status, and family PIR; and model 3 that included additional adjustments for lifestyle and comorbidity like alcohol consumption, smoking status, BMI, energy intake, hypertension, and hypercholesterolemia.

Results were presented as odds ratios (ORs) and 95% confidence intervals (CI). The dose-response relationship between CDAI and stroke risk was analyzed using restricted cubic spline functions. Additionally, subgroup analyses were conducted to further validate the stability of the results. All statistical analyses were performed with R software, version 4.3.2 (http://www.R-project.org). A two-tailed *P* value of less than 0.05 was considered statistically significant.

RESULTS

In this study, 6735 participants from the NHANES dataset were rigorously screened and included in the analysis. The mean age of the subjects was 59.5 ± 13.6 years, and 51.5% of the participants were males. Among these, 611 individuals were identified as having a history of stroke. The baseline characteristics of the study population, encompassing age, sex, race, education, marital status, family PIR, alcohol consumption status (drinker), smoking status, BMI, and histories of hypertension and hypercholesterolemia, are detailed in Table 1. A comparative analysis revealed significant distinctions in several clinical characteristics between the stroke and non-stroke groups. Notably, the stroke group comprised older participants ($P < 0.001$), and significant racial composition differences were observed ($P < 0.001$). Additionally, the stroke group demonstrated lower levels of educational and economic status compared to the non-stroke group. Prevalence rates of hypertension and hypercholesterolemia were also found to be significantly higher in the stroke group, underscoring the potential impact of these conditions on stroke occurrence. The non-stroke group exhibited significantly higher levels of vitamin A, vitamin E, zinc, selenium, and carotenoids compared to their counterparts in the stroke group (Table 2). However, no significant difference in vitamin C was observed between the two groups ($P = 0.093$).

As a continuous variable, CDAI exhibited a negative correlation with stroke prevalence, with an OR of 0.91 (95%CI: 0.89-0.94) in unadjusted logistic regression analysis (Table 3). After adjusting for potential confounders, the negative association between CDAI and stroke remained statistically significant (OR = 0.96, 95%CI: 0.92-0.99). Of note, individuals with the highest quintile of CDAI (Q5) displayed a 43% lower stroke risk compared to those in the lowest quintile (Q1) (OR = 0.57, 95%CI: 0.40-0.83). Moreover, a dose-response relationship was observed, indicating a gradual increase in stroke risk as CDAI levels decreased (Figure 2).

Additionally, a comprehensive subgroup analysis was conducted to further elucidate the association between CDAI and stroke risk across various demographic and clinical subgroups. These subgroups were delineated based on age, sex, BMI, race, smoking status, alcohol consumption, hypertension, and hypercholesterolemia (Table 4). However, the subgroup analysis did not reveal any significant statistical interactions, suggesting a consistent relationship between CDAI and stroke risk across these diverse groups.

Table 1 Characteristics of subjects with or without stroke

Characteristics	Total, *n* = 6735	Non-stroke, *n* = 6124	Stroke, *n* = 611	*P* value
Age in years	59.5 ± 13.6	58.8 ± 13.6	67.4 ± 10.7	< 0.001
Sex				0.156
Male	51.5	51.8	48.7	
Female	48.5	48.2	51.3	
Race				< 0.001
Non-Hispanic White	60.7	60.3	65.0	
Non-Hispanic Black	15.4	15.2	17.2	
Mexican American	9.8	10.1	6.4	
Other Hispanic	5.7	6.0	2.5	
Other race	8.4	8.4	8.8	
Education				< 0.001
Lower than high school	10.6	10.4	13.2	
High school	39.4	38.6	48.1	
Higher than high school	50.0	51.0	38.6	
Marital status				0.053
Married/living with partner	62.5	63.3	54.7	
Widowed/divorced/separated	27.9	26.8	40.1	
Never married	9.6	10.0	5.2	
Poverty income ratio				< 0.001
≤ 1.30	26.2	25.5	33.1	
1.3 to ≤ 3.5	39.7	39.1	47.3	
> 3.5	34.1	35.4	19.6	
Smoking status				0.007
Nonsmoker	48.6	49.2	42.7	
Former smoker	34.7	34.4	37.1	
Current smoker	16.7	16.4	20.2	
Alcohol use				0.002
No	33.3	32.7	40.1	
Yes	66.7	67.3	59.9	
Energy intake, kcal	1940.82 ± 900.52	1967.09 ± 909.80	1655.64 ± 734.62	< 0.001
BMI in kg/m^2				0.429
< 25.0	11.77	11.77	11.86	
25 to < 30	25.68	25.88	23.36	
≥ 30	62.55	62.35	64.78	
Hypertension				< 0.001
No	34.3	36.0	16.4	
Yes	65.7	64.1	83.6	
Hypercholesterolemia				0.002
No	38.6	39.1	32.5	
Yes	61.4	60.9	67.5	
CDAI	0.28 ± 3.97	0.38 ± 4.01	-0.77 ± 3.29	< 0.001

Data are presented as mean (SD) or *n* (%). BMI: Body mass index; CDAI: Composite dietary antioxidant index.

