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Research study

Prognosis

Prevalence of and risk factors for non-alcoholic fatty liver disease in community-dwellers of Beijing, China

G Li[1]*, Z Cheng[2], C Wang[3], A Liu[4], Y He[5], P Wang[5]

Abstract

Introduction

Non-alcoholic fatty liver disease is becoming a major public health problem worldwide. Evidence investigating the prevalence of and risk factors for non-alcoholic fatty liver disease in Beijing is scanty. The aim of this study was to discuss prevalence of and risk factors for non-alcoholic fatty liver disease in community-dwellers of Beijing.

Materials and Methods

A cross-sectional study by random simple sampling in adults in a Beijing community was conducted using questionnaires (including socio-demographic characteristics, semi-quantitative food-frequency questionnaire, eating habits and cooking styles), anthropometric measurement, biochemical test and liver ultrasonography.

Results

A total of 1,583 study subjects were enrolled for health check-ups and interviews between October 2010 and January 2011. The overall prevalence of non-alcoholic fatty liver disease was 18.1% (17.6% for males and 12.0% for females, respectively). The results of analysing 1,215 qualified participants showed that for males, high frequency of animal oil (odds ratio = 1.71, 95% confidence interval: 1.11–2.63, for high vs. low intake) and high intake of oil were positively related to non-alcoholic fatty liver disease (odds ratio: 2.00; 95% CI: 1.04–3.82), while high consumption of tea was associated with a decreased risk (odds ratio: 0.57; 95% confidence interval: 0.36–0.90). For both males and females, results of relationship between non-alcoholic fatty liver disease and anthropometric and biochemical measurements showed that incremental triglyceride was related to an increased risk of non-alcoholic fatty liver disease with the highest odds ratios (2.24 for males and 1.88 for females, respectively).

Conclusion

Non-alcoholic fatty liver disease in adults was highly prevalent in the Beijing community. High consumption of tea was associated with a decreased risk of non-alcoholic fatty liver disease, while high frequency of animal oil, high intake of oil and triglyceride were positively related to non-alcoholic fatty liver disease. These findings need to be confirmed in prospective studies and randomised controlled trials designed to further clarify the pathogenesis of non-alcoholic fatty liver disease and to establish evidence-based dietary recommendations for its prevention and treatment.

*Corresponding author
Email: lig28@mcmaster.ca

[1]Department of Clinical Epidemiology & Biostatistics, McMaster University, 1280 Main Street West, Hamilton, ON L8S 4L8, Canada
[2]Faculty of Education, Brock University, 500 Glenridge Avenue, St. Catharines, ON L2S 3A1, Canada
[3]Beijing University of Aeronautics and Astronautics Hospital, Beijing 100191, China
[4]Department of Social Medicine & Health Education, School of Public Health, Peking University, Beijing 100191, China
[5]Department of Nutrition & Food Hygiene, School of Public Health, Peking University, Beijing 100191, China

Introduction

Non-alcoholic fatty liver disease (NAFLD) is defined as fatty infiltration of the liver exceeding 5 to 10% by weight. It is an acquired metabolic stress-related liver disorder originally assumed to be largely confined to residents of developed Western countries[1]. NAFLD is now likely to be the most common cause of chronic liver disease in some countries and is strongly associated with risk of metabolic syndrome, coronary heart disease, hepatic cirrhosis, and even hepatocellular carcinoma[2–5].

Nowadays, NAFLD is becoming a major public health problem due to the rising prevalence of obesity and type 2 diabetes mellitus (T2DM) worldwide[6]. NAFLD currently affects 20–30% of the general population in affluent industrialised Western countries[1,7,8]. However, the prevalence of NAFLD in China remains uncertain, because no prospective studies or national surveys have been conducted. According to some recent studies, the prevalence of NAFLD in the general population of Shanghai (East China)[9] and Guangdong (South China)[10] was roughly 15%, which implied that NAFLD was also highly prevalent in China.

