

An observational study on the association between major dietary patterns and non-alcoholic fatty liver disease in Chinese adolescents

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Abstract

Data on the association of dietary patterns with non-alcoholic fatty liver disease (NAFLD) among adolescents are scarce. Hence, the purpose of this study was to ascertain the influence of dietary patterns and key foods on NAFLD among adolescents in Shandong, China. Data were extracted from Linyi Nutrition and Health study during 2015 to 2016. This cross-sectional study population comprised 1639 participants aged between 16 and 23 years. Dietary intake was assessed by the use of a semiquantitative food frequency questionnaire (FFQ), containing 85 food items. NAFLD diagnosis was defined as individuals whose ultrasound examination disclosed hepatic steatosis at any stage, in the absence of excess intake of alcoholic beverages. The odds ratio (OR) and 95% confidence interval (CI) were estimated for each quartile of the dietary pattern adherence scores using logistic regression analysis. Of 1639 participants, 221 (13.5%) were classified as having NAFLD. Three major dietary patterns were derived from factor analysis: traditional Chinese, Western, and high-energy dietary patterns. There were significant differences in the intake of whole grains, tuber, and vegetable across quartiles of the traditional Chinese and Western pattern ($P < .05$). Besides, compared with adolescents in the lowest quartile, those in the highest quartile for whole grains intake had a lower OR for NAFLD (OR=0.72; 95%CI: 0.61–0.98; $P < .05$), and for red meat and soft drink consumption had greater OR for NAFLD (OR=1.34; 95% CI: 1.06–1.72; OR=1.69; 95% CI: 1.34–2.56; respectively, $P < .05$). After adjustment for several potential confounders, participants in the highest quartile of the traditional Chinese pattern scores had lower OR for NAFLD (OR=0.726; 95% CI: 0.383–0.960, $P < .05$) than did those in the lowest quartile, whereas those in the highest quartile of the Western pattern score had greater OR for NAFLD (OR=1.197; 95% CI: 1.013–1.736, $P < .01$) than did those in the lowest quartile. No statistically significant association was found between the high-energy pattern and the risk of NAFLD.

Our findings demonstrated that the traditional Chinese dietary pattern was associated with a lower risk, whereas the Western dietary pattern was associated with a higher risk of NAFLD.

Abbreviations: ANOVA = analysis of variance, BMI = body mass index, CI = confidence interval, FFQ = food frequency questionnaire, NAFLD = non-alcoholic fatty liver disease, NASH = non-alcoholic steatohepatitis, OR = odds ratio, WC = waist circumference, WHR = waist to hip ratio.

Keywords: adolescent, china, dietary patterns, non-alcoholic fatty liver disease

1. Introduction

Non-alcoholic fatty liver disease (NAFLD) includes a wide spectrum of liver diseases, from simple steatosis to non-alcoholic steatohepatitis (NASH), which can progress to cirrhosis and hepatocellular carcinoma.^[1] In China, NAFLD has been recognized as a serious health problem, and the incidence of NAFLD is increasing year by year.^[2] In the United States and Asia, NAFLD has also attracted increasing attention given its

high prevalence, estimated at 24% to 30%.^[3] Presently, NAFLD is considered to be a hepatic component of metabolic syndrome, and elements of metabolic syndrome, such as obesity, insulin resistance and dyslipidemia, all of which are important risk factors for NAFLD.^[4,5]

During the last several decades, diet has been considered as an important pathogenic factor of NAFLD. There are a number of studies reporting the associations between diet and NAFLD risk, concentrating on the effects of individual foods or nutrients.^[6–9] However, nutrients or foods are not consumed in isolation but in numerous different combinations.^[10] To address this problem, dietary pattern analysis has emerged as an alternative and complementary approach to reporting the association of diet with the risk of chronic diseases, and it encompasses complex relations and synergistic effects of nutrients and foods consider the complexity of overall diet and facilitate nutritional recommendations.^[11]

Nowadays, rapid economic growth, globalization, and urbanization are all leading to a dramatic shift in the traditional dietary patterns to Western patterns in China. Consequently, the nutritional transition is fuelling the epidemic of chronic diseases.^[12] Herein, it is important to investigate the associations between dietary patterns and the risk of noncommunicable chronic disease among Chinese, particularly in adolescents, who

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are easy to suffer from these chronic diseases.^[13] To date, only 1 study has been performed to elucidate the association of dietary patterns with the risk of NAFLD in Australian adolescents.^[7] Therefore, the purpose of this study was to corroborate the associations between dietary patterns and its major components and NAFLD in Chinese adolescents.

