Nutrition 62 (2019) 32–38

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Applied nutritional investigation

Dietary patterns are associated with the prevalence of nonalcoholic fatty liver disease in Korean adults

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ARTICLE INFO

Article History:
Received 17 May 2018
Received in revised form 29 October 2018
Accepted 17 November 2018

Keywords:
Nonalcoholic fatty liver disease
Dietary pattern
Prevalence
Association
Korean

ABSTRACT

Objectives: There is minimal research on the effect of overall dietary patterns on the development of nonalcoholic fatty liver disease (NAFLD) in the Korean population. The present study investigated the association between dietary patterns and NAFLD.
Methods: A prospective cross-sectional study was performed on participants who visited a health care center for a health checkup. A semiquantitative food frequency questionnaire was administered to the participants to assess their food intake, and factor analysis was used to identify dietary patterns. Relationships between the dietary patterns and the risk of NAFLD were evaluated.
Results: A total of 331 of the 1190 participants (27.8%) analyzed were diagnosed with NAFLD. Three factors were generated and defined as the traditional pattern, Western and high-carbohydrate pattern, and simple meal pattern using a factor analysis procedure. The traditional pattern revealed a positive correlation with NAFLD, and the simple meal pattern exhibited an inverse correlation with NAFLD. We adjusted for confounding factors, such as age, sex, waist circumference, smoking status, total energy intake, diabetes, and hypertension, and participants in the highest quartile of the traditional dietary pattern exhibited a higher prevalence of NAFLD (*P* for trend = 0.0373; odds ratio, 1.85; 95% confidence interval, 1.11–3.08) than participants in the lowest quartile. Participants in highest quintile of the simple meal pattern exhibited a decreased risk of NAFLD compared with the lowest quintile (*P* for trend = 0.0233; odds ratio 0.59; 95% confidence interval 0.34–1.00).
Conclusions: The traditional dietary pattern was associated with an increased risk of NAFLD, and the simple meal pattern was associated with a decreased risk of NAFLD in the Korean population. This finding supports the use of dietary patterns to predict the risk of NAFLD and potentially serve as a dietary prevention strategy in individuals who are at high risk of developing NAFLD.

Introduction

Nonalcoholic fatty liver disease (NAFLD) is the most common chronic liver disease, with an increasing prevalence of 20% to 30% in Western nations and 16% to 33% in Korea [1,2]. NAFLD is characterized by hepatic steatosis that may develop into steatohepatitis, fibrosis, cirrhosis, and hepatocellular carcinoma in some individuals [3]. Triglyceride accumulation in hepatocytes is associated with insulin resistance, visceral obesity, diet, and nutrition [4]. Nutrition may be a potential environmental factor in the development and progression of NAFLD [5,6]. Greater adherence to the Mediterranean diet was associated with the severity of NALFD [7], and increased polyunsaturated fatty acid consumption significantly improved markers of nonalcoholic steatohepatitis [8]. Dietary factors play important roles in the composition of the gut microbiome, which may contribute to the development of NAFLD [9].

Several studies evaluated the relationships between the intake of individual nutrients and the risk of developing NAFLD. A dietary pattern analysis enables the assessment of the overall effects of diet via quantification of the cumulative effect of multiple nutrients. An examination of dietary patterns instead of individual foods more closely parallels real-world situations, in which multiple nutrients and foods are consumed simultaneously, and

This work was supported by grant no 04-2010-0910 from the Seoul National University Hospital Research Fund.
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https://doi.org/10.1016/j.nut.2018.11.021

consideration of the entire dietary pattern may be the best approach to investigate the combined effects of consumed foods [10,11]. A Western dietary pattern for 14 years was associated with a higher risk of NAFLD in 17-year-old obese adolescents [12]. A randomized controlled trial found that a Mediterranean diet produced significant benefits in liver fat and insulin sensitivity independently of weight loss, and these changes were sustained at 12 months [13]. A recent animal-based dietary pattern was associated with an increased risk of NAFLD in the Chinese population [14]. Therefore evaluating dietary contributions to the risk of NAFLD is critical, and dietary pattern analysis may be useful in determining dietary recommendations for NAFLD.

To the best of our knowledge, no studies have investigated the association between dietary patterns and the development of NAFLD in Korean adults. Therefore we prospectively investigated the association between dietary pattern and NAFLD in the Korean population using a validated a food frequency questionnaire (FFQ).

Methods

Study population

The Institutional Review Board of the Seoul National University Hospital approved this study. Informed consent was waived because the present study was performed using a retrospective design from a database and medical records and researchers only accessed and analyzed deidentified data from a previously described cohort [15]. Briefly, participants who underwent health checkups, including dietary intake assessment using an FFQ, at the Seoul National University Hospital Gangnam Healthcare Center in Seoul, Korea, between May 2011 and December 2011 were included in this study. Most of the study population voluntarily paid for their health checkups, but some employers supported the participants. We excluded all participants with chronic liver disease, including 70 participants who were positive for the hepatitis B virus, 15 participants who were positive for the hepatitis C virus, and 751 participants with significant alcohol consumption (>20 g/d for men and >10 g/d for women) [16]. We excluded 50 participants who did not respond to more than 50 questions on the FFQ or whose energy intake was more or less than 3 standard deviations of the mean log-transformed energy intake. The study protocol followed the Declaration of Helsinki of 1975, as revised in 1983.

