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Association between dietary fiber intake and peripheral artery disease in hypertensive patients

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Abstract

Background At present, no studies explored whether dietary fiber intake was associated with the risk of peripheral artery disease (PAD) in hypertensive patients. This study assessed the association between dietary fiber intake and PAD in hypertensive patients.

Methods This cross-sectional study collected the data of 4628 participants with the measurement of ankle-brachial pressure index in the National Health and Nutrition Examination Surveys database. Univariate logistic regression analysis was applied to identify variables associated with PAD as confounding factors. Univariate and multivariable logistic regression analyses were used to explore the association between dietary fiber intake and PAD in hypertensive patients. Subgroup analysis was stratified by age, cardiovascular disease, dyslipidemia, diabetes, smoking, and physical activity.

Results After adjusting for confounding factors, decreased risk of PAD was observed in hypertensive patients with dietary fiber intake > 21 g [odds ratio (OR) = 0.67, 95% confidence interval (CI) 0.46–0.99]. Compared with people with dietary fiber intake ≤ 21 g, those with dietary fiber intake > 21 g were associated with decreased risk of PAD in hypertensive patients < 60 years (OR = 0.23, 95%CI 0.08–0.66). In hypertensive patients without dyslipidemia, dietary fiber intake > 21 g were associated with reduced risk of PAD (OR = 0.33, 95%CI 0.12–0.95). Decreased risk of PAD was also found in hypertensive patients without diabetes in dietary fiber intake > 21 g group (OR = 0.50, 95%CI 0.31–0.78). Dietary fiber intake > 21 g was linked with reduced risk of PAD in hypertensive patients in never smoke group (OR = 0.46, 95%CI 0.24–0.86).

Conclusion Higher dietary fiber intake was associated with reduced risk of PAD in hypertensive patients, suggesting the importance of increase the daily dietary quality especially fiber intake in hypertensive people.

Keywords Dietary fiber intake, Peripheral artery disease, Hypertensive patients, Cross-sectional study, Smoking, Physical activity

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Introduction

Peripheral artery disease (PAD) is defined as an atherosclerotic vascular disease of the lower extremities characterized by narrowing and obstruction of the peripheral arteries, and the main pathogenic factor is athermanous plaques [1]. PAD is a significant global health problem affecting about 10% of people all over the world, and approximately 15%-20% of them are more than 70 years [2]. PAD causes leg pain, impaired health-related quality of life, immobility, tissue loss and a high risk of major adverse events [3]. Multiple studies have reported that blood pressure is closely related to the risk of PAD and the risk of PAD was increased with the increase of blood pressure [4, 5]. Recent studies have found that PAD is associated with poor outcomes in hypertensive patients, including left ventricular hypertrophy [6, 7], increased risk of cardiovascular events [8], and increased risk of all-cause mortality and cardiovascular mortality in hypertensive population [9]. To explore the related factors affecting the risk of PAD in hypertensive patients was of great importance.

Dietary nutrient intake has been previously identified to be associated with cardiovascular diseases, including peripheral artery disease (PAD) [10]. However, Horina et al. revealed that only 5% subjects achieved the recommended daily fiber intake [11]. Several cross-sectional or cohort studies found that patients with PAD tend to consume lower amounts of dietary fiber [12, 13]. A prospective cohort study and a cross-sectional study indicated that people who consume higher amounts of total dietary fiber were found to be associated with a reduced risk of PAD [14, 15]. These studies were performed in general population, whether dietary fiber intake had association with the risk of PAD in hypertensive patients was still unclear.

The purpose of the current study was to identify the association between dietary fiber intake and the risk of PAD in hypertensive patients based on the data from the National Health and Nutrition Examination Surveys (NHANES).

Methods

Study design and population

This cross-sectional study collected the data of 9970 participants with the measurement of ankle-brachial pressure index (ABPI) in the National Health and Nutrition Examination Surveys (NHANES) database. The NHANES is a cross-sectional, population-based study of the non-institutionalized, civilian population in the US assessing the health and nutritional status of adults and children. The data collected in NHANES included an in-home interview portion and a physical exam portion in a mobile examination center. The interview consists of demographic, socioeconomic, dietary, and health-related questions, and the physical exam portion includes medical, dental, physiological and laboratory measurements [16]. The ABPI was measured in 1999–2000, 2001–2002 and 2003–2004 cycles, and the current study used the data from these three cycles. Those without complete data to diagnose PAD, without data on dietary recall, weight, or height, people with no dietary fiber intake, non-hypertensive population, energy intake < 800 kcal or 60,000 kcal in males, or energy intake < 600 kcal or > 4000 kcal in females (extreme energy intake might affect fiber intake) were excluded. Finally, 4628 participants were included. The study got the NCHS Ethics Review Board (ERB) approval [NHANES 1999–2004 (approval number: Protocol #98–12)]. Our research was exempt from review by the Ethics Review Board of Shenzhen People's Hospital (The Second Clinical Medical College, Jinan University; The First Affiliated Hospital, Southern University of Science and Technology) because the NHANES is de-identified. All individuals provided written informed consent before participating in the study. All methods were carried out in accordance with relevant guidelines and regulations (declaration of Helsinki).