2. Subjects and methods

2.1. Study population

The subjects were students recruited in the dietetic course at 6 universities and/or colleges in the city of Linyi, Shandong Province in China from September 2015. A total of 1875 subjects (aged between 16 and 23 years), were invited to attend the new entrance health examination at the Medical Center for Physical Examination, Linyi People's Hospital. Meanwhile, these study participants were interviewed face-to face by a trained staff with written questionnaire. For this analysis, 129 participants were excluded based on the following reasons: had missing or incomplete dietary information in their questionnaires ($n=47$); self-reported a history of usage of drugs or drinking ($n=65$); had a history of hereditary diseases ($n=17$). We further excluded 107 participants who did not provide information on dietary intake or had more than 8 items blank on the food frequency questionnaire (FFQ). After all these exclusions, we considered 1639 participants remained for the analysis. Approval for the present study was obtained from the Ethics Committee of Linyi People's Hospital, China, and all participants provided written informed consent.

2.2. Assessment of dietary intake

Dietary data were collected using a semiquantitative FFQ including 85 food items (27 food groups) based on the 2012 China National Nutrition and Health Survey. Study subjects were asked about their frequency of consumption of each food group during the previous 12 months and the estimated portion size, using local weight units (1 Liang=50g) or natural units (cups). For instance, the frequency response for food consumption included 9 categories, as follows: never, less than once/month, 1 to 3 times/month, 1 to 2 times/week, 3 to 4 times/week, 5 to 6 times/week, 1 time/day, 2 times/day, and 3 times/day. Consequently, individual food items were converted into an average daily consumption.

2.3. Assessment of biomarker

Blood samples were obtained after 12 hours of fasting overnight. After blood was collected, samples were allowed to clot at room temperature for 1 to 3 hours and serum was separated. Subsequently, a separation of serum was via centrifugation for 15 minutes at 3000 rpm. Then samples were analyzed in the Medical Center for Physical Examination, Zhejiang Hospital for fasting glucose, total cholesterol, triglycerides, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, serum uric acid, alanine aminotransferase and asparagine aminotransferase using a Hitachi 7600 automatic analyzer (Hitachi, Tokyo, Japan).

2.4. Blood pressure measurement

After participants rested for 10 minutes in the sitting position, blood pressure was measured by using a standard mercury sphygmomanometer. A trained nurse measured the blood

pressure 3 times in seated participants, and thereafter the means of 3 measurements of systolic blood pressure and diastolic blood pressure were calculated and considered for analysis.

2.5. Definition of terms (ascertainment)

Hypertension was defined as a systolic pressure of ≥ 140 mmHg and/or a diastolic pressure of ≥ 90 mmHg. Obesity was defined by body mass index (BMI) ≥ 28 kg/m² and abdominal adiposity was defined as: male: waist circumference (WC) ≥ 85 cm; female: WC ≥ 80 cm.^[10] NAFLD was defined as the presence of moderate-severe hepatic steatosis (by B-ultrasonic examination), the absence of excessive alcohol use (>20 g/day in men and 10 g/day in women), no use of steatogenic medications within the last 6 months, no exposure to hepatotoxins, and no history of bariatric surgery.^[14]

2.6. Statistical analyses

The Kaiser-Meyer-Olkin measure of sampling adequacy and the Bartlett test of sphericity were used to evaluate the adequacy of correlation matrices with the data. Factor analysis (principal component) was used to assess the dietary patterns based on the frequency of consumption of 27 food groups in the FFQ. The factors identified were rotated using an orthogonal transformation (varimax rotation) to achieve uncorrelated factors and greater interpretability. In determining the number of factors to retain, we applied eigen value (>1) and a scree plot in the present study.^[15] In view of the factor scores in 3 patterns overlapping, only food groups with a factor loading $>|0.30|$ were considered to be important contributors to this pattern and included in the present study. Then, we only observed that 2 factors (snack food and carbonated beverages) were overlapped. Finally, labeling of dietary patterns was based on the interpretation of foods with high factor loadings for each dietary pattern.^[16] Participant scores were categorized into quartiles separately for each dietary pattern. Thus, for each dietary pattern, quartile 4 was composed of persons whose diets conformed most closely to that particular pattern.