Clinical and laboratory assessments

Each participant completed a questionnaire based on their medical history and current lifestyle. All participants received an anthropometric assessment, and laboratory and radiologic tests were performed as previously described [17]. Briefly, body weight and height were measured using a digital scale, and body mass index (BMI) was calculated by dividing the weight (kg) by the square of the height (m^2). A well-trained examiner measured the waist circumference (WC) at the midpoint between the lower costal margin and the anterior superior iliac crest using a tape measure. Systolic and diastolic blood pressures were measured twice, and the mean values were recorded. Hypertension was defined as systolic blood pressure ≥140 mm Hg, diastolic blood pressure ≥90 mm Hg, or the use of antihypertensive medication. Blood samples were collected before 010:00 h after a 12-h overnight fast, and all laboratory tests, including the serum levels of alanine aminotransferase (ALT), aspartate aminotransferase (AST), γ-glutamyl transferase (GGT), total cholesterol, triglycerides, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, fasting glucose, hepatitis B surface antigen, and antibody to hepatitis C virus, were performed using standard laboratory methods. Diabetes mellitus was defined as a fasting serum glucose level ≥126 mg/dL or the use of antidiabetic medication. A current smoker was defined as a person who smoked at least one cigarette per day for the previous 12 mo.

Assessment of dietary intake and dietary patterns

Dietary intake was assessed during health checkups before acquisition of the anthropometric measurements, and a dietician administered the laboratory and radiologic tests on the same day using a validated FFQ [18]. Participants were asked to estimate their usual consumption frequency of various foods and the typical portion sizes within the year preceding the interview date. Each food item had nine options for frequency that ranged from “never or less than once per month” to “3 times per day” and three options for portion size. We classified the foods into 36 unique categories based on culinary preferences or similarities in nutrient composition for factor analysis in our study. We performed a principal component analysis via varimax rotation to construct the factors that interpreted the maximum variability of the data [19]. The factor loadings of the food items to account for the correlation between each food item and the dietary pattern were calculated, and individual participants were assigned factor scores for the patterns defined by addition of the intake of all 36 food items, each of which were weighted by the factor loadings.

Assessment of fatty liver

Experienced radiologists who were blinded to any relevant clinical information determined the diagnosis of NAFLD was based on ultrasonography (Acusion, Sequoia 512, Siemens, Mountain View, CA, USA) findings. The following sonographic features of a fatty liver were included [20]: 1) normal echogenicity; 2) mild, slightly diffuse increase in bright homogenous echoes in the parenchyma, with normal visualization of the diaphragm and the hepatic and portal vein borders, and normal hepatorenal contrast; 3) moderate, diffuse increase in bright echoes in the parenchyma, with slightly impaired visualization of the peripheral hepatic and portal vein borders; and 4) severe, marked increase in bright echoes at a shallow depth, with deep attenuation and impaired visualization of the diaphragm and marked vascular blurring. Participants with moderate or severe NAFLD were combined into a moderate-to-severe category because of the small number of individuals with severe NAFLD in the cohort.

Statistical analysis

We compared the baseline characteristics between participants with and without NAFLD using Student's *t* test for continuous variables and the χ^2 test for categorical variables. We performed analysis of variance for continuous variables and χ^2 tests for categorical variables between quintiles of each dietary pattern score. Associations between the three dietary patterns and NAFLD were estimated from the odds ratios (ORs) and the 95% confidence intervals (CIs) using multiple logistic regression adjusted for age, sex, WC, smoking status, total energy intake (kcal/day, quintiles), diabetes, and hypertension. We examined the trends across the associations between the quintiles of each dietary patterns and NAFLD by defining the median value of the factor scores in each quintile as a continuous variables in the models. Two-sided P values < 0.05 were considered statistically significant. All statistical analyses were performed using SAS version 9.3 (SAS Institute, Inc., Cary, NC, USA).

Results

Dietary patterns

Three dietary patterns were identified by factor analysis. The first pattern was characterized by high intakes of vegetables; fermented vegetables such as kimchi and jjangajji; fish and seafood; mushrooms; and fermented, processed, natural soybeans. The factors were composed of more Korean traditional foods than the other foods, including kimchi, deonjang (fermented soy paste), tofu, and namool (seasoned cooked vegetables). The second pattern was highly correlated with intakes of processed meats, bread, soft drinks, pork, noodles, beef, cakes, snacks, beef soup, sugar, coffee, chicken, processed fish, and refined grains. Because these foods were less consumed in Korea compared with Western countries [21], we labeled the second pattern “Western and high-carbohydrate pattern.” The third pattern was correlated with intakes of fruits, root and yellow vegetables, eggs, dairy products, and nuts. Because this factor included foods that are consumed alone and of which cooking is relatively simple compared with traditional Korean food, we labeled this the “simple meal pattern.” We represented the food group list and the factor loadings of each food group more than 0.30 or less than −0.30 for these dietary patterns in Table 1. These three dietary patterns accounted for 3.58%, 2.97%, and 2.81% of the variance in total food intake, respectively. Supplementary Table 1 shows the total energy intake of the three dietary patterns.

