BMC Public Health

RESEARCH

Open Access

Association between dietary fiber intake and atherosclerotic cardiovascular disease risk in adults: a cross-sectional study of 14,947 population based on the National Health and Nutrition Examination Surveys

Shutang Zhang[1†], Jie Tian[1†], Min Lei[1], Canye Zhong[1] and Yan Zhang[2*]

Abstract

Background: This study aimed to investigate the association between dietary fiber intake and long-term cardiovascular disease (CVD) risk based on the National Health and Nutrition Examination Survey (NHANES) database.

Methods: A total of 14,947 participants aged 20–79 from the NHANES database were included in this study between 2009 and 2018. The atherosclerotic cardiovascular disease (ASCVD) score was utilized to predict the 10-year risk of CVD in individuals (low, borderline, intermediate, and high risk). Weighted univariate and multinomial multivariate logistic regression analyses were used to analyze the association between dietary fiber intake and long-term CVD risk.

Results: Higher dietary fiber density may be associated with a reduced ASCVD risk in participants with intermediate risk [odds ratio (OR) = 0.76; 95% confidence interval (CI), 0.61–0.94] and high risk (OR = 0.60; 95%CI, 0.45–0.81) compared with those in the group with low risk. Higher total dietary fiber intake may also reduce ASCVD risk in participants with high risk (OR = 0.84; 95%CI, 0.75–0.95). Subgroup analyses showed that higher dietary fiber density may be related to reduced ASCVD risk in intermediate-risk participants aged 20–39 (OR = 0.62; 95%CI, 0.43–0.89) and 40–59 (OR = 0.67; 95%CI, 0.49–0.94). In high-risk participants, higher dietary fiber density may reduce ASCVD risk in 20–39-year-old (OR = 0.38; 95%CI, 0.19–0.77), 40–59-year-old (OR = 0.37; 95%CI, 0.20–0.70), male (OR = 0.47; 95%CI, 0.23–0.97) and female (OR = 0.57; 95%CI, 0.38–0.86) participants.

Conclusion: Higher dietary fiber density and total dietary fiber intake were associated with a lower long-term CVD risk, especially in the 20–39 and 40–59 age groups, where the reduction was most significant.

Keywords: Dietary fiber intake, Framingham risk score, Cardiovascular disease, 10-year risk

Introduction

Cardiovascular diseases (CVD), the world's leading cause of death, are a group of disorders of the heart and blood vessels, including coronary heart disease, cerebrovascular disease, rheumatic heart disease and other diseases, claiming an estimated 17.9 million lives each year [1, 2]. CVD presents a heavy burden for the world due to its high treatment cost and extensive preventive

†Shutang Zhang and Jie Tian contributed equally to this study and should be considered co-first authors.

*Correspondence: yanzhangccu@outlook.com

[2] Department of Cardiovascular Medicine CCU, Hanzhong People's Hospital, No.251 North Unity Street, Hantai District, Hanzhong 723000, Shaanxi, People's Republic of China
Full list of author information is available at the end of the article

interventions [3, 4]. Evidence demonstrated that the occurrence of most CVD can be attributed to a series of factors, such as smoking, obesity, diabetes, dyslipidemia, hypertension, diet, excessive alcohol consumption, and mental state [5, 6]. Early prevention can effectively reduce the incidence of CVD, but CVD-related deaths still account for a large proportion of all-cause deaths.

Dietary fiber can affect the cardiometabolic pathways, improve lipid or lipoprotein metabolism, insulin homeostasis, and so on [7]. Epidemiologic studies have shown that dietary fiber intake is associated with the CVD risk in short and medium-term follow-up [8–10]. Murai et al. indicated that seaweed intake was inversely associated with the risk of ischemic heart disease [8]. Song et al. found that total fruit and whole fruit intake were inversely related to cardiovascular risk factors such as obesity, metabolic syndrome and hypertension [9]. Wang et al. showed that higher fiber intake and fiber intake density may be associated with a lower risk of major adverse cardiovascular events [10]. An in-depth understanding of the role of dietary fiber intake in predicting the long-term CVD risk can help the public identify optimal dietary patterns and improve long-term survival. The atherosclerotic cardiovascular disease (ASCVD) score, recommended by the American College of Cardiology (ACC) and American Heart Association (AHA), is a commonly and widely used to evaluate the 10-year CVD [11]. In this study, we applied this score to identify people at high risk of CVD over the next ten years and assessed the association between dietary fiber intake and the CVD risk based on the National Health and Nutrition Examination Survey (NHANES) database.

Methods

Study population

Data in this study were extracted from the NHANES database between 2009 and 2018, which is a cross-sectional survey of the health and nutrition status of the U.S. civilian and non-institutionalized population conducted by the National Center of Health Statistics (NCHS) and the Centers for Disease Control and Prevention (CDC). Subjects were randomly screened based on a complex, stratified multi-stage cluster sampling design. The information collection was carried out through interviews. Additional information was available at: https://www.cdc.gov/nchs/tutorials/dietary/SurveyOrientation/Resource Dietary Analysis/intro.htm. A total of 14,947 participants with complete data were included in this study.

Data collection

Participants' information including age (20–79 years old), gender (male and female), body mass index (BMI, kg/m^2), race (Mexican Americans, Hispanics, non-Hispanic whites, non-Hispanic blacks, and others), marital status (married, widowed, divorced/separated, and unmarried), education level (< high school, high school/GED, and > high school), family income (< 20,000$ and ≥ 20,000$), smoking status (yes and no), hypertension (yes and no), diabetes (yes and no), metabolic syndrome (yes and no), use of high blood pressure medication (yes and no), now increasing exercise (yes and no), systolic blood pressure (SBP), diastolic blood pressure (DBP), high-density lipoprotein (HDL), total cholesterol (TC), total bilirubin, creatinine (Cr), total energy, total dietary fiber intake, and dietary fiber density was collected.