The characteristics of study participants were calculated across quartiles of each dietary pattern. Data were expressed as the mean values and standard deviation for continuous variables and as sum (proportions) for categorical variables. The χ^2 tests and independent samples *t* test or Mann-Whitney *U* test were used to compare the characteristics of study participants, according to NAFLD diagnosis. Besides, the odds ratio (OR) and 95% confidence interval (CI) were assessed using multiple logistic regression to confirm the NAFLD risk depending on the quartile categories of each dietary pattern scores, with the Q1 (the lowest) category used as the reference. Furthermore, to further explore the association between the dietary pattern and NAFLD, intakes of the major food groups in each pattern were examined in relation to NAFLD risk.

All data were analyzed using the Statistical Package for Social Sciences (version 21.0, SPSS Inc, Chicago, IL), and *P* values $<.05$ were considered statistically significant.

3. Results

Total prevalence of NAFLD in the present study was 13.5%, with male was 9.0% and female was 4.5%. The demographic and clinical characteristics of subjects with and without NAFLD are shown in Table 1. There were significant differences between

Table 1
Demographic and lifestyle characteristics of participants and non-alcoholic fatty liver disease in Chinese adolescents.

	Total, n	NAFLD, n (%)		P*
		Yes	No	
Demographic	1639	221 (13.5)	1418 (86.5)	
Age, y	1639	18.2 ± 1.3	18.6 ± 1.5	.563
Sex				
Female	759	74 (9.7)	685 (90.3)	$\chi^2 = 16.897$ P = .000
Male	880	147 (16.7)	733 (83.3)	
Smoking status				
Yes	45	10 (4.5)	35 (2.5)	$\chi^2 = 3.029$ P = .082
No	1594	211 (95.5)	1383 (97.5)	
Family income (%)				
≤2000 (RMB) per month per person	272	78 (24.3)	194 (29.5)	$\chi^2 = 5.013$ P = .078
2000–4000 (RMB) per month per person	386	142 (44.2)	244 (37.1)	
>4000 (RMB) per month per person	320	101 (31.5)	219 (33.3)	
Physical activity (%)				
<1 time per wk	646	168 (76.0)	478 (33.7)	$\chi^2 = 143.4$ P = .000
1–3 times per wk	803	42 (19.0)	761 (53.7)	
>4 times per wk	190	11 (5.0)	179 (12.6)	
BMI, kg/m ²	1639	25.44 ± 3.02	19.78 ± 1.68	.000
WC, cm	1639	81.49 ± 8.82	68.48 ± 6.35	.000
Obese (%)	159	53 (24.0)	106 (7.5)	.000

Categorical variables are presented as sum and percentages, and continuous variables are presented as mean ± SD. BMI = body mass index, NAFLD = non-alcoholic fatty liver disease, WC = waist circumference. * P for continuous variables (analysis of variance) and for categorical variables (χ^2 test).

participants with and without NAFLD by sex and physical activity. In addition, participants with NAFLD had higher BMI, WC, and the prevalence of obesity than without NAFLD.

Three major dietary patterns were identified in this population which together accounted for 34.6% of the total variance in food items (Table 2). We labeled the first pattern “traditional Chinese,” as it was mainly characterized by high intake of whole grains, tubers, vegetables, fresh fruits, salted and preserved eggs, soybean and its products, miscellaneous bean, fruit/vegetable juice, and tea. The second pattern was named as “Western” dietary pattern, which is characterized by high intakes of refined grains, red meat, processed and preserved meat, seafood, dairy products, western fast food, snack food, carbonated beverages, alcoholic beverages, and coffee. The third pattern was named as “high-energy” dietary pattern, which is characterized to have high consumption of mushrooms, poultry and organs, freshwater fish and shrimp, eggs, fat/oils, nuts, snacks, chocolates, and carbonated beverages. The factor-loading matrixes for three dietary patterns were shown in Table 3.