Study population

A total of 1190 participants (mean age 51.5 ± 10.3 y, women = 57.8%) were analyzed, and 331 (27.8%) participants were diagnosed with NAFLD. Individuals with NAFLD were older and exhibited a higher prevalence of diabetes and hypertension;

Table 1
Rotated factor loading matrix for the three dietary patterns identified from the food frequency questionnaires

Food or food groups	Dietary pattern		
	Traditional pattern	Western and high-CHO pattern	Simple meal pattern
Other vegetables	0.70537	–	–
Green vegetables	0.70216	–	–
Cruciferous vegetables	0.59979	–	–
Fermented vegetables	0.57889	–	–
Fish	0.55964	–	–
Mushroom	0.52811	–	–
Fermented soybeans	0.49391	–	–
Seaweed	0.42729	–	–
Shellfish	0.36710		–
Soybean and soybean products	0.31744	–	–
Processed meats	–	0.56645	–
Bread	–	0.51563	0.37429
Soft drinks	–	0.50345	–
Pork	–	0.48993	–
Noodles	–	0.48357	–
Beef		0.47146	
Cakes and snacks	–	0.41489	0.3470
Beef soup	–	0.39885	–
Added sugar		0.39557	
Coffee	–	0.35640	–
Chicken	–	0.31621	–
Processed fish	–	0.31619	–
Refined grains	–	0.39373	−0.42534
Mixed grains		−0.36729	
Other fruit	–	–	0.63468
Citrus fruits	–	–	0.60454
Root and yellow vegetables	0.3144	–	0.53557
Dairy products	–	–	0.41072
Eggs	–	–	0.38174
Nuts	–	–	0.32752

CHO, carbohydrate.
Absolute values <0.3 were not presented for simplicity.

increased systolic and diastolic blood pressure, BMI, and WC; elevated AST, ALT, triglycerides, low-density lipoprotein cholesterol, fasting glucose, and HbA1c levels; and lower levels of high-density lipoprotein cholesterol than individuals without NAFLD. NAFLD participants were also more likely to be men ($P < 0.001$, Table 2).

Dietary pattern and NAFLD

Table 3 shows the characteristics of the study participants across the quintile categories of the dietary pattern scores. Participants in the highest quintile of the Western and high-carbohydrate patterns were more likely to be male, younger, and a current smoker and exhibit higher BMI, WC, and ALT and TG values and a lower prevalence of diabetes mellitus and hypertension than individuals in the lowest quintile. Participants in the highest quintile of the simple meal pattern were more likely to be female and nonsmokers and exhibited significantly lower systolic and diastolic blood pressure; reduced BMI, WC, ALT, TG, and glucose values; and a lower prevalence of diabetes mellitus than individuals in the lowest quintile.

Table 4 shows the associations between dietary patterns and the risk of NAFLD. The traditional pattern revealed a positive correlation, and the simple meal pattern exhibited an inverse correlation with NAFLD. Individuals in the highest quintile In the age- and sex-adjusted model exhibited an increased risk of NAFLD compared with the lowest quintile of the transitional and the Western and high-carbohydrate pattern (*P* for trend = 0.0079, odds ratio [OR] 1.77, 95% confidence interval [CI] 1.16–2.72; and *P* for trend = 0.0018, OR 2.00, 95% CI 1.28–3.13, respectively). We adjusted for confounding factors, such as age, sex, WC, smoking status, total energy intake, diabetes, and hypertension, and the statistical significance remained only in the traditional pattern (*P* for trend = 0.0373, OR 1.85, 95% CI 1.11–3.08 in the highest quintile compared with the lowest quintile). Participants in the highest quintile of the simple meal pattern exhibited a decreased risk of

Table 2
Comparison of baseline characteristics between participants with and without NAFLD

Variables	No NAFLD ($n = 859$)	NAFLD ($n = 331$)	P*
Age (y)	51.1 ± 9.6	52.9 ± 9.3	0.003
Male (%)	289 (33.6)	212 (64.1)	<0.001
Smoking (%)			<0.001
Never smoker	484 (56.3)	128 (38.7)	
Ex-smoker	137 (16.0)	91 (27.5)	
Current smoker	63 (7.3)	61 (18.4)	
Diabetes mellitus (%)	113 (13.2)	137 (41.4)	<0.001
Hypertension (%)	203 (23.6)	155 (46.8)	<0.001
Systolic BP (mm Hg)	112.9 ± 13.0	119.0 ± 13.1	<0.001
Diastolic BP (mm Hg)	71.7 ± 10.2	76.9 ± 9.7	<0.001
BMI (kg/m^2)	22.1 ± 2.5	25.09 ± 3.0	<0.001
WC (cm)	80.5 ± 7.7	89.0 ± 7.5	<0.001
AST (IU/L)	22.9 ± 7.4	29.0 ± 18.9	<0.001
ALT (IU/L)	20.9 ± 11.4	34.8 ± 18.8	<0.001
Cholesterol (mg/dL)	199.1 ± 34.7	205.2 ± 37.5	0.010
TG (mg/dL)	74.2 ± 36.4	128.5 ± 70.9	<0.001
HDL-C (mg/dL)	54.9 ± 11.1	47.3 ± 9.0	<0.001
LDL-C (mg/dL)	124.0 ± 30.5	133.3 ± 33.4	<0.001
FBS (mg/dL)	89.7 ± 13.2	101.7 ± 20.9	<0.001
HbA1c (%)	5.6 ± 0.4	6.0 ± 0.8	<0.001

ALT, alanine aminotransferase; AST, aspartate aminotransferase; BMI, body mass index; BP, blood pressure; FBS, fasting blood sugar; HbA1c, hemoglobin A1c; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; NAFLD, nonalcoholic fatty liver disease; TG, triglycerides; WC, waist circumference.
Data are shown as the mean ± standard deviation or numbers and percentages.
**P* values for continuous variables (*t* test) and for categorical variables (chi-square test).