Table 2 Comparison of each component of the composite dietary antioxidant index among the non-stroke group and stroke group

Variables	Total, *n* = 6735	Non-stroke, *n* = 6124	Stroke, *n* = 611	*P* value
Vitamin A in mcg	449 (252-736)	453 (255-743)	400 (220-676)	0.026
Vitamin C in mg	50.6 (21.4-105.2)	51.3 (22.0-105.4)	44.2 (18.0-101.3)	0.093
Vitamin E in mg	5.99 (3.77-9.23)	6.10 (3.81-9.38)	5.13 (3.28-7.46)	< 0.001
Zinc in mg	8.99 (6.10-13.06)	9.09 (6.20-13.18)	7.81 (5.04-11.66)	< 0.001
Selenium in mcg	94.3 (65.1-131.2)	95.9 (66.3-133.4)	79.1 (55.8-111.5)	< 0.001
Carotenoid in mcg	4740.0 (1675.0-10809.0)	4851.0 (1759.2-10902.8)	3655.0 (1124.0-9827.0)	0.001

Data are presented as the median (interquartile range).

Table 3 Association of composite dietary antioxidant index and stroke

Factor	Model 1		Model 2		Model 3	
	OR (95%CI)	*P* value	OR (95%CI)	*P* value	OR (95%CI)	*P* value
CDAI (continuous)	0.91 (0.89-0.94)	< 0.001	0.93 (0.90-0.96)	< 0.001	0.96 (0.92-0.99)	0.019
CDAI-Q1	Ref.	-	Ref.	-	Ref.	-
CDAI-Q2	0.70 (0.55-0.88)	0.003	0.70 (0.55-0.89)	0.004	0.74 (0.57-0.96)	0.024
CDAI-Q3	0.59 (0.46-0.75)	< 0.001	0.60 (0.46-0.77)	< 0.001	0.68 (0.51-0.90)	0.007
CDAI-Q4	0.56 (0.43-0.72)	< 0.001	0.62 (0.48-0.80)	< 0.001	0.72 (0.53- 0.98)	0.037
CDAI-Q5	0.38 (0.29-0.51)	< 0.001	0.46 (0.34-0.61)	< 0.001	0.57 (0.40-0.83)	0.003
P for trend	< 0.0001		< 0.0001		0.007	

Model 1 was unadjusted; Model 2 was adjusted for age, sex, race, education, marital status and poverty income ratio; Model 3 was further adjusted for drinker, smoker, body mass index, energy intake, hypertension and hypercholesterolemia. Subjects with a composite dietary antioxidant index in the lowest quintile group served as the reference group. CDAI: Composite dietary antioxidant index; CI: Confidence interval; OR: Odds ratio; Q: Quintile; Ref.: Reference.

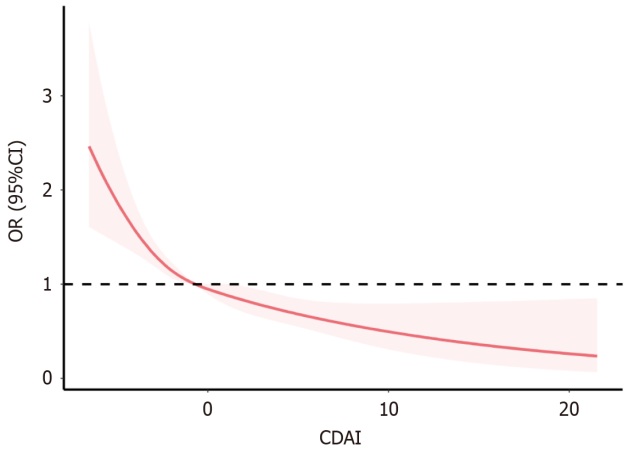

Figure 2 Restricted cubic spline plot of the association between composite dietary antioxidant index and stroke. The shaded part represented the 95% confidence interval (CI). CDAI: Composite dietary antioxidant index; OR: Odds ratio.

