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ORIGINAL

INTERACTIVE EFFECTS OF DIETARY FIBER INTAKE AND PHYSICAL ACTIVITY LEVELS ON HEART FAILURE OUTCOMES IN CARDIOVASCULAR POPULATIONS: A CROSS-SECTIONAL STUDY

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ABSTRACT

Background and Objectives: Previous studies suggest a potential link between dietary fiber intake and the prevalence of heart failure (HF) among the general population. However, the specifics of this relationship among those with cardiovascular conditions remain less explored. This study aims to examine the correlation between dietary fiber intake and HF among patients with a history of cardiovascular diseases, integrating physical activity levels to provide a broader perspective on lifestyle impacts. **Methods:** This cross-sectional study included non-pregnant individuals aged ⩾20 years from the NHANES database. Dietary fiber intake was assessed through two 24-hour dietary recalls, and HF status was determined via questionnaires. Physical activity levels were quantified using MET-minutes/week based on responses in NHANES. Demographic characteristics and comparisons between groups were analyzed using SPSS software, and logistic regression was applied to assess the impact of dietary fiber and physical activity on HF outcomes. **Results:** A total of 17,534 participants with a history of cardiovascular conditions were evaluated, classified into HF (n = 1,268) and non-HF (n = 16,266) groups. HF participants had significantly lower dietary fiber intake (12.59±8.39 g/day) compared to the non-HF group (13.51±8.51 g/day, p=0.010). Individuals with dietary fiber intake below 12.45 g/day exhibited a higher incidence rate of HF (53.7% vs. 49.4%, p=0.038). Additionally, the HF incidence was higher among participants with minimal physical activity (8.3% vs. 5.8%, p=0.021). Participants engaging in moderate to high levels of physical activity with adequate fiber intake demonstrated the lowest odds of HF (odds ratio <0.716). **Conclusions:** The findings from NHANES data suggest that among those with cardiovascular conditions, both higher dietary fiber intake and increased physical activity levels are associated with reduced odds of developing HF. This study underscores the importance of a multifaceted lifestyle approach in managing heart health within this vulnerable population.

KEYWORDS: Dietary fiber, NHANES, heart failure, cardiovascular population, Female athletes

1. INTRODUCTION

The physical demands placed on female athletes can lead to various health challenges, among which bone stress injuries are notably prevalent. These injuries often result from high training loads and insufficient recovery, but emerging research suggests a potential link to another factor: irregular menstrual cycles. Menstrual irregularities are common in female athletes, exacerbated by what is often referred to as the "female athlete triad" — a syndrome involving disordered eating, amenorrhea, and osteoporosis. This complex interplay of nutritional, physiological, and hormonal factors can severely impact an athlete's health and performance (Mosterd & Hoes, 2007). Heart failure (HF) has been a concerning global health problem recently, it is estimated the more than 37.7 million individuals suffering from HF. HF is characterized by cardiac dysfunction accompanied with a series syndromes and signs, and finally resulting in decreased quality of life and reduced longevity(Ziaeian & Fonarow, 2016). Although with significant efforts and advanced drug in treating and managing HF, its mortality and hospitalization is still unabated(Roger, 2021). It is believed that nutrition, lifestyle genetic predisposition and environmental exposure are the factors implicating in the prevention and development of HF(Billingsley, Hummel, & Carbone, 2020; Taesuwan, Vermeylen, Caudill, & Cassano, 2019). Nutrition is responsible for providing energy for heart function, including myocardial contractility and daily activity(Chien et al., 2019). Various studies provided evidence that nutritional intervention is beneficial for HF treatment(Bianchi, 2020). Dietary fiber is mainly obtained from nutrition intake, and finally fermented by gut microbiome to SCFAs in colon, which has protective properties reducing inflammation and improving vascular tone(Tang, Li, & Hazen, 2019; Zhou et al., 2020). Thus, emerging points suggests dietary fiber is associated with HF prognosis by gut microbial-derived SCFAs(Beale et al., 2021), Recently, it is reported that low intake of dietary fiber increases the risk of hypertension, heart failure and other cardiovascular diseases, which may due to deficient SCFA production metabolized by fiber, imbalance of gut microbiome and regulation of GPR43/109A signaling(Kaye et al., 2020). A prospective cohort study with large population (123330 postmenopausal women) pointed out that the plant-based dietary portfolio (containing dietary fiber) decreased the risk and incidence of cardiovascular disease 11% (Glenn et al., 2021), but it only referred to postmenopausal women. Another retrospective study with 19067 population reported that dietary intervention benefits HF athletic patients by decreasing inflammatory index and presenting as a promising method for HF(Liu et al., 2021). A latest research put forward that intakes of fiber had lower HF incidence in adult athletes, whereas it did not consider the difference of the characteristics of participants between HF and non-HF athletic patients(Zhang et al., 2022), which may results in difference between HF population and non-HF population(Kaczmarski, Sozio, Chen, Sang, & Shafi, 2019), however, and the history diseases of the included participates were various and not standardized in this study, which may also result to false positive result.

In this study, we extracted the data of participants with a diagnostic history of cardiovascular diseases, including heart attack, stroke, coronary heart disease, hypertension, or angina, and then they were divided into HF group and non-HF group according to their diagnostic history of HF or not, we also conducted propensity score matching (PSM, 1:1) regarding of their clinical characteristics including sex, aging, BMI, race etc., aiming to eliminate the effects of deviations and confounding variables, which may provide an actual correlation, risk or prevalence odds of between the intake of dietary fiber and heart failure.