Potential confounders and definitions

Age (years), gender, race (Mexican American, other Hispanic, non-Hispanic White, non-Hispanic Black or other race-including multi-racial), education [less than 9th grade, 9-11th grade (includes 12th grade with no diploma), high school graduate/general equivalent diploma (GED) or equivalent, some college or associate degree, or college graduate or above], physical activity (yes or no), smoking (never, former smoker or current smoker), drinking (once/week or ≥ once/week), CVD (yes or no), dyslipidemia (yes or no), diabetes (yes or no), height (cm), weight (kg), body mass index (BMI; kg/m^2), waist circumference (cm) and energy (kcal were potential confounders analyzed in this study.

Physical activity was defined based on the answer of "yes" to the variables PAD200 (whether you have done at least 10 min of vigorous exercise in the past 30 days?), PAD020 (whether you have done walking or cycling in the past 30 days?), PAD320 (whether you have done at least 10 min of moderate intensity exercise in the past 30 days?) or PAD100 (whether you have done at least 10 min of labor in your home, yard, or garden in the past 30 days?) [17]. Never smoking was identified based on the answer of "No" to SMQ020 (smoked at least 100 cigarettes in life). Former smoker was defined based on the answer of "No" to SMQ020 and "Yes" to SMQ040 (do you now smoke cigarettes?). Current smoker was identified based on the answer of "Yes" to SMQ020 and SMQ040

[18]. CVD was defined based on the answer of "Yes" to variable MCQ160D (Ever told you had angina or heart failure?), MCQ160E (Ever told you had heart attack?), MCQ160C (Has a doctor or other health professional ever told you that you had coronary heart disease?), MCQ160F (Ever told you had a stroke?), MCQ160B (Ever told had congestive heart failure?), or those received CVD drugs based on 40-CARDIOVASCULAR AGENTS-41, 43, 44, 45, 46, 50, 51, 52, 53, 54, 56, 303, 340, 342, 430, 433, 483. Dyslipidemia was defined based on total cholesterol ≥ 200 mg/dL (5.2 mmol/L) or triglyceride ≥ 150 mg/dL (1.7 mmol/L) or low-density lipoprotein cholesterol ≥ 130 mg/dL (3.4 mmol/L) or high-density lipoprotein cholesterol ≤ 40 mg/dL (1.0 mmol/L), self-reported hypercholesterolemia (BPQ080) or receiving cholesterol-lowering treatment (BPQ090D) or lipid-lowering drugs (358-metabolic agents-19-antihyperlipemic agents). Hypertension was defined as systolic blood pressure ≥ 130 mmHg and or diastolic blood pressure ≥ 80 mmHg or self-reported hypertension (BPQ020) or take blood pressure medications (BPQ040A or drug code 40-CARDIOVASCULAR AGENTS-42, 47, 48, 49, 482, 55). Diabetes was diagnosed based on glycated hemoglobin ≥ 6.5%, fasting glucose ≥ 126 mg/dL, 2 h oral glucose tolerance test blood glucose ≥ 200 mg/dL, self-reported diagnosis of diabetes [DIQ010 (Doctor told you have diabetes)], insulin use (DIQ050) or antidiabetic agents (DIQ070 or 358-metabolic Agents-99-antidiabetic agents). Energy was calculated based on energy intake from Day 1 dietary recall, and the variable in the NHANES database from 1999 to 2002 was DRXTKCAL and from 2003–2004 was DR1TKCAL.

Main variable and outcome variable

The Day 1 dietary fiber intake was the main variable in our study, which was collected in the Mobile Exam Center (MEC). The variable in the NHANES database from 1999 to 2002 was DRXTFIBE, from 2003–2004 was DR1TFIBE.

PAD was the outcome in this study, which was diagnosed based on left or right ABPI < 0.9 [19]. The left ABPI was obtained via the LEXLABPI variable and the right ABPI was obtained via the LEXRABPI variable in the NHANES database. The ABPI exam in the NHANES database was strictly conducted according to certain protocol and procedure, and quality assurance and quality control were performed (https://wwwn.cdc.gov/Nchs/Nhanes/2001-2002/LEXAB_B.htm).

