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The Association Between Food Quality Score (FQS) and Metabolic Syndrome Risk Factors in Overweight and Obese Individuals: A Cross-Sectional Study

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ABSTRACT

Obesity and overweight pose a significant public health problem, as they are associated with an elevated risk of metabolic syndrome (MetS). Several studies have shown that diet quality is associated with the development of MetS risk factors. Analyzing dietary patterns may be more helpful in determining the relationship between eating habits and chronic diseases compared to focusing on single foods or nutrients. In this study, our objective was to evaluate the association of food quality score (FQS) with risk factors for MetS in individuals with obesity and overweight. The participants in this cross-sectional study were 340 adults with overweight and obesity. Participants' food intake was measured using a Food Frequency Questionnaire, then the FQS was calculated. A fasting blood sample assessed serum glucose, triglycerides, total cholesterol (TC), high-density lipoprotein cholesterol, and serum insulin levels. Fat-free mass, height, basal metabolic rate, socio-economic score, and waist-to-hip ratio significantly differed among FQS tertiles. TC, systolic and diastolic blood pressure, and fasting blood glucose were significantly lower in the highest tertile of FQS. After multivariable adjustment, our results showed that individuals in the third tertile of FQS had reduced risk of higher levels of TC (odds ratio [OR], 0.982; 95% confidence interval [CI], 0.970–0.984) and higher levels of low-density lipoprotein cholesterol (OR, 0.974; 95% CI, 0.974–0.999). Our findings demonstrate an inverse relationship between diet quality, as measured by FQS, and MetS risk factors. However, further experimental and longitudinal investigations are warranted to elucidate the causal nature of this association.

Keywords: Obesity; Food quality score; Metabolic syndrome; Metabolic parameters

INTRODUCTION

Overweight and obesity continue to be significant public health concerns and risk factors of major importance that contribute to the overall disease burden [1-3]. Overweight and obesity are linked to a higher risk of metabolic disorders, including type 2 diabetes mellitus, cardiovascular disease, several types of cancer, hypertension [4], and metabolic syndrome (MetS) [5]. MetS, a global epidemic with high socioeconomic costs, is a collection of health conditions marked by increased blood pressure, dyslipidemia, glucose dysregulation, central adiposity, and insulin resistance [6]. Identifying these patients allows us to

emphasize the need for a healthy lifestyle to further reduce the risk [7]. MetS is estimated to affect approximately one-quarter of the world's population. Furthermore, MetS and its associated health conditions account for approximately two-thirds of deaths caused by non-communicable diseases [8]. Additionally, compared with people without MetS, those with MetS are more likely to develop cardiovascular diseases, type 2 diabetes, and heart attacks or strokes [9]. MetS prevalence has surged in recent decades owing to socioeconomic status, lifestyle, and dietary habits alterations [10].

Numerous studies represented that an individual's diet is related to the development of MetS risk factors. Current approaches to determining the effect of diet on chronic diseases primarily focus on analyzing dietary patterns rather than individual foods and nutrients [11]. Dietary patterns provide a broader view of people's eating habits as people do not eat single nutrients but rather a combination of foods, resulting in the overall effect of individual nutrients and their interactions. Moreover, there are synergistic effects between different nutrients in foods, and the impact of a single nutrient is challenging to detect; analyzing dietary patterns may be more helpful in determining the relationship between eating habits and chronic diseases [12-14]. Dietary patterns and overall diet quality of individuals can be assessed by diet-quality indices with regard to chronic disease risk [15,16]. Food quality score (FQS) is a simple food-based diet-quality index that can be easily applied without requiring nutrient calculations. FQS is calculated by adding various food group scores that fall into healthy and unhealthy categories [17]. A limited number of studies have evaluated FQS in association with metabolic syndrome [18], coronary heart disease [17], cardiovascular disease [19], breast cancer [20], inflammatory biomarkers and antioxidant capacity [21], and mental health [22].

The FQS stands out as one of the rare diet quality indices formulated considering the entire diet. Remarkably, the relation between FQS and MetS risk factors remains unexplored in adults characterized by overweight and obesity. Consequently, our study was designed to delve into the connection between FQS and MetS risk factors in individuals grappling with overweight and obesity.