2. METHODS

2.1 Included population

This cross-sectional research and secondary date analysis that extracted data from a publicly accessible NHANES survey database, thus it required no ethical review. In the present study, HF was identified from the MCQ questionnaire “Someone ever told you had congestive heart failure?”. Participates would be included according to the following inclusion criteria: 1) non-pregnant participates; 2) aged not less than 20 years old; 3) completed two 24-h recalls with dietary fiber intake from 2005 to 2018; 4) with complete information about diagnosis on HF.

In this study, participants with a diagnostic history of cardiovascular diseases, including heart attack, stroke, coronary heart disease, hypertension, or angina, were included for analysis, among which those were accompanied with HF were defined as the HF group, and others were defined as control group, aiming to reduce the effects induced by confounding variates.

2.2 The measurement of the intake of dietary fiber

In the questionnaire, the recorded about dietary behavior and intake amount were collected twice by dietary recalls according to a similar protocol. The intake of dietary fiber of participates were collected by the method of recall interview in the Mobile Examination Center (MEC) first time, and then after 3 to 10 days, the intake of dietary fiber was collected again by a second interview. The amounts of dietary fiber intake were calculated and then average was calculated as continuous variables for analyses.

2.3 Covariates design

Sex, age, race (White; Black; Other Hispanic, Mexican American, and others), the level of education (graduate, college, high-school, 9–11th grade, <9th grade), BMI, married status (non-married, married) and smoke (never, now, former) were considered as possible confounding variables. BMI(kg/m^2) was calculated by standardized methods(Kaczmarski et al., 2019).

Covariates that were associated that had a demonstrable and potential influence on the results were considered as confounding factors and retained in the models. Finally, age, race, sex, married status, smoke, BMI, and education level were regarded as covariates.

2.4 Statistical analysis

The data was extracted by R 4.1.0 software. Comparison of continuous data was analyzed by Student's t-test between the two groups. Categorical variables comparison was analyzed by Chi-square test by constituent ratio of each group. Propensity score matching (PSM, 1:1) regarding of their clinical characteristics including sex, aging, BMI, race etc. was conducted to eliminate the effects of deviations and confounding variables.

Logistic regression analysis was applied to explore the correlation between HF and dietary fiber in unadjusted and multivariable adjusted model. Subgroup analysis on the associations between the intake of dietary fiber and odds of HF were assessed by random forest analysis. $P<0.05$ were considered statistically differences between groups.

3. RESULTS

3.1 Selection Process and Results of Participants

70190 participants in NHANES database from 2005 to 2018 was extracted, then remained a total of 39041 non-pregnant participants aged ≥20 years old. After removing 113 participants with missing information about on congestive heart failure diagnosis and 21394 individuals with no history of cardiovascular diseases, a total of 17534 participants were finally included and divided into HF group (n1=1268) and non-HF group (n2=16266). We further matched the participants in the two groups by propensity score matching (PSM, 1:1, n1=n2=1122), aiming to eliminate the effects of deviations and confounding variables. Figure 1 illustrates the flow chart of participant's selection process.

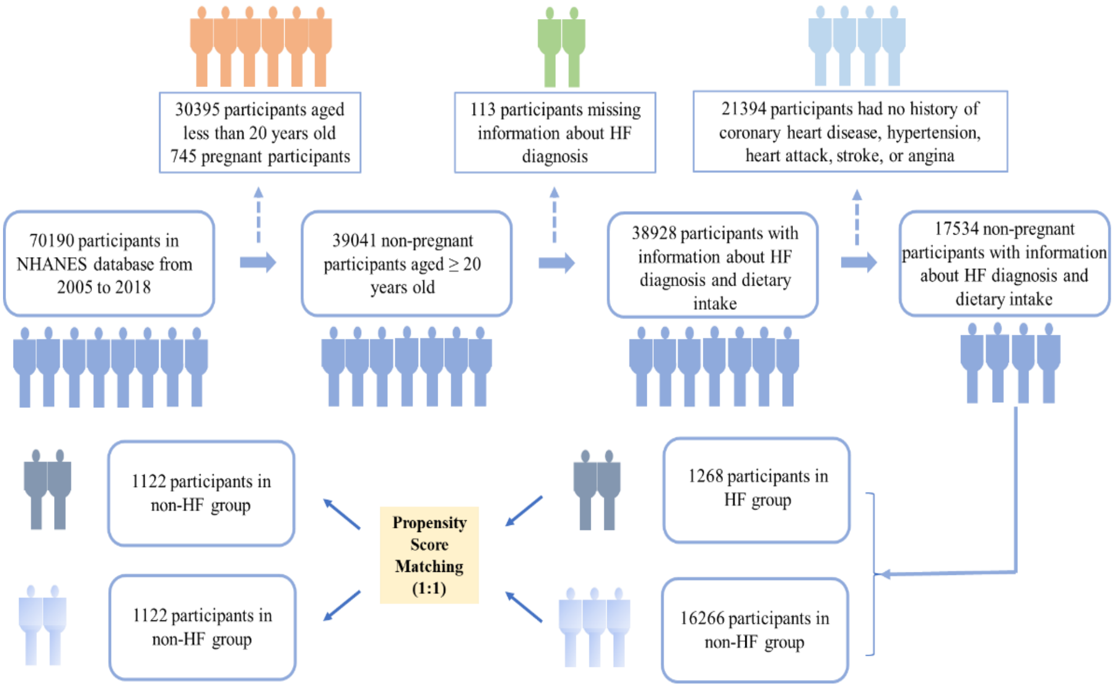

Figure 1: Flow chart of including participants

3.2 Demographic Characteristics of included participants

Table 1 showed the characteristics of all the included participants before and after PSM. Before PSM, HF group had an average age of 67.71±11.87 years old, consisting of consist of 710(56.0%) male and 558(44.0%) female, non-HF group had 8084(49.7%) male and 8182(50.3%) female athletes, their mean ages were 59.55±15.22 years old. HF participants had a higher BMI (32.15±8.47 vs. 30.61±7.23 kg/m^2) than the non-HF group.