The characteristics of study participants across quartile categories of the dietary pattern scores were shown in Table 4. Compared with the lowest quartile of the “traditional Chinese” dietary pattern, those participants in the highest quartile were more likely to be female, and had a lower prevalence of obesity, hypertension, and NAFLD, lower BMI, WC, waist to hip ratio (WHR), higher physical activity level than those in the lowest quartile. Besides, subjects in the top quartile of the “Western” dietary pattern were more likely to be male, and had higher prevalence of obesity, hypertension, and NAFLD, higher BMI, WC, WHR, family income, and lower physical activity level than those in the lowest quartile. Similarly, subjects in the highest quartile of the “high-energy” dietary pattern were more likely to be male and had a higher BMI than those in the lowest quartile.

There were significant differences in the intake of whole grains, tuber, fresh fruits, and vegetable across quartiles of the traditional Chinese dietary pattern. Participants in the top quartile of the

traditional Chinese dietary pattern had a lower intake of energy and fat than those in the lowest quartile. However, no significant difference was observed in the intake of refined grains, red meat, and soft drinks across quartiles of this pattern. In addition, we did not find the significant difference in the intake of fresh fruits and energy intake across quartiles of the Western dietary pattern. Meanwhile, there were also significant differences in consumption of refined grains, red meat, soft drinks across quartiles of the high-energy dietary pattern (Table 5).

The associations between the components of the major dietary pattern and NAFLD risk were shown in Table 6. Compared with adolescents in the lowest quartile, those in the highest quartile for whole grains intake had a lower OR for NAFLD (OR = 0.72; 95% CI: 0.61–0.98; $P < .05$). Meanwhile, adolescents in the top quartile for red meat and soft drink consumption had greater OR for NAFLD (OR = 1.34; 95% CI: 1.06–1.72; OR = 1.69; 95% CI: 1.34–2.56; respectively, $P < .05$). However, we observed no significant association between refined grains, fresh fruits and vegetables and the risk of NAFLD.

The relationship between dietary patterns and NAFLD risk by multivariate regression analysis is shown in Table 7. After control for potential confounders, participants in the highest quartile of the traditional Chinese pattern scores had lower OR for NAFLD (OR = 0.726; 95% CI: 0.383–0.960, $P < .05$) than did those in the lowest quartile, whereas those in the highest quartile of the Western pattern score had greater OR for NAFLD (OR = 1.197; 95% CI: 1.013–1.736, $P < .01$) than did those in the lowest quartile. However, no statistically significant association was found between the high-energy pattern and the risk of NAFLD in the present study.

4. Discussion

Limited epidemiological studies have reported the association of major dietary patterns with the risk of NAFLD in Chinese

Table 2**The 27 food items in the FFQ with examples.**

Food groups	Food items
Refined grains	Rice, noodles, wonton, dumplings
Whole grains	Corn, sorghum, millet, oats
Tubers	Sweet potato, potato, taro
Vegetables	Carrot, green peppers, tomato Chinese cabbage, radish, cucumber
Fresh fruits	Spinach, orange, apple, peach, pear
Pickled vegetables	Salted vegetables, Chinese sauerkraut
Mushrooms	Mushroom, shiitakes, enoki
Red meat	Pork, mutton, beef
Poultry and organs	Chicken, duck, liver
Processed and preserved meat	Ham, sausage, preserved pork, roast duck
Freshwater fish and shrimp	Fish, shrimp
Eggs	Duck eggs, chicken eggs
Seafood	Sea-fish/ shrimp, crab, squid, shellfish
Salted and preserved eggs	Salted duck and chicken eggs, preserved eggs
Dairy products	Liquid milk, milk powder, yoghurt
Soybean and its products	Tofu, dried bean curd, soy milk
Miscellaneous bean	Mung beans, red beans, hemp beans
Fats/oil	Soybean oil, tea oil, rapeseed oil, olive oil, lard, butter
Western fast food	KFC, McDonald, fried dough sticks and twists, fried cakes, pizza
Nuts	Walnut, peanuts, almonds, melon seeds
Snacks	Cookies, sachima, bread, cake, ice cream, candy, sweets, potato chips, shrimp roll, popcorn
Chocolate	Chocolate, chocolate wafer
Carbonated beverages	Coca-cola, sprite,
Fruit/vegetable juice	Orange juice, vegetable juice
Alcoholic beverages	Beer, fruit wine, grape wine
Coffee	Coffee
Tea	Tea, scented tea, wong Lo Kat

FFQ = food frequency questionnaire.