Definition

The data on dietary fiber intake were obtained through two 24-h dietary recall interviews. The first dietary recall interview was conducted in the mobile examination center (MEC), and the second interview was conducted using phones 3 to 10 days later. The first dietary recall interview was a face-to-face interview. A set of measurement guidelines (various glasses, bowls, mugs, bottles, household spoons, measuring cups and spoons, a ruler, thickness sticks, bean bags, and circles) was available in the MEC dietary interview room for participants to use to report the amount of food. There were more checks on weekends than on weekdays, and food intake may vary between weekdays and weekends. Therefore, the use of the MEC weight disproportionately represents weekend intake. Dietary fiber intake was calculated according to the United States Department of Agriculture (USDA) food and nutrient database for dietary studies [1]. Total dietary fiber intake was obtained based on an average of the two interviews. Dietary fiber density (10 g/1000 kcal) was defined as the ratio of dietary fiber intake to total energy intake.

Smoking status was confirmed according to two items, including SMQ020 (Have you smoked at least 100 cigarettes in your lifetime?) and SMQ935 (Do you smoke cigarettes now?). The subjects were divided into a smoking group (meeting the two items) and a non-smoking group (meeting items ≤ 1).

ASCVD score

The ASCVD risk score was utilized to predict the 10-year risk of CVD in individuals based on the age, sex, race, cholesterol levels, blood pressure, medication use, diabetic status, and smoking status of the participants [11]. The predictive criteria of the 10-year risk of CVD were as follows: (1) low risk (< 5%); (2) borderline risk (5% to 7.5%); (3) intermediate risk (≥ 7.5% to < 20%); (4) high risk (≥ 20%). The participants with low risk served as the

control group for CVD, and others with borderline/intermediate/high risk served as the case group.

Statistical analysis

Shapiro–Wilk test was conducted to test the normality of the data. Measurement data with normal distribution were described by mean ± standard deviation (SD). The t-test was used for comparison between the two groups, and analysis of variance was used for comparison between multiple groups. Data with abnormal distribution were presented by the median and interquartile range [M (Q1, Q3)]. The Man-Whitney U rank-sum test was used for comparison between two groups, and the Kruskal–Wallis H rank-sum test was used for comparison between multiple groups. Enumeration data were described by the numbers and percentage [n (%)]. Chi-square test or Fisher's exact probability test was used to perform the comparison between groups. All statistical analyses were performed by SAS9.4 software (SAS Institute Inc., Cary, NC, USA) using a two-sided test. *P*-value < 0.05 was considered statistically significant.

Differences between the low-risk, borderline-risk, intermediate-risk, and high-risk groups were analyzed to find possible confounders. The association between dietary fiber density and total dietary fiber and long-term CVD risk was analyzed in different CVD risk groups. Model 1 was a weighted univariate multinomial logistic regression model. Model 2 was a weighted multinomial multivariate logistic regression model that adjusted for age, gender, family income, education levels, and marital status. Model 3 was a weighted multinomial multivariate logistic regression model that adjusted for age, gender, family income, education levels, marital status, total bilirubin, creatinine, and metabolic syndrome. The normality test for continuous variables was shown in Supplement Fig. 1. The multicollinearity diagnosis for weighted models was presented in Supplement Table 1.

Results

Baseline characteristics of participants

A total of 19,693 participants were extracted from the NHANES database, 1,231 participants aged < 20 or ≥ 80, 601 participants diagnosed with CVD, and 2,914 participants with incomplete data were excluded. Finally, 14,947 participants were included in the study (Fig. 1). Among the included participants, the median age was 46.00 (33.00, 60.00) years, including 7,183 (48.06%) males and 7,764 (51.94%) females. The median total dietary fiber intake and dietary fiber density were 15.45 (10.75, 21.85) g and 0.78 (0.58, 1.06) 10 g/1000 kcal, respectively. According to the ASCVD, the predicted number of participants at low risk, borderline risk, intermediate risk, and high risk for CVD over the next 10 years were 5,735 (38.37%), 1,082 (7.24%), 3,329 (22.27%), and 4,801 (32,12%), respectively. The characteristics of individuals were shown in Table 1.

Difference analysis between the low-risk, borderline-risk, intermediate-risk, and high-risk ASCVD groups