Table 3
Comparison of baseline characteristics by quintile of three dietary patterns

	Traditional pattern			Western and high-CHO pattern			Simple meal pattern		
Variables	Q1 (*n* = 238)	Q5 (*n* = 238)	*P*	Q1 (*n* = 238)	Q5 (*n* = 238)	*P*	Q1 (*n* = 238)	Q5 (*n* = 238)	*P*
Age (y)	59.8 ± 11.0	53.4 ± 8.6	<0.001	56.2 ± 8.1	47.1 ± 9.1	<0.001	53.0 ± 8.8	49.4 ± 9.6	<0.001
Male (%)	81 (34.0)	100 (42.0)	0.007	68 (28.6)	135 (56.7	<0.001	150 (62.6)	63 (26.5)	<0.001
Smoking (%)			<0.001			<0.001			<0.001
Never smoker	139 (58.4)	123 (51.7)		133 (55.9)	116 (48.7)		90 (37.5)	154 (64.7)	
Ex-smoker	33 (13.9)	48 (20.2)		38 (16.0)	46 (19.3)		47 (20.0)	33 (13.9)	
Current smoker	21 (8.8)	21 (8.8)		4 (1.7)	48 (20.2)		54 (22.5)	11 (4.6)	
DM (%)	48 (20.2)	55 (23.2)	0.838	60 (25.2)	37 (15.6)	0.045	55 (22.9)	44 (18.5)	0.078
HT (%)	68 (28.6)	75 (31.5)	0.555	92 (38.7)	60 (25.2)	0.003	76 (31.7)	67 (28.2)	0.016
Systolic BP	114.6 ± 13.0	114.7 ± 14.0	0.952	117.0 ± 13.9	114.3 ± 12.8	0.006	115.6 ± 12.6	112.9 ± 12.5	0.012
Diastolic BP	72.0 ± 9.2	74.0 ± 10.4	0.255	73.5 ± 10.0	73.8 ± 10.5	0.257	73.8 ± 9.7	71.4 ± 10.6	0.002
BMI (kg/m^2)	22.7 ± 2.9	23.6 ± 3.2	0.007	22.7 ± 2.6	23.7± 3.4	<0.001	23.7 ± 2.9	22.5 ± 3.3	<0.001
WC (cm)	82.0 ± 8.1	84.4 ± 8.4	0.035	81.9 ± 8.7	84.7 ± 8.9	0.011	84.9 ± 8.2	81.4 ± 8.9	<0.001
AST (IU/L)	24.6 ± 20.6	25.3 ± 8.8	0.190	24.8 ± 8.2	25.5 ± 20.7	0.517	25.1 ± 9.0	24.3 ± 9.9	0.162
ALT (IU/L)	22.9 ± 14.2	26.2 ± 15.2	0.014	23.7 ± 13.2	27.4 ± 16.8	0.027	27.1 ± 16.0	23.4 ± 14.1	0.003
CHO (mg/dL)	199.0 ± 35.5	201.7 ± 35.4	0.634	202.0 ± 36.5	202.5 ± 33.7	0.204	199.5 ± 36.3	201.6 ± 35.7	0.662
TG (mg/dL)	83.8 ± 47.6	92.3 ± 56.1	0.477	83.9 ± 48.7	101.2± 63.2	0.004	108.9 ± 67.6	79.0 ± 47.2	<0.001
HDL-C (mg/dL)	54.6 ± 11.4	52.1 ± 10.5	0.034	52.9 ± 11.0	51.7 ± 10.6	0.514	49.3 ± 10.0	56.0 ± 11.6	<0.001
LDL-C (mg/dL)	123.8 ± 31.6	128.1 ± 30.0	0.546	128.1 ± 33.2	128.0± 30.4	0.182	127.3 ± 31.4	124.3 ± 30.4	0.539
FBS (mg/dL)	91.8 ± 13.5	94.3 ± 17.4	0.245	94.3 ± 15.4	91.4 ± 14.2	0.237	94.8 ± 17.2	90.6 ± 12.5	0.003
HbA1c	5.7 ± 0.4	5.8 ± 0.6	0.298	5.8 ± 0.5	5.7 ± 0.6	0.640	5.8 ± 0.6	5.6 ± 0.4	0.014

ALT, alanine aminotransferase; AST, aspartate aminotransferase; BMI, body mass index; BP, blood pressure; CHO, cholesterol; DM, diabetes mellitus; FBS, fasting blood sugar; HbA1c, hemoglobin A1c; HDL-C, high-density lipoprotein cholesterol; HT, hypertension; LDL-C, low-density lipoprotein cholesterol; NAFLD, nonalcoholic fatty liver disease; Q, quintile; TG, triglycerides; WC, waist circumference.
Data are shown as mean ± standard deviation.

