Association of meat consumption with NAFLD risk and liver-related biochemical indexes in older Chinese: a cross-sectional study

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Abstract

Background: Non-alcohol fatty liver disease (NAFLD) is the most common liver disease and an unhealthy lifestyle can lead to an increased risk of NAFLD. The present study aims to evaluate the association of meat consumption with NAFLD risk and liver-related biochemical indexes in middle-aged and elderly Chinese.

Methods: A cross-sectional study was conducted in individuals who were 45 years or older and underwent a physical examination from April 2015 to August 2017 in Southeast China. To evaluate associations between meat intake and NAFLD risk, inverse probability of treatment weighting and subgroup analyses were performed with logistic regressions. Spearman's rank correlation was carried out to examine the relationship between meat consumptions and liver-related biochemical indexes.

Results: High consumptions of red meat (28.44-49.74 and >71.00 g/day) ($OR_{adjusted}=1.948$; $P<0.001$; $OR_{adjusted}=1.714$; $P=0.002$) was positively associated with NAFLD risk on inverse probability of treatment weighting analysis, adjusting for smoking, tea intake, weekly hours of physical activity and presence of hypertension, dyslipidemia and diabetes. Exposure-response relationship analysis presented that red meat intake was positively associated with NAFLD risk. Significant associations of red meat intakes with serum levels of γ -glutamyl transferase, alanine transaminase, aspartate aminotransferase, total triglyceride and high-density lipoprotein cholesterol were found ($r_s=0.176$; $P<0.001$; $r_s=0.128$; $P<0.001$; $r_s=0.060$; $P=0.016$; $r_s=0.085$; $P=0.001$; $r_s=-0.074$; $P=0.003$).

Conclusions: These findings suggest that the reduction of meat consumption may decrease NAFLD risk and should warrant further investigations.

Background

Non-alcoholic fatty liver disease (NAFLD) is the most common liver disease associated with the metabolic syndrome or its components and is becoming a major global health and economic burden, with a 25% prevalence worldwide [1]. It is defined as the presence of more than 5% of hepatic steatosis, with little or no secondary causes of fatty liver, such as alcohol, virus, and drugs. Besides, NAFLD is associated not only with adverse hepatic outcomes including cirrhosis and liver cancer, but also with non-liver-associated adverse outcomes, such as cardiovascular diseases and diabetes [2–4]. Elderly individuals are the fastest-growing age group worldwide due to great improvements in medications and medical treatments, as well as quality of life. Aging promotes the development of hepatocellular injury and inflammation [5], and the prevalence of NAFLD increases with age [1]. These data highlight a serious concern for the future, and the enormous increasing health burden of NAFLD.

Lifestyle including dietary habits positively influenced the development and progression of NAFLD [6, 7]. Unhealthy dietary patterns including high intakes of soft drinks and meat have been demonstrated to be significantly increased the NAFLD risk [8–11]. Meat is an important source of energy and some indispensable nutrients, including proteins and some micro-nutrients such as iron, zinc, selenium and B-vitamins [12, 13]. However, increased consumption of meat contributes to high intakes of dietary cholesterol, saturated fat, and other harmful compounds, which are closely connected to the NAFLD [14]. The global average per capita consumption of meat is rising, especially in China [12]. Chinese meat consumption increased from 58.9 g/d to 89.7 g/d from 1992 to 2012, which was far beyond the recommendation for Chinese adults [14]. Moreover, high consumption of meat was related to insulin resistance, type 2 diabetes, lipodystrophy, cardiovascular diseases, hepatocellular carcinoma and hypertension [15–18], which coexist and share similar pathogenesis of NAFLD [19, 20]. Therefore, it is important to examine the relationship of meat intake with NAFLD among the Chinese population, especially in middle-aged and elders, who are predisposed to NAFLD [21, 22].

Furthermore, liver-related biochemical parameters such as γ -glutamyl transferase (GGT), aspartate aminotransferase (AST), and alanine transaminase (ALT) were associated with NAFLD [23]. TG/HDL-C was found to be independently associated with fatty liver diseases [24, 25]. However, epidemiological studies regarding the associations of meat subtypes intake with NAFLD risk and liver-related biochemical indexes were not fully addressed.