Table 3**Rotated factor loading matrix for the 3 dietary patterns among 1639 Chinese adolescents aged 16 to 23 years*.**

Food groups	Dietary patterns		
	Traditional Chinese	Western	High-energy
Refined grains	—	0.641	—
Whole grains	0.753	—	—
Tubers	0.471	—	—
Vegetables	0.603	—	—
Fresh fruits	0.562	—	—
Pickled vegetables	0.445	—	—
Mushrooms	—	—	0.570
Red meat	—	0.683	—
Poultry and organs	—	—	0.662
Processed and preserved meat	—	0.502	—
Freshwater fish and shrimp	—	—	0.486
Eggs	—	—	0.346
Seafood	—	0.647	—
Salted and preserved eggs	0.334	—	—
Dairy products	—	0.659	—
Soybean and its products	0.506	—	—
Miscellaneous bean	0.418	—	—
Fat/oils	—	—	0.447
Western fast food	—	0.707	—
Nuts	—	—	0.603
Snack food	—	0.595	0.409
Chocolates	—	—	0.435
Carbonated beverages	—	0.472	0.315
Fruit/vegetable juice	0.309	—	—
Alcoholic beverages	—	0.510	—
Coffee	—	0.610	—
Tea	0.352	—	—
Variance of intake explained (%)	18.7	9.5	6.4

* Absolute values <0.3 were excluded for simplicity.

Table 4**Characteristics of the study participants by quartile (Q) categories of dietary pattern scores in Linyin.**

	Traditional Chinese			Western			High-energy		
	Q1 (n = 410)	Q4 (n = 409)	P*	Q1 (n = 410)	Q4 (n = 410)	P*	Q (n = 409)	Q4 (n = 410)	P*
Age, y	20.3 ± 1.33	20.2 ± 3.53	.305	20.4 ± 1.33	20.1 ± 3.53	.122	20.4 ± 3.53	20.1 ± 1.25	.064
BMI, kg/m ²	20.91 ± 2.15	20.14 ± 2.06	<.05	21.27 ± 2.11	23.53 ± 3.02	<.01	20.19 ± 2.68	21.96 ± 3.10	<.05
WC, cm	70.48 ± 5.26	69.35 ± 5.35	<.01	68.15 ± 8.16	72.33 ± 8.14	<.01	71.49 ± 8.93	72.08 ± 9.05	.687
WHR	0.88 ± 0.04	0.86 ± 0.03	<.05	0.87 ± 0.06	0.89 ± 0.07	<.05	0.87 ± 0.04	0.88 ± 0.04	.536
Obesity (%)	63 (15.4)	34 (8.3)	<.01	44 (10.8)	71 (17.3)	<.01	47 (11.5)	66 (16.1)	.056
Hypertension (%)	31 (7.6)	15 (3.7)	<.05	28 (6.9)	46 (11.2)	<.05	34 (8.3)	42 (10.2)	.341
NAFLD (%)	76 (18.5)	51 (12.5)	<.05	69 (16.8)	115 (28.0)	<.001	83 (20.3)	105 (25.6)	.070
Sex (%)			<.001			<.001			<.001
Male	234 (57.1)	144 (35.2)		131 (32.0)	230 (56.1)		205 (50.1)	277 (67.6)	
Female	176 (42.9)	265 (64.8)		279 (68.0)	180 (43.9)		204 (49.9)	133 (32.4)	
Family incomes (%)			.409			<.01			.948
≤2000 (RMB) per month per person	137 (33.4)	124 (30.3)		117 (28.5)	87 (21.2)		108 (26.4)	110 (26.8)	
2000–4000 (RMB) per month per person	164 (40.0)	160 (39.1)		165 (40.3)	151 (36.8)		172 (42.1)	175 (42.7)	
>4000 (RMB) per month per person	109 (26.6)	125 (30.6)		128 (31.2)	172 (42.0)		129 (31.5)	125 (30.5)	
Physical activity (%)			<.01			<.001			.576
<1 times per wk	312 (76.1)	287 (70.2)		307 (74.9)	350 (85.4)		330 (80.7)	338 (82.4)	
1–3 times per wk	72 (17.6)	65 (15.9)		68 (16.6)	46 (11.2)		58 (14.2)	57 (13.9)	
>4 times per wk	26 (6.3)	57 (13.9)		35 (8.5)	14 (3.4)		21 (5.1)	15 (3.7)	

Categorical variables are presented as sum and percentages, and continuous variables are presented as mean ± SD. BMI = body mass index, NAFLD = non-alcoholic fatty liver disease, WC = waist circumference, WHR = waist to hip rate.