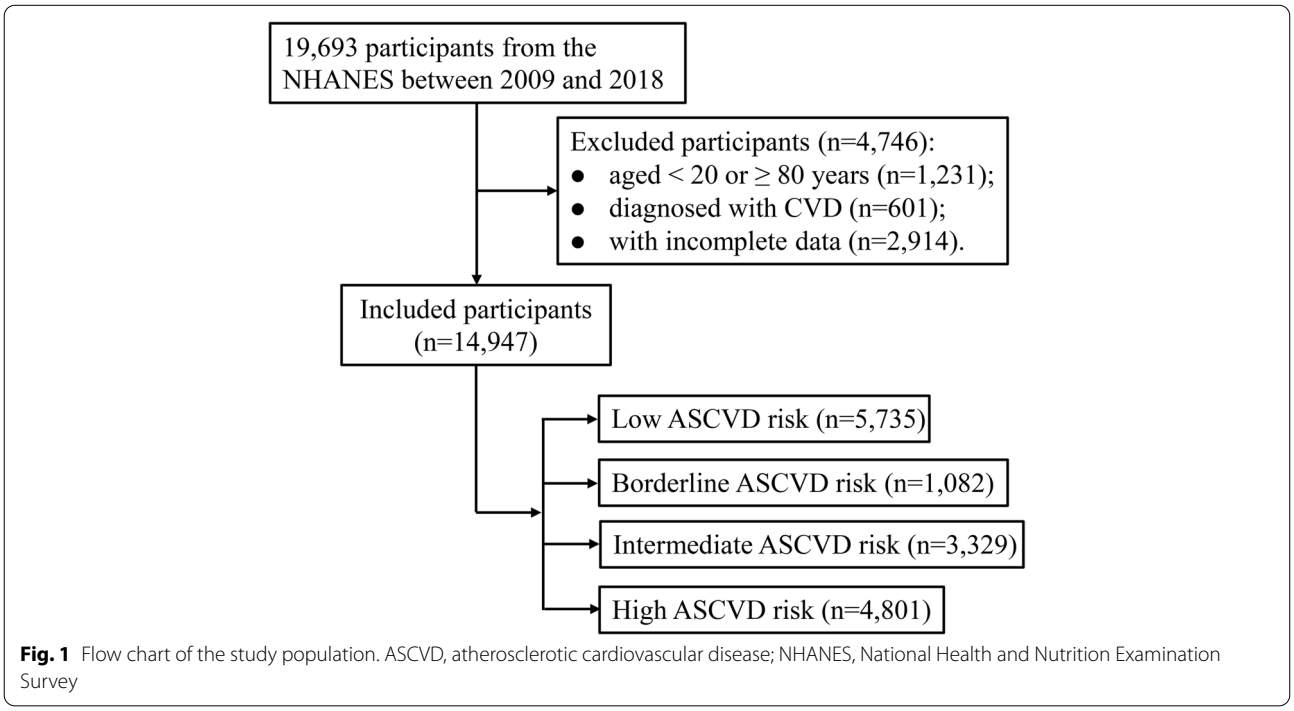

Fig. 1 Flow chart of the study population. ASCVD, atherosclerotic cardiovascular disease; NHANES, National Health and Nutrition Examination Survey

Table 1 Difference analysis between different atherosclerotic cardiovascular disease (ASCVD) risk groups

Characteristics	Total ($n=14,947$)	Low risk group ($n=5735$)	Borderline risk group ($n=1082$)	Intermediate risk group ($n=3329$)	High risk group ($n=4801$)	Statistics	*P*
Age, M (Q_1, Q_3)	46.00 (33.00, 60.00)	32.00 (25.00, 40.00)	43.00 (34.00, 50.00)	50.00 (41.00, 57.00)	64.00 (57.00, 70.00)	$\chi^2=8719.967$	< 0.001
Gender, n (%)						$\chi^2=533.159$	< 0.001
Female	7764 (51.94)	3468 (60.47)	622 (57.49)	1821 (54.70)	1853 (38.60)		
Male	7183 (48.06)	2267 (39.53)	460 (42.51)	1508 (45.30)	2948 (61.40)		
BMI, kg/m^2, mean ± SD	29.37 ± 6.97	28.23 ± 7.23	30.24 ± 7.41	30.56 ± 7.15	29.70 ± 6.19	F = 94.140	< 0.001
Race, n (%)						$\chi^2=264.033$	< 0.001
Mexican Americans	2242 (15.00)	936 (16.32)	178 (16.45)	508 (15.26)	620 (12.91)		
Hispanics	1531 (10.24)	480 (8.37)	101 (9.33)	356 (10.69)	594 (12.37)		
Non-Hispanic whites	6183 (41.37)	2107 (36.74)	469 (43.35)	1416 (42.54)	2191 (45.64)		
Non-Hispanic blacks	3140 (21.01)	1290 (22.49)	202 (18.67)	643 (19.32)	1005 (20.93)		
Others	1851 (12.38)	922 (16.08)	132 (12.20)	406 (12.20)	391 (8.14)		
Marital status, n (%)						$\chi^2=1902.546$	< 0.001
Married	7776 (52.02)	2548 (44.43)	581 (53.70)	1844 (55.39)	2803 (58.38)		
Widowed	689 (4.61)	32 (0.56)	22 (2.03)	135 (4.06)	500 (10.41)		
Divorced/separation	2114 (14.14)	507 (8.84)	157 (14.51)	589 (17.69)	861 (17.93)		
Unmarried	4368 (29.22)	2648 (46.17)	322 (29.76)	761 (22.86)	637 (13.27)		
Education level, n (%)						$\chi^2=331.585$	< 0.001
< high school	2899 (19.40)	806 (14.05)	203 (18.76)	727 (21.84)	1163 (24.22)		
High school/GED	3323 (22.23)	1085 (18.92)	262 (24.21)	769 (23.10)	1207 (25.14)		
> high school	8725 (58.37)	3844 (67.03)	617 (57.02)	1833 (55.06)	2431 (50.64)		
Income family, n (%)						$\chi^2=64.207$	< 0.001
< 20,000 $	12,205 (81.66)	4844 (84.46)	892 (82.44)	2703 (81.20)	3766 (78.44)		
≥ 20,000 $	2742 (18.34)	891 (15.54)	190 (17.56)	626 (18.80)	1035 (21.56)		
Smoking, n (%)						$\chi^2=6.324$	0.097
Yes	10,493 (70.20)	3980 (69.40)	757 (69.96)	2321 (69.72)	3435 (71.55)		
No	4454 (29.80)	1755 (30.60)	325 (30.04)	1008 (30.28)	1366 (28.45)		
Hypertension, n (%)						$\chi^2=1857.847$	< 0.001
Yes	4669 (31.24)	725 (12.64)	278 (25.69)	1216 (36.53)	2450 (51.03)		
No	10,278 (68.76)	5010 (87.36)	804 (74.31)	2113 (63.47)	2351 (48.97)		
Diabetes, n (%)						$\chi^2=335.823$	< 0.001
Yes	1695 (11.34)	310 (5.41)	132 (12.20)	510 (15.32)	743 (15.48)		
No	13,252 (88.66)	5425 (94.59)	950 (87.80)	2819 (84.68)	4058 (84.52)		
Metabolic syndrome, n (%)						$\chi^2=916.488$	< 0.001
Yes	12,957 (86.69)	5487 (95.68)	979 (90.48)	2855 (85.76)	3636 (75.73)		
No	1990 (13.31)	248 (4.32)	103 (9.52)	474 (14.24)	1165 (24.27)		
Use of high blood pressure medication, n (%)						$\chi^2=575.659$	< 0.001
Yes	905 (6.05)	65 (1.13)	47 (4.34)	204 (6.13)	589 (12.27)		
No	14,042 (93.95)	5670 (98.87)	1035 (95.66)	3125 (93.87)	4212 (87.73)		
Now increasing exercise, n (%)						$\chi^2=1.019$	0.797
Yes	567 (79.52)	87 (78.38)	40 (85.11)	159 (79.50)	281 (79.15)		

