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The association between dietary fiber intake and all-cause mortality and cardiovascular disease mortality in patients with stroke: a retrospective cohort study of NHANES

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ABSTRACT

BACKGROUND/OBJECTIVES: Stroke represents the primary cause of death and persistent disability globally, leading to around 5.5 million annual patient fatalities. The objective was to explore the relationship of dietary fiber with all-cause and cardiovascular disease (CVD) mortality risk in patients with stroke.
SUBJECTS/METHODS: We extracted stroke patients' data from the National Health and Nutrition Examination Survey (NHANES) database. All-cause and CVD mortality were outcomes. Dietary fiber consists of non-digestible forms of carbohydrates, usually polysaccharides that originate from plant-based foods. Covariates including demographic data, vital signs, comorbidities, laboratory parameters, and medication use were screened using the weighted multivariate Cox regression models with backward elimination. Weighted univariate and multivariate Cox regression models were performed to explore the relationship between dietary fiber intake and all-cause/CVD mortality, with hazard ratios (HRs) and 95% confidence intervals (CIs). The association was further investigated in different subgroups.
RESULTS: A total of 1,578 patients with stroke were included, of whom 688 (43.6%) died. Total fiber and vegetable fiber intake were analyzed as categorical variables, and the lowest intake was considered reference groups. High intake of total fiber (HR, 0.73; 95% CI, 0.57–0.94) and high intake of vegetable fiber (HR, 0.63; 95% CI, 0.48–0.82) were related to lower all-cause mortality risk in individuals with stroke. Similar findings were also observed between higher total fiber (HR, 0.56; 95% CI, 0.37–0.85) and vegetable fiber intake (HR, 0.57; 95% CI, 0.36–0.89) with decreased CVD mortality risk. The relationship between higher total fiber intake and lower all-cause mortality risk was discovered in individuals aged ≥ 60 yrs, smoking, non-CVD, and chronic kidney disease (CKD). High total fiber, or vegetable fiber consumption was linked to lower CVD mortality risk in stroke individuals aged ≥ 60 yrs, females, body mass index ≥ 30 kg/m^2, non-smoking, and CKD.
CONCLUSION: Dietary fiber intake and vegetable fiber intake may benefit the prognosis of patients with stroke. Increasing dietary fiber consumption, especially vegetable fiber intake, potentially benefits the prognosis of stroke patients.

Keywords: Dietary fiber; mortality; cause of death; stroke

Conflict of Interest
The authors declare no potential conflicts of interests.

Author Contributions
Conceptualization: Liu L, Yang Z; Data curation: Li M, Tang T; Formal analysis: Li M, Tang T; Investigation: Li M, Tang T; Project administration: Li Y, Liu L, Yang Z, Li M, Tang T, Xu J; Writing - original draft: Li Y; Writing - review & editing: Xu J.

INTRODUCTION

Stroke stands as the primary contributor to global mortality and enduring disability, leading to around 5.5 million patient fatalities in 2020 [1,2]. Cardiovascular disease (CVD) mortality from other causes is closely associated with stroke, and approximately 1 million individuals succumb annually to post-stroke cardiovascular complications [3,4]. Surveys showed that survivors from stroke experienced poor diet, and inadequate nutrient intake was linked to a heightened risk of stroke relapse, readmission, and mortality [5,6]. It is essential to recommend dietary modification as a primary approach to improve prognosis in patients with stroke.

Dietary fiber consists of non-digestible forms of carbohydrates, usually polysaccharides that originate from plant-based foods [7]. Dietary fiber has a positive role in inflammation reduction, improving lipid and lipoprotein metabolism, controlling low-density lipoprotein cholesterol (LDL-C), and maintaining insulin homeostasis [8,9]. Inadequate consumption of dietary fiber was related to various health outcomes-breast cancer [10], diabetes [11], and CVD [12]. High dietary fiber consumption was related to lower all-cause mortality and CVD mortality risk in participants without CVD [13,14]. Zhang *et al.* [15] found the association of elevated dietary fiber consumption with decreased all-cause and CVD mortality risk in elderly individuals with hypertension. Dietary fiber consumption from various sources, including fruits, vegetables, and cereals, was linked to decreased risk of CVD and all-cause mortality [14,16]. However, the association of dietary fiber with various sources with mortality risk in patients with stroke remains unclear.

Herein, we explored the relationship between dietary fiber from various sources and all-cause/CVD mortality risk in patients with stroke, and further explored whether this association remains in patients with different subgroups, which could offer specific guidance for formulating diet-related strategies, and eventually improve the prognosis of patients with stroke.

SUBJECTS AND METHODS

Study design and patients

Information concerning individuals who had experienced strokes for our retrospective study was collected from the National Health and Nutrition Examination Survey (NHANES) database (1999–2018), and a research project carried out by the National Center of Health Statistics (NCHS) and the Centers for Disease Control and Prevention (CDC) was aimed to evaluate the health status and nutritional welfare for the U.S civilian population [17]. Data collection involved both interview and physical examinations, encompassing inquiries on demographics, financial status, dietary habits, and overall health [18]. NHANES, an open-access repository, received authorization from the NCHS Ethics Review Board, with patients providing written consent. The ethical approval requirement was waived by Beijing Boai Hospital, as the dataset was publicly available. All research protocols adhered to pertinent standards and laws.

The inclusion criteria were: 1) patients diagnosed with stroke [19]; 2) patients aged ≥ 18 yrs old; 3) patients with complete information on total fiber, cereal fiber, vegetable fiber, and fruit fiber consumption. The criteria for exclusion were as follows: 1) patients who missed survival data; 2) patients with missing data on body mass index (BMI), white blood cell (WBC),

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albumin, alanine transaminase (ALT), dyslipidemia, education level, and marital status. Finally, 1,578 individuals with stroke were included. The flowchart was presented in **Fig. 1**.