Statistical analysis

The measurement data were reported as Mean [standard error (SE)], and comparisons between the two groups was performed by t-test. The enumeration data were presented as the numbers and percentages of cases [n (%)], and group comparisons were conducted using either the χ^2 test or Fisher's exact probability method. SDMVSTRA and SDMVPSU were taken as weighted variables [20]. Multiple imputation was applied to handle the missing values (Supplementary Table 1), and comparisons of the data before and after missing values imputation were performed (Supplementary Table 2). Univariate logistic regression analysis was utilized to identify potential confounding factors, while both univariate and multivariable logistic regression analyses were employed to investigate the relationship between dietary fiber intake and PAD in hypertensive patients. In the multivariable logistic regression model, age, education, physical activity, smoking, drinking, CVD, dyslipidemia, diabetes, and energy were adjusted. Hosmer–Lemeshow goodness-of-fit test was applied for evaluating the goodness-of-fit of the model (Supplementary Table 3). Whether there were multicollinearity among variables was evaluated, and no multicollinearity was found among variables (Supplementary Table 4). Subgroup analysis was stratified by age, CVD, dyslipidemia, diabetes, smoking, and physical activity. The confidence level was 0.05. SAS9.4 software (SAS Institute Inc., Cary, NC, USA) was used for statistical analysis and R Studio version 4.2.1 was used for plotting the forest map.

Results

Comparisons of the characteristics between participants with and without PAD

In total, 9970 participants with the measurement of ABPI were identified from NHANES. Among them, subjects without the complete data to diagnose PAD (n = 3030), without data on dietary recall, or no dietary fiber intake (n = 178), without data on height (n = 54) or weight (n = 6), non-hypertensive population (n = 1908), energy intake < 800 kcal or 60000 kcal in males (n = 87), or energy intake < 600 kcal or > 4000 kcal in females (n = 79) were excluded. Finally, 4628 participants were included. The screen process was exhibited in Fig. 1.

The mean age of the PAD group was higher than the non-PAD group (68.22 years vs. 58.02 years). The percentage of participants with physical activity (69.58% vs. 81.76%), drank ≥ once/week (21.84% vs. 33.00%) in the PAD group was lower than the non-PAD group. The percentage of people with CVD (77.87% vs 53.08%), dyslipidemia (90.35% vs 85.69%), and diabetes (52.19% vs 32.29%) in the PAD group was higher than the non-PAD group. The mean standing height in the PAD group was lower than the non-PAD group (166.33 cm vs. 168.87 cm). The mean weight in the PAD group was lower than the non-PAD group (80.37 kg vs. 82.73 kg). The mean fiber intake (0.66 gm vs 0.32 gm) and energy