This cross-sectional study, therefore, is intended to evaluate the associations of meat subtypes intake with the risk of NAFLD and liver-related biochemical indexes among the middle-aged and elder Chinese population.

Methods

Study Subjects and Design

This was a cross-sectional study, conducted in the health examination center of the Affiliated Nanping First Hospital, Fujian Medical University from April 2015 through August 2017. As shown in Figure 1, we included individuals aged ≥ 45 years old and who permanently resided in Nanping. Further exclusion criteria in our study were as follows: (A) Individuals whose daily consumptions of alcohol >40g (men) or >20g (women). (B) Individuals who had any other liver disease history, such as drug-induced liver disease, viral hepatitis, Wilson's disease, autoimmune hepatitis and total parenteral nutrition. (C) Individuals who were taking hypolipidemic or diet pills. (D) Individuals who did not answer more than 25 food-related items on the questionnaire. (E) Individuals who did not provide information on smoking and tea consumption. All subjects provided their informed consent before participating in this study.

The current study was carried out in compliance with the Declaration of Helsinki, and the Ethics Committee of Fujian Medical University approved the study protocol (ethics number 2014096).

Data Collection

NAFLD ascertainment

NAFLD was diagnosed by abdominal ultrasonography using established criteria [26]. An abdominal ultrasonography examination was done by experienced radiologists who were unaware of the laboratory and clinical data.

Meat intakes assessment

Dietary information on typical food consumption of participants was collected using a semi-quantitative food frequency questionnaire consisting of 110 food-related items, which was developed and validated in a sample from southern China [27]. And the information was obtained from participants interviewed face to face by trained investigators. For each food item, participants used the following response options to indicate how often they ate the selected food on average: 3 times/day, twice/day, once/day, 5–6 times/week, 3–4 times/week, 1–2 times/week, 1–3 times/month, <once/month and rarely. Red meat consisted of pork, beef and lamb. Poultry was composed of chicken and duck. Processed meat contained fried and smoked meat. Fish included: fish, shellfish and crab. The nutritional components of each food item were taken from the *China Food Composition* [28].

Covariate assessment

The following variables were self-reported: age, sex, marital status, income, educational level, smoking status, tea intake status, physical activity, medication use and medical conditions. All subjects underwent physical examinations (height, weight, waistline, hipline and blood pressure) and blood tests (fasting plasma-glucose, low-density lipoprotein cholesterol, total cholesterol, TG, HDL-C, AST, ALT and GGT) performed by trained physicians. BMI was calculated as $\text{weight}/(\text{height})^2$. Participants with a systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg were defined as having hypertension. And subjects who had one or more of the following abnormalities were diagnosed as dyslipidemia: total cholesterol ≥ 6.2 mmol/L, TG > 2.25 mmol/L, low-density lipoprotein cholesterol > 4.13 mmol/L or HDL-C < 1.03 mmol/L [29]. Diabetes was diagnosed as follows: fasting plasma glucose of 7.0 mmol/L or greater or 2-hour postprandial glucose greater than or equal to 11.1 mmol/L.

Statistical Analysis

Participants were classified into 4 groups based on the quartile of total meat consumption. The baseline characteristics of subjects were analyzed using the Nonparametric Kruskal-Wallis test for non-normal continuous variables and Chi-Square test for nominal variables. Continuous variables were expressed as median (interquartile range, *IQR*). Propensity scores were used to explain potential confounders by observed characteristics at baseline [30]. Age, gender and BMI were used to calculate the propensity score. Inverse probability of treatment weighting analysis was performed to evaluate associations of red meat, processed meat, poultry and fish intakes with NAFLD, adjusting for smoking status, tea intake status, weekly hours of physical activity, and presence of hypertension, dyslipidemia and diabetes. The lowest quartile (Q_1) of each type of meat intake was served as the reference group and P for trend was calculated by setting the meat intake quartiles as a continuous variable. To evaluate dose-response relationships between continuous exposure variables (red meat, processed meat, poultry and fish intakes) and NAFLD, a logistic model with restricted cubic spline using five knots at 0.05, 0.275, 0.5, 0.725 and 0.95 was built, adjusting for age, sex, BMI, smoking status, tea intake status, weekly hours of physical activity, and presence of hypertension, dyslipidemia and diabetes.