Research has identified that obesity, central obesity, dyslipidaemia, T2DM, hypertension, oxidative stress, insulin resistance, etc. are the major risk factors for NAFLD[1,11,12]. But results of the studies on the relationship between dietary intake or habits and the risk of NAFLD are not uniform. Some studies reported the positive association between histological inflammation and carbohydrate intake[13], or a higher intake of saturated fat and cholesterol and a lower intake of poly-unsaturated fat in patients with NAFLD[14]. Others presented an association between higher intake of total fat with a higher n-6/n-3 fatty acid ratio[15], or supplementation of n-3 polyunsaturated fatty acids[16], while Zelber-Sagi et al. concluded patients with NAFLD had higher consumption of soft drinks and meat[17]. Nevertheless, few similar studies had been conducted in China, especially none in Beijing (the capital of China) so far. Besides, the evidence

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related to eating habits and cooking styles in patients with NAFLD was scanty. Thus, we performed a cross-sectional study in a Beijing community to assess the prevalence and, more importantly, to identify the risk factors (i.e., dietary intake, other known risk factors for chronic diseases, and dietary habits) for NAFLD in adults, from the viewpoint of nutritional epidemiology.

Materials and methods

All the participants provided a written informed consent before enrolment. The study protocol was approved by the Peking University Institutional Review Board.

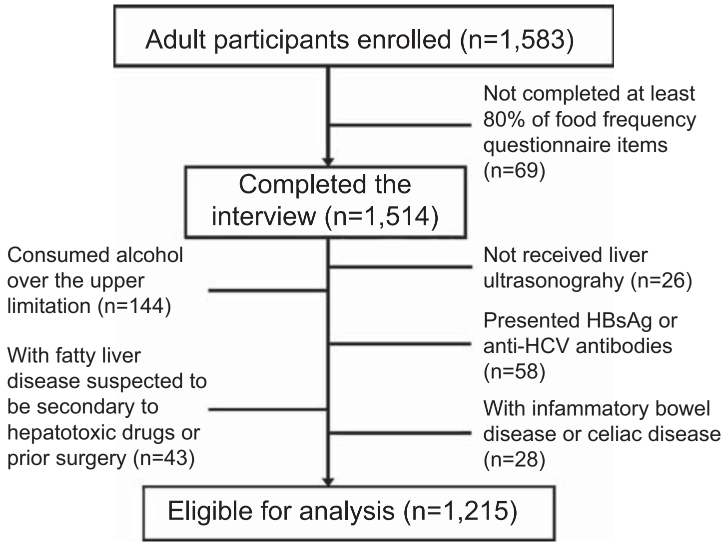

Figure 1: Flow diagram of the process in selecting study participants for analysis.

Study design

Data were all collected from participants aged 18 years and older by simple random sampling according to computerised random numbers in a Beijing community which covered roughly 50,000 residents nearby and was located close to some colleges. A total of 1,583 study adults (18–61 years of age) were enrolled into the community hospital for health check-ups and interviews between October 2010 and January 2011.

Individuals with any of the following were excluded from the study: alcohol consumption ≥140 g/week in men or 70 g/week in women, presence of hepatitis B surface antigen or anti-hepatitis C virus antibodies, fatty liver suspected to be secondary to hepatotoxic drugs, prior surgery that could cause fatty liver, inflammatory bowel disease or celiac disease. Participants who did not receive liver ultrasonography, or complete at least 80% of the food frequency questionnaire (FFQ) items, were also excluded. Therefore, the study population for analysis consisted of 1,215 subjects after the application of exclusion criteria (Figure 1).

Data collection

The one-time evaluation included an interview, anthropometric measurements, biochemical tests and liver ultrasonography, all performed on the same day.

Interview

To minimise the information bias, participants were required to finish the interviews before they started health check-ups, thereby keeping them unaware of the results of health examination when they answered questionnaires.

A face-to-face interview was carried out in all cases by the trained interviewers using two questionnaires validated by our pilot study. The first questionnaire included socio-demographic characteristics (e.g., sex, age, educational level), cigarette smoking habit and current alcohol intake. The second questionnaire was a semi-quantitative FFQ adapted to the Chinese population. The FFQ was modified according to *Dietary Guidelines for Chinese People (2007)*[18], and consisted of 11 food groups: cereals, fruits, vegetables, meat, seafood, eggs, dairy food, legumes, plant oil, animal oil and tea. Information on frequencies of the 11 food groups was acquired by asking subjects to select a category best applicable to them in the recent three months: consumed rarely, once to three times a month, once a week, twice to four times a week, five to six times a week, once a day, twice to three times a day or more than four times a day. Besides frequencies, participants were required to choose the range of daily amount consumed (in grams), where there were three options for each food group based on the recommendations of daily consumption in the Dietary Guidelines[18]. For instance, for cereals consumption, after the selection of frequency, participants were also requested to select the rough daily consumption category per person from low (less than 300 grams), moderate (300–400 grams) and high (more than 400 grams)[18]. Another five questions on eating habits were also asked: breakfast frequency, midnight snack frequency, meal time regularity, dining out frequency, snacking frequency. Furthermore, there were three questions as regards cooking styles (i.e., sugary, oily and salty), in which participants were interviewed to estimate the approximate amount (in grams) per person per day.