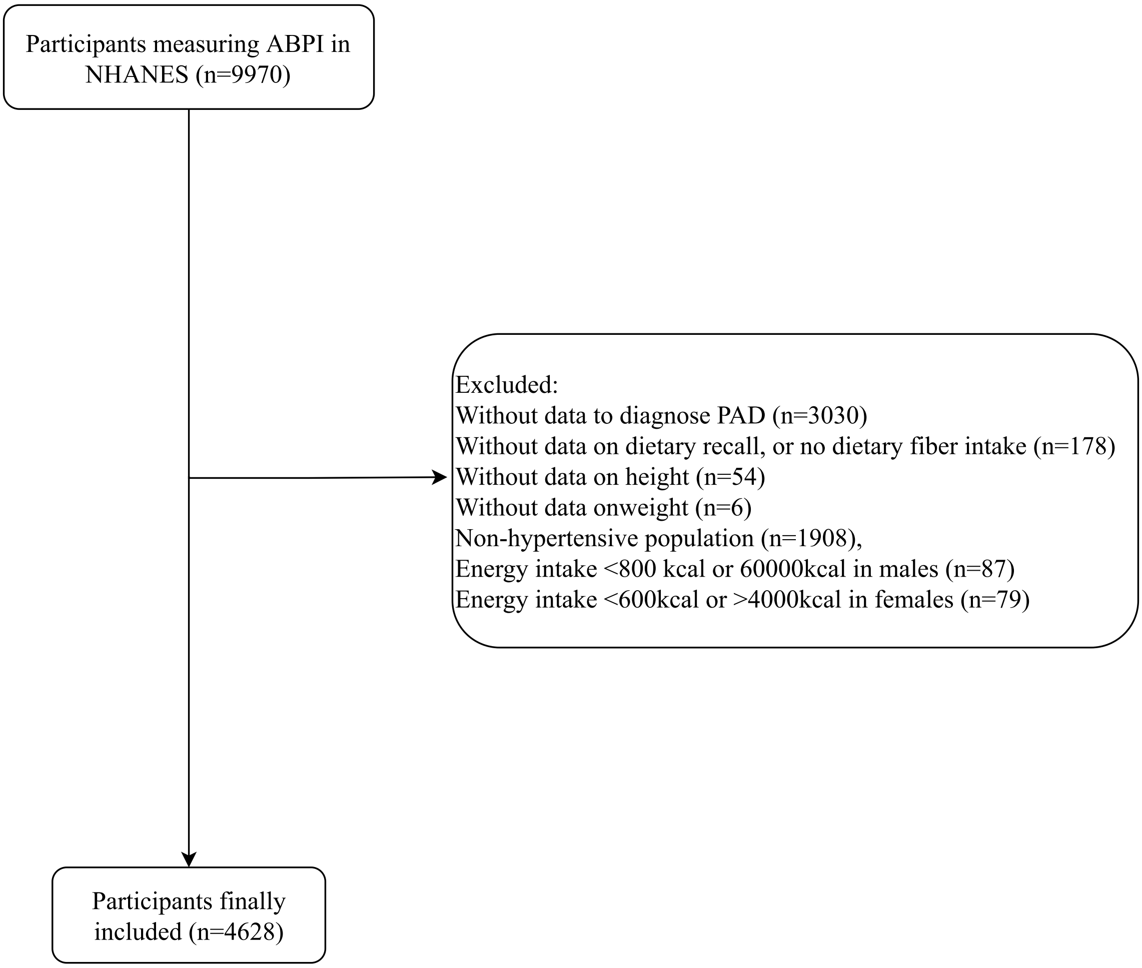

Fig. 1 The screen process of the study population

intake (39.73 kcal vs. 21.46 kcal) in the PAD group was higher than the non-PAD group (Table 1).

Potential confounding factors for the risk of PAD in hypertensive population

Variables might be related to PAD were regarded as covariates, which were explored by univariate logistic regression analysis. Variables were identified. Potential confounding factors with statistical association with PAD in hypertensive population were identified. As exhibited in Table 2, age (OR = 1.07, 95%CI 1.06–1.08), education-high school graduate/GED or equivalent (OR = 0.62, 95%CI 0.42–0.90), education-some college or AA degree (OR = 0.49, 95%CI 0.32–0.74), education-college graduate or above (OR = 0.36, 95%CI 0.23–0.56), physical activity (OR = 0.51, 95%CI 0.39–0.67), smoking-former smoker (OR = 1.83, 95%CI 1.30–2.59), smoking-current smoker (OR = 2.06, 95%CI 1.52–2.81), drinking (OR = 0.57, 95%CI 0.42–0.76), CVD (OR = 3.11, 95%CI 2.22–4.36), dyslipidemia (OR = 1.56, 95%CI 1.12–2.18), and diabetes (OR = 2.29, 95%CI 1.78–2.94) might be confounding factors associated with the risk of PAD in hypertensive population.

Association between dietary fiber intake and PAD in hypertensive patients

Univariate and multivariable regression analysis were applied to assess the association between dietary fiber intake and PAD in hypertensive patients. The results delineated that dietary fiber intake > 21 g might be associated with decreased risk of PAD in hypertensive patients (OR = 0.53, 95%CI 0.37–0.77). After adjusting for age, education, physical activity, smoking, drinking, CVD, dyslipidemia, diabetes, and energy, decreased risk of PAD was observed in hypertensive patients with dietary fiber intake > 21 g (OR = 0.67, 95%CI 0.46–0.99) (Table 3, Fig. 2). Also sensitivity analysis was performed by dividing fiber intake into two categories according to 75% fractile (< 20.3 g and ≥ 20.3 g). The results depicted that fiber intake ≥ 20.3 g might be associated with decreased