We also performed subgroup analysis to examine relationships of red meat, processed meat, poultry, and fish with NAFLD by the following subgroups: age (< 60 years or ≥ 60 years), gender (men or women), BMI (< 24 kg/m² or ≥ 24 kg/m²), smoking status (never, former or current), tea consumption status (yes or no), hypertension (yes or no), dyslipidemia (yes or no), diabetes (yes or no), and weekly hours of physical activity (< 9 hours/week or ≥ 9 hours/week). P value for interaction was calculated. Two sensitivity analyses were conducted: (1) logistic regression analysis without IPTW; and (2) propensity score-matching logistic regressions. Furthermore, to investigate the associations of meat subtypes intakes with the concentrations of serum GGT, ALT, AST, fasting plasma glucose, total cholesterol, TG, low-density lipoprotein cholesterol and HDL-C, spearman's rank correlation was performed.

For statistical analyses, SPSS, version 19.0.0.1 (IBM SPSS, 2010, Chicago, IL, USA) and R, version 4.0.0 (R Project for Statistical Computing) were performed. All P values were two-tailed and results were considered to be statistically significant at P values < 0.05 .

Results

Baseline characteristics

A total of 1594 individuals were included in this analysis. In the entire study sample, 53.5% were men, the average age was 53.54 ± 6.90 years and the average body mass index (BMI) was 23.77 ± 2.99 kg/m². As shown in Table 1, compared with participants with lower total intakes of red, processed meat, poultry and fish, participants with higher total intakes (1) were younger and more likely to be married persons, male, smokers, and tea drinkers; (2) had higher educational level, higher income, higher BMI, higher waist and hip circumference; (3) had higher levels of plasma γ -glutamyl transferase and alanine aminotransferase; and (4) had a higher prevalence rate of NAFLD (each $P < 0.05$).

Meat subtypes consumptions and NAFLD

As presented in Table 2, after propensity score weighting, red meat intake was positively related to the risk of NAFLD (OR per 50 g/day of red meat: 1.128, 95%CI: 1.005-1.266). After further adjustment for smoking status, tea intake status, weekly hours of physical activity and the presence of hypertension, dyslipidemia, and diabetes, the association with NAFLD remained significant ($OR_{\text{adjusted}} = 1.143$). High consumptions of red (Q_2 and Q_4) were significantly relevant to higher odds for NAFLD ($OR_{\text{adjusted}} = 1.948$ and 1.716, respectively), adjusting for those potential confounders. Furthermore, the results did not change appreciably after further adjusted for energy and cholesterol intakes (see Additional file 1: Table S1).

The restricted cubic splines analysis was applied to explain the exposure-response association between meat subtypes intakes and the risk of NAFLD (Figure 2). The *ORs* of NAFLD increased with red meat and poultry consumptions but decreased with the fish intake (Figure 2A, 2C and 2D). Moreover, the trend for *OR* of processed meat intake was not found (Figure 2B).

Stratified analyses

The positive association between meat intake and NAFLD was consistent across strata of age, sex, smoking status, tea intake status, BMI, weekly hours of physical activity, and the presence of hypertension, dyslipidemia and diabetes. Significant associations between red meat intake and the risk of NAFLD were not only found in males but also existed in people whose BMI ≥ 24 kg/m², tea-drinkers, people with hypertension and people without dyslipidemia. Adjusted *ORs* were estimated to be 1.177, 1.195, 1.229, 1.304 and 1.203, respectively. Moreover, fish intake was found positively relevant to NAFLD in people with diabetes (*OR*_{adjusted}=1.447). Nonetheless, no significant interactions of meat subtypes intakes and potential confounders were identified (Table 3).

Sensitivity analyses

Results from unweighted analysis was similar to those from propensity score-weighted analysis. Compared with the lowest quartile of meat intake, high intakes of red meat (*Q*₂ and *Q*₄) were significantly associated with NAFLD risk without the inverse probability of treatment weighting (*OR*_{adjusted}=1.484 and 1.558, respectively) (see Additional file 2: Table S2). Nonetheless, positive associations of red meat (*Q*₄) and processed meat (*Q*₃) consumptions with NAFLD risk were observed on propensity score matching analysis, with adjusted *OR* of 1.673 and 1.800, respectively (see Additional file 3: Table S3).