* P for continuous variables including age, BMI, WC and WHR (Analysis of variance) and for categorical variables (including obesity, hypertension, NAFLD, gender, family incomes and physical activity χ^2 test).

Table 5
Food and nutrient intakes across quartiles (Q) of the dietary patterns at baseline in Chinese adolescents.

	Traditional Chinese			Western			High-energy			P
	Q1 (n=410)	Q4 (n=409)	P	Q1 (n=410)	Q4 (n=410)	P	Q (n=409)	Q4 (n=410)	P	
Refined grains, g/d	245.86 ± 140.65	282.69 ± 171.42	.322	282.00 ± 149.89	365.76 ± 188.20	<.01	295.14 ± 164.89	349.17 ± 156.10	<.05	
Whole grains, g/d	19.28 ± 20.81	36.22 ± 35.01	<.01	21.97 ± 25.11	14.95 ± 23.02	<.01	18.43 ± 20.67	18.86 ± 21.32	.304	
Tuber, g/d	19.76 ± 17.49	28.88 ± 34.63	<.01	20.90 ± 35.50	14.39 ± 23.77	<.01	18.63 ± 19.35	19.78 ± 28.47	.587	
Fresh fruits, g/d	29.09 ± 13.69	40.06 ± 13.28	<.05	28.54 ± 14.63	30.92 ± 18.20	.146	23.63 ± 15.45	26.09 ± 13.79	.058	
Vegetable, g/d	327.31 ± 169.13	457.81 ± 149.59	<.01	440.32 ± 112.60	372.48 ± 125.70	<.05	388.68 ± 149.95	393.54 ± 286.24	.122	
Red meat, g/d	69.57 ± 39.18	65.46 ± 30.22	.07	56.80 ± 34.91	67.93 ± 46.52	<.05	60.03 ± 31.61	74.48 ± 42.20	<.01	
Soft drinks, g/d	217.16 ± 56.56	204.51 ± 60.78	.576	210.69 ± 61.76	266.38 ± 51.50	<.05	210.69 ± 48.85	233.12 ± 58.14	<.05	
Energy, g/d	2030.6 ± 336.2	1830.6 ± 296.5	<.05	1730.6 ± 256.7	1931.2 ± 316.0	<.05	1738.4 ± 263.6	2108.2 ± 306.4	<.01	
Carbohydrate, g/d	345.9 ± 66.2	334.51 ± 60.7	.183	295.1 ± 55.3	284.5 ± 48.7	.113	283.2 ± 69.03	358.0 ± 58.27	<.01	
Fat, g/d	56.4 ± 14.8	50.8 ± 16.0	<.05	70.4 ± 23.8	87.8 ± 29.2	<.001	75.3 ± 16.2	80.0 ± 18.3	<.05	
Protein, g/d	72.5 ± 23.5	68.6 ± 21.3	.057	64.8 ± 15.1	79.1 ± 19.3	<.001	66.0 ± 20.7	68.6 ± 24.5	.064	

Table 6
Quartiles of components of the major dietary patterns (g/d) and risk of NAFLD in Chinese adolescents (n=1639)*.

Total	Mean, g/d	Median, g/d	Interquartile range, g/d	Risk of NAFLD, OR (95% CI)		P
				Q1	Q4	
Refined grains	184.4	168.5	119.3–232.3	1.00	1.15 (0.94–1.53) [†]	.116
Whole grains	28.5	22.4	15.0–48.3	1.00	0.72 (0.61–0.98) [†]	<.05
Fresh fruits	35.6	33.1	20.4–59.7	1.00	0.84 (0.67–1.07)	.398
Vegetable	377.8	320.6	291.3–498.0	1.00	0.81 (0.66–1.04)	.336
Red meat	62.1	56.2	34.7–85.2	1.00	1.34 (1.06–1.72) [†]	<.05
Soft drinks	256.5	175.8	45.5–320.0	1.00	1.69 (1.34–2.56) [†]	<.01

CI=confidence interval, NAFLD=non-alcoholic fatty liver disease, OR=odds ratio.