The HF group had a lower level of education (especially in college and Graduate) than the non-HF group. HF group had a higher proportion of the white participates, while Mexican and other race accounts for higher rate in non-HF group. Interestingly, the HF group seems more likely to be non-married and former smoker. After PSM, HF group had the same sample size (n=1122) as that of non-HF group.

HF group had similar age, sex, married status, smoke, and the incidence of hypertension and angina as that of the non-HF group. While compared with non-HF group, there remained higher BMI and a higher rate of black population, high school education and college education, heart attack, coronary heart diseases, and stroke in the HF group.

Table 1(a): Characteristics of participants included for analysis (2005-2018)

Index	Pre-Match			Psm Match		
	HF GROUP GROUP (N=1268)	NON-HF GROUP GROUP (N=16266)	*P*	HF GROUP GROUP (N=1122)	NON-HF GROUP GROUP (N=1122)	*p*
Age	67.71±11.87	59.55 ± 15.22	<0.001	67.48±11.90	67.15±13.55	0.542
Bmi	32.15±8.47	30.61±7.23	<0.001	32.11±8.48	31.26±8.36	0.018
Sex						
Male	710(56.0%)	8084(49.7%)	<0.001	634(56.5%)	627(55.9%)	0.766
Female Athletes	558(44.0%)	8182(50.3%)		488(43.5%)	495(44.1%)	
Race						
White	635(50.1%)	7059 (43.4%)	<0.001	564 (50.3%)	690 (61.5%)	<0.001
Black	348(27.4%)	4225(26.0%)		310(27.6%)	236(21.0%)	
Mexican	113(8.9%)	2040 (12.5%)		97(8.6%)	123 (11.0%)	
Other Hispanic	93(7.3%)	1422(8.7%)		87(7.8%)	42(3.7%)	
Other Race	79(6.2%)	1520(9.3%)		64(5.7%)	31(2.8%)	
Education Level						
<9th Grade	212(16.7%)	2112(13.0%)	<0.001	186(16.6%)	216(16.6%)	0.020
9-11th Grade	251(19.8%)	2482(15.3%)		217(19.3%)	217(19.3%)	
High School	324(25.6%)	3947 (24.3%)		293(26.1%)	278 (24.8%)	
College	340(26.8%)	4573(28.1%)		307(27.4%)	262(23.4%)	
Graduate	139(11.0%)	3121(19.2%)		117(10.4%)	153(13.6%)	
Married Status						
Married	573(45.2%)	8475(52.1%)	<0.001	517(46.1%)	557(49.6%)	0.091
Non-Married	695(54.8%)	7791 (47.9%)		605(53.9%)	565 (50.4%)	
Smoke						
Never	515(40.6%)	8257(50.8%)	<0.001	448(39.9%)	452(40.3%)	0.711
Now	234(18.5%)	3140(19.3%)		216(19.3%)	205(18.3%)	
Former	518(40.9%)	4854(29.8%)		465(41.4%)	457(40.7%)	
Missing Data	1(0.1%)	15(0.1%)		0(0.0%)	1(0.1%)	
Hypertension						
Yes	1146(90.4%)	15539(95.5%)	<0.001	1013(90.3%)	994(88.6%)	0.192
No	122(9.6%)	727 (4.5%)		109(9.7%)	128 (11.4%)	

Table 1(b): Characteristics of participants included for analysis (2005-2018)

Index	Pre-Match HF GROUP GROUP (N=1268)	Pre-Match NON-HF GROUP GROUP (N=16266)	*P*	Psm Match HF GROUP GROUP (N=1122)	Psm Match NON-HF GROUP GROUP (N=1122)	*p*
Coronary Heart Diseases						
Yes	533(42.0%)	1081 (6.6%)	<0.001	466(41.5%)	400(35.7%)	0.014
No	696(54.9%)	15122(93.0%)		626(55.8%)	684(61.0%)	
Missing Data	39(3.1%)	63(0.4%)		30(2.7%)	38(3.4%)	
Angina						
Yes	308(24.3%)	708(4.4%)	<0.001	266(23.7%)	253(22.5%)	0.808
No	935(73.7%)	15501 (95.3%)		837(74.6%)	850 (75.8%)	
Missing Data	25(2.0%)	57(0.4%)		19(1.7%)	19(1.7%)	
Heart Attack						
Yes	588(46.4%)	1145(7.0%)	<0.001	520(46.3%)	460(41.0%)	<0.001
No	674(53.2%)	15087(92.8%)		599(53.4%)	642(57.2%)	
Missing Data	6(0.5%)	34(0.2%)		3(0.3%)	20(1.8%)	
Stroke						
Yes	298(23.5%)	1340(8.2%)	<0.001	254(22.6%)	215(19.2%)	0.007
No	966(76.2%)	14896(91.6%)		865(77.1%)	894(79.7%)	
Missing Data	4(0.3%)	30(0.2%)		3(0.3%)	13(1.2%)	

Continuous variables Categorical variables mean ±SD, and categorical factors were presented as the frequency and the percentage (n, %).