Meat subtypes intakes and liver-related biochemical indexes

Associations between meat subtypes intakes and liver-related biochemical indexes were shown in Figure 3. Red meat intake was positively correlated with levels of GGT, ALT, AST and total triglyceride (TG), but inversely with high-density lipoprotein cholesterol (HDL-C) (Spearman test correlation coefficient=0.176, 0.128, 0.060, 0.085 and -0.074, respectively). Processed meat intake was significantly associated with GGT, ALT, TG and HDL-C (Spearman test correlation coefficient=0.141, 0.115, 0.081 and -0.067, respectively). Similarly, significant associations were observed between poultry intake and GGT, ALT, TG and HDL-C (Spearman test correlation coefficient=0.111, 0.104, 0.085 and -0.066, respectively). Besides, GGT was also found to be significantly related to the consumption of fish (Spearman test correlation coefficient= 0.063).

Discussion

In this cross-sectional study, we observed that NAFLD was associated with higher intake levels of red meat. Significant associations of serum levels of GGT, ALT, AST, TG and HDL-C with meat subtypes intakes were found as well. Additionally, no significant interactions between meat consumptions and potential confounders for NAFLD were detected.

Significant associations between high meat consumptions and NAFLD were demonstrated in a few studies [8, 10, 11, 31]. Our results are in accordance with the previous studies, indicating a positive association between high red meat intake and NAFLD. Two cross-sectional studies have presented that red meat was significantly correlated with NAFLD [8, 11]. In another cross-sectional study, high intakes of total meat, especially red meat and/or processed meat were positively linked to NAFLD and insulin resistance, while processed meat alone was only relevant to insulin resistance. This is mainly due to a relatively low level of processed meat consumption in their research set [10]. In addition, a nested case-control study also showed that high consumptions of red meat, processed red meat and poultry were positively associated with NAFLD [31]. Due to the better accuracy of the continuous *ORs* [32], the dose-response analysis we have employed can better measure the overall trends of the *ORs* for meat intakes. The 95% *CI* for red meat intake beyond 200 g/day was slightly wider, because that less than 2% of participants had red meat intake >200 g/day, that was, the tendency of red meat intake within the range 0~200 g/day was relatively reliable and stable.

There are several plausible mechanisms by which meat intake is related to NAFLD. NAFLD was reported to be closely linked to hepatic insulin resistance, which had a strong correlation with liver-related biochemical indexes such as ALT, AST and GGT [33]. GGT and ALT had been considered as biomarkers of hepatic fat accumulation, which can lead to hepatic insulin resistance and increase the contribution of gluconeogenesis to total endogenous glucose production [34]. A cross-sectional study of 2198 European reported a significant positive association between red meat and GGT. As GGT is also a potential nonspecific marker of oxidative stress, the author suggested that oxidative stress may play a vital role underlying the development of chronic diseases with red meat intake [35]. Another cross-sectional study indicated that TG/HDL-C was independently relevant to the risk of NAFLD. The author attributed this result to insulin resistance [36]. Positive associations of serum levels of GGT, ALT and TG with red meat intakes were found in this study. Inversely, serum HDL-C concentration was negatively relevant to red meat and processed meat intakes. Hence, it's plausible that increased hepatic lipid accumulation and insulin resistance play a substantial role in the relationship of meat intakes with the development of NAFLD. In addition, a study by Avila *et al.* found that red meat was positively relevant to serum ferritin [37], which can increase the risk of NAFLD [38, 39]. Fried food will produce some hazardous chemicals, such as advanced glycation end products and trans fatty acids [40, 41], which were reported to play a critical role in NAFLD [42, 43].

Significant associations were found in several subgroups. A positive association was observed between red meat and NAFLD in males, perhaps it is because males had higher meat intakes and a higher prevalence of fatty liver than females [44]. Moreover, several studies had found significant associations of high meat intakes with obesity, type 2 diabetes and hypertension [15, 18, 45], which were considered as risk factors in the development of NAFLD [20, 46, 47]. In our study, a positive association of red meat intake with NAFLD was found in people with BMI ≥ 24 kg/m² and people with hypertension.