DISCUSSION

In our study, higher CDAI scores were associated with a decreased prevalence of stroke specifically in individuals with diabetes, a novel focus on this high-risk group. The observed dose-response relationship indicated that the risk of stroke inversely correlated with CDAI levels, gradually increasing as CDAI decreased. Importantly, this association remained significant even after accounting for conventional risk factors such as BMI, hypertension, and hypercholesterolemia. These findings suggested that a higher intake of antioxidants, as quantified by the CDAI, may confer a protective effect against stroke in individuals with diabetes, highlighting the unique impact of antioxidants on this population's heightened oxidative stress, a recognized risk factor for stroke.

Previous studies have not specifically focused on patients with diabetes when examining the relationship between dietary antioxidants and stroke. Our research is the first to highlight the significant role of CDAI in reducing stroke risk among individuals with diabetes, and through restricted cubic splines, we observed that as CDAI increased, the risk of stroke gradually decreased. Our study's finding contributes to a growing understanding of the impact of diet on chronic inflammation and oxidative stress, key factors in metabolic diseases and cardiovascular health[34,35]. The CDAI, which is designed to reflect the anti-inflammatory potential of dietary components, underscores the role of antioxidants in neutralizing oxidative stress and is implicated in the pathogenesis of atherosclerosis and vascular diseases[36]. Diets rich in antioxidants, targeting ROS, may not only protect against CVD but also are inversely associated with all-cause and CVD-related mortality in adults with diabetes, providing unique insights into the dietary management of this high-risk group[17,37].

This aligns with research indicating that dietary antioxidants can act as neuroprotective agents, safeguarding brain tissues and potentially ameliorating conditions leading to stroke[18-20]. A deficiency in dietary antioxidants is postulated to elevate stroke risk, likely through mechanisms linked to oxidative stress. Excessive ROS, in conjunction with lipid peroxidation, neuroinflammatory responses, and blood-brain barrier disruption, contribute to brain tissue injury[2-4]. Moreover, post-ischemic ROS activity can stimulate nuclear transcription factors and trigger the release of proinflammatory factors, leading to a localized neuroinflammatory response[25].

Oxidative stress also plays a role in the destruction of tissue surrounding hematomas following cerebral hemorrhage [26], and the capacity of the central nervous system for maintaining redox homeostasis is vital for post-stroke brain tissue recovery[5]. The efficacy of antioxidants involves electron donation to free radicals, thus diminishing cellular damage and curbing inflammatory responses[14]. The protective potential of antioxidants extends to the prevention and management of atherosclerosis, a key stroke risk factor, by reducing ROS generation and preventing oxidative damage to lipoproteins [21,22].

The components of CDAI, especially vitamins A, C, and E, are crucial in this context. These non-enzymatic antioxidants help neutralize oxidative stress, a key mechanism in stroke pathogenesis. Vitamin E, for example, effectively scavenges free radicals and protects cell structures, including lipoproteins, from oxidative damage[38,39]. In adult stroke-prone spontaneously hypertensive rats, vitamins C and E mitigate oxidative stress, enhance vascular function and structure, and inhibit hypertension progression potentially through the modulation of enzyme systems responsible for free radical generation[40].

In a 22-year prospective population-based study, it was found that higher dietary intakes of antioxidant vitamins A, C, and E significantly reduced the risk of adverse cardiovascular outcomes among Chinese individuals[41]. Carotenoids offer neuroprotection through the inhibition of neuroinflammation, microglial activation, and the excitotoxic pathway, as well as by modulating autophagy, attenuating oxidative damage, and activating defensive antioxidant enzymes[42]. This protective effect was shown in a 13-year cohort study in which higher plasma levels of carotenoids, indicative of fruit and vegetable intake, were associated with a reduced risk of ischemic stroke[43]. In addition to vitamins, micronutrients in the CDAI, such as zinc and selenium, also contribute significantly to mitigating oxidative stress and inflammation. Zinc acts by suppressing oxidative stress through inhibition of NADPH oxidase[44,45], while selenium, along with selenoproteins, prevents cellular damage due to lipid peroxidation[46].