4. Difference of Dietary Fiber Intake between the two groups

As shown in the Table 2, Before PSM, it suggested a higher intake of dietary fiber in non-HF group by comparing with the HF group (13.64±9.44 vs 11.75±8.65). When in term of intaking dietary fiber or not, it indicated that participants in non-HF group had a higher rate of dietary fiber intake (up to 89.8%, $p<0.001$) than that of HF group. In order to further investigate whether the intake of dietary fiber was correlated with HF, intake of dietary fiber was divided into different groups according to its median value (<12.45gm/d group and ≥12.45gm/d group).

The results showed that in the <12.45gm/d group, HF population had a higher proportion in the HF group, while in the ≥12.45gm/d group, the rate of participates with HF was significantly lower. After PSM match, it showed the same trend of results as before PSM. All above results seem to suggest that intake of dietary fiber had negative relationship with the incidence of HF.

Table 2: Difference of dietary fiber intake between groups (2005-2018)

Index	Pre-Match		*P*	Psm Match		*p*
	HF GROUP GROUP (n=1268)	Non-HF GROUP GROUP (n=16266)		HF GROUP GROUP (n=1122)	Non-HF GROUP GROUP (n=1122)	
Dietary Fiber[1]	11.75±8.65	13.64±9.44	<0.001	12.59±8.39	13.51±8.51	0.010
Intake						
Yes	1090(86.0%)	14607(89.8%)	<0.001	1029(91.7%)	1057(94.2%)	0.021
No	178(14.0%)	1659(10.2%)		93(8.3%)	65(5.8%)	
Dietary Fiber[2]						
<12.45gm/D	722(56.9%)	8015(49.3%)	<0.001	603(53.7%)	554(49.4%)	0.038
≥ **12.45 Gm/D**	546(43.1%)	8251(50.7%)		519(46.3%)	568(50.6%)	

Continuous variables Categorical variables mean ±SD, and categorical factors were presented as the frequency and the percentage (n, %).

4.1 Characteristics of HF Participants grouped by Median of Dietary Fiber Intake

As Table 3 showed, participants in <12.45mg/d group had a similar composition of race, hypertension, coronary heart diseases, heart attack and stroke as the ⩾12.45mg/d group before and after PSM. <12.45mg/d group seemed to have higher education level (high school to graduated) than the ⩾12.45mg/d group before PSM, but after PSM, it had a contrast trend by the comparison between the two groups. In addition, former smokers in ⩾12.45mg/d group occupied a highest proportion of smokers both before and after PSM. Although non-married participants accounted for 58.9% in the <12.45mg/d group compared with ⩾12.45mg/d group, it had no difference between the two groups after PSM.

Table 3(a): Characteristics of the participants included for Analysis (2005-2018)

Index	Pre-Match		*P*	Psm Match		*P*
	<12.45mg/d (n=722)	≥ 12.45mg/d (n=546)		<12.45mg/d (n=603)	≥ 12.45mg/d (n=519)	
Age	67.63±12.09	67.82±11.57	0.775	67.24±12.12	67.76±11.66	0.461
Bmi	32.10±8.87	32.21±8.00	0.774	32.03±8.87	32.20±8.03	0.737
Sex						
Male	367(50.8%)	343(62.8%)	<0.001	308(51.1%)	326(62.8%)	<0.001
Female Athletes	355(49.2%)	203(37.2%)		295(48.9%)	193(37.2%)	

Table 3(b): Characteristics of the participants included for analysis (2005-2018)

Index	Pre-Match			Psm Match		
	<12.45mg/d (n=722)	≥ 12.45mg/d (n=546)	*P*	<12.45mg/d (n=603)	≥ 12.45mg/d (n=519)	*P*
Race						
White	342(47.4%)	293(53.7%)	0.164	286 (47.4%)	278 (53.6%)	0.100
Black	216(29.9%)	132(24.2%)		186(30.8%)	124(23.9%)	
Mexican	63(8.7%)	50 (9.2%)		48(8.0%)	49 (9.4%)	
Other Hispanic	54(7.5%)	39(7.1%)		48(8.0%)	39(7.5%)	
Other Race	47(6.5%)	32(5.9%)		35 (5.8%)	29(5.6%)	
Education Level						
<9th Grade	138(19.1%)	74(13.6%)	0.009	197(16.4%)	248(20.6%)	0.007
9-11th Grade	157(21.7%)	94(17.2%)		226(18.8%)	229(19.0%)	
High School	172(23.8%)	152 (27.8%)		319(26.5%)	302 (25.1%)	
College	186 (25.8%)	154(28.2%)		327(27.2%)	267(22.2%)	
Graduate	68(9.4%)	71(13.0%)		134(11.1%)	157(13.1%)	
Married Status						
Married	297(41.1%)	276(50.5%)	0.001	559(46.5%)	590(49.0%)	0.206
Non-Married	425(58.9%)	270 (49.5%)		644(53.5%)	613 (51.0%)	
Smoke						
Never	296(41.0%)	219(40.1%)	<0.001	238(39.5%)	210(40.5%)	<0.001
Now	163(22.6%)	71(13.0%)		147(24.4%)	69(13.3%)	
Former	262(36.3%)	256(46.9%)		217(36.0%)	240(46.2%)	
Missing Data	1(0.1%)	0(0.0%)		1(0.2%)	0(0.0%)	
Hypertension						
Yes	653(90.4%)	493(90.3%)	0.928	543(90.0%)	470(90.6%)	0.774
No	69(9.6%)	53 (9.7%)		60(10.0%)	49 (9.4%)	
Coronary Heart Diseases						
Yes	301(41.7%)	232(42.5%)	0.289	244(40.5%)	222(42.8%)	0.082
No	394(54.6%)	302(55.3%)		337(55.9%)	289(55.7%)	
Missing Data	27(3.7%)	12(2.2%)		22(3.6%)	8(1.5%)	
Angina						
Yes	172(23.8%)	136(5.2%)	0.292	142(23.5%)	124(23.9%)	0.707
No	532(73.7%)	403(73.8%)		449(74.5%)	388 (74.8%)	
Missing Data	18(2.5%)	7(1.3%)		12(2.0%)	7(1.3%)	
Heart Attack						
Yes	326(55.4%)	262(44.6%)	0.555	277(45.9%)	243(46.8%)	0.870
No	392(54.3%)	282(51.6%)		324(53.7%)	275(53.0%)	
Missing Data	4(0.6%)	2(0.4%)		2(0.3%)	1(0.2%)	
Stroke						
Yes	187(25.9%)	111(20.3%)	0.067	151(5.0%)	103(19.8%)	0.061
No	533(73.8%)	433(79.3%)		451(74.8%)	414(79.8%)	
Missing Data	2(0.3%)	2(0.4%)		1(0.2%)	2(0.4%)	