Anthropometric measurements

All subjects underwent measurements of weight, height, waist circumference and blood pressure. If the two measurements differed by more than 0.5 cm or 5 mmHg, a third measurement was taken. When the

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two measurements were similar, their mean was calculated. When a third measurement was required, the mean of the third measurement and the closest to it of the first two measurements was calculated.

Biochemical tests

Biochemical tests were measured from venous blood samples taken after at least 8 hours of fasting, for serum lipid profiles, fasting serum glucose and blood uric acid. All biochemical assessments were performed in the same laboratory by standard laboratory methods.

Liver ultrasonography

NAFLD was diagnosed by abdominal ultrasonography using standardised criteria, and based on the degrees of fatty infiltration of liver cells, NAFLD was further divided into three levels: mild, moderate and severe[19]. Ultrasonography was performed on all subjects with the same equipment (Hitachi EUB 6500 with a 3.5 MHz convex probe). The same operators, who were unaware of the results from questionnaires and biochemical tests, performed all the ultrasonography procedures.

Data analysis

Characteristics of the study subjects were compared using the χ^2 test. Continuous variables were presented as means ± standard deviation (SD). The FFQ items and dietary habits were classified into three categories based on the distribution of the NAFLD-free participants[20]. P values for trend were calculated using the Mantel–Haenszel χ^2 test. Ordinal logistic regression model was used to evaluate relationship between risk factors and NAFLD after testing the proportional odds assumption. Multivariable analyses adjusting for age, educational level, smoking and alcohol consumption were performed to investigate the association between NAFLD and individual risk factors by putting one risk factor each time into the model. Further, multivariable analyses including significant risk factors were then conducted to quantify the relationship with NAFLD, given the potential multi-collinearity and interaction of the identified significant risk factors. All statistical analysis was performed using SPSS software (version 19.0, SPSS Inc., Chicago, IL, USA), and the level of significance adopted was $p < 0.05$.

Results

Characteristics of participants and prevalence of NAFLD

Among the 1,583 study subjects enrolled, 26 did not receive liver ultrasonograhy. Thus, in this study, 341 participants were diagnosed as NAFLD among all the remaining 1,557 subjects, leading to the overall prevalence of NAFLD 21.9% (25.9% for males and 17.2% for females, respectively). By using the data in Beijing from the Sixth National Population Census of China[21], the standardised prevalence of NAFLD was 18.1% (17.6% for males and 12.0% for females, respectively).

One thousand two hundred and fifteen participants (mean age 37.5 ± 9.5 years, 48.4% for males) who met the selection criteria, were included for analysis. There were 76.1% of participants holding college degree or above. The mean body mass index (BMI) was 23.7 ± 3.3 kg/m^2, and the mean of waist circumferences (WC) was 79.9 ± 10.1 cm. No abnormality was found for the mean of systolic blood pressure and diastolic blood pressure. The means of serum lipid profiles including total cholesterol (TC), triglyceride (TG), high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C) were all within the normal range. Blood uric acid (BUA) was 313.6 ± 81.9 μmol/l, and fasting blood glucose (FBG) was 5.12 ± 0.82 mmol/l.

There were 341 participants diagnosed with NAFLD by ultrasonography in the study population (61.3% mild, 33.7% moderate, 5.0% severe). Table 1 shows general characteristics and comparisons between participants diagnosed as NAFLD versus normal liver. NAFLD group had significantly larger proportion of males (63.6%). Compared with subjects with normal liver, age, smoking and alcohol status were significantly different for participants with NAFLD. No significant difference of educational level was found between participants with NALFD and normal liver ($p = 0.088$). Moreover, results of anthropometric measurements and biochemical tests were significantly different between the two groups ($p < 0.001$).

Comparison of intake frequencies for each food group between participants diagnosed as NAFLD vs. normal liver

Because the prevalence of NAFLD for males was significantly higher than for females ($p < 0.001$), we analysed the relationship between NAFLD and its risk factors stratified by sex. The associations of food frequencies for males with the odds ratios (OR) of NAFLD and the comparisons between case and control group are shown in Table 2. Among all the 11 food groups, only animal oil and tea presented dose–response relationship significantly (p value for trend: <0.01). After adjusted for age, educational level, smoking and alcohol consumption, subjects with high intake of tea (i.e., more than 6 times a week) displayed a significantly decreased risk of NAFLD (OR: 0.57, 95% confidence interval [CI]: 0.36–0.89 for high vs. low intake), whereas participants with high intake of animal oil (i.e., more than four times a week) showed an increased risk (OR: 1.72, 95% CI: 1.12–2.64 for high vs. low intake).