Dietary fiber intake

The mean dietary fiber consumption level was evaluated according to two 24-h dietary recall interviews carried out by experienced interviewers specializing in dietary habits. Data on the first day were obtained by face-to-face interview, followed by a subsequent phone interview occurring 3 to 10 days later. Dietary fiber intake was determined using information from the United States Department of Agriculture (USDA), and Food and Nutrition Dietary Studies Database [20], and dietary fiber from different sources was obtained based on food codes. In this study, fiber (g/day) intakes were divided into tertiles.

Covariates

Covariates for our study included age, sex, poverty income ratio (PIR), marital status, smoking status, physical activity (PA), CVD, chronic kidney disease (CKD), WBC, albumin, and total energy. Smoking status was classified as never smoker/former smoker/current smoker according to the questions "Have you smoked at least 100 cigarettes in your entire life?" and "Do you now smoke cigarettes?" [21]. PA was divided into 4 groups: < 450, 450–750, ≥ 750 min/week, and unknown. The diagnosis of CVD was determined by a self-reported physician during an individual interview using a standardized medical condition questionnaire. The participants were asked, "Has a doctor or other health expert ever informed you that you have congestive heart failure/coronary heart disease/angina/myocardial infarction?" A person was regarded as having CVD if he or she replied "yes" to any of the above questions. CKD was identified by a urine albumin-to-creatinine ratio (UACR) ≥ 30 mg/g, or an estimated glomerular filtration rate (eGFR) < 60 mL/min/1.73 m^2 [22].

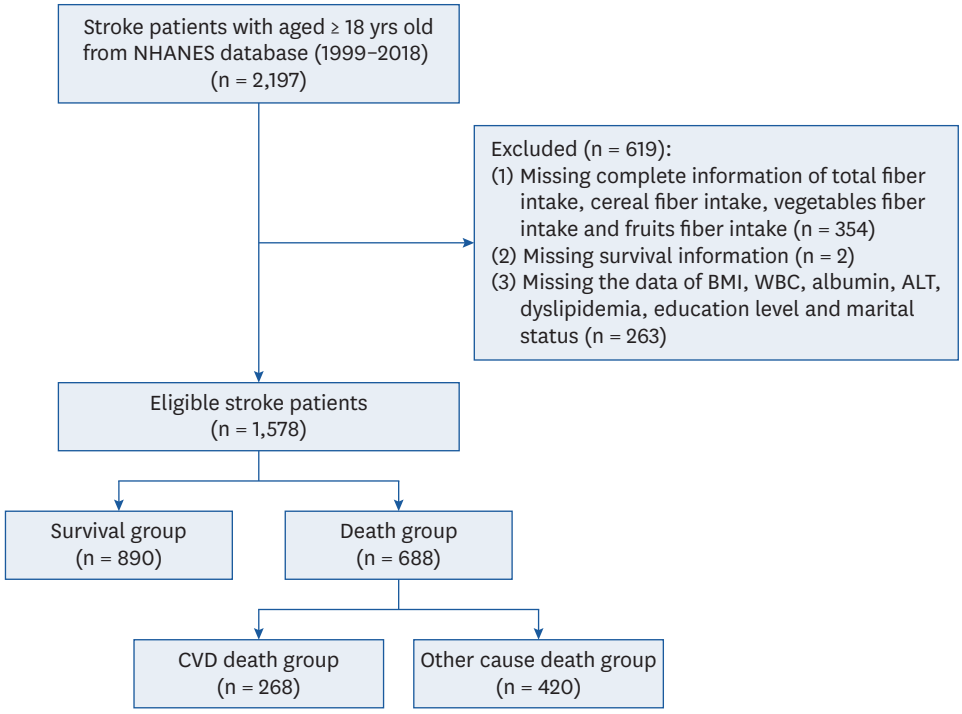

Fig. 1. The screening flowchart of stroke patients.
NHANES, National Health and Nutrition Examination Survey; BMI, body mass index; WBC, white blood cell; ALT, alanine transaminase; CVD, cardiovascular disease.

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Outcomes

Data on mortality was obtained by the National Death Index until December 31, 2019. The Ten Revision for the International Classification of Disease (ICD-10) codes were applied to pinpoint reasons for mortality. Mortality from all causes was specified as death from any origin [23]. CVD mortality was confirmed via ICD-10 codes I00–I09, I11, I13, I20–I51, or I60–I69. The duration of follow-up had a median of 77 (38–124) mon.

Statistical analysis

All data were weighted with SDMVPSU and SDMVSTRA as weighting variables. SDMVPSU represented a concealed pseudo-PSU variable for estimating variance. SDMVSTRA represented a masked pseudo-stratum variable for estimating variance. Quantitative data was presented as mean and SE, while intergroup comparison adopted weighted Student's *t*-tests. Qualitative data was represented as numbers and percentages, and comparisons between 2 groups were performed by utilizing the Rao-Scott χ^2 tests.

The covariates were screened via the weighted univariate Cox proportional hazards models and the backward elimination [24]. Energy was forcibly adjusted in this study due to its effect on dietary consumption. The relationship of dietary fiber consumption with all-cause/CVD mortality risk was detected utilizing weighted univariate and multivariate Cox regression models for patients with stroke, with hazard ratios (HRs) and 95% confidence intervals (CIs). The relationship was further investigated in different age, sex, BMI, smoking status, CVD, and CKD subgroups. R version 4.2.3 (2023-03-15 ucrt) was conducted for all statistical analyses. $P < 0.05$ was recognized statistical differences.