This study, however, had several limitations. Firstly, because of the cross-sectional study design, the casual inference was not allowed. Secondly, measurement error was unavoidable for self-reported diet and other data. Nevertheless, since all participants and researchers in this study were blinded to the results of abdominal ultrasonography and blood test, a reporting bias without differences is likely only to attenuate our observed association. Thirdly, since the study subjects were middle-aged and elders, it should be cautious in generalizing our findings to the wider population. Fourthly, the biopsy diagnosis not abdominal ultrasonography examination was identified as the gold standard. A meta-analysis reported that compared to histology, ultrasonography can reliably and accurately detect moderate-severe fatty liver, with an overall sensitivity of 84.8% (95% confidence interval [CI]: 79.5-88.9) and specificity of 93.6% (87.2-97.0). In addition, the overall sensitivity of ultrasound was 93.6% (60.5-99.3), specificity was 80.1% (53.3-93.4), compared with other imaging techniques such as computed tomography and magnetic resonance imaging [48]. Ultrasonography examination was widely used for screening of liver disease, because of its low costs, noninvasive nature and simplicity. Moreover, ultrasonography examination was done by experienced radiologists who were unaware of the laboratory and clinical data. Hence, an investigative bias may exist but it is not likely to have a significant impact. Lastly, although a comprehensive set of confounders were considered, as an observational study, the presence of unmeasured confounders is possible. For example, as thyroid function was reported to be associated with NAFLD risk [49, 50], related data were lack in our study. However, we have performed subgroup analysis to examine the relationships of meat consumption with NAFLD by the following subgroups: age, sex, BMI, smoking status, tea consumption status, hypertension, dyslipidemia, diabetes, and weekly hours of physical activity. Sensitivity analyses were also used to examine the association of meat intakes with NAFLD. Hence, the results in our study may not be significantly interfered.

Conclusions

In conclusion, a positive relationship between high consumptions of red meat and the risk of NAFLD was observed. In addition, serum levels of liver-related biochemical indexes were significantly relevant to red meat intake. Our findings suggested that the reduction of meat consumption may decrease the risk of NAFLD.

Abbreviations

NAFLD: Non-alcoholic fatty liver disease

BMI: Body mass index

GGT: γ -glutamyl transferase

AST: Aspartate aminotransferase

ALT: Alanine transaminase

TG: Total triglyceride

HDL-C: High-density lipoprotein cholesterol

IQR: Interquartile range

IPTW: Inverse probability of treatment weighting analysis

Declarations

Ethics approval and consent to participate

The current study was carried out in compliance with the Declaration of Helsinki, and the Ethics Committee of Fujian Medical University approved the study protocol (ethics number 2014096). All subjects provided their informed consent prior to participating in this study.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used can be available from the corresponding author on reasonable request.

Competing interests

All the authors declare that there are no financial or other relationships that might lead to a conflict of interest of the present article.

Authors' contributions

PHW and XXX are joint first authors. PXE, HZJ and ZYD designed the study. PHW, PXT, ZJ and CXL collected the data. PHW, XXX and PXT analysed the data. HZJ, ZJ, ZYD and CXL contributed to the interpretation of results. PHW, XXX and PXE wrote and reviewed the manuscript. All authors have discussed the results and commented on the manuscript.

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Tables

Table 1. Baseline characteristics of the study population by quartiles of the total intake of red, processed meat, poultry and fish