A further multivariable analysis including animal oil and tea presented consistent relationship to NAFLD, with an OR of 0.57

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Table 1 General characteristics and comparison between subjects diagnosed as NAFLD vs. normal liver

Characteristics	NAFLD (n = 341)	Normal liver (n = 874)	p Value
Gender (%)			
Males	63.6	42.4	<0.001
Females	36.4	57.6	
Age (in years)	41.3±9.7	36.0±8.9	<0.001
Educational level (%)			
High school or less	20.5	25.2	0.088
College or more	79.5	74.8	
Smoking status			
Current smokers	13.1	9.4	0.024
Ex-smokers	2.7	1.2	
Non-smokers	84.2	89.4	
Alcohol consumption			
Current drinkers	36.4	28.0	0.016
Ex-drinkers	0.3	0.6	
Non-drinkers	63.3	71.4	
BMI (kg/m^2)	26.6 ± 3.0	22.6 ± 2.6	<0.001
WC (cm)	88.4 ± 9.0	76.7 ± 8.6	<0.001
SBP (mmHg)	130.5 ± 15.9	119.1 ± 14.4	<0.001
DBP (mmHg)	82.9 ± 11.3	74.1 ± 9.4	<0.001
BUA (μmol/l)	358.9 ± 84.3	295.1 ± 73.3	<0.001
TC (mmol/l)	5.11 ± 0.83	4.69 ± 0.79	<0.001
TG (mmol/l)	1.94 ± 1.30	1.10 ± 1.23	<0.001
HDL-C (mmol/l)	1.34 ± 0.26	1.57 ± 0.34	<0.001
LDL-C (mmol/l)	2.88 ± 0.69	2.51 ± 0.66	<0.001
FBG (mmol/l)	5.51 ± 1.20	4.96 ± 0.52	<0.001

BMI, body mass index; BUA, blood uric acid; DBP, diastolic blood pressure; FBG, fasting blood glucose; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; NAFLD, non-alcoholic fatty liver disease; SBP, systolic blood pressure; TC, total cholesterol; TG, triglyceride; WC, waist circumferences.

(95% CI: 0.36–0.90) and 1.71 (95% CI: 1.11–2.63) for high intake of tea and animal oil, respectively (Table 3). No multi-collinearity or interaction between animal oil and tea was observed.

For females, no food group was found to be significantly associated with the risk of NAFLD, while only subjects with intermediate consumption of dairy food (i.e., 2 to 5 times a week) showed a marginally inverse association with NAFLD (OR: 0.57; 95% CI: 0.32–1.01 for intermediate vs. low consumption, p = 0.054).

Comparison of eating habits and cooking styles between participants diagnosed as NAFLD vs. normal liver

Table 4 shows the difference of five eating habits between case and control group for males. No significant dose–response relationship was found. There was marginal but not significant relationship between NAFLD and midnight snack frequency, with an OR of 0.70 (95% CI: 0.47–1.03 for often vs. always, p = 0.059).

For cooking styles, high intake of salt (more than 12 grams per person per day) and oil (more than 44 grams per person per day) were significantly associated with increased risk of NAFLD (OR: 1.70; 95% CI: 1.01–2.87 for salt and OR: 2.31; 95% CI: 1.26–4.24 for oil, respectively, comparing high with low intake), while no significant relationship was found between NAFLD and sugar. When a

Table 2 Comparison of intake frequencies for each food group between male participants diagnosed as NAFLD vs. normal liver

Food group	Consumption frequency	NAFLD		Normal liver		p For trend	Multivariable[a]	
		n	%	N	%		OR	95% CI
Cereals[b]	Low	44	20.8	60	16.6	0.326	1.00	
	Intermediate	422	19.8	78	21.5		0.71	0.41–1.22
	High	126	59.4	224	61.9		0.77	0.49–1.20
Fruits[c]	Low	58	27.4	131	35.6	0.118	1.00	
	Intermediate	120	56.6	181	49.2		1.45	0.98–2.14
	High	34	16.0	56	15.2		1.07	0.62–1.83