Table 1 (continued)

Characteristics	Total ($n=14,947$)	Low risk group ($n=5735$)	Borderline risk group ($n=1082$)	Intermediate risk group ($n=3329$)	High risk group ($n=4801$)	Statistics	*P*
No	146 (20.48)	24 (21.62)	7 (14.89)	41 (20.50)	74 (20.85)		
SBP, mmHg, mean ± SD	122.67 ± 17.23	114.15 ± 12.14	119.23 ± 13.30	122.92 ± 15.16	133.44 ± 18.54	F = 1424.593	< 0.001
DBP, mmHg, mean ± SD	71.10 ± 12.15	68.72 ± 10.92	72.64 ± 11.25	73.12 ± 11.56	72.20 ± 13.59	F = 126.362	< 0.001
HDL mg/dl, mean ± SD	53.26 ± 16.12	56.07 ± 15.58	52.77 ± 16.01	51.15 ± 15.29	51.49 ± 16.85	F = 98.361	< 0.001
TC, mmol/l, mean ± SD	193.53 ± 41.65	179.56 ± 35.02	194.59 ± 35.97	201.79 ± 40.34	204.24 ± 46.07	F = 393.357	< 0.001
Total bilirubin, umol/L, M (Q_1, Q_3)	10.26 (6.84, 13.68)	10.26 (6.84, 13.68)	10.26 (6.84, 13.68)	10.26 (6.84, 11.97)	10.26 (8.55, 13.68)	$\chi^2 = 32.228$	< 0.001
Cr, mg/dL, M (Q_1, Q_3)	0.84 (0.71, 0.99)	0.79 (0.67, 0.93)	0.82 (0.69, 0.96)	0.83 (0.71, 0.97)	0.90 (0.77, 1.07)	$\chi^2 = 826.562$	< 0.001
Total energy, kcal, M (Q_1, Q_3)	1956.00 (1504.00, 2517.50)	1983.00 (1532.00, 2549.50)	1946.25 (1526.00, 2524.00)	1975.00 (1516.50, 2534.00)	1911.50 (1458.50, 2469.50)	$\chi^2 = 31.348$	< 0.001
Total dietary fiber intake, g, M (Q_1, Q_3)	15.45 (10.75, 21.85)	15.40 (10.85, 21.60)	15.10 (10.70, 22.20)	15.30 (10.60, 21.90)	15.65 (10.75, 21.95)	$\chi^2 = 1.106$	0.776
Dietary fiber density, 10 g/1000 kcal, M (Q_1, Q_3)	0.78 (0.58, 1.06)	0.78 (0.57, 1.03)	0.76 (0.58, 1,04)	0.77 (0.57, 1.05)	0.82 (0.60, 1.10)	$\chi^2 = 36.806$	< 0.001

BMI Body mass index, *SBP* Systolic blood pressure, *DBP* Diastolic blood pressure, *HDL* High-density lipoprotein, *TC* Total cholesterol, *Cr* Creatinine

showed statistical difference in age, gender, BMI, race, marital status, education level, family income, hypertension, diabetes, metabolic syndrome, use of high blood pressure medication, SBP, DBP, HDL, TC, total bilirubin, creatinine, total energy, and dietary fiber density among the four groups (all $P<0.001$). However, no statistical difference was found in total dietary fiber intake among the four groups ($P=0.776$; Table1).

Association of dietary fiber density and total dietary fiber with ASCVD risk

The relationships between dietary fiber density and ASCVD risk were shown in Fig. 2. There were no statistically significant between dietary fiber density and ASCVD risk in different risk groups (model 1; $P>0.05$). After adjustment for age, gender, family income, education levels, and marital status (model 2), higher dietary fiber density may reduce the ASCVD risk in participants with intermediate risk [odds ratio (OR) = 0.70; 95% confidence interval (CI), 0.57–0.86] and high risk (OR = 0.53; 95%CI, 0.40–0.71) compared with those in low-risk group. After further adjustment for total bilirubin, creatinine, and metabolic syndrome (model 3), higher dietary fiber density was still associated with a reduced ASCVD risk in participants with intermediate-risk (OR = 0.76; 95%CI, 0.61–0.94) and high-risk (OR = 0.60; 95%CI, 0.45–0.81).