* Adjusted for age, sex, body mass index, economic income, smoking status, educational level, physical activity, family history of diabetes and stroke, and energy intake.

[†] Individual quartile compared with reference quartile.

population. In the present study, 3 dietary patterns were identified: traditional Chinese, Western, and high-energy. We found that the traditional Chinese dietary pattern was associated with a decreased risk, whereas the Western dietary pattern was associated with an increased risk of NAFLD. Moreover, no association was observed between the high-energy dietary pattern and the risk of NAFLD. To the best of our knowledge,

the present study is the first study to assess the associations between dietary patterns and NAFLD risk in Chinese adolescents.

In our analysis, the traditional Chinese dietary pattern was associated with a decreased risk of NAFLD. Our results were inconsistent with previous study,^[17] reporting that the traditional Chinese pattern was not associated with the risk of NAFLD. The

Table 7
Multivariable models adjusted for NAFLD across the quartile (Q) categories of the dietary patterns in Shandong Province, China.

	Model 1*		Model 2 [†]		Model 3 [‡]	
	OR	95% CI	OR	95% CI	OR	95% CI
Traditional Chinese						
Q1	1.00		1.00		1.00	
Q4	0.512	0.273, 0.756	0.617	0.309, 0.813	0.726	0.383, 0.960
P	<.01		<.01		<.05	
Western						
Q1	1.00		1.00		1.00	
Q4	1.703	1.395, 2.264	1.538	1.216, 1.938	1.197	1.013, 1.736
P	<.001		<.01		<.01	
High-energy						
Q1	1.00		1.00		1.00	
Q4	1.382	1.081, 1.635	1.038	0.849, 1.553	0.933	0.754, 1.208
P	<.05		.362		.579	

CI=confidence interval, NAFLD=non-alcoholic fatty liver disease, OR=odds ratio.

* Adjusted for age.

[†] Further adjusted age, gender, body mass index, income, smoking status, educational level, physical activity, and family history of diabetes, and stroke.

[‡] Additionally adjusted for energy intake.

apparently protective effect of the traditional Chinese pattern on the prevention of NAFLD could be related to this pattern's healthy constituents (e.g., whole grains, vegetables, and fruits). Whole grains contain large amounts of dietary fiber, which has been shown to be positively associated with insulin resistance, an important risk factor for NAFLD.^[18] In addition, antioxidant and phytonutrient-rich vegetables and fruits may contain active dietary components linking NAFLD and antioxidative constituents because the inverse association has been shown between vitamin C and E intake and NAFLD.^[19] Furthermore, some foods in the traditional Chinese pattern have a low glycemic index (GI), which have been found to decrease total cholesterol levels, resulting in the decreased risk of NAFLD.^[20] Likewise, in a Chinese population, Kong et al^[21] also found that high low GI intake might decrease the risk of visceral obesity. The fundamental cause of obesity is the long-term imbalance in energy intake and expenditure (e.g., positive energy balance) leading to the increased body mass including the accumulation of subcutaneous and visceral fat. In previous a review, Finelli et al^[22] have emphasized that visceral obesity is a main determinant of developing NAFLD. However, in this study, we also observed that participants in the highest quartile of the traditional Chinese pattern had a lower BMI and WC than those in the lowest quartile. Some epidemiological studies have also implicated visceral fat as a major risk factor for insulin resistance, type 2 diabetes mellitus, cardiovascular disease and metabolic syndrome,^[23,24] some major risk factors for NAFLD. Finally, epidemiological and animal studies also indicated that drinking green tea was associated with a decreased risk of obesity and chronic disease, which is considered as a risk factor for NAFLD.^[25,26]