NAFLD compared with the lowest quintile in the age- and sex-adjusted model and multiple logistic regression model (*P* for trend = 0.0331, OR 0.69, 95% CI 0.45–1.06; and *P* for trend = 0.0233, OR 0.59, 95% CI 0.34–1.00, respectively). We analyzed the data after stratifying the cohort by gender, and the result was consistent only in the traditional pattern in men (Table 5).

Discussion

A healthy diet is beneficial for NAFLD patients, and unhealthy dietary patterns are associated with the development and progression of NAFLD [12,13]. Dietary patterns determined by factor analysis may be proxy indicators of the availability and consumption of real food, which provide a more realistic representation of everyday eating habits [22]. Traditionally, unhealthy diet patterns in patients with NAFLD include overconsumption of fructose, soft drinks, meats, or saturated fat and cholesterol, and reduced intake of fiber, fish or omega-3 fatty acids, and some vitamins [23,24]. A previous case-control study in Iran reported that higher egg consumption was associated with a higher risk of NAFLD [25]. Therefore nutritional management is important for the prevention of NAFLD and its complications.

The present study identified three major dietary patterns—traditional pattern, Western and high-carbohydrate pattern, and simple meal pattern—using collected data and factor analysis

Table 4
Multivariable analysis for risk of NAFLD by quintiles of dietary patterns

Dietary pattern	Age and sex adjusted OR (95% CI)	*P**	Multiple logistic regression model OR (95% CI)	*P**
Traditional		0.0079		0.0373
Q1	1 (reference)		1 (reference)	
Q2	1.30 (0.84–2.00)		1.47 (0.89–2.42)	
Q3	1.03 (0.66–1.62)		1.29 (0.77–2.14)	
Q4	1.30 (0.85–2.01)		1.37 (0.83–2.27)	
Q5	1.77 (1.16–2.72)		1.85 (1.11–3.08)	
Western and high-CHO		0.0018		0.125
Q1	1 (reference)		1 (reference)	
Q2	1.09 (0.70–1.69)		1.06 (0.65–1.73)	
Q3	1.22 (0.79–1.90)		1.12 (0.69–1.84)	
Q4	1.09 (0.70–1.71)		1.00 (0.60–1.66)	
Q5	2.00 (1.28–3.13)		1.58 (0.92–2.73)	
Simple meal		0.0331		0.0233
Q1	1 (reference)		1 (reference)	
Q2	0.83 (0.56–1.23)		0.81 (0.51–1.27)	
Q3	0.87 (0.58–1.29)		0.97 (0.61–1.55)	
Q4	0.56 (0.37–0.86)		0.54 (0.33–0.90)	
Q5	0.69 (0.45–1.06)		0.59 (0.34–1.00)	

CI, confidence interval; CHO, carbohydrate; NAFLD, nonalcoholic fatty liver disease; OR, odds ratio; Q, quintile.
The multivariable model was adjusted for age, sex, waist circumference, smoking status, total energy intake, diabetes, and hypertension.
**P* value for the test of trend of odds.

Table 5
Multivariable analysis for risk of NAFLD by quintiles of dietary patterns according to gender

Men	Age adjusted OR (95% CI)	P*	Multivariable model OR (95% CI)	P*
Traditional		0.004		0.0094
Q1	1 (reference)		1 (reference)	
Q2	1.85 (1.04–3.31)		2.02 (1.03–3.97)	
Q3	1.26 (0.70–2.28)		1.48 (0.74–2.96)	
Q4	2.17 (1.21–3.87)		2.52 (1.25–5.09)	
Q5	2.38 (1.33–4.27)		2.80 (1.35–5.80)	
Western and high-CHO		0.0163		0.1234
Q1	1 (reference)		1 (reference)	
Q2	1.56 (0.88–2.78)		1.76 (0.90–3.43)	
Q3	1.69 (0.94–3.02)		1.71 (0.86–3.40)	
Q4	1.24 (0.68–2.24)		1.32 (0.66–2.64)	
Q5	2.54 (1.38–4.66)		2.31 (1.08–4.92)	
Simple meal		0.072		0.1127
Q1	1 (reference)		1 (reference)	
Q2	1.00 (0.57–1.75)		1.24 (0.65–2.35)	
Q3	1.15 (0.66–2.01)		1.35 (0.70–2.58)	
Q4	0.75 (0.42–1.31)		0.89 (0.46–1.73)	
Q5	0.66 (0.37–1.16)		0.66 (0.33–1.31)	
Women	**Age adjusted OR (95% CI)**	**P***	**Multivariable model OR (95% CI)**	**P***
Traditional		0.4517		0.6251
Q1	1 (reference)		1 (reference)	
Q2	1.11 (0.59–2.08)		1.30 (0.63–2.68)	
Q3	0.77 (0.38–1.48)		0.93 (0.43–1.98)	
Q4	0.71 (0.36–1.39)		0.82 (0.38–1.74)	
Q5	1.33 (0.72–2.44)		1.33 (0.65–2.74)	
Western and high-CHO		0.0395		0.4799
Q1	1 (reference)		1 (reference)	
Q2	1.14 (0.59–2.19)		0.93 (0.45–1.92)	
Q3	1.46 (0.76–2.77)		1.35 (0.66–2.77)	
Q4	1.61 (0.84–3.09)		1.15 (0.55–2.39)	
Q5	1.90 (0.97–3.73)		1.32 (0.57–3.06)	
Simple meal		0.2926		0.1367
Q1	1 (reference)		1 (reference)	
Q2	0.99 (0.55–1.77)		1.23 (0.64–2.39)	
Q3	0.71 (0.38–1.23)		0.72 (0.35–1.49)	
Q4	0.50 (0.26–0.98)		0.43 (0.19–0.98)	
Q5	0.87 (0.47–1.61)		0.72 (0.32–1.61)	