MATERIALS AND METHODS

Participants
For this cross-sectional study, 340 overweight and obese individuals were recruited from previous projects [23-25]. Participants were recruited from outpatient clinics through convenience sampling, facilitated by public advertisements using various tools such as flyers and posters. The eligibility criteria encompassed individuals between 20 and 50, with a body mass index (BMI) exceeding 25 kg/m^2. Conversely, the exclusion criteria encompassed menopause, lactation, pregnancy, and history of type 2 diabetes, cardiovascular disease, cancer, renal disease, or taking any weight-affecting medications. Prior to participating in the study, all participants provided both verbal and written informed consent.

Baseline characteristics
Socio-demographic information, encompassing age, gender, marital status, educational attainment, smoking status, and family size, was collected through interviews. Additionally, socioeconomic status (SES) was determined using the methodology outlined by Khodarahmi et al. [25].

Anthropometric measurements

Body weight, height, waist circumference (WC), and hip circumference (HC) were measured. BMI and waist-to-hip ratio (WHR) were also calculated. Further, physical activity was assessed via a short form of the International Physical Activity Questionnaire (IPAQ) [26]. After at least 15 minutes of rest, blood pressure was measured using a standard mercury sphygmomanometer (Riester Diplomat 1002; Rudolf Riester GmbH, Jungingen, Germany). Body composition was determined using bioelectrical impedance analysis (BIA) (Tanita BC-418 MA; Tanita Corp., Tokyo, Japan).

Dietary assessment and FQS calculation

Participants' dietary intake was measured using a 168-item validated semi-quantitative Food Frequency Questionnaire (FFQ) [27]. To determine the frequency of consumption of each food item in the previous year, a qualified nutritionist conducted an interview with participants. Subsequently, the food intake was recalculated and expressed in grams per day [28]. The U.S. Department of Agriculture database was used to assess the participants' daily dietary intake. The approach outlined before by Fung et al. [17] was then applied to calculate FQS. This score covered important foods and dietary categories representing overall diet quality. Each food group was categorized as favorable or unfavorable based on its health effects. The healthy food group included nuts, fruits, whole grains, vegetables, yogurt, and coffee. In contrast, the unhealthy food group consisted of desserts, red meats, ice cream, potatoes, refined grains, sugar-sweetened beverages, processed meats, potato chips, and fried foods prepared away from home. Thus, there were fourteen food groups in total. Participants' intakes were ranked into quintiles for each food group. Scores ranging from 1 to 5 were assigned based on these quintile rankings. Notably, participants with the highest intake of each food group deemed healthy received a score of 5, indicating optimal adherence to a health-promoting diet in those specific categories, and individuals with the lowest intake of these food groups received a score of 1 for each group. Conversely, quintile rankings were reversed for the unhealthy food groups, with a score of 1 assigned to individuals with the highest consumption and 5 to the ones with the lowest intake of unhealthy food groups. To derive the overall FQS, the assigned scores for each food group were cumulatively tallied, resulting in a comprehensive score ranging from 14 to 70 for each participant. It was important to note that a higher total score corresponds to a diet emphasizing healthier food choices across all evaluated categories.

Biochemical assessment

Prior studies [23-25] have provided detailed methods for the biochemical assessment. Total cholesterol (TC), serum glucose, triglyceride (TG), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), serum insulin levels, homeostatic model assessment for insulin resistance (HOMA-IR), and quantitative insulin-sensitivity check index (QUICKI) were assessed from blood samples collected after an overnight fast.

Statistical analysis

Data analysis was performed using SPSS version 26 (IBM Corp., Armonk, NY, USA), maintaining a significance level of 0.05. Categorical data were expressed as percentages, while continuous variables were summarized as mean and standard deviation. Continuous variables were compared using analysis of covariance, while categorical variables were evaluated through the χ^2 test. Furthermore, multinomial logistic regression was applied to explore the relationship between FQS tertiles and biochemical variables. This approach allowed for the estimation of odds ratios (ORs) and 95% confidence intervals (CIs) in both crude and multivariable-adjusted models.

Ethics approval and consent to participate

Participants in the study all furnished written informed consent before their involvement. The study protocol was reviewed and registered by the ethics committee of Tabriz University of Medical Sciences (registration code: IR.TBZMED.REC.1401.1010, IR.TBZMED. REC.1398.460). It is confirmed that the research methods adhered to the guidelines and regulations outlined in the Declaration of Helsinki. In instances involving illiterate participants, written informed consent was obtained from their legal guardians.