Table 1 The characteristics of participants with and without PAD

Variables	Total (n = 4628)	PAD status		Statistics	P
		No PAD (n = 4157)	PAD (n = 471)		
Age, years, Mean (S.E)	58.77 (0.30)	58.02 (0.29)	68.22 (0.54)	t = -21.51	< .001
Gender, n (%)				χ^2 = 1.120	0.290
Male	2427 (50.54)	2187 (50.80)	240 (47.36)		
Female	2201 (49.46)	1970 (49.20)	231 (52.64)		
Race, n (%)				χ^2 = 12.916	0.012
Mexican American	903 (3.98)	824 (3.98)	79 (3.95)		
Other Hispanic	162 (3.51)	150 (3.58)	12 (2.55)		
Non-Hispanic White	2546 (78.41)	2276 (78.42)	270 (78.29)		
Non-Hispanic Black	876 (10.19)	772 (9.89)	104 (13.91)		
Other Race—Including Multi-Racial	141 (3.91)	135 (4.12)	6 (1.29)		
Education Level, n (%)				χ^2 = 23.492	< .001
Less than 9th grade	823 (7.65)	712 (7.23)	111 (12.97)		
9-11th grade (Includes 12th grade with no diploma)	741 (13.63)	659 (13.35)	82 (17.07)		
High school graduate/GED or equivalent	1164 (27.76)	1035 (27.55)	129 (30.40)		
Some college or associate degree	1082 (26.66)	993 (26.92)	89 (23.46)		
College graduate or above	818 (24.30)	758 (24.95)	60 (16.10)		
Physical activity, n (%)				χ^2 = 21.952	< .001
No	1166 (19.13)	985 (18.24)	181 (30.42)		
Yes	3462 (80.87)	3172 (81.76)	290 (69.58)		
Smoking, n (%)				χ^2 = 23.696	< .001
Never	2119 (45.67)	1957 (46.79)	162 (31.52)		
Former smoker	1700 (35.98)	1493 (35.37)	207 (43.67)		
Current smoker	809 (18.34)	707 (17.83)	102 (24.81)		
Drinking, n (%)				χ^2 = 14.648	< .001
< once/week	3322 (67.81)	2955 (67.00)	367 (78.16)		
≥ once/week	1306 (32.19)	1202 (33.00)	104 (21.84)		
CVD, n (%)				χ^2 = 49.386	< .001
No	1951 (45.10)	1852 (46.92)	99 (22.13)		
Yes	2677 (54.90)	2305 (53.08)	372 (77.87)		
Dyslipidemia, n (%)				χ^2 = 7.490	0.006
No	654 (13.97)	605 (14.31)	49 (9.65)		
Yes	3974 (86.03)	3552 (85.69)	422 (90.35)		
Diabetes, n (%)				χ^2 = 44.781	< .001
No	2914 (66.25)	2687 (67.71)	227 (47.81)		
Yes	1714 (33.75)	1470 (32.29)	244 (52.19)		
Standing Height, cm, Mean (S.E)	168.69 (0.16)	168.87 (0.18)	166.33 (0.59)	t = 3.97	< .001
Weight, kg, Mean (S.E)	82.55 (0.44)	82.73 (0.45)	80.37 (1.10)	t = 2.05	0.046
Body Mass Index, kg/m^2, Mean (S.E)	28.89 (0.14)	28.89 (0.15)	28.96 (0.32)	t = -0.19	0.852
Waist Circumference, cm, Mean (S.E)	100.64 (0.33)	100.52 (0.36)	102.21 (0.86)	t = -1.81	0.077
Left ABPI, Mean (S.E)	1.12 (0.00)	1.14 (0.00)	0.83 (0.01)	t = 28.20	< .001
Right ABPI, Mean (S.E)	1.11 (0.00)	1.13 (0.00)	0.81 (0.01)	t = 28.45	< .001
Fiber, gm, Mean (S.E)	15.93 (0.31)	16.04 (0.32)	14.51 (0.66)	t = 2.34	0.024
Fiber level, n (%)				χ^2 = 11.847	< .001
≤ 21 g	3547 (76.44)	3154 (75.73)	393 (85.40)		
> 21 g	1081 (23.56)	1003 (24.27)	78 (14.60)		
Energy, kcal, Mean (S.E)	2030.49 (20.05)	2050.52 (21.46)	1777.34 (39.73)	t = 6.09	< .001

PAD: Peripheral artery disease, S.E: Standard error, GED: General equivalent diploma, CVD: Cardiovascular disease, ABPI: Ankle-brachial pressure index

Table 2 Potential confounding factors for the risk of PAD in hypertensive population

Variables	OR (95%CI)	*P*
Age	1.07 (1.06–1.08)	<.001
Gender		
Male	Ref	
Female	1.15 (0.88–1.49)	0.293
Race		
Mexican American	Ref	
Other Hispanic	0.72 (0.29–1.79)	0.469
Non-Hispanic White	1.01 (0.62–1.62)	0.978
Non-Hispanic Black	1.42 (0.77–2.60)	0.253
Other Race—Including Multi-Racial	0.32 (0.10–1.00)	0.051
Education Level		
Less than 9th grade	Ref	
9-11th grade (Includes 12th grade with no diploma)	0.71 (0.48–1.05)	0.084
High school graduate/GED or equivalent	0.62 (0.42–0.90)	0.014
Some college or AA degree	0.49 (0.32–0.74)	0.001
College graduate or above	0.36 (0.23–0.56)	<.001
Physical activity		
No	Ref	
Yes	0.51 (0.39–0.67)	<.001
Smoking		
Never	Ref	
Former smoker	1.83 (1.30–2.59)	<.001
Current smoker	2.06 (1.52–2.81)	<.001
Drinking		
<1 times/week	Ref	
≥1 times/week	0.57 (0.42–0.76)	<.001
CVD		
No	Ref	
Yes	3.11 (2.22–4.36)	<.001
Dyslipidemia		
No	Ref	
Yes	1.56 (1.12–2.18)	0.009
Body Mass Index	1.00 (0.98–1.02)	0.851
Waist Circumference	1.01 (1.00–1.02)	0.076
Diabetes		
No	Ref	
Yes	2.29 (1.78–2.94)	<.001