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Table 2 *(Continued)*

Food group	Consumption frequency	NAFLD		Normal liver		p For trend	Multivariable[a]	
		n	%	N	%		OR	95% CI
Vegetables[d]	Low	29	13.7	56	15.2	0.472	1.00	
	Intermediate	36	17.0	68	18.5		1.04	0.56–1.92
	High	147	69.3	244	66.3		1.15	0.70–1.91
Meat[e]	Low	58	27.2	98	26.7	0.811	1.00	
	Intermediate	65	30.5	122	33.2		0.94	0.60–1.46
	High	90	42.3	147	40.1		1.13	0.74–1.71
Seafood[f]	Low	57	27.0	91	24.9	0.784	1.00	
	Intermediate	100	47.4	183	50.0		0.92	0.61–1.38
	High	54	25.6	92	25.1		0.94	0.59–1.51
Eggs[g]	Low	76	35.5	119	32.2	0.691	1.00	
	Intermediate	28	13.1	61	16.5		0.95	0.56–1.62
	High	110	51.4	189	51.2		1.003	0.69–1.46
Dairy food[h]	Low	58	27.2	104	28.3	0.600	1.00	
	Intermediate	79	37.1	141	38.4		1.14	0.75–1.74
	High	76	35.7	122	33.2		1.12	0.73–1.73
Legumes[i]	Low	54	25.4	113	30.8	0.166	1.00	
	Intermediate	104	48.8	171	46.6		1.36	0.90–2.04
	High	55	25.8	83	22.6		1.41	0.88–2.26
Plant oil[j]	Low	43	20.2	87	23.8	0.293	1.00	
	Intermediate	44	20.7	76	20.8		0.98	0.58–1.66
	High	126	59.2	202	55.3		1.20	0.78–1.83
Animal oil[k]	Low	49	24.5	122	34.8	0.003	1.00	
	Intermediate	60	30.0	110	31.3		1.28	0.81–2.02
	High	91	45.5	119	33.9		1.72	1.12–2.64
Tea[l]	Low	89	42.0	127	34.5	0.009	1.00	
	Intermediate	74	34.9	116	31.5		0.99	0.66–1.48
	High	49	23.1	125	34.0		0.57	0.36–0.89

[a]Adjusted for age, educational level, smoking and alcohol consumption.
[b]Low=less than 5 times a week (less than 300 grams per person per day), intermediate=between 5 to 6 times a week and once a day (between 300 and 400 grams per person per day), high=more than once a day (more than 400 grams per person per day).
[c]Low=less than 5 times a week (less than 200 grams per person per day), intermediate=between 5 to 6 times a week and once a day (between 200 and 400 grams per person per day), high=more than once a day (more than 400 grams per person per day).
[d]Low=less than once a day (less than 300 grams per person per day), intermediate=once a day (between 300 and 500 grams per person per day), high=more than once a day (more than 500 grams per person per day).
[e]Low=less than once a day (less than 50 grams per person per day), intermediate=once a day (between 50 and 75 grams per person per day), high=more than once a day (more than 75 grams per person per day).
[f]Low=less than once a week (less than 50 grams per person per day), intermediate=1 to 4 times a week (between 50 and 100 grams per person per day), high=more than 4 times a week (more than 100 grams per person per day).
[g]Low=less than 5 times a week (less than 25 grams per person per day), intermediate=5 to 6 times a week (between 25 and 50 grams per person per day), high=more than 6 times a week (more than 50 grams per person per day).
[h]Low=less than 2 times a week (less than 300 grams per person per day), intermediate=2 to 6 times a week (between 300 and 500 grams per person per day), high=more than 6 times a week (more than 500 grams per person per day).
[i]Low=less than 2 times a week (less than 25 grams per person per day), intermediate=2 to 6 times a week (between 25 and 50 grams per person per day), high=more than 6 times a week (more than 50 grams per person per day).
[j]Low=less than once a day (less than 25 grams per person per day), intermediate=once a day (between 25 and 35 grams per person per day), high=more than once a day (more than 35 grams per person per day).
[k]Low=rarely (less than 25 grams per person per day), intermediate=between once a month and 2 to 4 times a week (between 25 and 30 grams per person per day), high=more than 4 times a week (more than 30 grams per person per day).
[l]Low=less than once a week (less than 5 grams per person per day), intermediate=between 1 to 6 times a week (between 5 and 15 grams per person per day), high=more than 6 times a week (more than 15 grams per person per day).
NAFLD, non-alcoholic fatty liver disease.