RESULTS

Characteristics of stroke patients

One thousand five-hundred seventy-eight individuals with stroke were included, of whom 688 (43.6%) died. The characteristics of patients with stroke were presented in **Table 1** and **Supplementary Table 1**. The average age of the entire patient cohort was 64.04 ± 0.64 yrs, with a median follow-up time of 77 (38–124) mon. Additionally, age, race, PIR, marital status, education level, weight, BMI, smoking, drinking, PA, hypertension, CVD, CKD, depression, cardiovascular agents, anticoagulants, antiplatelet agents, energy, hemoglobin, albumin,

Table 1. Characteristics of stroke patients

Variables	Total (n = 1,578)	Survival group (n = 890)	All-cause mortality group (n = 688)	Statistics[1)2)]	*P*-value
Age (yrs)	64.04 ± 0.64	59.55 ± 0.81	72.38 ± 0.59	t = 13.278	< 0.001
Sex				χ^2 = 3.644	0.058
Male	42.04 (1.92)	39.52 (2.50)	46.71 (2.72)		
Female	57.96 (1.92)	60.48 (2.50)	53.29 (2.72)		
Race				χ^2 = 6.672	< 0.001
Non-Hispanic White	70.11 (1.93)	65.43 (2.31)	78.77 (2.09)		
Non-Hispanic Black	14.97 (1.22)	17.11 (1.47)	11.01 (1.37)		
Mexican American	4.84 (0.70)	5.40 (0.86)	3.80 (0.94)		
Other races	10.09 (1.12)	12.06 (1.47)	6.42 (1.24)		
PIR				χ^2 = 4.751	0.003
< 1.3	30.26 (1.82)	31.08 (2.17)	28.74 (2.43)		
1.3–1.85	14.94 (1.21)	11.77 (1.34)	20.82 (1.70)		
≥ 1.85	48.52 (2.16)	51.45 (2.80)	43.10 (2.68)		
Unknown	6.27 (0.78)	5.70 (1.06)	7.33 (1.23)		

(continued to the next page)

Table 1. (Continued) Characteristics of stroke patients

Variables	Total (n = 1,578)	Survival group (n = 890)	All-cause mortality group (n = 688)	Statistics[1)2)]	*P*-value
Marital status				χ^2 = 5.110	0.025
Married/living with partner	56.25 (1.87)	59.64 (2.52)	49.95 (2.86)		
Spinsterhood/divorced/widowed/separated	43.75 (1.87)	40.36 (2.52)	50.05 (2.86)		
Education level				χ^2 = 9.541	0.002
High school or below	57.80 (1.95)	53.88 (2.57)	65.06 (2.13)		
High school or above	42.20 (1.95)	46.12 (2.57)	34.94 (2.13)		
Height (cm)	165.50 ± 0.36	165.86 ± 0.45	164.85 ± 0.54	t = −1.472	0.143
Weight (kg)	82.46 ± 0.88	84.44 ± 1.16	78.77 ± 1.19	t = −3.403	0.001
BMI (kg/m^2)				χ^2 = 5.713	0.004
< 25	25.06 (1.34)	23.75 (1.72)	27.50 (1.99)		
25–29.9	30.14 (1.60)	27.51 (2.12)	35.03 (1.94)		
≥ 30	44.79 (2.06)	48.74 (2.57)	37.47 (2.48)		
Smoking				χ^2 = 6.034	0.003
Never	40.75 (1.66)	41.91 (2.26)	38.59 (2.30)		
Former	33.89 (1.53)	29.84 (2.20)	41.40 (1.85)		
Now	25.36 (1.82)	28.24 (2.58)	20.01 (1.97)		
Drinking				χ^2 = 19.265	< 0.001
Never	27.94 (1.90)	22.05 (1.86)	38.84 (3.40)		
< 1	30.39 (1.80)	38.21 (2.30)	15.90 (1.65)		
≥ 1	17.51 (1.46)	19.17 (1.97)	14.43 (1.57)		
Unknown	24.16 (1.73)	20.57 (2.15)	30.83 (2.77)		
PA (min/week), MET				χ^2 = 31.249	< 0.001
< 450	46.77 (2.20)	43.83 (2.84)	52.23 (2.60)		
450–750	6.64 (0.96)	6.75 (1.27)	6.44 (1.25)		
≥ 750	34.83 (2.01)	44.70 (2.73)	16.52 (1.60)		
Unknown	11.76 (1.48)	4.72 (1.30)	24.82 (2.50)		
Total fiber (g)	13.89 ± 0.31	14.35 ± 0.41	13.02 ± 0.44	t = −2.230	0.027
Total fiber (g)				χ^2 = 1.176	0.309
≤ 9.3	32.14 (1.49)	31.10 (2.11)	34.06 (2.58)		
9.3–15.3	34.27 (1.68)	33.32 (2.30)	36.02 (2.44)		
> 15.3	33.59 (1.73)	35.57 (2.27)	29.91 (2.44)		
Cereal fiber (g)	5.19 ± 0.22	5.58 ± 0.28	4.46 ± 0.29	t = −2.860	0.005
Cereal fiber (g)				χ^2 = 1.200	0.302
≤ 2.3	33.66 (1.97)	32.05 (2.05)	36.65 (3.24)		
2.3–5.8	33.34 (1.74)	33.03 (2.28)	33.93 (2.53)		
> 5.8	33.00 (1.81)	34.92 (2.34)	29.43 (2.77)		
Fruits fiber (g)	1.62 ± 0.10	1.53 ± 0.12	1.78 ± 0.17	t = 1.221	0.224
Fruits fiber (g), % (SE)				χ^2 = 2.289	0.104
0	52.61 (1.88)	55.31 (2.16)	47.59 (2.75)		
0–1.6	15.06 (1.39)	13.73 (1.74)	17.54 (1.86)		
> 1.6	32.33 (1.94)	30.96 (2.41)	34.87 (2.67)		
Vegetables fiber (g)	2.69 ± 0.15	2.96 ± 0.20	2.19 ± 0.17	t = −3.010	0.003
Vegetables fiber (g)				χ^2 = 7.857	0.001
≤ 0.06	32.22 (1.95)	27.48 (1.92)	41.01 (3.07)		
0.06–3	34.64 (2.03)	36.71 (2.70)	30.79 (2.34)		
> 3	33.14 (1.63)	35.81 (2.16)	28.21 (2.29)		

The data were analyzed using the complex sample module. Values are expressed as mean ± SE or weighted % (SE).
PIR, income-to-poverty ratio; BMI, body mass index; PA, physical activity; MET, metabolic equivalent task.
[1)]Weighted *t*-test.
[2)]Rao-Scott χ^2 test.