CI, confidence interval; CHO, carbohydrate; NAFLD, nonalcoholic fatty liver disease; OR, odds ratio; Q, quintile.
The multivariable model was adjusted for age, sex, waist circumference, smoking status, total energy intake, diabetes, and hypertension.
**P* value for the test of trend of odds.

procedures, similar to a previous study [26,27]. We identified that the traditional dietary pattern was associated with an increased risk of NAFLD, and the simple meal pattern was associated with decreased risk of NAFLD in the Korean population. This association was independent of age, sex, WC, smoking status, total energy intake, diabetes, and hypertension. However, the Western and high-carbohydrate pattern was not significantly associated with NAFLD. This might be the first study to report an association between dietary pattern and NAFLD in the Korean population.

The traditional dietary pattern is characterized by a high consumption of fermented, cruciferous, and green vegetables; fish; mushrooms; fermented soybeans; seaweed; and shellfish. Some foods in the traditional pattern are low fat and high carbohydrate, which promote the development of fatty liver via increased de novo fatty acid synthesis [28]. A previous study in China found that a traditional Chinese dietary pattern was not associated with NAFLD [14]. The complex nature of dietary pattern may explain the different results between studies.

The simple meal dietary pattern is characterized by a high intake of fruit, root and yellow vegetables, dairy products, eggs, and nuts. The consumption of fruits and vegetables likely contributes to a high intake of antioxidant vitamins, which are protective against oxidative stress [29]. The simple meal pattern is associated with a decreased risk of NAFLD [30,31].

The Western and high-carbohydrate dietary pattern was characterized by increased intakes of processed meats, bread, soft drinks, pork, noodles, beef, cakes, snacks, beef soup, additional sugar, coffee, chicken, processed fish, and refined grains. However, we did not find a significant positive association of this pattern with NAFLD using the odds ratio of NAFLD for the highest quintile of this pattern, which was higher than the lowest quintile. A large prospective study found that a high-carbohydrate/high-sugar pattern characterized by elevated intake of fruits, cakes, soft drinks, ice cream, preserved bean curd, and candied fruits was associated with higher rates of NAFLD in women [32]. This result partially agrees with a previous study that reported that a Western dietary pattern, which is characterized by a predominant intake of red meat, soft drinks, takeout food, and full-fat dairy products in 14 y olds, was prospectively associated with the development of NAFLD during adolescence [6]. A recent study in China found that the animal food dietary pattern, which is characterized by a high intake of seaweed, mushroom, pork, beef, mutton, poultry, and eggs, was associated with the risk of NAFLD after adjustment for confounding factors [14]. We did not identify a relationship between the Western and high-carbohydrate dietary pattern and the risk of NAFLD, but the possible explanations for this discrepancy are that dietary patterns vary between ethnicities, cultural groups, and gender, and dietary patterns may change over time as a result of personal preferences and the availability of food [4].

A traditional Korean diet includes high-salt fermented foods, such kimchi and doenjang. The Korean National Health and Nutrition Examination Survey reported that the mean intake of sodium in Koreans was 3889.9 mg/d, and 79.4% of the population had a higher intake than the World Health Organization's recommended daily intake of 2000 mg [33]. A recent study of a Korean population found that the high-salt dietary pattern was associated with an increased risk of NAFLD [34]. However, there was no significant association between a high-salt dietary pattern and NAFLD in the Chinese population [14]. Further studies are needed to elucidate this association.

Stratification of the analysis by sex revealed that our finding was consistent only in the traditional pattern in men. This result was partially explained by different dietary patterns between men and women. A previous study suggested sex differences in the association between dietary patterns and obesity in the Chinese populations [35].

Previous studies found that some dietary supplements with polyunsaturated fatty acids and synbiotics enhanced the effects of lifestyle modification in the treatment of NAFLD. A randomized controlled clinical trial reported that flaxseed supplementation in combination with a lifestyle modification was an effective treatment for NAFLD, and a randomized, double-blinded, placebo-controlled trial found that symbiotic supplementation improved NAFLD via an attenuation of inflammation in nonobese patients with NAFLD [36,37]. We could not evaluate the dietary effect of supplements on NAFLD because of the lack of data on polyunsaturated fatty acids or symbiotics. Further studies are needed to confirm this beneficial effect in Korean patients with NAFLD.