RESULTS

The total sample size included 340 subjects with a mean age of 40.64 ± 9.18 years and a BMI of 32.66 ± 4.84 kg/m². The characteristics of participants by FQS tertiles are presented in **Table 1**. Tertiles of FQS differed significantly (p < 0.05) in height, fat-free mass, SES, WHR, and basal metabolic rate. There were no significant differences across tertiles of FQS for other characteristics (p ≥ 0.05). After multivariable adjustment, no significant differences in baseline characteristics were observed among FQS tertiles (p ≥ 0.05).

Table 2 demonstrates the MetS risk factors among study participants across different tertiles of FQS. Systolic blood pressure (SBP) (p = 0.007), diastolic blood pressure (DBP) (p = 0.023), TC (p = 0.021), and fasting blood glucose (FBG) (p = 0.032) were significantly lower in higher tertiles of FQS. However, HDL-C, TG, LDL-C, insulin, QUICKI, and HOMA-IR were not significantly different across tertiles of FQS (p ≥ 0.05). Nevertheless, after adjustments for multiple variables, there were no significant differences in cardiometabolic parameters among tertiles of FQS, except for TC (p ≥ 0.05).

Participants' dietary intake of FQS components and FQS mean are represented in **Table 3**. The subjects in the third tertile of the FQS showed a greater dietary intake of whole grains, nuts, vegetables, fruits, and legumes (p < 0.05). In contrast, intakes of red meat, refined grains, processed meat, sugar-sweetened beverages, and potatoes were significantly lower in the third tertile of FQS (p < 0.05). Subjects in the third tertile of FQS had lower fat consumption and higher intake of potassium, iron, vitamin B6, magnesium, calcium, and vitamin C (**Table 4**).

Table 1. Demographic and anthropometric characteristics of participants across different tertiles of FQS

Variables	Tertiles of FQS			p value	p value*
	1st tertile (n = 114)	2nd tertile (n = 113)	3rd tertile (n = 113)		
Age (yr)	40.17 ± 9.30	39.84 ± 8.77	41.93 ± 9.40	0.185	-
Weight (kg)	93.71 ± 14.11	93.08 ± 14.93	89.51 ± 14.21	0.063	0.589
Height (cm)	170.21 ± 9.91	168.97 ± 9.89	164.68 ± 9.01	**< 0.001**	0.886
BMI (kg/m²)	32.40 ± 4.73	32.60 ± 5.24	32.97 ± 4.54	0.666	0.440
Sex (male)	79 (69.30)	71 (62.83)	46 (40.71)	**< 0.001**	-
SES score	10.54 ± 2.38	9.88 ± 2.46	9.43 ± 2.61	**0.043**	-
WC (cm)	107.52 ± 9.20	107.17 ± 10.62	105.43 ± 9.01	0.219	0.661
HC (cm)	114.02 ± 9.05	115.36 ± 10.31	115.33 ± 8.23	0.506	0.181
WHR	0.95 ± 0.07	0.93 ± 0.08	0.92 ± 0.07	**0.015**	0.475
FM (kg)	32.85 ± 7.92	34.16 ± 10.12	34.48 ± 9.37	0.567	0.310
FFM (kg)	65.45 ± 11.81	63.16 ± 12.81	58.01 ± 11.41	**0.002**	0.903
BMR (kcal)	2,015.59 ± 458.71	1,921.54 ± 365.62	1,772.77 ± 315.18	**0.002**	0.767
PA (MET-min/week)	2,341.74 ± 3,444.68	2,188.67 ± 3,310.24	1,946.82 ± 2,911.89	0.787	-

Data are expressed as mean ± standard deviation or number of patients (%). The p values derived from analysis of covariance (bold-face values are significance level of < 0.05).
FQS, food quality score; BMI, body mass index; WC, waist circumference; HC, hip circumference; WHR, waist to hip ratio; FM, fat mass; FFM, fat-free mass; BMR, basal metabolic rate; PA, physical activity; MET, metabolic equivalent of task.
*Anthropometric variables were adjusted for demographic characteristics including age, sex, socioeconomic status, and physical activity.