Continuous variables Categorical variables mean ±SD, and categorical variables were presented as frequency and percentage (n, %).

4.2 Associations Between the Intake of Dietary Fiber and Incidence of Heart Failure

The unadjusted and adjusted models were performed by Logistic regression analysis, which aimed to explore the relationship between the intake of dietary fiber and the incidence of HF. The unadjusted model revealed lower intake of dietary fiber had an increased odd of HF before PSM match [OR (95% CI) =0.997 (0.970-0.983), p<0.001]. Its odds rate was 0.979 in model 1 after it was adjusted by age, and 0.982 in model 2 after adjusting by age, sex, race, education, smoke, and married status. When BMI was introduced in the model 3, It still indicated the same result by comparison [OR (95% CI) =0.984 (0.977-0.992), p<0.001]. After PSM match, it still indicated a similar result (Table 4). When considering participants with or without intake of dietary fiber (user vs nonuser), the result also showed that participates with higher intake of dietary fiber were significantly correlated with decreased odds rate of HF. Interestingly, when BMI was introduced into model 3, it showed intake of dietary of fiber had no relationship with HF (p=0.296), but after PSM match, the results still supported that the intake of dietary fiber decreased the odds rate of HF.

Table 4: Logistic regression analysis on the correlation between the intake of dietary fiber and HF

Model	Index	Dietary Fiber Intake	Intake of Dietary Fiber (User Vs Nonuser)
Pre-Match			
Non-Adjusted Model	OR (95% CI)	0.977(0.970-0.983)	0.695(0.589-0.821)
	P	<0.001	<0.001
Adjusted Model1	OR (95% CI)	0.979(0.972-0.985)	0.804(0.679-0.952)
	P	<0.001	0.011
Adjusted Model2	OR (95% CI)	0.982(0.975-0.989)	0.794(0.669-0.943)
	P	<0.001	0.009
Adjusted Model3	OR (95% CI)	0.984(0.977-0.992)	0.885(0.704-1.113)
	P	<0.001	0.296
Psm Match			
Non-Adjusted Model	OR (95% CI)	0.987(0.977-0.997)	0.680(0.490-0.945)
	p	0.010	0.022
Adjusted Model1	OR (95% CI)	0.987(0.977-0.997)	0.683(0.492-0.949)
	p	0.010	0.023
Adjusted Model2	OR (95% CI)	0.987(0.976-0.997)	0.716(0.513-0.998)
	P	0.009	0.049
Adjusted Model3	OR (95% CI)	0.986(0.976-0.997)	0.708(0.507-0.989)
	P	0.009	0.043

Logistic regression: Adjusted model1 was adjusted by age; Adjusted model2 was adjusted by sex, age, smoke, race, education, and married status; Adjusted model3 was adjusted by age, sex, race, education, smoke, BMI and married status.

5. Random Forest analysis by Subgroup

In addition, the model by multivariate-adjust suggested that the correlation of the intake of dietary fiber and the incidence of HF was differed by education level, sex, married status and smoke, (all P-interaction<0.001, Figure 2). But after PSM match, the correlation of dietary fiber intake with the incidence of HF was only differed by race and education level (P_{race} interaction <0.001, $P_{education\ level}$ interaction =0.013, Figure 3.). Specifically, white population and participants with high education level (college to graduated) consuming higher amounts of dietary fiber seemed to have lower probability of prevalent HF (($P_{race=White}$=0.001, $P_{education\ level=College}$=0.025, $P_{education\ level=Graduated}$=0.038, Figure 4).