ALT, uric acid, status-CVD, total fiber, cereal fiber, fruit fiber, and vegetable fiber were statistical differences between survival and all-cause mortality groups (all $P < 0.05$).

Relationships of dietary fiber having various sources with all-cause and CVD mortality in patients with stroke

The relationship between various sources of dietary fiber and all-cause/CVD mortality risk for stroke was presented in **Table 2**. Covariates were adjusted age, sex, PIR, marital status,

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Table 2. Association of dietary fiber intake with the risk of all-cause and CVD mortality in stroke patients

Variables	n (%)	All-cause mortality[1]		CVD mortality[2]	
		HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Total fiber					
≤ 5.83	505 (33.29)	Ref		Ref	
5.83–8.87	491 (33.28)	0.64 (0.49–0.83)	0.001	0.53 (0.35–0.80)	0.003
> 8.87	582 (33.43)	0.73 (0.57–0.94)	0.015	0.56 (0.37–0.85)	0.006
Cereal fiber					
≤ 1.45	498 (33.27)	Ref		Ref	
1.45–3.39	519 (33.19)	0.87 (0.67–1.13)	0.287	0.74 (0.49–1.11)	0.139
> 3.39	561 (33.54)	0.91 (0.70–1.18)	0.489	0.75 (0.47–1.18)	0.207
Fruits fiber[3]					
0	789 (52.61)	Ref		Ref	
≤ 1.6	398 (23.66)	1.04 (0.80–1.33)	0.788	0.84 (0.56–1.25)	0.383
> 1.6	391 (23.73)	1.18 (0.91–1.53)	0.204	0.81 (0.51–1.27)	0.350
Vegetables fiber					
≤ 0.10	553 (33.26)	Ref		Ref	
0.10–1.64	492 (33.41)	0.93 (0.75–1.16)	0.513	0.69 (0.46–1.05)	0.082
> 1.64	533 (33.33)	0.63 (0.48–0.82)	< 0.001	0.57 (0.36–0.89)	0.014

CVD, cardiovascular disease; HR, hazard ratio; CI, confidence interval; PIR, poverty income ratio; PA, physical activity; CKD, chronic kidney disease; WBC, white blood cell.
[1]All-cause mortality adjusted for age, sex, PIR, marital status, smoking, PA, CVD, CKD, WBC, and albumin.
[2]CVD mortality adjusted for age, PIR, drinking, PA, CVD, CKD, depression, and anticoagulants.
[3]Fiber intakes were adjusted according to fiber * 1,000/energy.

smoking, PA, CVD, CKD, WBC, and albumin for all-cause mortality. The dietary total fiber intake > 8.87 (HR, 0.73; 95% CI, 0.57–0.94) and vegetables fiber intake > 1.64 (HR, 0.63; 95% CI, 0.48–0.82) were related to decreased all-cause mortality risk in patients with stroke compared to those having total fiber intake ≤ 5.83 or vegetables fiber intake ≤ 0.10. Similar findings were also observed between dietary total fiber intake > 8.87 (HR, 0.56; 95% CI, 0.37–0.85) or vegetable fiber intake > 1.64 (HR, 0.57; 95% CI, 0.36–0.89) and lower CVD mortality risk.

Relationships between different sources of dietary fiber and all-cause mortality in different subgroups

As illustrated in **Table 3**, the relationship was further investigated between dietary fiber from various sources and all-cause mortality risk in different age, sex, BMI, smoking status, CVD, and CKD subgroups. Total fiber intake > 8.87 was linked to lower all-cause mortality risk in those aged ≥ 60 yrs (HR, 0.75; 95% CI, 0.58–0.96), BMI < 30 kg/m^2 (HR, 0.70; 95% CI, 0.51–0.95), smoking (HR, 0.64; 95% CI, 0.47–0.85), non-CVD (HR, 0.65; 95% CI, 0.48–0.89), and CKD (HR, 0.66; 95% CI, 0.50–0.89). Vegetable fiber intake > 1.64 was related to decreased all-cause mortality risk in those aged ≥ 60 yrs (HR, 0.68; 95% CI, 0.53–0.87), males (HR, 0.65; 95% CI, 0.46–0.92), females (HR, 0.62; 95% CI, 0.44–0.87), BMI ≥ 30 kg/m^2 (HR, 0.49; 95% CI, 0.31–0.79), smoking (HR, 0.60; 95% CI, 0.44–0.81), non-CVD (HR, 0.73; 95% CI, 0.53–0.99), CVD (HR, 0.57; 95% CI, 0.39–0.83), and CKD (HR, 0.55; 95% CI, 0.40–0.74).