PAD: Peripheral artery disease, OR: Odds ratio, CI: Confidence interval, GED: General equivalent diploma, CVD: Cardiovascular disease

risk of PAD in hypertensive patients (OR = 0.68, 95%CI 0.47–0.98) (Supplementary Table 5). Sensitivity analysis was performed to compare the results before and after the missing values imputation, and similar results were obtained (Supplementary Table 6).

Table 3 Association between dietary fiber intake and PAD in hypertensive patients

Variables	Model 1		Model 2	
	OR (95%CI)	*P*	OR (95%CI)	*P*
Fiber level				
Fiber ≤ 21 g	Ref		Ref	
Fiber > 21 g	0.53 (0.37–0.77)	0.001	0.67 (0.46–0.99)	0.043

OR: odds ratio, CI: confidence interval

Model 1: The crude model

Model 2: Adjusted for age, education, physical activity, smoking, drinking, CVD, dyslipidemia, diabetes, and energy

Subgroup analysis of association between dietary fiber intake and PAD in hypertensive patients

Compared with people with dietary fiber intake ≤ 21 g, those with dietary fiber intake > 21 g were associated with decreased risk of PAD in hypertensive patients < 60 years (OR = 0.23, 95%CI 0.08–0.66). Decreased risk of PAD was found in hypertensive patients without dyslipidemia (OR = 0.33, 95%CI 0.12–0.95), without diabetes (OR = 0.50, 95%CI 0.31–0.78) or in never smoke group (OR = 0.46, 95%CI 0.24–0.86) in dietary fiber intake > 21 g group (Table 4).

Discussion

The current study measured the association between dietary fiber intake and the risk of PAD in hypertensive patients. The results revealed that dietary fiber intake greater than 21 g was associated with decreased risk of PAD in hypertensive patients. Subgroup analysis indicated that the association between dietary fiber intake greater than 21 g and decreased risk of PAD in hypertensive patients was statistical different in those less than 60 years, without dyslipidemia, without diabetes or never smoke population. The findings might offer a reference for the improvement of dietary quality in hypertensive people.

Dietary fiber has recently been a focus of research attention due to the wide availability of refined grains and the importance of the human gut microbiome [21]. Previously, a series of studies have demonstrated high fiber intake was associated with reduced risk of diseases. A systematic review and meta-analysis identified that high fiber consumption was linked with a considerable reduction of the risk for non-communicable diseases [22]. Another systematic review of prospective cohorts showed that a reduction in CVD risk of 9% in those with 7 g higher intake of total fiber [23]. Song et al. revealed that dietary fiber intake was associated with overall metabolic health and a variety of

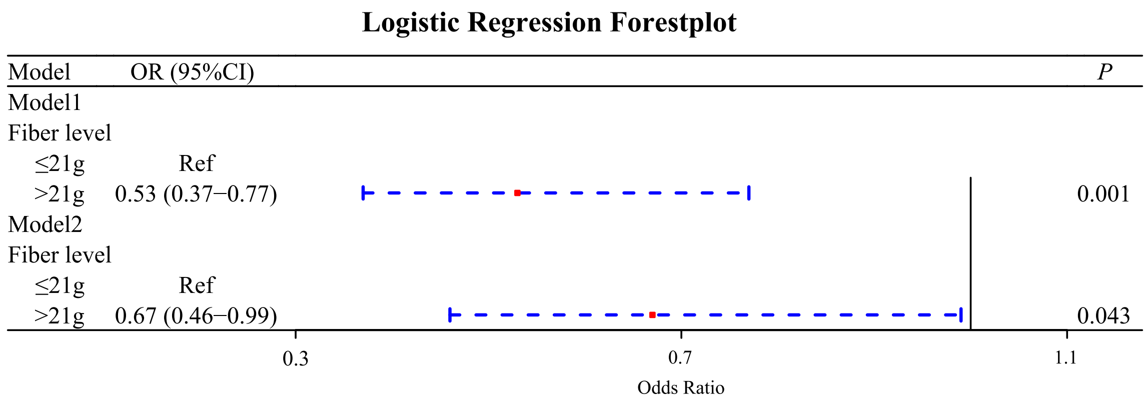

Fig. 2 Forest plot showing the association between dietary fiber intake and the risk of PAD in hypertensive patients. The red dot represented the ORs of the variables, while the blue dotted lines represented the 95%CIs