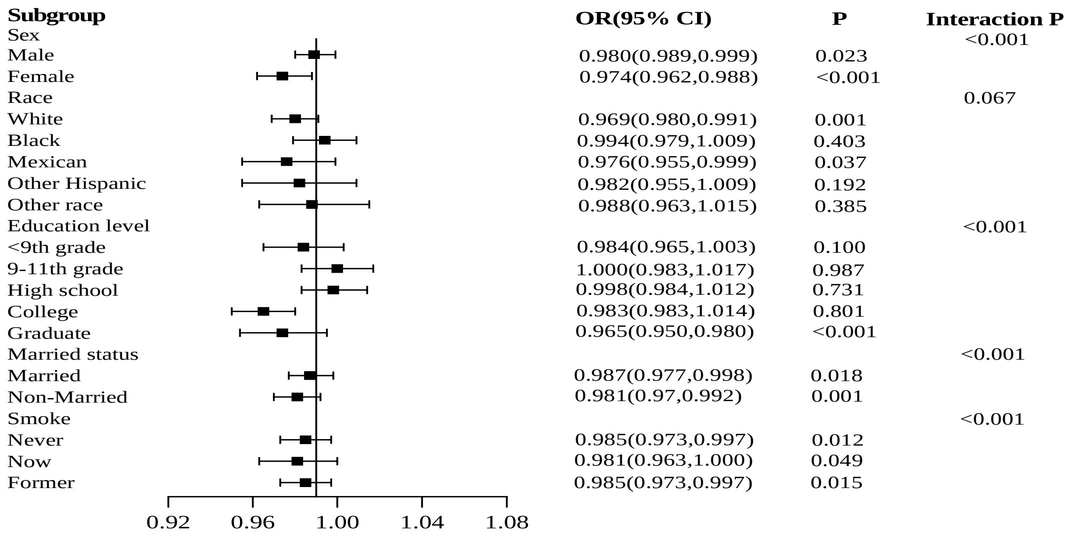

Figure 2: Associations of pre-match between the intake of dietary fiber and incidence of heart failure by subgroups. All the models were adjusted by race, BMI, age, education, sex, married status, and smoke.

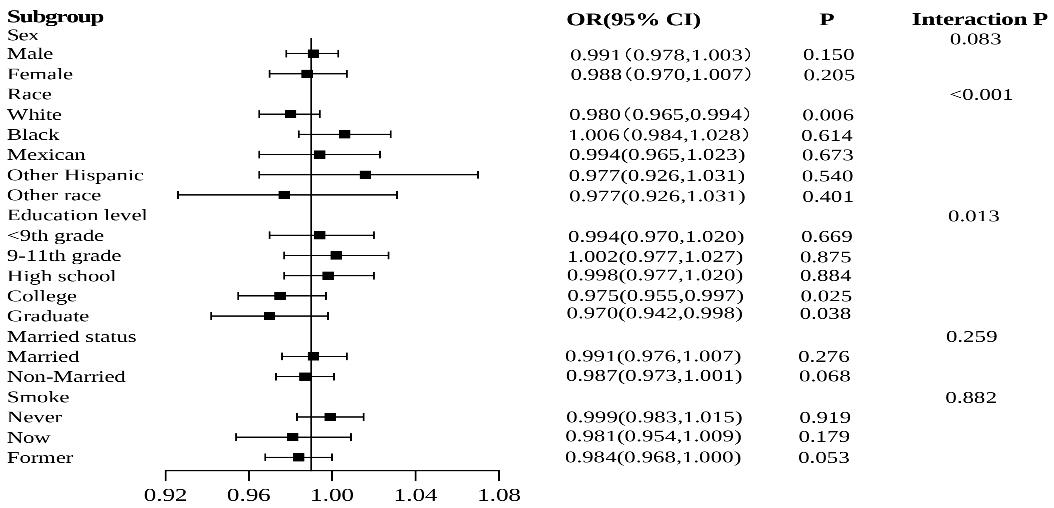

Figure 3: After PSM match, the correlation between the intake of dietary fiber and incidence of heart failure by subgroups. All the models were adjusted for age, BMI, race, married status, sex, education and smoke.

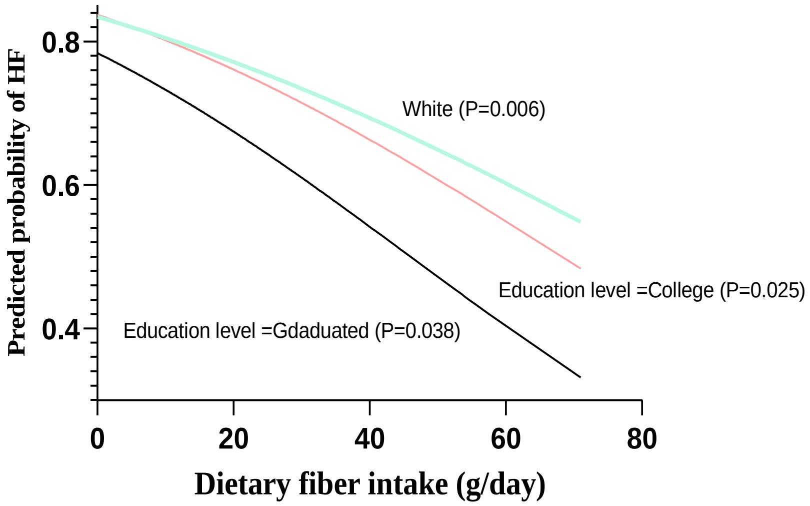

Figure 4: Predicted probabilities of having HF over a range value of dietary fiber intake for individuals who were male, had a college degree, white, and had mean age (70 y), BMI (30.21 kg/m^2), non-married and former smokers. Interaction P values were obtained from logistic regression (age, BMI, race, education level, married status, and smoke).