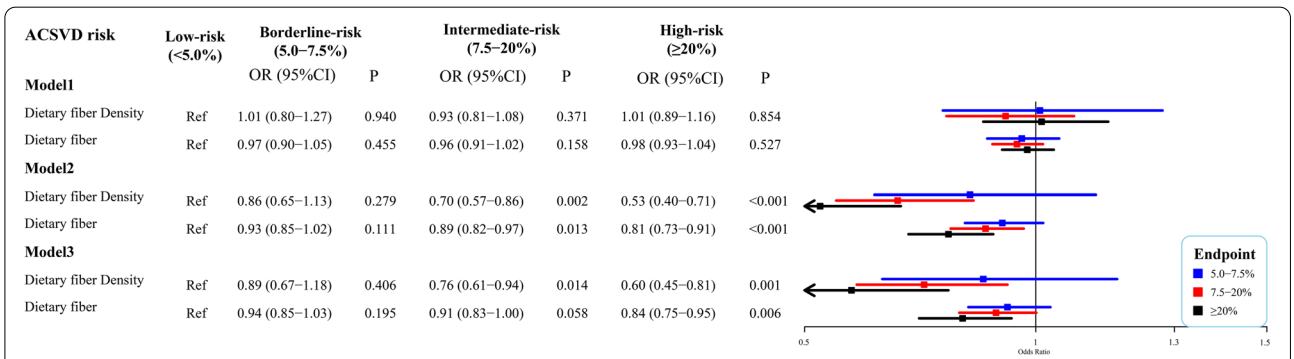

Fig. 2 Weighted logistic regression analysis between dietary fiber and cardiovascular disease (CVD) risk. Model 1, weighted univariate multinomial logistic regression model; Model 2, weighted multinomial multivariate logistic regression model that adjusted for age, gender, family income, education levels, and marital status; Model 3, weighted multinomial multivariate logistic regression model that adjusted for age, gender, family income, education levels, marital status, total bilirubin, creatinine, and metabolic syndrome

The association between total dietary fiber intake and ASCVD risk was also analyzed (Fig. 2). Compared with participants in the ASCVD low-risk group, higher total dietary fiber intake was related to a reduced ASCVD risk in participants with intermediate risk (OR = 0.89; 95%CI, 0.82–0.97) and high risk (OR = 0.81; 95%CI, 0.73–0.91) when adjustment for age, gender, family income, education levels, and marital status. After further adjustment for total bilirubin, creatinine, and metabolic syndrome, higher total dietary fiber intake may still reduce ASCVD risk in participants with high risk (OR = 0.84; 95%CI, 0.75–0.95), while no statistical significance was found among participants in the intermediate-risk group ($P = 0.058$).

Further analysis of the relationship between dietary fiber density and ASCVD risk based on age and gender

As summarized in Fig. 3, subgroup analysis was to further explore the relationship between dietary fiber density and ASCVD risk in age and gender subgroups. The results showed that higher dietary fiber density was associated with a reduced ASCVD risk in intermediate-risk participants aged 20–39 (OR = 0.62; 95%CI, 0.43–0.89) and 40–59 (OR = 0.67; 95%CI, 0.49–0.94) after adjustment for all confounders, while no statistical significances were observed in participants aged ≥ 60 ($P = 0.405$), males ($P = 0.062$) and females ($P = 0.279$). Compared with participants in the low-risk group, higher dietary fiber density may also reduce ASCVD risk in high-risk 20–39-year-old (OR = 0.38; 95%CI, 0.19–0.77), 40–59-year-old (OR = 0.37; 95%CI, 0.20–0.70), male (OR = 0.47; 95%CI, 0.23–0.97) and female (OR = 0.57; 95%CI, 0.38–0.86) participants after adjustment for all confounders, while no statistical significance was found in participants aged ≥ 60 ($P = 0.498$).

Discussion

In this study, we analyzed the association between dietary fiber density and total dietary fiber and long-term CVD risk in different ASCVD risk groups based on a

ACSVD risk	Low-risk (<5.0%)	Borderline-risk (5.0–7.5%)		Intermediate-risk (7.5–20%)		High-risk (≥20%)	
Age		OR (95%CI)	P	OR (95%CI)	P	OR (95%CI)	P
20–39							
Model1	Ref	0.60 (0.43–0.84)	0.004	0.37 (0.25–0.54)	<0.001	0.16 (0.07–0.34)	<0.001
Model2	Ref	0.74 (0.53–1.02)	0.073	0.59 (0.40–0.86)	0.008	0.39 (0.20–0.76)	0.007
Model3	Ref	0.75 (0.53–1.07)	0.115	0.62 (0.43–0.89)	0.012	0.38 (0.19–0.77)	0.009
40–59							
Model1	Ref	0.94 (0.66–1.34)	0.722	0.57 (0.45–0.73)	<0.001	0.36 (0.26–0.49)	<0.001
Model2	Ref	0.85 (0.58–1.25)	0.426	0.59 (0.44–0.80)	0.001	0.38 (0.22–0.68)	0.002
Model3	Ref	0.85 (0.57–1.27)	0.422	0.67 (0.48–0.94)	0.024	0.37 (0.20–0.70)	0.003
≥60							
Model1	Ref	1.23 (0.33–4.53)	0.760	1.23 (0.33–4.53)	0.760	0.65 (0.21–2.02)	0.461
Model2	Ref	1.23 (0.21–7.16)	0.819	1.23 (0.21–7.16)	0.819	0.81 (0.35–1.87)	0.627
Model3	Ref	2.20 (0.35–13.94)	0.405	2.20 (0.35–13.94)	0.405	0.70 (0.24–1.98)	0.498
Gender							
Male							
Model1	Ref	1.23 (0.91–1.66)	0.182	1.22 (0.99–1.50)	0.062	1.40 (1.16–1.68)	<0.001
Model2	Ref	0.84 (0.57–1.22)	0.364	0.67 (0.45–0.98)	0.042	0.43 (0.21–0.88)	0.024
Model3	Ref	0.83 (0.57–1.21)	0.340	0.69 (0.48–1.01)	0.062	0.47 (0.23–0.97)	0.046
Female							
Model1	Ref	0.89 (0.65–1.21)	0.452	0.80 (0.65–0.99)	0.043	0.97 (0.80–1.18)	0.751
Model2	Ref	0.89 (0.62–1.27)	0.517	0.81 (0.61–1.07)	0.149	0.53 (0.35–0.79)	0.003
Model3	Ref	0.93 (0.65–1.33)	0.681	0.85 (0.64–1.14)	0.279	0.57 (0.38–0.86)	0.010