other pathologies including cardiovascular diseases, colonic health, gut motility and risk for colorectal carcinoma [24]. A review demonstrated that the molecular structure of cereal dietary fiber played a crucial role in regulating blood glucose and insulin levels, as well as maintaining gut health [25]. Higher fiber intake was reported to reduce the risk for CVD (both heart disease and stroke) and lower risk of type 2 diabetes, lower blood pressure, lower low density lipoprotein -cholesterol, as well as some cancers [26]. In another study, fruit fiber intake was reported to be inversely associated with cardiovascular risk factors, including obesity, hypertension, and type 2 diabetes, in Korean adults [27]. Fruit fiber intake has also been reported to be inversely associated with metabolic syndrome in Iranian adults [28], and negatively associated with insulin resistance in US adults [29]. A Tehran Lipid and Glucose Study identified that the intakes of total fiber, fruit fiber, cereal, and legume fiber were linked with a decreased prevalence of metabolic syndrome, and after three years of follow-up, fruit fiber intake protected against metabolic syndrome [30]. Since PAD shares the same pathogenic mechanisms with other CVDs, these findings might provide evidence to the results in this study. A prospective cohort study delineated that fiber intake was associated with decreased risk of incident symptomatic PAD [31]. Another prospective cohort study including 46,036 men followed-up for 12 years reported a reduced risk of PAD in men with higher folate intake, a vitamin commonly found in fiber-rich foods [32]. In our study, we observed that higher dietary fiber intake was associated with decreased risk of PAD in hypertensive patients. The mechanisms underlying this might be that dietary fiber intake was reported to have benefit on cholesterol [33]. Another study indicated that dietary fibers from beans, fruits, and vegetables were associated with the gut microbiome composition [8], whose changes were identified to be associated with obesity and related disorders [34]. Subgroup analysis indicated that the association between dietary fiber intake greater than 21 g and decreased risk of PAD in hypertensive patients was statistical different in those less than 60 years, without dyslipidemia, without diabetes or never smoke population. This might because those less than 60 years, without dyslipidemia, without diabetes or never smoke population might have healthier lifestyles, and the association between dietary fiber intake and the risk of PAD was significant in hypertensive patients.

The current study initially evaluated the association between dietary fiber intake and the risk of PAD was significant in hypertensive patients, which might provide a reference for the clinicians to recommend those with hypertension to increase the fiber intake in daily diet. Dietary intervention had a marked effect on hypertension, and dietary guidance from clinicians for hypertensive patients to improve the fiber intake guidance might be helpful. Regular follow-up in hypertensive patients might include dietary fiber evaluation. More fiber extracts, or diets rich in fiber were recommended, and primary prevention programs directed against PAD in hypertensive patients might include a fiber recommendation. More attention should be paid on the quality of diet in hypertensive people. Future studies might explore whether the policy of incorporating of high fiber foods interventions in hypertension management is necessary.

There were several limitations in this study. Firstly, this was a cross-sectional study, only association between dietary fiber intake and the risk of PAD in hypertensive patients could be observed. The causal relationship between dietary fiber intake and the risk of PAD in hypertensive patients was not clear. Secondly,

Table 4 Subgroup analysis of association between dietary fiber intake and PAD in hypertensive patients