Table 2. Cardiometabolic parameters of study participants by tertiles of FQS

Variables	Tertiles of FQS			p value	p value*
	1st tertile (n = 114)	2nd tertile (n = 113)	3rd tertile (n = 113)		
SBP (mmHg)	125.47 ± 16.04	122.97 ± 12.92	119.49 ± 13.38	**0.007**	0.069
DBP (mmHg)	83.77 ± 12.61	81.31 ± 9.70	79.73 ± 12.37	**0.023**	0.096
TC (mg/dL)	196.99 ± 36.90	194.18 ± 33.30	184.12 ± 38.69	**0.021**	**0.016**
TG (mg/dL)	161.25 ± 85.34	144.01 ± 79.53	147.58 ± 93.18	0.339	0.273
HDL-C (mg/dL)	43.39 ± 9.53	44.67 ± 10.28	42.43 ± 8.56	0.206	0.370
LDL-C (mg/dL)	127.35 ± 29.42	125.26 ± 28.49	118.23 ± 36.83	0.080	0.131
Glucose (mg/dL)	94.74 ± 15.49	94.63 ± 27.08	88.84 ± 11.62	**0.032**	0.249
Insulin (μIU/mL)	16.40 ± 17.35	15.20 ± 10.81	16.53 ± 11.50	0.782	0.710
HOMA-IR	3.77 ± 3.78	3.77 ± 3.32	3.67 ± 2.48	0.974	0.710
QUICKI	0.33 ± 0.03	0.33 ± 0.03	0.33 ± 0.04	0.907	0.878

All data are expressed as mean ± standard deviation. The p values derived from analysis of covariance (bold-face values are significance level of < 0.05).
FQS, food quality score; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; LDL, low-density lipoprotein cholesterol; HOMA-IR, homeostatic model assessment for insulin resistance; QUICKI, quantitative insulin-sensitivity check index.
*All variables were adjusted for demographic characteristics including age, sex, socioeconomic status, and physical activity.

Table 3. Consumption rates of FQS components

FQS components (g/d)	Tertiles of FQS			p value	p value*
	1st tertile (n = 114)	2nd tertile (n = 113)	3rd tertile (n = 113)		
FQS score	37.40 ± 5.36	41.54 ± 4.56	46.87 ± 5.24	**< 0.001**	**< 0.001**
Whole grains	126.25 ± 111.01	146.64 ± 106.74	164.87 ± 121.66	**0.038**	**0.005**
Fruits	549.17 ± 479.25	681.19 ± 549.16	775.34 ± 514.19	**0.004**	**< 0.001**
Vegetables	329.38 ± 227.59	395.42 ± 324.76	390.53 ± 218.10	0.106	**0.016**
Legumes and nuts	51.51 ± 41.01	77.86 ± 65.84	83.57 ± 73.93	**0.002**	**< 0.001**
Coffee	24.69 ± 66.72	14.68 ± 32.73	24.64 ± 45.87	0.230	0.240
Yogurt	140.72 ± 179.35	162.48 ± 174.69	155.52 ± 232.55	0.697	0.409
Red meat	20.53 ± 17.20	22.16 ± 31.87	14.43 ± 16.02	**0.029**	**0.047**
Processed meat	11.70 ± 18.84	9.43 ± 14.21	6.06 ± 11.94	**0.021**	**0.038**
Refined grains	420.73 ± 246.77	339.87 ± 180.77	315.08 ± 203.59	**0.001**	**0.001**
Sugar-sweetened beverages	63.63 ± 83.63	36.05 ± 45.02	25.54 ± 67.40	**< 0.001**	**< 0.001**
Desserts and ice cream	64.76 ± 55.38	54.29 ± 35.87	52.41 ± 58.56	0.145	0.306
Potato	37.40 ± 41.67	33.61 ± 40.67	22.60 ± 22.25	**0.006**	**0.018**
Potato chips	8.52 ± 17.52	7.19 ± 17.05	4.88 ± 13.62	0.231	0.397
Fried foods	16.15 ± 20.20	18.58 ± 42.16	19.25 ± 56.62	0.845	0.764

All data are expressed as mean ± standard deviation. The p values derived from analysis of covariance (bold-face values are significance level of < 0.05).
FQS, food quality score.
*All variables were adjusted for dietary energy intake.