The CDAI is a widely utilized metric in nutritional research to explore the correlation between dietary antioxidant intake and diverse diseases, particularly those associated with oxidative stress. Previous investigations have indicated a negative correlation between the CDAI and diabetes prevalence[47]. Additionally, research has shown that higher CDAI levels might mitigate the risk of diabetic kidney disease and mortality among individuals with diabetes[48]. Moreover, higher CDAI levels exhibit a significant association with reduced CVD mortality in individuals with diabetes, with those in the highest quartile experiencing a 53% decrease in risk compared to those in the lowest quartile[37]. Collectively, these findings suggest that higher CDAI levels confer protective benefits against multiple health risks, particularly cardiovascular risks, for individuals with diabetes.

Aligning with our findings in individuals with diabetes, the study in the general population has observed an inverse relationship between CDAI and stroke[29]. In the general population, the highest tertile of CDAI was associated with a 23% reduction in stroke prevalence compared to the lowest tertile (OR = 0.77; 95%CI: 0.64-0.92). Remarkably, in our cohort of individuals with diabetes, those in the highest quintile of CDAI exhibited a 43% lower prevalence of stroke compared to those in the lowest quintile, even after adjusting for various confounders. However, it is noteworthy that our study population had a higher prevalence of hypertension, indicating a higher baseline risk for stroke.

However, there exists a degree of heterogeneity in the findings across various studies. While our research supports the notion that increased antioxidant intake is correlated with reduced stroke risk, some studies have reported no significant associations or conflicting results[39,49]. This discrepancy could stem from variations in study designs, population demographics, and the specific types of antioxidants analyzed. For instance, our study's focus on a composite index rather than individual antioxidants might explain some of these differences. Moreover, the relationship between dietary antioxidants and stroke risk is intricate, as demonstrated by studies showing varied impacts among different sex and age

Table 4 Stratified analyses of the associations between the composite dietary antioxidant index and stroke

Characteristics	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	*P* for interaction
Sex						0.135
Male	Ref.	0.88 (0.62-1.24)	0.58 (0.39-0.88)	0.63 (0.40-0.99)	0.58 (0.34-0.98)	
Female	Ref.	0.60 (0.40-0.88)	0.77 (0.52-1.14)	0.82 (0.53-1.26)	0.56 (0.33-0.95)	
Age in years						0.088
≤ 60	Ref.	0.44 (0.25-0.78)	0.46 (0.25-0.85)	0.74 (0.41-1.34)	0.41 (0.19-0.88)	
> 60	Ref.	0.88 (0.65-1.17)	0.80 (0.58-1.11)	0.74 (0.52-1.07)	0.68 (0.45-1.03)	
BMI						0.300
< 30	Ref.	0.65 (0.45-0.95)	0.48 (0.31-0.74)	0.57 (0.36-0.91)	0.45 (0.26-0.79)	
≥ 30	Ref.	0.81 (0.58-1.14)	0.85 (0.60-1.21)	0.86 (0.58-1.26)	0.67 (0.42-1.07)	
Race						0.424
White	Ref.	0.75 (0.50-1.13)	0.86 (0.55-1.33)	0.94 (0.58-1.51)	0.74 (0.42-1.31)	
Others	Ref.	0.73 (0.52-1.02)	0.56 (0.38-0.81)	0.59 (0.39-0.88)	0.48 (0.29-0.78)	
Smoker						0.611
Yes	Ref.	0.68 (0.49-0.95)	0.54 (0.37-0.79)	0.67 (0.45-1.00)	0.48 (0.29-0.78)	
No	Ref.	0.77 (0.51-1.16)	0.83 (0.54-1.27)	0.74 (0.46-1.19)	0.67 (0.39-1.17)	
Drinker						0.225
Yes	Ref.	0.61 (0.42-0.88)	0.44 (0.29-0.68)	0.52 (0.33-0.81)	0.40 (0.24-0.68)	
No	Ref.	0.94 (0.59-1.48)	0.89 (0.54-1.47)	1.04 (0.61-1.78)	0.84 (0.44-1.59)	
Hypertension						0.843
Yes	Ref.	0.75 (0.57-1.00)	0.66 (0.48-0.90)	0.71 (0.51-1.00)	0.55 (0.36-0.82)	
No	Ref.	0.69 (0.36-1.30)	0.87 (0.44-1.71)	0.84 (0.40-1.75)	0.79 (0.32-1.91)	
Hypercholesterolemia						0.375
Yes	Ref.	0.68 (0.49-0.95)	0.66 (0.46-0.95)	0.57 (0.38-0.85)	0.47 (0.29-0.76)	
No	Ref.	0.87 (0.56-1.34)	0.61 (0.37-1.00)	1.01 (0.61-1.70)	0.72 (0.38-1.34)	