The Western dietary pattern was characterized by high consumption of red meat, processed and preserved meat, fish and shrimp, seafood, dairy products, western fat food, snack food, carbonated beverages, alcoholic beverages, and coffee. In the present study, we found the positive association between the Western dietary pattern and NAFLD in Chinese adolescence. Our findings were agreement with previous studies, which showed that the "animal food" pattern was associated with an increased risk of NAFLD.^[17] The detrimental effect of Western dietary pattern could be attributed to this pattern's unhealthy constituents (e.g., red and processed meat and carbonated beverages). First, the Western dietary pattern contains high amounts of saturated fat, trans-fatty acids, and cholesterol. A large number of studies have indicated that high intakes of fat may play an important role in hepatic steatosis.^[27,28] Second, Oddy et al^[7] showed that a higher intake of soft drink was associated with a greater risk of NAFLD. It is well-known that soft drinks contain large amounts of high-fructose corn syrup, which has been found to be positively associated with the risk of NAFLD.^[29] In addition, it is also rich in caramel and aspartame that potentially increase insulin resistance and inflammation.^[30] In this study, the subjects are predominately a group of Chinese teenagers aged 16 to 23 years, who consumed large amounts of carbonated beverages in per day. Third, the refined grains included in this pattern have a high GI. Animal studies indicated that high GI foods could cause increased hepatic fat storage.^[31] Previous study also found that foods with high GI were associated with increased hepatic steatosis.^[32] Last, fast foods in the Western dietary pattern have been reported to be positively associated with the risk of obesity, insulin resistance, and diabetes, all of which are the risk factors for NAFLD.^[7,33]

In the present study, we found no significant association between high-energy pattern and NAFLD risk, although the prevalence of NAFLD for the highest quartile of this pattern was higher compared with the lowest quartile (10.2% vs. 8.3%). There are several possible explanations for this null association. On one hand, previous studies have reported a positive association between consumption of soft drinks and NAFLD.^[29] Besides, some foods (e.g., nuts, snack food, and chocolate) in this pattern have been reported to increase the risk of obesity, an important risk factor for NAFLD.^[34] On the other hand, it is known that freshwater fish and shrimp contain large amounts of unsaturated fatty acids, for example, omega-3 PUFA, which have been shown to be negatively associated with NAFLD.^[35] In addition, the mushroom included in this pattern is low-fat and healthy food, and constituents of this food have been reported to be associated with a reduced risk of NAFLD.^[36] Furthermore, the study subjects were a group of Chinese adolescents aged 16 to 23 years, who often participate physical exercise. However, physical activity as a form of energy expenditure has been considered as a standard clinical recommendation for obese people.^[37] Previous researches have reported that higher physical activity level has a protective effect against long-term gain in weight.^[38,39] As mentioned above, obesity is an important risk factor for NAFLD.^[26] A recent systematic review and meta-analysis of physical activity and hypertension risk also concluded that the level of physical activity was significantly associated with the risk of hypertension,^[40] major risk factor for NAFLD. Above all, Mouzaki et al^[41] have reported that physical activity can decrease the risk of developing NAFLD. Finally, the null association could also be to because of reverse causality. These students with risk of NAFLD may be advised to change dietary habits during the process of entrance examination, such as limiting the intake of high-energy foods. Thus, these possibilities could not be excluded in the present study.

5. Strengths and limitations

Our study had several strengths and limitations. First, to our knowledge, this is the first study examining the influence of dietary patterns with NAFLD among Chinese adolescents. Second, dietary data were obtained from a validated semiquantitative FFQ by face-to-face interview. This method ensured the data on food intake we collected more accurate. Third, our findings are reliable because we have controlled for potential known confounders in our analysis. Nonetheless, several limitations of our study warrant mention. First, the data we used were cross-sectional; therefore, causal relations could not be determined. Our results need to be confirmed in prospective studies. Second, principal component analysis includes several subjective decisions in choosing the number of retained factors and method of rotation, labelling, and explaining the dietary patterns.^[42] Third, the measurement errors in reporting diet using the FFQ affected our results by introducing random variation and lowering the significance of the associations. Fourth, it is hard to classify 1 individual into certain independent pattern group in performing factor analysis. Last, although potential confounding factors were adjusted for, the presence of unmeasured confounders is possible.

In conclusion, we found that the traditional Chinese pattern was associated with a decrease risk, whereas the Western dietary pattern was associated with an increased risk of NAFLD. Our findings may guide dietary interventions based on dietary pattern

for the prevention of NAFLD. However, further studies are needed to clarify these findings.

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Author contributions

The authors' responsibilities were as follows: Y.P. And S.-H. C contributed to the study design. Y.P. and X.-N.L performed the statistical analysis for the manuscript and drafted the paper. Q.-Y. S. and X.-N.L conducted research. All authors contributed to a critical review of the manuscript during the writing process. All authors approved the final version to be published.

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