ORs and 95% CIs for MetS risk factors by tertile of FQS were reported in **Table 5** in 2 different models, crude and adjusted for multiple variables. Participants in the highest tertile of FQS in the crude model had lower odds of SBP (OR, 0.971; 95% CI, 0.952–0.989) DBP (OR, 0.968; 95% CI, 0.946–0.991), FBG (OR, 0.974; 95% CI, 0.955–0.993), TC (OR, 0.990; 95% CI, 0.983–0.998). Following multivariable adjustment, in the model I, odds of SBP (OR, 0.968; 95% CI, 0.947–0.988), DBP (OR, 0.962; 95% CI, 0.938–0.987), FBG (OR, 0.968; 95% CI, 0.947–0.989), TC (OR, 0.989; 95% CI, 0.981–0.996), LDL-C (OR, 0.990; 95% CI, 0.981–0.998) were lower in the highest tertile of FQS. Likewise, in model II, participants in the highest tertile of FQS had lower odds of TC (OR, 0.982; 95% CI, 0.970–0.984) and LDL-C (OR, 0.986; 95% CI, 0.974–0.999). No other significant associations were seen in the two models, crude and adjusted for multiple variables (p ≥ 0.05).

Table 4. Dietary intakes of participants across different tertiles of FQS

Dietary components	Tertiles of FQS			p value
	1st tertile (n = 114)	2nd tertile (n = 113)	3rd tertile (n = 113)	
Energy (kcal/d)	3,050.73 ± 1,133.13	2,980.54 ± 1,076.36	2,847.78 ± 791.75	0.309
Protein (g/d)	99.42 ± 36.97	101.28 ± 39.76	98.56 ± 34.85	0.055
Fat (g/d)	109.89 ± 53.03	99.79 ± 45.03	93.19 ± 36.16	**0.008**
CHO (g/d)	447.90 ± 167.82	444.83 ± 162.20	437.27 ± 136.69	0.067
Total fiber (g/d)	66.88 ± 43.52	64.33 ± 36.23	66.97 ± 35.70	0.246
SFA (g/d)	30.51 ± 17.09	29.60 ± 13.07	27.89 ± 14.47	0.954
MUFA (g/d)	34.17 ± 17.53	33.06 ± 15.79	32.60 ± 16.84	0.684
PUFA (g/d)	23.24 ± 13.46	22.14 ± 13.30	22.42 ± 13.10	0.466
Cholesterol (mg/d)	313.58 ± 171.05	283.60 ± 125.31	261.38 ± 148.84	0.093
Sodium (mg/d)	4,927.69 ± 2,758.89	4,713.54 ± 1,892.31	4,420.01 ± 1,919.91	0.579
Iron (mg/d)	23.40 ± 9.56	23.33 ± 9.20	24.68 ± 13.14	**0.005**
Magnesium (mg/d)	510.40 ± 200.23	557.26 ± 281.55	563.85 ± 202.90	**< 0.001**
Potassium (mg/d)	4,421.16 ± 1,812.71	4,805.49 ± 2,241.73	5,012.03 ± 2,049.89	**< 0.001**
Calcium (mg/d)	1,266.96 ± 580.49	1,261.37 ± 539.55	1,342.84 ± 584.03	**0.003**
Vitamin B1 (mg/d)	2.69 ± 1.12	2.60 ± 1.00	2.58 ± 1.06	0.640
Vitamin B6 (mg/d)	2.26 ± 0.86	2.34 ± 0.92	2.40 ± 0.95	**0.001**
Folic acid (mg/d)	724.30 ± 301.14	720.49 ± 281.60	720.65 ± 295.38	0.169
Vitamin B12 (mg/d)	5.86 ± 7.51	5.49 ± 5.43	4.66 ± 4.54	0.499
Vitamin C (mg/d)	208.77 ± 160.11	237.03 ± 173.20	273.95 ± 197.90	**0.001**

All data are expressed as mean ± standard deviation. The p values derived from analysis of covariance (bold-face values are significance level of < 0.05).
CHO, carbohydrates; SFA, saturated fatty acids; MUFA, mono-unsaturated fatty acids; PUFA, poly-unsaturated fatty acids.
*All variables were adjusted for dietary energy intake, except for daily energy intake.

Table 5. Crude and multivariable adjusted ORs and 95% CIs for cardiometabolic risk factors across different tertiles of FQS