The odds ratio and 95% confidence interval were obtained from multivariable logistic regression models after adjusting for age, sex, race, education, marital status, poverty income ratio, drinker, smoker, body mass index, energy intake, hypertension and hypercholesterolemia. BMI: Body mass index; Ref.: Reference.

groups. For example, a Swedish cohort study observed a link between dietary antioxidants and ischemic stroke risk in females but not in males. In light of these findings, our study underscored the potential benefit of a holistic dietary approach, emphasizing a high antioxidant intake in managing stroke risk among individuals with diabetes. Nevertheless, the specific mechanisms underlying the CDAI-stroke relationship warrant further investigation to elucidate the complex interplay between diet, oxidative stress, and vascular health in patients with diabetes.

Our study's strength lies in its use of a comprehensive, multicomponent index to assess dietary antioxidant intake and its large, representative sample. Despite the strengths of our study, it is important to acknowledge certain limitations. First, the cross-sectional study was unable to establish a causal relationship between the CDAI and stroke. Future research should aim to elucidate this relationship through long-term follow-up and cohort studies. Second, the assessment of dietary intake, which forms the basis for calculating CDAI, is not without potential errors and inaccuracies. Dietary data collected through self-report can be subject to recall bias and may not accurately capture day-to-day variations in individual dietary patterns. Third, stroke assessment relied on questionnaire responses, lacking a more detailed classification of stroke types. Fourth, although numerous relevant covariates were included in the analysis, it is possible that not all confounding factors were accounted for. Unidentified confounders might skew the results. Future studies should aim for more comprehensive control of these factors to validate and refine our findings. Moreover, our study's findings are most applicable to the American population, given that dietary habits can vary significantly across different racial and ethnic groups. This geographic and cultural specificity limits the generalizability of our conclusions. Therefore, further research in diverse populations is needed to broaden our understanding of the association between CDAI and stroke risk globally.

CONCLUSION

In summary, this cross-sectional study found that adults diagnosed with diabetes in the United States with high levels of the CDAI, which measures the overall antioxidant quality of the diet, tend to have a lower risk of stroke. Furthermore, our smooth curve fitting analysis revealed a negative relationship between CDAI and stroke. Based on these findings, it is recommended that patients with diabetes maintain an appropriate intake of dietary antioxidants to increase their CDAI, thereby reducing stroke-related risk factors. In the future, rigorous prospective studies are imperative to validate our findings and provide deeper insights.

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FOOTNOTES

Author contributions: Wang CF and Ding Y designed the research; Zhang HQ and Shi J performed data processing and statistical analysis, drafted the manuscript, and revised the manuscript; Zheng XY, Luo SH, and Yue T provided valuable insights and guidance throughout the research process; Weng JH, Wang XL, Wang H, and Su XY participated in the revision of the manuscript; Wang CF and Ding Y contributed to data interpretation and manuscript discussion; All authors contributed to the article and approved the final manuscript. Zhang HQ and Shi J contributed equally to this work as co-first authors. The reasons for designating Zhang HQ and Shi J as co-first authors are as follows. First, Zhang HQ and Shi J provided their respective specialized skills and knowledge, playing a critical role in data analysis and interpretation. Second, Zhang HQ and Shi J conducted extensive literature reviews together, providing a solid theoretical foundation for the study. Third, they played a significant role in writing and revising the manuscript, ensuring its high quality and rigor. In summary, Zhang HQ and Shi J were actively involved in every stage of the project, from initial design to data collection and final analysis, demonstrating their comprehensive involvement and substantial contributions. There are several reasons for designating Wang CF and Ding Y as co-corresponding authors. First, they provided important guidance and supervision throughout the study, ensuring scientific rigor and accuracy. Second, they combined expertise and skills from different fields, offering a comprehensive perspective that enriched the diversity of the research. Third, Wang CF and Ding Y played key roles in resource coordination and project management, and both provided funding support, facilitating the smooth conduct of the study. Additionally, they will continue to support and guide the research in the post-submission stages, ensuring the ongoing quality and impact of the research findings. This dual leadership also enhanced the credibility and reliability of the manuscript, reflecting the team's collaborative spirit and interdisciplinary approach. In conclusion, designating Zhang HQ and Shi J as co-first authors and Wang CF and Ding Y as co-corresponding authors not only reflects the highly collaborative spirit of our team during the research process but also highlights the equal contributions and diverse expertise of each member in their respective fields. This team collaboration model ensures the comprehensiveness, rigor, and innovation of the research, making our findings more reliable and impactful.

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