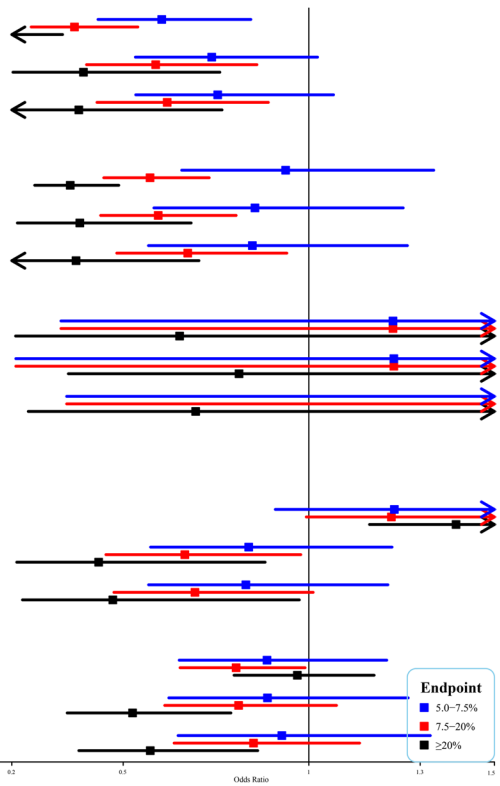

Fig. 3 Weighted logistic regression analysis between dietary fiber density and CVD risk in age and gender subgroups. Model 1, weighted univariate multinomial logistic regression model; Model 2, weighted multinomial multivariate logistic regression model that adjusted for age/gender, family income, education levels, and marital status; Model 3, weighted multinomial multivariate logistic regression model that adjusted for age/gender, family income, education levels, marital status, total bilirubin, creatinine, and metabolic syndrome

large sample from the NHANES database. Our results found that both higher dietary fiber density and total dietary fiber were associated with a reduced long-term ASCVD risk in the intermediate-risk and high-risk groups. Subgroup analyses showed that higher dietary fiber density was still related to a reduced ASCVD risk in intermediate-risk and high-risk participants aged 20–39 and 40–59, as well as in high-risk male and female participants.

Dietary fiber has been shown to have multiple health benefits, but the average daily intake for most Americans is 15 g/day, which is below the recommended amount [12]. According to the results of epidemiological studies on the protective effect of dietary fiber intake, the recommended dietary reference intake of dietary fiber is 14 g/1000 kcal [13]. Our results showed that higher dietary fiber density and total dietary fiber intake were associated with a lower long-term CVD risk. Previous studies have focused on the association between dietary fiber intake and short-term and medium-term CVD risk [8–10], while our results provided the relationship between dietary fiber density and total dietary fiber intake and long-term CVD risk. Numerous studies suggested that total dietary fiber was inversely related to the risk of weight gain [14], coronary heart disease [15], high blood pressure [16], and CVD death [17]. Several biological mechanisms may explain the association between higher dietary fiber intake and lower CVD risk. First, dietary fiber may reduce the CVD risk by reducing the coagulation activity of type 1 plasminogen activator inhibitor and coagulation factor VII [18, 19]. Second, higher dietary fiber intake may be related to lower inflammatory response. Several studies have reported that higher dietary fiber intake can reduce the levels of inflammatory markers such as C-reactive protein [20, 21]. Third, the protective effect of dietary fiber on CVD may be associated with metabolic diseases, that is, dietary fiber may regulate the intestinal microbiota, which plays an important role in the development of metabolic diseases such as atherosclerosis, obesity and type 2 diabetes [22–24].

Our results found that higher dietary fiber density was significantly associated with a lower CVD risk in participants aged 20–39 and 40–59. The possible explanation was that the relationship between high dietary fiber intake and low CVD risk was related to the general health of the population, the absorption of fiber, and the incidence of obesity. Edwards et al. demonstrated that young people in many countries had insufficient intake of dietary fiber [25]. Yamada et al. indicated that adults aged 30–40 had a rapid increase in BMI [26]. These may be due to the fact that the consumption of a large number of refined carbohydrates, lipids, and low dietary fiber foods was conducive to weight gain [27–29]. In addition, dietary fiber has been used for the prevention and treatment of obesity [30, 31]. Studies have shown that obesity is an important risk factor for CVD [32, 33]. The type and absorption of dietary fiber may also affect the CVD risk. McKeown et al. demonstrated that cereal fiber intake was associated with a reduction in the prevalence of metabolic syndrome, but not with total fiber and fruit fiber intake [34]. Mirmiran et al. found that the intake of different types of dietary fiber was related to a reduced CVD risk, especially soluble dietary fiber [35]. Our results may also indicate that the earlier intake of high dietary fiber, the better the protection against CVD.