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Table 3 Further multivariable[a] analyses of the associations between male participants diagnosed as NAFLD vs. normal liver

Dietary factors	Consumption frequency	Multivariable		p Value
		OR	95% CI	
Food group				
Animal oil[b]	Low	1.00	—	—
	Intermediate	1.18	0.74–1.89	0.480
	High	1.71	1.11–2.63	0.016
Tea[c]	Low	1.00	—	—
	Intermediate	0.99	0.65–1.51	0.970
	High	0.57	0.36–0.90	0.016
Cooking style				
Salty[d]	Low	1.00	—	—
	Intermediate	1.06	0.62–1.81	0.822
	High	1.45	0.82–2.58	0.205
Oily[e]	Low	1.00	—	—
	Intermediate	1.36	0.80–2.32	0.254
	High	2.00	1.04–3.82	0.036

[a]Adjusted for age, educational level, smoking, and alcohol consumption.
[b]Low=rarely (less than 25 grams per person per day), intermediate=between once a month and 2 to 4 times a week (between 25 and 30 grams per person per day), high=more than 4 times a week (more than 30 grams per person per day).
[c]Low=less than once a week (less than 5 grams per person per day), intermediate=between 1 to 6 times a week (between 5 and 15 grams per person per day), high=more than 6 times a week (more than 15 grams per person per day).
[d]Low=less than 7 grams per person per day, intermediate=between 7 and 12 grams per person per day, high=more than 12 grams per person per day.
[e]Low=less than 26 grams per person per day, intermediate=between 26 and 44 grams per person per day, high=more than 44 grams per person per day.

further multivariable analysis including salt and oil consumption was conducted, high intake of oil was consistently related to increased risk of NAFLD (OR: 2.00; 95% CI: 1.04–3.82), whereas high intake of salt showed no significant association (OR: 1.45; 95% CI: 0.82–2.58) (Table 3). There was no multi-collinearity or interaction between oil and salt found. However, no significant associations were shown for females between NAFLD and eating habits and cooking styles.

Multivariable analyses of the relationship between other known risk factors for chronic diseases and NAFLD vs. normal liver

As shown in Table 5, BMI, WC, blood pressure, BUA, TG, LDL-C and FBG were positively associated with the risk of NAFLD, whilst there was a significantly inverse association found in incremental HDL-C with an OR of 0.04 for males and 0.13 for females, respectively. Among all the blood biochemical parameters and anthropometric measurements, the highest OR was between incremental TG and the risk of NAFLD, with an OR of 2.24 for males and 1.88 for females respectively. Nevertheless, TC was

Table 4 Comparison of eating habits between male participants diagnosed as NAFLD vs. normal liver

Eating habit	Category	NAFLD		Normal liver		p For trend	Multivariable[a]	
		N	%	n	%		OR	95% CI
Breakfast frequency[b]	Always	151	69.6	250	70.5	0.739	1.00	
	Often	34	15.7	59	16.0		1.04	0.65–1.68
	Rarely	32	14.7	50	13.6		1.24	0.75–2.05
Midnight snack frequency[c]	Always	125	57.9	183	49.6	0.085	1.00	
	Often	57	26.4	117	31.7		0.70	0.47–1.03
	Rarely	34	15.7	69	18.7		0.77	0.48–1.23
Meal time regularity	Regularly	18	8.4	22	6.0	0.059	1.00	
	Often	171	79.9	278	76.4		0.82	0.43–1.56
	Irregularly	25	11.7	64	17.6		0.58	0.27–1.26
Dining out frequency[d]	Always	35	16.2	60	16.4	0.155	1.00	
	Often	138	63.9	204	55.7		1.35	0.84–2.18
	Rarely	43	19.9	102	27.9		0.93	0.53–1.64

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Table 4 (Continued)

Eating habit	Category	NAFLD		Normal liver		p For trend	Multivariable[a]	
		N	%	n	%		OR	95% CI
Snacking frequency[e]	Always	50	23.1	66	18.1	0.280	1.00	
	Often	67	31.0	124	34.0		0.87	0.54–1.39
	Rarely	99	45.8	175	47.9		0.91	0.59–1.42

[a]Adjusted for age, educational level, smoking and alcohol consumption.
[b]Always=more than 5 times a week, often= 4 to 5 times a week, rarely= less than 4 times a week.
[c,d]Always=more than 2 times a week, often= 1 to 2 times a week, rarely= less than once a week.
[e]Always=more than 6 times a week, often= 1 to 6 times a week, rarely= less than once a week.
NAFLD, non-alcoholic fatty liver disease.