Variables	Tertiles of FQS								
	Crude ORs (95% CI)			Model I[a] ORs (95% CI)			Model II[b] ORs (95% CI)		
	1st tertile (n = 114)	2nd tertile (n = 113)	3rd tertile (n = 113)	1st tertile (n = 114)	2nd tertile (n = 113)	3rd tertile (n = 113)	1st tertile (n = 114)	2nd tertile (n = 113)	3rd tertile (n = 113)
SBP (mmHg)	1	0.988 (0.969–1.005)	**0.971 (0.952–0.989)***	1	0.989 (0.970–1.009)	**0.968 (0.947–0.988)***	1	0.996 (0.968–1.025)	0.972 (0.941–1.003)
DBP (mmHg)	1	0.979 (0.957–1.003)	**0.968 (0.946–0.991)***	1	0.980 (0.956–1.004)	**0.962 (0.938–0.987)***	1	0.973 (0.940–1.006)	0.965 (0.931–1.001)
FBG (mg/dL)	1	1.000 (0.988–1.012)	**0.974 (0.955–0.993)***	1	1.000 (0.988–1.013)	**0.968 (0.947–0.989)***	1	1.004 (0.989–1.018)	0.975 (0.946–1.005)
TC (mg/dL)	1	0.998 (0.991–1.005)	**0.990 (0.983–0.998)***	1	0.998 (0.991–1.005)	**0.989 (0.981–0.996)***	1	0.995 (0.984–1.006)	**0.982 (0.970–0.994)***
LDL-C (mg/dL)	1	0.998 (0.990–1.006)	0.991 (0.982–1.001)	1	0.998 (0.990–1.006)	**0.990 (0.981–0.998)***	1	0.995 (0.983–1.007)	**0.986 (0.974–0.999)***
HDL-C (mg/dL)	1	1.014 (0.987–1.042)	0.989 (0.961–1.017)	1	1.010 (0.981–1.040)	0.965 (0.935–1.005)	1	1.026 (0.983–1.072)	0.950 (0.906–1.005)
TG (mg/dL)	1	0.998 (0.995–1.001)	0.999 (0.996–1.001)	1	0.998 (0.995–1.001)	0.999 (0.996–1.002)	1	0.995 (0.989–1.002)	0.996 (0.990–1.003)
Insulin (μIU/mL)	1	0.993 (0.968–1.017)	1.001 (0.979–1.022)	1	0.992 (0.967–1.017)	0.998 (0.976–1.021)	1	1.003 (0.961–1.047)	1.016 (0.974–1.060)

OR, odds ratio; CI, confidence interval; FQS, food quality score; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose; TC, total cholesterol; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; TG, triglyceride.
*p < 0.05; [a]Model I: adjusted for age, sex, and BMI; [b]Model II: additionally adjusted for socioeconomic status, and energy intake.

DISCUSSION

In this cross-sectional study, we investigated the association between FQS and risk factors of MetS in adults with overweight and obesity in Iran. Our findings indicate that SBP, DBP, TC, and FBG were significantly lower among the subjects in the highest tertile of FQS. However, after adjustments for multiple variables, only TC remained significantly different. Furthermore, our results revealed that a higher FQS tertile was significantly associated with a lower risk of elevated SBP, DBP, FBG, TC, and LDL-C in a multivariable-adjusted model.

There is a paucity of research assessing the association between FQS and health outcomes, leading to a limited body of evidence exploring the relationship between MetS risk factors and FQS. In a cross-sectional research by Lavigne-Robichaud et al. [18] which contradicts our findings, FQS and the risk of MetS were not observed to be significantly associated. Likewise, Darooghegi Mofrad et al. [19], reported that FQS and risk factors for cardiovascular diseases were not significantly associated among 368 adult women. Regarding the positive health effects of FQS, Mozaffarian et al. [29] found that a 4-year weight change was inversely associated with the healthy food components of FQS. Additionally, in a long-term follow-up, Fung et al. [17] reported that higher FQS was related to a lesser chance of coronary artery disease compared to other diet-based indices such as the Dietary Approach to Stop Hypertension (DASH), alternative Mediterranean diet score, and Alternative Healthy Eating Index-2010. Furthermore, other studies showed that FQS is related to a lower risk of breast cancer [20], lower levels of inflammatory biomarkers in young women [21], and better mental health in women [22].

In this study, we discovered a significant relationship between an increased FQS and reduced odds of MetS risk factors (**Figure 1**). In point of fact, a higher FQS with higher consumption of healthy foods and a lower intake of unhealthy foods indicates superior diet quality. Consistent with our findings, several studies reported that higher diet quality, represented by the DASH diet score, is related to a better status of MetS risk factors [13,30-37]. Likewise, a population-based cohort study [38] showed that a higher Mediterranean diet score, which indicates higher diet quality, is associated with a better lipid profile and lower blood pressure. In a meta-analysis of observational studies, Bakaloudi et al. [39] found that a higher Mediterranean diet score can positively affect all MetS parameters.