Relationships between various sources of dietary fiber and CVD mortality in different groups

To delve deeper into the relationship of dietary fiber from various sources with CVD mortality risk in different subgroups. In **Table 4**, Total fiber intake > 8.87 was related to lower CVD mortality risk in stroke patients aged ≥ 60 yrs (HR, 0.64; 95% CI, 0.41–0.97), females (HR, 0.42; 95% CI, 0.22–0.77), BMI ≥ 30 kg/m^2 (HR, 0.42; 95% CI, 0.21–0.83), smoking (HR, 0.49; 95% CI, 0.31–0.78), and CKD (HR, 0.55; 95% CI, 0.35–0.87). Vegetable fiber intake > 1.64 was

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Table 3. Association of dietary fiber intake with the risk of all-cause mortality in subgroups

Subgroups[1)]	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Subgroup I: Age	Age < 60 (n = 414)		Age ≥ 60 (n = 1,164)	
Total fiber				
≤ 5.83	Ref		Ref	
5.83–8.87	1.50 (0.78–2.90)	0.225	0.62 (0.47–0.80)	< 0.001
> 8.87	0.91 (0.39–2.11)	0.823	0.75 (0.58–0.96)	0.023
Cereal fiber				
≤ 1.45	Ref		Ref	
1.45–3.39	1.55 (0.89–2.68)	0.118	0.81 (0.59–1.10)	0.177
> 3.39	1.69 (0.70–4.09)	0.238	0.96 (0.74–1.26)	0.785
Fruits fiber				
0	Ref		Ref	
≤ 1.6	1.31 (0.60–2.87)	0.493	1.15 (0.83–1.57)	0.399
> 1.6	1.37 (0.59–3.18)	0.454	1.30 (1.01–1.69)	0.051
Vegetables fiber				
≤ 0.10	Ref		Ref	
0.10–1.64	0.84 (0.40–1.75)	0.635	0.90 (0.70–1.16)	0.396
> 1.64	0.94 (0.45–1.98)	0.866	0.68 (0.53–0.87)	0.003
Subgroup II: Sex	Male (n = 782)		Female (n = 796)	
Total fiber				
≤ 5.83	Ref		Ref	
5.83–8.87	0.67 (0.48–0.93)	0.016	0.62 (0.42–0.91)	0.015
> 8.87	0.75 (0.55–1.01)	0.058	0.71 (0.48–1.04)	0.081
Cereal fiber				
≤ 1.45	Ref		Ref	
1.45–3.39	1.30 (0.97–1.76)	0.083	0.62 (0.40–0.95)	0.028
> 3.39	1.04 (0.74–1.46)	0.832	0.81 (0.55–1.21)	0.302
Fruits fiber				
0	Ref		Ref	
≤ 1.6	1.07 (0.78–1.45)	0.686	1.07 (0.73–1.56)	0.744
> 1.6	1.20 (0.88–1.63)	0.246	1.17 (0.80–1.71)	0.409
Vegetables fiber				
≤ 0.10	Ref		Ref	
0.10–1.64	1.15 (0.87–1.52)	0.324	0.75 (0.51–1.10)	0.137
> 1.64	0.65 (0.46–0.92)	0.016	0.62 (0.44–0.87)	0.006
Subgroup III: BMI	< 30 kg/m^2 (n = 906)		≥ 30 kg/m^2 (n = 672)	
Total fiber				
≤ 5.83	Ref		Ref	
5.83–8.87	0.67 (0.48–0.94)	0.019	0.64 (0.41–0.99)	0.044
> 8.87	0.70 (0.51–0.95)	0.024	0.93 (0.64–1.37)	0.725
Cereal fiber				
≤ 1.45	Ref		Ref	
1.45–3.39	1.03 (0.75–1.40)	0.865	0.61 (0.40–0.92)	0.019
> 3.39	0.94 (0.68–1.30)	0.705	0.86 (0.56–1.32)	0.497
Fruits fiber				
0	Ref		Ref	
≤ 1.6	0.84 (0.61–1.16)	0.283	1.25 (0.79–1.97)	0.345
> 1.6	1.09 (0.81–1.47)	0.551	1.27 (0.86–1.87)	0.228
Vegetables fiber				
≤ 0.10	Ref		Ref	
0.10–1.64	0.84 (0.62–1.14)	0.259	1.06 (0.71–1.58)	0.785
> 1.64	0.76 (0.54–1.05)	0.097	0.49 (0.31–0.79)	0.004
Subgroup IV: Smoke	No (n = 626)		Yes (n = 952)	
Total fiber				
≤ 5.83	Ref		Ref	
5.83–8.87	0.57 (0.37–0.89)	0.014	0.68 (0.48–0.95)	0.023
> 8.87	0.89 (0.61–1.30)	0.542	0.64 (0.47–0.85)	0.003
Cereal fiber				
≤ 1.45	Ref		Ref	
1.45–3.39	0.78 (0.53–1.15)	0.206	0.93 (0.68–1.27)	0.663
> 3.39	0.77 (0.53–1.14)	0.192	0.95 (0.69–1.29)	0.728

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Table 3. (Continued) Association of dietary fiber intake with the risk of all-cause mortality in subgroups