Table 5 Multivariable analyses of the relationship between other risk factors and non-alcoholic fatty liver disease vs. normal liver

Parameter*	Males		Females	
	OR (95% CI)	Wald-statistics#	OR (95% CI)	Wald-statistic#
BMI (kg/m^2)	1.81 (1.66–1.98)	178.38	1.55 (1.42–1.69)	96.74
WC (cm)	1.18 (1.15–1.21)	142.16	1.16 (1.12–1.20)	80.09
SBP (mmHg)	1.04 (1.02–1.05)	29.86	1.04 (1.02–1.06)	26.55
DBP (mmHg)	1.08 (1.06–1.10)	61.86	1.06 (1.03–1.08)	22.78
BUA (μmol/l)	1.009 (1.007–1.011)	50.94	1.012 (1.008–1.015)	37.86
TC (mmol/l)	1.77 (1.42–2.20)	26.14	1.22 (0.93–1.60)	2.11
TG (mmol/l)	2.24 (1.85–2.71)	67.18	1.88 (1.51–2.35)	31.20
HDL-C (mmol/l)	0.04 (0.02–0.09)	55.71	0.13 (0.06–0.27)	27.82
LDL-C (mmol/l)	1.93 (1.48–2.51)	24.04	1.49 (1.06–2.10)	5.29
FBG (mmol/l)	2.18 (1.75–2.73)	46.50	1.74 (1.36–2.22)	19.98

*Adjusted for age, educational level, smoking and alcohol consumption.
#When Wald-statistic is equal to 3.84, p value is 0.05.
BMI, body mass index; BUA, blood uric acid; DBP, diastolic blood pressure; FBG, fasting blood glucose; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SBP, systolic blood pressure; TC, total cholesterol; TG, triglyceride; WC, waist circumferences.

not significantly associated with the risk of NAFLD for females (OR: 1.22; 95% CI: 0.93–1.60).

Discussion

In this cross-sectional study involving 1,583 community-dwellers, the prevalence of NAFLD diagnosed by ultrasonography was 18.1% (17.6% for males and 12.0% for females, respectively) in Beijing. Results of analyses from 1,215 qualified subjects showed that for males, high tea drinking was related to reduced risk of NAFLD significantly, while high frequency of animal oil and high intake oil was positively associated with NAFLD. For females, no dietary factors were found to be associated with NAFLD significantly. For both males and females, results of relationship between NAFLD and anthropometric and biochemical measurements showed that incremental TG was related to an increased risk of NAFLD with the highest ORs.

The prevalence of NAFLD for males was significantly higher than for females, which was consistent with other studies' findings[9,22,23]. However, the overall prevalence of NAFLD in Beijing was higher than in the east and south of China[9,10]. The discrepancy was probably due to the diversity of life styles and dietary habits in different areas. Another potential interpretation related to the population was that the community selected was near some colleges, thus most participants' educational level was college or more (76.1%), which should not be ignored. Unlike others' conclusion[11,24], the educational background was related to the high prevalence of NAFLD, probably because the participants in Beijing with a higher educational level tended to have sedentary life styles, sustain greater pressure and therefore take less exercise and eat more irregularly.

Drinking tea, mostly green tea, is very popular and time-honoured in Chinese general population[25,26]. In this study, high tea consumption (i.e., more than 6 times a week) was

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found to be strongly and inversely related to NAFLD (OR = 0.57; 95% CI: 0.36–0.90, Table 3), which was similar to Peng's finding that tea intake was associated with the reduced risk of NAFLD by 28% in South China[27]. However, we failed to collect data on types of tea, because in our pilot study (n = 43) adding more detail on the dietary questionnaires, most participants (58%) were overburdened and therefore declined to complete the interview. Nevertheless, results of the pilot study showed that 87% of tea drinkers (n = 37) consumed only green tea regularly. Thus, the decision that the interviewers only focused on collecting data on green tea from the FFQ, was made. Biologically, NAFLD was an acquired metabolic stress-related liver disorder, which indicated that adipose accumulation, oxidative stress, insulin resistance, etc. played a very important role in the pathogenesis. The therapeutic potential of green tea in NAFLD probably relied on decreasing adipose lipogenesis and lipolysis, which reduced the delivery of adipose-derived non-esterified fatty acid to the liver[28]. Another explanation was that, tea restored the level of hepatic total glutathione and enzymatic antioxidant activities, which could avoid hepatic lipid peroxidation and hepatic injury[29]. Moreover, tea may play an effect on insulin resistance by increasing insulin receptor substrate-mediated downstream signalling, thereby reducing the risk of NAFLD[30,31].