Subgroup	OR (95%CI)	*P*
Age < 60, n = 1871, means = 15.92		
Fiber ≤ 21 g, n = 1438, means = 11.51	Ref	
Fiber > 21 g, n = 433, means = 30.08	0.23 (0.08–0.66)	0.008
Age ≥ 60, n = 2757, means = 15.93		
Fiber ≤ 21 g, n = 2109, means = 12.07	Ref	
Fiber > 21 g, n = 648, means = 28.66	0.87 (0.56–1.35)	0.538
CVD, n = 2677, means = 15.68		
Fiber ≤ 21 g, n = 2093, means = 11.89	Ref	
Fiber > 21 g, n = 584, means = 29.40	0.68 (0.44–1.04)	0.074
Non-CVD, n = 1951, means = 16.23		
Fiber ≤ 21 g, n = 1454, means = 11.63	Ref	
Fiber > 21 g, n = 497, means = 29.50	0.70 (0.28–1.74)	0.437
Dyslipidemia, n = 3974, means = 16.02		
Fiber ≤ 21 g, n = 3038, means = 11.84	Ref	
Fiber > 21 g, n = 936, means = 29.59	0.73 (0.47–1.11)	0.138
Non-dyslipidemia, n = 654, means = 15.32		
Fiber ≤ 21 g, n = 509, means = 11.27	Ref	
Fiber > 21 g, n = 145, means = 28.59	0.33 (0.12–0.95)	0.041
Diabetes, n = 1714, means = 16.24		
Fiber ≤ 21 g, n = 1305, means = 11.94	Ref	
Fiber > 21 g, n = 409, means = 29.71	0.89 (0.50–1.58)	0.678
Non-diabetes, n = 2914, means = 15.77		
Fiber ≤ 21 g, n = 2242, means = 11.67	Ref	
Fiber > 21 g, n = 672, means = 29.31	0.50 (0.31–0.78)	0.003
Physical activity, n = 3462, means = 16.37		
Fiber ≤ 21 g, n = 2619, means = 12.01	Ref	
Fiber > 21 g, n = 843, means = 29.77	0.74 (0.40–1.38)	0.338
No physical activity, n = 1166, means = 14.04		
Fiber ≤ 21 g, n = 928, means = 10.76	Ref	
Fiber > 21 g, n = 238, means = 27.75	0.66 (0.38–1.13)	0.127
Never smoker, n = 2120, means = 16.35		
Fiber ≤ 21 g, n = 1603, means = 11.78	Ref	
Fiber > 21 g, n = 517, means = 29.40	0.46 (0.24–0.86)	0.017
Former smoker, n = 1700, means = 16.94		
Fiber ≤ 21 g, n = 1260, means = 12.56	Ref	
Fiber > 21 g, n = 440, means = 29.68	0.81 (0.41–1.60)	0.544
Current smoker, n = 808, means = 12.88		
Fiber ≤ 21 g, n = 684, means = 10.35	Ref	
Fiber > 21 g, n = 124, means = 28.85	1.02 (0.49–2.13)	0.966

PAD: Peripheral artery disease, OR: Odds ratio, CI: Confidence interval, CVD: Cardiovascular disease

the data on the dietary data of participants in the NHANES database might have bias, and those with extreme energy intake were excluded. Some of the data such as the self-reported dietary intake and reliance on cross-sectional data might have potential bias, this indicated the results should be interpreted with caution. Thirdly, the data processing and editing in the evaluation of ABPI data in the NHANES database was automatically calculated by the computer system, and might results in error. The right ABPI was obtained by dividing the mean systolic blood pressure in the right ankle by the mean blood pressure in the arm. The left ABPI was obtained by dividing the mean systolic blood pressure in the left ankle by the mean blood pressure in the arm. The mean blood pressure value for the arm and ankles are computed based on the first and second reading at each site. Since the second reading for all persons > 60 years is missing the mean values are in fact the first recorded blood pressure reading at a site. This may also be true for 40–59 years old persons who have a missing value for the first or second blood pressure reading. These might affect the diagnosis accuracy of PAD. In the future, more well-designed longitudinal studies were required to verify the findings of our study and to establish the causal relationship between dietary fiber intake and PAD. The intervention trials to evaluate the efficacy of dietary interventions for hypertensive patients were required.

Conclusions

The current study measured the association between dietary fiber intake and the risk of PAD in hypertensive patients based on the data from the NHANES. The results identified that higher dietary fiber intake was associated with reduced risk of PAD in hypertensive patients. The findings suggest the potential significance of enhancing daily dietary quality, particularly fiber intake, among individuals with hypertension, and more fiber extracts, or diets rich in fiber were recommended. More well-designed longitudinal studies or intervention trials to establish the causal relationship between dietary fiber intake and PAD in hypertensive patients.

Abbreviations

PAD	Peripheral artery disease
ABPI	Ankle-brachial pressure index
NHANES	National health and nutrition examination surveys
CVDs	Cardiovascular diseases
OR	Odds ratio
CI	Confidence interval
GED	General equivalent diploma
BMI	Body mass index
MEC	Mobile exam center
SE	Standard error (Supplementary Table 7)

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s41043-024-00610-7.

Additional file 1.

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Not applicable.

Author contributions
YL and YZ designed the study. YL wrote the manuscript. RW, ZT, GC, TX, ZL, HX, and CC collected, analyzed, and interpreted the data. YZ critically reviewed, edited, and approved the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets generated and/or analyzed during the current study are available in the NHANES database, https://wwwn.cdc.gov/nchs/nhanes/.

Declarations

Ethics approval and consent to participate
Our research was exempt from review by the Ethics Review Board of Shenzhen People's Hospital (The Second Clinical Medical College, Jinan University; The First Affiliated Hospital, Southern University of Science and Technology) because the NHANES is de-identified. All individuals provided written informed consent before participating in the study. All methods were carried out in accordance with relevant guidelines and regulations (declaration of Helsinki).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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