6. DISCUSSION

The present study investigated the correlation between the intake of dietary fiber and heart failure (HF) among cardiovascular population from the evidences of NHANES 2005–2018 data. The findings suggested that dietary fiber might be an important dietary factor in HF, which fit the hypothesized direction of association. In addition, among HF population, men, median to high education level (high school to college), and non-current smokers (never and former) tended to have a relative higher dietary fiber intake. Nutrition is considered as an important factor in the development and progression of HF, and malnutrition increases the aggravation of heart function of failure heart. Dietary fiber is mainly obtained from nutrition intake, and finally fermented by gut microbiome to short chain fatty acids (SCFAs) in colon, insufficient dietary fiber may lead to a low production of SCFAs(Kerley, 2019), their cardiovascular function of immune regulation, inflammation modulation, nutrients and energy support are inhibited, thus progress the development of cardiovascular diseases (CVDs). A meta-analysis showed that the intake of dietary fiber is related with lower risk of CVDs. Several studies demonstrated that higher intake of dietary fiber is correlated with lower risk of HF, which was inconsistent with the results of our study. In this study, our findings also suggested dietary fiber intake was consistent with these studies that the intake of dietary fiber was related to lower odds of HF, it seemed that a higher intake of dietary fiber tended to be related to lower prevalence of HF. Supplemental fiber (when compared use vs nonuser) was also significantly benefited with lower prevalence of HF. As previous research reported, several studies pointed that the education level was associated with cardiac dysfunction for HF and higher risk for CVD(Christensen, Mogelvang, Heitmann, & Prescott, 2011), educational attainment was inversely related to the increased risk of CVD (Kubota, Heiss, MacLehose, Roetker, & Folsom, 2017; Threapleton et al., 2013). In contrast, it was also reported that education levels were not correlated with the readmission or the mortality rates of HF (Elkhateeb & Salem, 2018), which resulted in inconsistent results of the influence of education level on HF odds. In our study, median to high education level (high school to college) had a relative higher intake of dietary fiber indicating a lower incidence of HF, which may due to we only aimed to participants with history of cardiovascular diseases but no the normal population. As reported, the intake of dietary fiber was correlated with the general health status and the immune functioning in men but not in women, which could be explained by their different dietary habits(Fernstrand, Bury, Garssen, & Verster, 2017), interestingly, we also found that men participants had a relative higher dietary fiber intake among the CVD population. In addition, many studies pointed out smokers have less healthy diets than the nonsmokers, because they tended to obtain energy from alcohol or saturated fats (SFA) but not vegetables, fiber or vitamin etc.(Dyer et al., 2003), one prospective population-based cohort study demonstrated that high fiber diet may ameliorated the harmful impact of smoke on the incidence of CVD mortality(Clark, Butler, Koh, Wang, & Yuan, 2013). In this study, it indicated the similar result among cardiovascular population that non-current smokers (never and former) tended to have a relative higher intake of dietary fiber and result in lower risk of HF, which was consistent with previous researches.

This study also had merits of prospective implications. We intended to explore the relationship between the intake of dietary fiber and HF risk regarding of both men and women among cardiovascular population but not between the normal population and the HF athletic patients, and we also conducted PSM analysis, which eliminated the effects of deviations and confounding variables and made our results more convincible. Previous studies also pointed out dietary fiber was associated with HF prevalence, we further found that among cardiovascular population, it existed the similar results, providing reference for clinical physicians to manage athletic patients with high fiber diet to prevent HF among cardiovascular athletic patients. Although the results were encouraging, we acknowledged several restrictions unavoidably presented in this study. This cross-sectional research collected data from 24-h recalls might only represent a short-time diet of individuals, which may explain some of the contradictory result. Next, classification of HF could not be categorized due to its lack of subtype information, questionnaire data also easily led to bias when assessed the evidence of final results. Last, participants with a diagnostic history of CVDs were considered as the control group but no the normal individuals, which might weaken the difference between the two groups.

7. CONCLUSION

The findings of this study underscore the significant impact of irregular menstrual cycles on bone stress injuries among female athletes. It has been demonstrated that irregularities in menstrual cycles, possibly exacerbated by rigorous training and inadequate dietary practices, are correlated with an increased risk of bone-related injuries. This relationship suggests that hormonal imbalances induced by disrupted menstrual cycles contribute to compromised bone health, making female athletes particularly susceptible to such injuries. Our research indicates that female athletes with irregular menstrual cycles exhibit a notably higher incidence of bone stress injuries compared to those with regular cycles. These results highlight the importance of monitoring menstrual health as a critical component of athletic training and healthcare protocols for female athletes. Proactive measures, including nutritional counseling and adjustments in training routines, should be considered to help regularize menstrual cycles and thus potentially mitigate the risk of bone stress injuries.Furthermore, the integration of dietary assessments into the regular health checks of female athletes could play a crucial role in maintaining optimal health. Since dietary fiber intake is related to overall health outcomes, ensuring a balanced diet could further support hormonal balance and bone health, thereby reducing injury risks. In this study advocates for a holistic approach to the health management of female athletes, emphasizing the need for a deeper understanding and support of menstrual health. Addressing these factors is not only crucial for the athletes' immediate performance and injury prevention but also for their long-term health and well-being

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REFERENCE

Beale, A. L., O'Donnell, J. A., Nakai, M. E., Nanayakkara, S., Vizi, D., Carter, K., . . . Carrington, M. J. (2021). The gut microbiome of heart failure with preserved ejection fraction. *Journal of the American Heart Association, 10*(13), e020654.