High intake of oil (i.e., more than 44 gram per person per day) was identified as a risk factor for NAFLD, with an OR of 2.00 (95% CI: 1.04–3.82, Table 3). Oily food could generate high energy, massive free fatty acid, TG, etc., which disturbed fatty acid metabolism with hepatic lipid accumulation in liver. The harmful side products (e.g., lysophosphatidylcholine, diacylglycerols and ceramides) of enhanced fatty-acid metabolism could directly sensitise the liver to hepatic injury and damage[32,33]. Furthermore, the outcomes of oily food had been proven to be strongly related with obesity, insulin resistance and T2DM which were the major risk factors of NAFLD[11]. Thirdly, a large proportion of participants (more than 33% of both case and control groups in males, see Table 2) reported heavy use of animal oil, in which high consumption of animal oil was related to an increased risk of NAFLD significantly (OR = 1.71; 95% CI: 1.11–2.63, Table 3) based on the data from FFQ. Animal oil was rich in saturated fat, and saturated fat consumed could promote the development of NAFLD by affecting liver steatosis and oxidative damage[14].

High intake of salt was strongly related to hypertension[34,35] which was one feature of metabolic syndrome, thereby being highly associated with NAFLD[5,24]. However, in this study, we identified that high intake of salt was not significantly related to NAFLD and could result in overestimation of the association between oil and NAFLD as a confounding factor.

The data from FFQ was strongly associated with the range of daily amount consumed based on the recommendations of daily consumption[18] (all the Pearson's correlation coefficients > 0.83; p < 0.001). For instance, participants reporting high frequency of cereal intake (more than once a day) also probably chose high amount (more than 400 grams per person per day) of cereals consumed (Pearson's correlation coefficient = 0.91). Therefore, we only conducted multivariable analyses using data from FFQ, given that the FFQ provided more detailed information on dietary intake.

Because people may often underreport consuming amount of alcohol, we analysed the non-drinkers (291 males and 549 females) diagnosed as NAFLD vs. normal liver specially, and found that all the results kept consistent with those using all the participants.

Some previous studies had identified hyperlipidaemia as a risk factor for NAFLD[11,12,36,37]. Nevertheless, the relationship in our cross-sectional study was not causal. However, results from anthropometric and biochemical measurements showed that incremental TG was strongly related to an increased risk of NAFLD with the highest ORs, which was consistent with the findings by Fan et al. that TG was the most significant predictor (OR: 1.39; 95% CI: 1.25–1.55) in all the blood biochemical indices[9]. The explanation was because, at least in part, excessive accumulation of TG in hepatocytes appeared to be the crucial candidate contributing to hepatic insulin resistance which was dramatically important in the pathogenesis of metabolic syndrome and NAFLD[10,38–41].

Critical appraisal of the validity of relevant articles

There were several limitations to our study. Initially, the cross-sectional design limited the causal inference for the factors involved in NAFLD, and long-term follow-up studies and randomised controlled trials are needed to more clearly establish the causation. Secondly, the study subjects mostly had received college-level or higher education and the sampling was only limited to adults, thus the prevalence of NAFLD could not be generalised into the whole Chinese population. Nevertheless, it was the internal validity, rather than external validity of the study, that was a matter of concern in risk factor analyses[20]. Furthermore, using FFQ introduced possible recall bias. But since completion of the FFQ was done without participant's awareness of the anthropometric and laboratory measurements, the possible recall bias would result in non-differential misclassification leading to the association towards to the null[42]. Moreover, recognising that we would overburden participants from our pilot study, we could not collect data on other important variables (e.g., physical activity as a potential confounder and further quantitative nutrient information), which might render our finding conservative.

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Though some uncertain bias and confounding still existed, specifically via the restricted data collected from questionnaires and health check-ups, our study offered an opportunity to explore the prevalence, the related dietary information and the risk factors of other chronic diseases in NAFLD, and more importantly, to identify that public health initiatives are imperative to halt or reverse NAFLD epidemic.

Conclusion

To conclude, in this cross-sectional study, NAFLD in adults was highly prevalent in the Beijing community. High consumption of tea was associated with a decreased risk of NAFLD, while high frequency of animal oil, high intake of oil and TG were positively related to NAFLD.

Clinical applicability

These findings need to be confirmed in prospective studies and randomised controlled trials designed to further clarify the pathogenesis of NAFLD and to establish evidence-based dietary recommendations for its prevention and treatment.

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