One strength of our study is that it is the first study to evaluate the associations between different dietary patterns and the risk of NAFLD in the Korean population in a prospectively conducted cohort using a validated semiquantitative FFQ. However, there are several possible limitations. First, the population may not be representative of the general population, and there may also be selection bias because the cohort included participants who visited a single health-screening center in Korea for health checkups. Second, recall bias exists, and the information on food intake may be incorrect because of the self-reporting nature of the questionnaire. Third, we were unable to obtain liver samples for pathologic testing, which is the gold standard for NAFLD diagnosis. Ultrasonography may produce false-negative results when fatty infiltration of the liver falls to less than 30% [38], and this technique is subject to inter- and intraobserver diagnostic variability. However, ethical restrictions prohibit the application of invasive tests in apparently healthy populations. Therefore ultrasonography was used as a first-line method to detect NAFLD according to clinical practice guidelines [2,16]. Fourth, we could not evaluate the physical activity of participants, which is an important factor about NAFLD [39]. Finally, the cross-sectional design of this study could not provide conclusive evidence of a causal relationship between dietary patterns and NAFLD.

Conclusions

We found that the traditional dietary pattern was associated with an increased risk of NAFLD and the simple meal pattern was associated with a decreased risk of NAFLD in the Korean population. This finding supports the use of dietary patterns to predict the risk of NAFLD, which may serve as a dietary prevention strategy in individuals who are at a high risk of developing NAFLD.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.nut.2018.11.021.

References

[1] Vernon G, Baranova A, Younossi ZM. Systematic review: the epidemiology and natural history of non-alcoholic fatty liver disease and non-alcoholic steatohepatitis in adults. Aliment Pharmacol Ther 2011;34:274–85.
[2] Korean Association for the Study of the L. KASL clinical practice guidelines: management of nonalcoholic fatty liver disease. Clin Mol Hepatol 2013;19:325–48.
[3] Angulo P. Nonalcoholic fatty liver disease. N Engl J Med 2002;346:1221–31.
[4] Fung TT, Rimm EB, Spiegelman D, Rifai N, Tofler GH, Willett WC, et al. Association between dietary patterns and plasma biomarkers of obesity and cardiovascular disease risk. Am J Clin Nutr 2001;73:61–7.
[5] Mouzaki M, Allard JP. The role of nutrients in the development, progression, and treatment of nonalcoholic fatty liver disease. J Clin Gastroenterol 2012;46:457–67.
[6] Zelber-Sagi S1, Ratziu V, Oren R. Nutrition and physical activity in NAFLD: an overview of the epidemiological evidence. World J Gastroenterol 2011;17:3377–89.
[7] Kontogianni MD, Tileli N, Margariti A, Georgoulis M, Deutsch M, Tiniakos D, et al. Adherence to the Mediterranean diet is associated with the severity of non-alcoholic fatty liver disease. Clin Nutr 2014;33:678–83.
[8] Li YH, Yang LH, Sha KH, Liu TG, Zhang LG, Liu XX. Efficacy of poly-unsaturated fatty acid therapy on patients with nonalcoholic steatohepatitis. World J Gastroenterol 2015;21:7008–13.
[9] Mokhtari Z, Gibson DL, Hekmatdoost A. Nonalcoholic fatty liver disease, the gut microbiome, and diet. Adv Nutr 2017;8:240–52.
[10] Hu FB. Dietary pattern analysis: a new direction in nutritional epidemiology. Curr Opin Lipidol 2002;13:3–9.
[11] Tucker KL. Dietary patterns, approaches, and multicultural perspective. Appl Physiol Nutr Metab 2010;35:211–8.
[12] Oddy WH, Herbison CE, Jacoby P, Ambrosini GL, O'Sullivan TA, Ayonrinde OT, et al. The Western dietary pattern is prospectively associated with nonalcoholic fatty liver disease in adolescence. Am J Gastroenterol 2013;108:778–85.
[13] Papamiltiadous ES, Roberts SK, Nicoll AJ, Ryan MC, Itsiopoulos C, Salim A, et al. A randomised controlled trial of a Mediterranean Dietary Intervention for Adults with Non Alcoholic Fatty Liver Disease (MEDINA): study protocol. BMC Gastroenterol 2016;16:14.
[14] Yang CQ, Shu L, Wang S, Wang JJ, Zhou Y, Xuan YJ, et al. Dietary patterns modulate the risk of non-alcoholic fatty liver disease in Chinese adults. Nutrients 2015;7:4778–91.
[15] Yang SY, Kim YS, Lee JE, Seol J, Song JH, Chung GE, et al. Dietary protein and fat intake in relation to risk of colorectal adenoma in Korean. Medicine (Baltimore) 2016;95:e5453.
[16] Chalasani N, Younossi Z, Lavine JE, Diehl AM, Brunt EM, Cusi K, et al. The diagnosis and management of non-alcoholic fatty liver disease: practice guideline by the American Gastroenterological Association, American Association for the Study of Liver Diseases, and American College of Gastroenterology. Gastroenterology 2012;142:1592–609.
[17] Chung GE, Kim D, Kwak MS, Yang JI, Yim JY, Lim SH, et al. The serum vitamin D level is inversely correlated with nonalcoholic fatty liver disease. Clin Mol Hepatol 2016;22:146–51.
[18] Ahn Y, Kwon E, Shim JE, Park MK, Joo Y, Kimm K, et al. Validation and reproducibility of food frequency questionnaire for Korean genome epidemiologic study. Eur J Clin Nutr 2007;61:1435–41.
[19] Castro MA, Baltar VT, Selem SS, Marchioni DM, Fisberg RM. Empirically derived dietary patterns: interpretability and construct validity according to different factor rotation methods. Cad Saude Publica 2015;31:298–310.
[20] Saadeh S, Younossi ZM, Remer EM, Gramlich T, Ong JP, Hurley M, et al. The utility of radiological imaging in nonalcoholic fatty liver disease. Gastroenterology 2002;123:745–50.
[21] FAO. FAOSTAT Database. Food balance sheets. Available at: http://www.fao.org/faostat/en/#home.
[22] Esmaillzadeh A, Kimiagar M, Mehrabi Y, Azadbakht L, Hu FB, Willett WC. Dietary patterns, insulin resistance, and prevalence of the metabolic syndrome in women. Am J Clin Nutr 2007;85:910–8.
[23] Asrih M, Jornayvaz FR. Diets and nonalcoholic fatty liver disease: the good and the bad. Clin Nutr 2014;33:186–90.
[24] Di Minno MN, Russolillo A, Lupoli R, Ambrosino P, Di Minno A, Tarantino G. Omega-3 fatty acids for the treatment of non-alcoholic fatty liver disease. World J Gastroenterol 2012;18:5839–47.
[25] Mokhtari Z, Poustchi H, Eslamparast T, Hekmatdoost A. Egg consumption and risk of non-alcoholic fatty liver disease. World J Hepatol 2017;9:503–9.