Subgroups[1)]	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Fruits fiber				
0	Ref		Ref	
≤ 1.6	0.93 (0.65–1.33)	0.677	1.08 (0.78–1.49)	0.626
> 1.6	1.41 (0.90–2.20)	0.133	0.98 (0.73–1.32)	0.891
Vegetables fiber				
≤ 0.10	Ref		Ref	
0.10–1.64	1.04 (0.68–1.58)	0.853	0.86 (0.69–1.08)	0.188
> 1.64	0.70 (0.48–1.02)	0.062	0.60 (0.44–0.81)	0.001
Subgroup V: CVD	No (n = 977)		Yes (n = 601)	
Total fiber				
≤ 5.83	Ref		Ref	
5.83–8.87	0.67 (0.48–0.92)	0.015	0.58 (0.37–0.89)	0.014
> 8.87	0.65 (0.48–0.89)	0.007	0.83 (0.58–1.20)	0.313
Cereal fiber				
≤ 1.45	Ref		Ref	
1.45–3.39	0.82 (0.56–1.20)	0.298	0.94 (0.65–1.36)	0.741
> 3.39	0.65 (0.46–0.91)	0.014	1.26 (0.94–1.68)	0.120
Fruits fiber				
0	Ref		Ref	
≤ 1.6	1.07 (0.76–1.51)	0.695	0.99 (0.69–1.42)	0.946
> 1.6	1.15 (0.80–1.65)	0.453	1.22 (0.85–1.73)	0.277
Vegetables fiber				
≤ 0.10	Ref		Ref	
0.10-1.64	0.98 (0.71–1.36)	0.908	0.87 (0.66–1.14)	0.304
> 1.64	0.73 (0.53–0.99)	0.048	0.57 (0.39–0.83)	0.004
Subgroup VI: CKD	No (n = 834)		Yes (n = 744)	
Total fiber				
≤ 5.83	Ref		Ref	
5.83–8.87	0.96 (0.58–1.59)	0.884	0.53 (0.40–0.70)	< 0.001
> 8.87	0.84 (0.56–1.24)	0.376	0.66 (0.50–0.89)	0.006
Cereal fiber				
≤ 1.45	Ref		Ref	
1.45–3.39	0.92 (0.62–1.36)	0.665	0.82 (0.57–1.16)	0.257
> 3.39	0.89 (0.58–1.37)	0.596	0.92 (0.67–1.27)	0.628
Fruits fiber				
0	Ref		Ref	
≤ 1.6	1.13 (0.77–1.67)	0.528	0.99 (0.72–1.35)	0.940
> 1.6	1.36 (0.95–1.96)	0.096	1.06 (0.78–1.45)	0.711
Vegetables fiber				
≤ 0.10	Ref		Ref	
0.10–1.64	0.90 (0.62–1.29)	0.552	1.01 (0.77–1.33)	0.950
> 1.64	0.80 (0.53–1.20)	0.285	0.55 (0.40–0.74)	< 0.001

HR, hazard ratio; CI, confidence interval; BMI, body mass index; CVD, cardiovascular disease; CKD, chronic kidney disease; PIR, poverty income ratio; PA, physical activity; WBC, white blood cell.
[1)]Subgroup I adjusted sex, PIR, marriage, smoking, PA, CVD, CKD, WBC, and albumin; Subgroup II adjusted age, PIR, marriage, smoking, PA, CVD, CKD, WBC, and albumin; Subgroup III adjusted age, sex, PIR, marriage, smoking, PA, CVD, CKD, WBC, and albumin; Subgroup IV adjusted age, sex, PIR, marriage, PA, CVD, CKD, WBC, and albumin; Subgroup V adjusted age, sex, PIR, marriage, smoking, PA, CKD, WBC, and albumin; Subgroup VI adjusted age, sex, PIR, marriage, smoking, PA, CVD, WBC, and albumin.

related to decreased CVD mortality risk in those aged ≥ 60 yrs (HR, 0.56; 95% CI, 0.37–0.85), females (HR, 0.48; 95% CI, 0.25–0.92), BMI ≥ 30 kg/m^2 (HR, 0.34; 95% CI, 0.17–0.68), non-smoking (HR, 0.32; 95% CI, 0.17–0.61), and CKD (HR, 0.52; 95% CI, 0.32–0.85).

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Table 4. Association of dietary fiber intake with the risk of CVD mortality in subgroups

Subgroups[1)]	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Subgroup I: Age	Age < 60 (n = 414)		Age ≥ 60 (n = 1,164)	
Total fiber				
≤ 5.83	Ref		Ref	
5.83–8.87	1.82 (0.81–4.12)	0.148	0.52 (0.33–0.81)	0.005
> 8.87	0.51 (0.10–2.63)	0.419	0.64 (0.41–0.97)	0.038
Cereal fiber				
≤ 1.45	Ref		Ref	
1.45–3.39	0.77 (0.20–3.00)	0.707	0.73 (0.45–1.19)	0.205
> 3.39	0.44 (0.11–1.74)	0.236	0.91 (0.55–1.49)	0.703
Fruits fiber				
0	Ref		Ref	
≤ 1.6	0.66 (0.22–2.05)	0.470	0.88 (0.55–1.40)	0.583
> 1.6	0.66 (0.22–2.02)	0.461	0.93 (0.57–1.50)	0.753
Vegetables fiber				
≤ 0.10	Ref		Ref	
0.10–1.64	0.11 (0.05–0.27)	< 0.001	0.73 (0.48–1.10)	0.135
> 1.64	1.22 (0.35–4.28)	0.756	0.56 (0.37–0.85)	0.007
Subgroup II: Sex	Male (n = 782)		Female (n = 796)	
Total fiber				
≤ 5.83	Ref		Ref	
5.83–8.87	0.77 (0.47–1.26)	0.295	0.34 (0.18–0.67)	0.002
> 8.87	0.77 (0.48–1.24)	0.279	0.42 (0.22–0.77)	0.006
Cereal fiber				
≤ 1.45	Ref		Ref	
1.45–3.39	0.95 (0.55–1.66)	0.861	0.57 (0.30–1.06)	0.074
> 3.39	0.86 (0.47–1.57)	0.624	0.66 (0.33–1.31)	0.231
Fruits fiber				
0	Ref		Ref	
≤ 1.6	0.95 (0.57–1.61)	0.861	0.68 (0.34–1.36)	0.274
> 1.6	1.23 (0.73–2.06)	0.437	0.53 (0.29–0.96)	0.036
Vegetables fiber				
≤ 0.10	Ref		Ref	
0.10–1.64	0.79 (0.42–1.48)	0.466	0.62 (0.37–1.05)	0.075
> 1.64	0.70 (0.41–1.18)	0.180	0.48 (0.25–0.92)	0.028
Subgroup III: BMI	< 30 kg/m^2 (n = 906)		≥ 30 kg/m^2 (n = 672)	
Total fiber				
≤ 5.83	Ref		Ref	
5.83–8.87	0.67 (0.38–1.19)	0.169	0.42 (0.21–0.83)	0.013
> 8.87	0.62 (0.35–1.08)	0.089	0.60 (0.27–1.31)	0.194
Cereal fiber				
≤ 1.45	Ref		Ref	
1.45–3.39	0.71 (0.43–1.17)	0.179	0.70 (0.33–1.53)	0.372
> 3.39	0.64 (0.36–1.13)	0.123	0.81 (0.40–1.66)	0.567
Fruits fiber				
0	Ref		Ref	
≤ 1.6	0.76 (0.46–1.28)	0.308	0.93 (0.50–1.74)	0.813
> 1.6	0.77 (0.42–1.42)	0.399	1.01 (0.60–1.70)	0.973
Vegetables fiber				
≤ 0.10	Ref		Ref	
0.10–1.64	0.78 (0.46–1.34)	0.373	0.68 (0.33–1.40)	0.294
> 1.64	0.77 (0.42–1.41)	0.390	0.34 (0.17–0.68)	0.003
Subgroup IV: Smoke	No (n = 626)		Yes (n = 952)	
Total fiber				
≤ 5.83	Ref		Ref	
5.83–8.87	0.44 (0.22–0.87)	0.019	0.61 (0.36–1.02)	0.058
> 8.87	0.58 (0.25–1.35)	0.202	0.49 (0.31–0.78)	0.003
Cereal fiber				
≤ 1.45	Ref		Ref	
1.45–3.39	0.54 (0.30–0.96)	0.036	0.82 (0.51–1.32)	0.415
> 3.39	0.54 (0.28–1.06)	0.072	0.77 (0.47–1.28)	0.316