Some strengths were presented in this study, we analyzed the impact of dietary fiber density and total dietary fiber on long-term CVD risk in different risk groups based on ASCVD. Dietary fiber density considered the factor of energy, which can better reflect the overall situation of individual dietary fiber in daily diet. Therefore, further analysis was performed to explore the relationship between dietary fiber density and ASCVD risk in age and gender subgroups. However, this study had some limitations. First, the effect of insoluble and soluble fiber intake on CVD risk could not be analyzed because of the lack of data. Second, we did not analyze the effect of different dietary fiber intake doses on CVD risk. Third, a dietary fiber intake of 14 g/1000 kcal had a better protective effect [12, 13], while the median dietary fiber intake of our study population was 7.81 g/1000 kcal, which may reduce the accuracy of our results. Fourth, some variables related to CVD, such as genetic factors could not be analyzed due to the database limitations. Fifth, mental state and sleep duration were associated with CVD risk [36, 37], but we did not analyze the effects of these variables, which may be potentially confounding.

Conclusion

Higher dietary fiber density and total dietary fiber were associated with a lower long-term CVD risk. Higher dietary fiber density was most significantly related to a lower ASCVD risk in people aged 20–39 and 40–59. Young people may benefit more from a high intake of dietary fiber to protect against CVD.

Abbreviations

CVD: Cardiovascular diseases; NHANES: National Health and Nutrition Examination Survey; NCHS: National Center of Health Statistics; CDC: Centers for Disease Control and Prevention; MEC: Mobile examination center; USDA: United States Department of Agriculture; TC: Total cholesterol; HDL: High-density lipoprotein; FRS: Framingham risk score; SD: Standard deviation; M (Q1, Q3): Median and interquartile range.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-022-13419-y.

Additional file 1.

Additional file 2: Supplement Table 1. Multicollinearity diagnosis for weighted models.

Acknowledgements
Not applicable.

Authors' contributions
SZ, JT and YZ designed the study. SZ and JT wrote the manuscript. ML and CZ collected, analyzed and interpreted the data. YZ critically reviewed, edited and approved the manuscript. All authors read and approved the final manuscript.

Funding
Not applicable.

Availability of data and materials
The datasets generated and/or analyzed during the current study are available in the National Health and Nutrition Examination Survey public database, https://www.cdc.gov/nchs/nhanes/index.htm.

Declarations

Ethics approval and consent to participate
This research analyzed de-identified information downloaded from the National Health and Nutrition Examination Survey public database, which is exempt from future Institutional Review Board approval. All experiments were performed in accordance with relevant guidelines and regulations.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Department of Geriatrics, Chongqing University Fuling Hospital, Chongqing Clinical Research Center for Geriatric Diseases, Chongqing 408000, People's Republic of China. [2]Department of Cardiovascular Medicine CCU, Hanzhong People's Hospital, No.251 North Unity Street, Hantai District, Hanzhong 723000, Shaanxi, People's Republic of China.