The positive effects of FQS on the risk factors of MetS can be explained by the effect of each component. As reported in **Table 3**, consumption of whole grains, fruits, legumes, and nuts was higher in the third tertile of FQS. The high dietary fiber content of whole grains has been
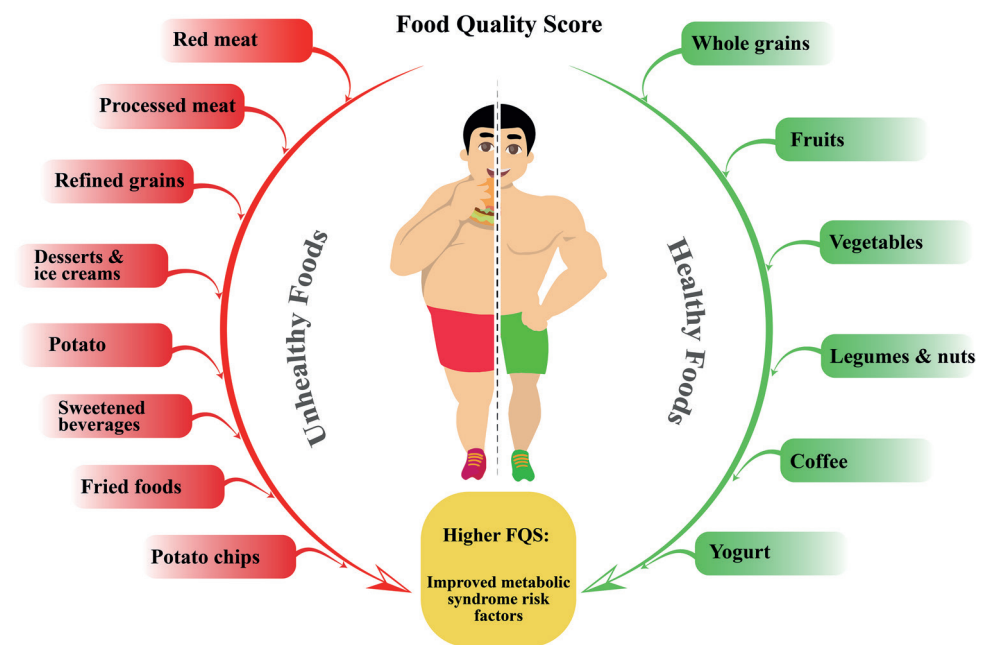
Figure 1. Mechanistic pathways Summary of the association between FQS and risk of metabolic syndrome. FQS, food quality score.

attributed to the multitude of health benefits associated with their consumption [40]. An umbrella review of meta-analyses showed that dietary fiber is related to the improved status of SBP, DBP, TC, LDL-C, and FBG [41]. Furthermore, the consumption of fruits and vegetables has been consistently associated with a decreased risk of MetS [42]. Legumes and nuts, owing to their high concentration of monounsaturated fatty acids, polyunsaturated fatty acids, and bioactive compounds, can improve the serum lipid profile, glucose levels, and blood pressure [43].

Moreover, the lower consumption of unhealthy foods, such as red and processed meat, refined grains, sugar-sweetened beverages, and potatoes, could explain the positive health effects of a higher FQS. Two meta-analysis studies reported that red and processed meat intake was associated with a higher risk of MetS [44,45]. Likewise, refined grains [46] and sugar-sweetened beverages [47] were also directly linked to a higher risk of MetS.

This cross-sectional study represents the initial attempt, to the best of our knowledge, to examine the relationship between FQS and risk factors of MetS. There are certain limitations to be aware of, though. Establishing a causal relationship between FQS and the odds of MetS risk factors is challenging due to the cross-sectional nature of the research. The dynamic nature of diet and MetS risk factors over time complicates the establishment of causality. Long-term evaluations of these factors would be beneficial in elucidating the causal relationship. Additionally, while FFQs are valuable tools for assessing long-term dietary intake, it is important to note that the data collected through FFQs may be influenced by recall bias. Moreover, dietary records might not always accurately represent dietary nutrient intake.

CONCLUSION

In conclusion, our findings demonstrate a significant association between the highest FQS tertile and a reduced risk of elevated SBP, DBP, FBG, TC, and LDL-C in a model adjusted for age, sex, and BMI. However, more experimental and longitudinal studies are warranted to obtain a holistic perception of the relationship between FQS and the risk factors of MetS.

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