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Table 4. (Continued) Association of dietary fiber intake with the risk of CVD mortality in subgroups

Subgroups[1)]	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Fruits fiber				
0	Ref		Ref	
≤ 1.6	0.60 (0.33–1.09)	0.096	0.93 (0.61–1.43)	0.751
> 1.6	0.67 (0.35–1.28)	0.227	0.76 (0.47–1.24)	0.270
Vegetables fiber				
≤ 0.10	Ref		Ref	
0.10–1.64	0.58 (0.34–0.99)	0.047	0.81 (0.46–1.43)	0.472
> 1.64	0.32 (0.17–0.61)	< 0.001	0.89 (0.54–1.46)	0.638
Subgroup V: CVD	No (n = 977)		Yes (n = 601)	
Total fiber				
≤ 5.83	Ref		Ref	
5.83–8.87	0.55 (0.34–0.89)	0.015	0.60 (0.30–1.21)	0.152
> 8.87	0.59 (0.28–1.24)	0.163	0.65 (0.34–1.22)	0.174
Cereal fiber				
≤ 1.45	Ref		Ref	
1.45–3.39	0.60 (0.35–1.01)	0.054	0.83 (0.47–1.48)	0.531
> 3.39	0.44 (0.25–0.77)	0.005	1.09 (0.60–1.97)	0.782
Fruits fiber				
0	Ref		Ref	
≤ 1.6	1.01 (0.63–1.61)	0.961	0.73 (0.39–1.40)	0.345
> 1.6	0.74 (0.42–1.32)	0.305	0.85 (0.48–1.52)	0.580
Vegetables fiber				
≤ 0.10	Ref		Ref	
0.10–1.64	0.54 (0.34–0.85)	0.009	0.96 (0.54–1.70)	0.881
> 1.64	0.56 (0.30–1.03)	0.061	0.68 (0.34–1.34)	0.264
Subgroup VI: CKD	No (n = 834)		Yes (n = 744)	
Total fiber				
≤ 5.83	Ref		Ref	
5.83–8.87	0.77 (0.37–1.60)	0.486	0.40 (0.25–0.64)	< 0.001
> 8.87	0.57 (0.31–1.05)	0.069	0.55 (0.35–0.87)	0.011
Cereal fiber				
≤ 1.45	Ref		Ref	
1.45–3.39	0.72 (0.44–1.19)	0.195	0.75 (0.40–1.41)	0.369
> 3.39	0.56 (0.30–1.05)	0.070	0.86 (0.47–1.57)	0.621
Fruits fiber				
0	Ref		Ref	
≤ 1.6	0.53 (0.31–0.90)	0.020	1.01 (0.59–1.74)	0.967
> 1.6	0.75 (0.39–1.45)	0.388	0.88 (0.51–1.51)	0.643
Vegetables fiber				
≤ 0.10	Ref		Ref	
0.10–1.64	0.51 (0.26–0.99)	0.050	0.82 (0.51–1.34)	0.425
> 1.64	0.67 (0.37–1.21)	0.187	0.52 (0.32–0.85)	0.010

HR, hazard ratio; CI, confidence interval; BMI, body mass index; CVD, cardiovascular disease; CKD, chronic kidney disease; PIR, poverty income ratio; PA, physical activity.
[1)]Subgroup I adjusted PIR, drinking, PA, CVD, CKD, depression, and anticoagulants; Subgroup II adjusted age, PIR, drinking, PA, CVD, CKD, depression, and anticoagulants; Subgroup III adjusted age, PIR, drinking, PA, CVD, CKD, depression, and anticoagulants; Subgroup IV adjusted age, PIR, drinking, PA, CVD, CKD, depression, and anticoagulants; Subgroup V adjusted age, PIR, drinking, PA, CKD, depression, and anticoagulants; Subgroup VI adjusted age, PIR, drinking, PA, CVD, depression, and anticoagulants.