Bianchi, V. E. (2020). Nutrition in chronic heart failure patients: a systematic review. *Heart Failure Reviews, 25*(6), 1017-1026.

Billingsley, H. E., Hummel, S. L., & Carbone, S. (2020). The role of diet and nutrition in heart failure: A state-of-the-art narrative review. *Progress in cardiovascular diseases, 63*(5), 538-551.

Chien, S. C., Lo, C. I., Lin, C. F., Sung, K. T., Tsai, J. P., Huang, W. H., . . . Liu, C. Y. (2019). Malnutrition in acute heart failure with preserved ejection fraction: clinical correlates and prognostic implications. *ESC heart failure, 6*(5), 953-964.

Christensen, S., Mogelvang, R., Heitmann, M., & Prescott, E. (2011). Level of education and risk of heart failure: a prospective cohort study with echocardiography evaluation. *European heart journal, 32*(4), 450-458.

Clark, M. L., Butler, L. M., Koh, W.-P., Wang, R., & Yuan, J.-M. (2013). Dietary fiber intake modifies the association between secondhand smoke exposure and coronary heart disease mortality among Chinese non-smokers in Singapore. *Nutrition, 29*(11-12), 1304-1309.

Dyer, A. R., Elliott, P., Stamler, J., Chan, Q., Ueshima, H., & Zhou, B.-F. (2003). Dietary intake in male and female smokers, ex-smokers, and never smokers: the INTERMAP study. *Journal of Human Hypertension, 17*(9), 641-654.

Elkhateeb, O., & Salem, K. (2018). Patient and caregiver education levels and readmission and mortality rates of congestive heart failure patients. *Eastern Mediterranean Health Journal, 24*(4).

Fernstrand, A. M., Bury, D., Garssen, J., & Verster, J. C. (2017). Dietary intake of fibers: differential effects in men and women on perceived general health and immune functioning. *Food & nutrition research, 61*(1), 1297053.

Glenn, A. J., Lo, K., Jenkins, D. J., Boucher, B. A., Hanley, A. J., Kendall, C. W., . . . Liu, S. (2021). Relationship Between a Plant-Based Dietary Portfolio and Risk of Cardiovascular Disease: Findings From the Women's Health Initiative Prospective Cohort Study. *Journal of the American Heart Association, 10*(16), e021515.

Kaczmarski, K. R., Sozio, S. M., Chen, J., Sang, Y., & Shafi, T. (2019). Resistant hypertension and cardiovascular disease mortality in the US: results from the National Health and Nutrition Examination Survey (NHANES). *BMC nephrology, 20*(1), 1-13.

Kaye, D. M., Shihata, W. A., Jama, H. A., Tsyganov, K., Ziemann, M., Kiriazis, H., . . . Vinh, A. (2020). Deficiency of prebiotic fiber and insufficient signaling through gut metabolite-sensing receptors leads to cardiovascular disease. *Circulation, 141*(17), 1393-1403.

Kerley, C. P. (2019). Dietary patterns and components to prevent and treat heart failure: a comprehensive review of human studies. *Nutrition research reviews, 32*(1), 1-27.

Kubota, Y., Heiss, G., MacLehose, R. F., Roetker, N. S., & Folsom, A. R. (2017). Association of educational attainment with lifetime risk of cardiovascular disease: the atherosclerosis risk in communities study. *JAMA internal medicine, 177*(8), 1165-1172.

Liu, Z., Liu, H., Deng, Q., Sun, C., He, W., Zheng, W., . . . Xie, Q. (2021). Association between dietary inflammatory index and heart failure: results from NHANES (1999–2018). *Frontiers in Cardiovascular Medicine, 8*, 702489.

Mosterd, A., & Hoes, A. W. (2007). Clinical epidemiology of heart failure. *heart, 93*(9), 1137-1146.

Roger, V. L. (2021). Epidemiology of heart failure: a contemporary perspective. *Circulation research, 128*(10), 1421-1434.

Taesuwan, S., Vermeylen, F., Caudill, M. A., & Cassano, P. A. (2019). Relation of choline intake with blood pressure in the National Health and Nutrition Examination Survey 2007–2010. *The American Journal of Clinical Nutrition, 109*(3), 648-655.

Tang, W. W., Li, D. Y., & Hazen, S. L. (2019). Dietary metabolism, the gut microbiome, and heart failure. *Nature Reviews Cardiology, 16*(3), 137-154.

Threapleton, D. E., Greenwood, D. C., Evans, C. E., Cleghorn, C. L., Nykjaer, C., Woodhead, C., . . . Burley, V. J. (2013). Dietary fibre intake and risk of cardiovascular disease: systematic review and meta-analysis. *Bmj, 347*.

Zhang, H., Lin, Z., Chen, J., Gan, D., Zhou, H., Ma, Z., . . . Zhan, Q. (2022). Association Between Dietary Fiber Intake and Heart Failure Among Adults: National Health and Nutrition Examination Survey 2009–2018. *Frontiers in Cardiovascular Medicine, 9*, 893436.

Zhou, W., Cheng, Y., Zhu, P., Nasser, M., Zhang, X., & Zhao, M. (2020). Implication of gut microbiota in cardiovascular diseases. *Oxidative medicine and cellular longevity, 2020*.

Ziaeian, B., & Fonarow, G. C. (2016). Epidemiology and aetiology of heart failure. *Nature Reviews Cardiology, 13*(6), 368-378.