[26] Hu FB, Rimm E, Smith-Warner SA, Feskanich D, Stampfer MJ, Ascherio A, et al. Reproducibility and validity of dietary patterns assessed with a food-frequency questionnaire. Am J Clin Nutr 1999;69:243–9.
[27] Ferretti F, Mariani M. Simple vs. Complex carbohydrate dietary patterns and the global overweight and obesity pandemic. Int J Environ Res Public Health 2017;14(10). pii: E1174.
[28] Hudgins LC, Hellerstein M, Seidman NR, Diakun J, Hirsch J. Human fatty acid synthesis is stimulated by a eucaloric low fat, high carbohydrate diet. J Clin Investig 1996;97:2081–91.
[29] Villaca Chaves G, Pereira SE, Saboya CJ, Ramalho A. Non-alcoholic fatty liver disease and its relationship with the nutritional status of vitamin a in individuals with class III obesity. Obes Surg 2008;18:378–85.
[30] Harrison SA, Torgerson S, Hayashi P, Ward J, Schenker S. Vitamin E and vitamin C treatment improves fibrosis in patients with nonalcoholic steatohepatitis. Am J Gastroenterol 2003;98:2485–90.
[31] Foster T, Budoff MJ, Saab S, Ahmadi N, Gordon C, Guerci AD. Atorvastatin and antioxidants for the treatment of nonalcoholic fatty liver disease: The St Francis Heart Study randomized clinical trial. Am J Gastroenterol 2011;106:71–7.
[32] Jia Q, Xia Y, Zhang Q, Wu H, Du H, Liu L, et al. Dietary patterns are associated with prevalence of fatty liver disease in adults. Eur J Clin Nutr 2015;69: 914–21.
[33] Ministry of Health and Welfare, Korea Centers for Disease Control and Prevention. Korea Health Statistics 2014: Korea National Health and Nutrition Examination Survey (KNHANES VI-2). Sejong, Korea: Ministry of Health and Welfare; 2016.
[34] Choi Y, Lee JE, Chang Y, Kim MK, Sung E, Shin H, et al. Dietary sodium and potassium intake in relation to non-alcoholic fatty liver disease. Br J Nutr 2016;116:1447–56.
[35] Yuan YQ, Li F, Meng P, You J, Wu M, Li SG, et al. Gender difference on the association between dietary patterns and obesity in Chinese middle-aged and elderly populations. Nutrients 2016;8(8). pii: E448.
[36] Yari Z, Rahimlou M, Eslamparast T, Ebrahimi-Daryani N, Poustchi H, Hekmatdoost A. Flaxseed supplementation in non-alcoholic fatty liver disease: a pilot randomized, open labeled, controlled study. Int J Food Sci Nutr 2016;67:461–9.
[37] Mofidi F, Poustchi H, Yari Z, Nourinayyer B, Merat S, Sharafkhah M, Malekzadeh R, Hekmatdoost A. Synbiotic supplementation in lean patients with non-alcoholic fatty liver disease: a pilot, randomised, double-blind, placebo-controlled, clinical trial. Br J Nutr 2017;117:662–8.
[38] Sanyal AJ. American Gastroenterological Association. AGA technical review on nonalcoholic fatty liver disease. Gastroenterology 2002;123:1705–25.
[39] Kwak MS, Kim D. Non-alcoholic fatty liver disease and lifestyle modifications, focusing on physical activity. Korean J Intern Med 2018;33:64–74.