DISCUSSION

Our findings showed that a high intake of total fiber as well as vegetable fiber was associated with lower all-cause mortality risk in patients with stroke. The relationship between higher total or vegetable fiber intake and lower all-cause mortality risk was discovered in individuals aged ≥ 60 yrs, smoking, non-CVD, and CKD. We also found that high total fiber intake as well as vegetable fiber was linked to lower CVD mortality risk in patients with stroke. Subgroup

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results also found that high total fiber or vegetable fiber consumption was linked to lower CVD mortality risk in stroke individuals aged ≥ 60 yrs, females, BMI ≥ 30 kg/m^2, non-smoking, and CKD.

Dietary fiber, a valuable nutrient for human well-being, exhibits a beneficial impact on health [25]. Epidemiological research found a negative relationship between elevated dietary fiber intake and mortality risk [8,26]. Elevated consumption of dietary fiber was linked to lower all-cause and CVD mortality risk [27]. Zhang *et al.* [15] reported that high dietary fiber consumption was linked to reduced all-cause and CVD mortality risk in older patients with hypertension. Our study has similar findings on the relationship between higher total fiber and vegetable fiber and reduced mortality risk in stroke. Dietary fibers from various food origins exhibit a diverse array of compounds, and yield varying impacts on both overall mortality and CVD mortality, particularly the soluble dietary fiber sourced from fruits and vegetables [14,16]. Ghorbani *et al.* [28] reported that increased dietary fiber intake, particularly soluble fiber found in fruits and vegetables, may lower overall mortality and mortality from specific causes. Yao *et al.* [13] found that intakes of fruit, vegetable, and soluble fiber were linked to all-cause and CVD mortality.

Potential explanations for the relationship of high total and vegetable fiber consumption with lower mortality risk were linked to general health. Silva *et al.* [29] reported that insufficient dietary fiber intake was more severe in the elderly. Furthermore, older people are more prone to suffer chronic diseases than the young, such as hypertension [30]. Changes may occur in the type and absorption of dietary fiber as diseases progress. Morrison *et al.* [31] found that consuming total and vegetable fiber, but not from fruits, was linked to reduced hypertension risk among U.S. Our results suggested sex differences in the relationship of fruit fiber consumption with mortality in stroke individuals. Some factors could contribute to this condition. Due to differences in body structure between males and females, they have different fruit fiber requirements [32]. In addition, different dietary habits make females more likely to benefit from fruity-derived dietary fiber on CVD mortality. Lai *et al.* [33] found that total fruit consumption was linked to lower CVD and coronary heart disease mortality risk. In stroke patients with BMI ≥ 30 kg/m^2, higher vegetable fiber intake may be beneficial to reducing mortality risk due to its known benefits in improving lipid profiles, reducing inflammation, and enhancing gut microbiota composition [34]. These factors collectively may mitigate cardiovascular risk factors commonly exacerbated in obese individuals, thereby lowering overall mortality rates. Furthermore, among stroke patients who were smoking, higher total fiber intake could potentially mitigate the detrimental effects of smoking on cardiovascular health. Fiber-rich diets are associated with improved cardiovascular outcomes, possibly through effects on oxidative stress, lipid metabolism, and systemic inflammation [35]. In stroke patients with CKD, elevated total and vegetable fiber intake were associated with lower mortality risk. This could be explained by fiber's ability to improve glycemic control, reduce systemic inflammation, and enhance gut health, all of which are critical in managing complications associated with CKD [36]. The antioxidant properties of dietary fibers may also play a role in reducing oxidative stress, which is implicated in the progression of kidney disease and cardiovascular complications.

Several mechanisms could elucidate the relationship of high dietary fiber consumption with lower mortality risk in stroke. First, inflammation was related to increased mortality risk [37]. Evidence showed that increased dietary fiber consumption potentially reduced the level of inflammatory indicators, like interleukin-6, and C-reactive protein [38]. Additionally, soluble

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fibers, abundant in vegetables, from viscous gels in the gastrointestinal tract, can lower cholesterol absorption, and improve lipid profiles, thus mitigating cardiovascular risk [39]. Second, dietary fiber acts as a prebiotic, promoting the growth of beneficial gut microbiota [40]. A healthy gut microbiome is linked to reduced systemic inflammation and improved immune function, which are protective against cardiovascular diseases and overall mortality [7]. Third, dietary fiber intake is closely related to metabolic benefits. Specifically, dietary fiber may influence microbial metabolite synthesis, contributing to the onset of metabolic disorders like obesity, atherosclerosis, and type 2 diabetes [7,31].

High total and vegetable fiber consumption was associated with decreased all-cause and CVD mortality risk in patients with stroke. The findings could offer valuable insights for crafting dietary interventions aimed at enhancing the prognosis of individuals recovering from stroke. Given that the mortality of stroke patients continues to increase globally, current public health strategies must include education about dietary fiber intake. Encourage patients with stroke to increase their intake of dietary fiber, such as vegetables.

This study has several limitations. First, dietary fiber consumption was evaluated through dietary recall interviews, potentially introducing reporting bias. Second, due to database limitations, stroke types could not be distinguished, which needs to be explored in the future. Third, the NHANES database lacked continuous dietary fiber intake records, the investigation failed to establish a definitive link between dynamic changes in dietary fiber consumption and mortality rates related to all causes, including cardiovascular events.

In conclusion, we found that high total fiber and vegetable fiber intake were linked to reduced risks of all-cause mortality and CVD mortality among patients with stroke. Increasing dietary fiber consumption, especially vegetable fiber, might improve the prognosis of patients with stroke. Our findings may offer guidelines for developing strategies aimed at enhancing stroke prognosis.

SUPPLEMENTARY MATERIAL

Supplementary Table 1

Characteristics of stroke patients

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