Received: 5 January 2022 Accepted: 3 May 2022
Published online: 31 May 2022

References

1. Zhou M, Wang H, Zhu J, Chen W, Wang L, Liu S, et al. Cause-specific mortality for 240 causes in China during 1990–2013: a systematic subnational analysis for the global burden of disease study 2013. Lancet (London, England). 2016;387(10015):251–72.
2. Yang G, Wang Y, Zeng Y, Gao GF, Liang X, Zhou M, et al. Rapid health transition in China, 1990–2010: findings from the global burden of disease study 2010. Lancet (London, England). 2013;381(9882):1987–2015.
3. Leong DP, Joseph PG, McKee M, Anand SS, Teo KK, Schwalm JD, et al. Reducing the global burden of cardiovascular disease, part 2: prevention and treatment of cardiovascular disease. Circ Res. 2017;121(6):695–710.
4. Liu S, Li Y, Zeng X, Wang H, Yin P, Wang L, et al. Burden of cardiovascular diseases in China, 1990–2016: findings from the 2016 global burden of disease study. JAMA Cardiology. 2019;4(4):342–52.
5. Yusuf S, Joseph P, Rangarajan S, Islam S, Mente A, Hystad P, et al. Modifiable risk factors, cardiovascular disease, and mortality in 155 722 individuals from 21 high-income, middle-income, and low-income countries (PURE): a prospective cohort study. Lancet (London, England). 2020;395(10226):795–808.
6. McEvoy JW. Lifetime risks of cardiovascular disease. N Engl J Med. 2012;366(17):1642–3.
7. Pereira MA, Liu S. Types of carbohydrates and risk of cardiovascular disease. J Women's Health (2002). 2003;12(2):115–22.
8. Murai U, Yamagishi K, Sata M, Kokubo Y, Saito I, Yatsuya H, et al. Seaweed intake and risk of cardiovascular disease: the Japan Public Health Center-based Prospective (JPHC) study. Am J Clin Nutr. 2019;110(6):1449–55.
9. Song S, Song Y. Dietary fiber and its source are associated with cardiovascular risk factors in Korean adults. Nutrients. 2021;13(1):160.
10. Wang AY, Sea MM, Ng K, Wang M, Chan IH, Lam CW, et al. Dietary fiber intake, myocardial injury, and major adverse cardiovascular events among end-stage kidney disease patients: a prospective cohort study. Kidney Int Rep. 2019;4(6):814–23.
11. Arnett DK, Blumenthal RS, Albert MA, Buroker AB, Goldberger ZD, Hahn EJ, et al. 2019 ACC/AHA guideline on the primary prevention of cardiovascular disease: a report of the American College of Cardiology/American heart association task force on clinical practice guidelines. Circulation. 2019;140(11):e596-646.
12. Lloyd-Jones DM, Hong Y, Labarthe D, Mozaffarian D, Appel LJ, Van Horn L, et al. Defining and setting national goals for cardiovascular health promotion and disease reduction: the American heart association's strategic impact goal through 2020 and beyond. Circulation. 2010;121(4):586–613.
13. Slavin JL. Position of the American Dietetic Association: health implications of dietary fiber. J Am Diet Assoc. 2008;108(10):1716–31.
14. Du H, van der AD, Boshuizen HC, Forouhi NG, Wareham NJ, Halkjaer J, et al. Dietary fiber and subsequent changes in body weight and waist circumference in European men and women. Am J Clin Nutr. 2010;91(2):329–36.
15. AlEssa HB, Cohen R, Malik VS, Adebamowo SN, Rimm EB, Manson JE, et al. Carbohydrate quality and quantity and risk of coronary heart disease among US women and men. Am J Clin Nutr. 2018;107(2):257–67.
16. Aljuraiban GS, Griep LM, Chan Q, Daviglus ML, Stamler J, Van Horn L, et al. Total, insoluble and soluble dietary fibre intake in relation to blood pressure: the INTERMAP Study. Br J Nutr. 2015;114(9):1480–6.
17. Kim Y, Je Y. Dietary fibre intake and mortality from cardiovascular disease and all cancers: a meta-analysis of prospective cohort studies. Arch Cardiovasc Dis. 2016;109(1):39–54.
18. Anderson JW, Tietyen-Clark J. Dietary fiber: hyperlipidemia, hypertension, and coronary heart disease. Am J Gastroenterol. 1986;81(10):907–19.
19. Anderson JW, Chen WJ, Plant fiber. Carbohydrate and lipid metabolism. Am J Clin Nutr. 1979;32(2):346–63.
20. North CJ, Venter CS, Jerling JC. The effects of dietary fibre on C-reactive protein, an inflammation marker predicting cardiovascular disease. Eur J Clin Nutr. 2009;63(8):921–33.
21. Ajani UA, Ford ES, Mokdad AH. Dietary fiber and C-reactive protein: findings from national health and nutrition examination survey data. J Nutr. 2004;134(5):1181–5.
22. Miele L, Giorgio V, Alberelli MA, De Candia E, Gasbarrini A, Grieco A. Impact of gut microbiota on obesity, diabetes, and cardiovascular disease risk. Curr Cardiol Rep. 2015;17(12):120.
23. Hamaker BR, Tuncil YE. A perspective on the complexity of dietary fiber structures and their potential effect on the gut microbiota. J Mol Biol. 2014;426(23):3838–50.
24. Parnell JA, Reimer RA. Prebiotic fiber modulation of the gut microbiota improves risk factors for obesity and the metabolic syndrome. Gut Microbes. 2012;3(1):29–34.
25. Edwards CA, Xie C, Garcia AL. Dietary fibre and health in children and adolescents. Proc Nutr Soc. 2015;74(3):292–302.
26. Yamada G, Castillo-Salgado C, Jones-Smith JC, Moulton LH. Differences in magnitude and rate of change in adult obesity distribution by age and sex in Mexico, Colombia and Peru, 2005–2010. Public Health Nutr. 2019;22(4):757–63.
27. Azeredo CM, de Rezende LF, Canella DS, Moreira Claro R, de Castro IR, Luiz Odo C, et al. Dietary intake of Brazilian adolescents. Public Health Nutr. 2015;18(7):1215–24.
28. Hoppu U, Lehtisalo J, Tapanainen H, Pietinen P. Dietary habits and nutrient intake of Finnish adolescents. Public Health Nutr. 2010;13(6a):965–72.
29. Moreno LA, Rodriguez G, Fleta J, Bueno-Lozano M, Lazaro A, Bueno G. Trends of dietary habits in adolescents. Crit Rev Food Sci Nutr. 2010;50(2):106–12.

30. Wanders AJ, van den Borne JJ, de Graaf C, Hulshof T, Jonathan MC, Kristensen M, et al. Effects of dietary fibre on subjective appetite, energy intake and body weight: a systematic review of randomized controlled trials. Obes Rev. 2011;12(9):724–39.
31. Bulló M, Casas-Agustench P, Amigó-Correig P, Aranceta J, Salas-Salvadó J. Inflammation, obesity and comorbidities: the role of diet. Public Health Nutr. 2007;10(10a):1164–72.
32. Ortega FB, Lavie CJ, Blair SN. Obesity and cardiovascular disease. Circ Res. 2016;118(11):1752–70.
33. Mandviwala T, Khalid U, Deswal A. Obesity and cardiovascular disease: a risk factor or a risk marker? Curr Atheroscler Rep. 2016;18(5):21.
34. McKeown NM, Meigs JB, Liu S, Saltzman E, Wilson PW, Jacques PF. Carbohydrate nutrition, insulin resistance, and the prevalence of the metabolic syndrome in the Framingham Offspring Cohort. Diabetes Care. 2004;27(2):538–46.
35. Mirmiran P, Bahadoran Z, Khalili Moghadam S, Zadeh Vakili A, Azizi F. A prospective study of different types of dietary fiber and risk of cardiovascular disease: Tehran Lipid and Glucose Study. Nutrients. 2016;8(11):686.
36. Ai S, Zhang J, Zhao G, Wang N, Li G, So HC, et al. Causal associations of short and long sleep durations with 12 cardiovascular diseases: linear and nonlinear Mendelian randomization analyses in UK Biobank. Eur Heart J. 2021;42(34):3349–57.
37. Kubzansky LD, Huffman JC, Boehm JK, Hernandez R, Kim ES, Koga HK, et al. Positive psychological well-being and cardiovascular disease: JACC health promotion series. J Am Coll Cardiol. 2018;72(12):1382–96.

Publisher's Note