	<i>Q</i> ₁ (<71.22 g/day)	<i>Q</i> ₂ (71.22-97.31 g/day)	<i>Q</i> ₃ (97.32-147.50 g/day)	<i>Q</i> ₄ (>147.50 g/day)	<i>P</i>
Age (years), <i>M (IQR)</i>	53(49-58)	52(48-57)	52(48-57)	52(48-57)	0.036
Gender					<0.001
Male	179(40.7)	241(54.8)	276(62.7)	308(70.0)	
Female	261(59.3)	199(45.2)	164(37.3)	132(30.0)	
NAFLD, n (%)	107(24.3)	122(27.7)	151(34.3)	143(32.5)	0.004
Educational level, n (%)					<0.001
primary school and less than junior middle school	85(19.3)	57(13.0)	49(11.1)	36(8.2)	
high school	210(47.7)	215(48.9)	220(50.0)	228(51.8)	
junior college or above	145(33.0)	168(38.2)	171(38.9)	176(40.0)	
Income (yuan/month), n (%)					<0.001
< 2000	61(13.9)	28(6.4)	34(7.7)	25(5.7)	
2000-3000	166(37.7)	153(34.8)	131(29.8)	127(28.9)	
>3000	213(48.4)	259(58.9)	275(62.5)	288(65.5)	
Marital status, n (%)					0.001
Married	424(96.4)	437(99.3)	433(98.4)	438(99.5)	
Single or other	16(3.6)	3(0.7)	7(1.6)	2(0.5)	
Smoking status, n (%)					<0.001
Never	61(13.9)	91(20.7)	111(25.2)	135(30.7)	
Former	26(5.9)	28(6.4)	26(5.9)	38(8.6)	
Current	353(80.2)	321(73.0)	303(68.9)	267(60.7)	
Alcohol intake status, n (%)					<0.001
Never	94(21.4)	138(31.4)	173(39.3)	201(45.7)	
Former	14(3.2)	6(1.4)	9(2.0)	12(2.7)	
Current	332(75.5)	296(67.3)	258(58.6)	227(51.6)	
BMI (kg/m ²), <i>M (IQR)</i>	22.86(21.10-25.27)	23.66(21.30-25.35)	23.65(22.05-26.01)	24.06(22.29-26.11)	<0.001
Waist circumference (cm), <i>M (IQR)</i>	83(75-89)	84(77-90)	85(79-92)	86(80-92)	<0.001
Hip circumference (cm), <i>M (IQR)</i>	94(91-99)	95(91-99)	96(93-100)	97(93-101)	<0.001
SBP (mmHg), <i>M (IQR)</i>	124(113-138)	120(112-132)	122(112-135)	122(113-136)	0.088
DBP (mmHg), <i>M (IQR)</i>	80(76-88)	80(77-88)	80(76-90)	80(78-90)	0.247
Hypertension	178(40.5)	156(35.5)	177(40.2)	179(40.7)	0.323
Dyslipidemia	279(63.4)	269(61.1)	269(61.1)	282(64.1)	0.723
Diabetes	83(18.9)	87(19.8)	92(20.9)	73(16.6)	0.412
GGT (U/L), <i>M (IQR)</i>	22(17-33)	25(19-38)	27(18-43)	30(21-46)	<0.001
ALT (U/L), <i>M (IQR)</i>	19(15-25)	20(15-27)	21(16-30)	21(16-29)	<0.001
AST (U/L), <i>M (IQR)</i>	22(19-26)	22(19-26)	23(19-27)	23(19-27)	0.057
FPG (mg/dL), <i>M (IQR)</i>	469.44(441.98-513.73)	467.67(443.76-516.39)	467.67(438.44-505.76)	469.44(441.10-510.19)	0.975
TC (mg/dL), <i>M (IQR)</i>	460.58(410.98-505.76)	467.67(416.30-513.73)	465.90(420.73-528.79)	460.58(420.73-523.47)	0.686
TG (mg/dL), <i>M (IQR)</i>	119.57(85.92-170.95)	127.55(91.23-174.49)	126.66(92.12-178.03)	130.20(93.00-183.35)	0.009
LDL (mg/dL), <i>M (IQR)</i>	293.18(239.15-339.24)	296.72(248.89-344.55)	293.18(248.89-350.75)	294.07(239.15-336.58)	0.917
HDL (mg/dL), <i>M (IQR)</i>	116.92(101.86-129.32)	116.92(100.97-129.32)	116.92(100.97-129.32)	114.26(98.32-127.55)	0.094
Physical activity (hours/week), <i>M (IQR)</i>	10.5(4.5-17.5)	9.0(4.0-14.4)	8.0(4.0-15.8)	7.5(3.5-15.5)	0.025

Statistical analysis performed by Kruskal-Wallis H test and Chi-Square test.

BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; GGT, γ -glutamyl transferase; ALT, alanine aminotransferase; AST, aspartate aminotransferase; FPG, fasting plasma-glucose; TC, total cholesterol; TG, total triglyceride; LDL, low-density lipoprotein; HDL, high-density lipoprotein; NAFLD, non-alcoholic fatty liver disease; *M (IQR)* = Median (Interquartile range); *Q* = quartile.

Table 2. Propensity score weighted univariable and multivariable analysis of associations between meat subtypes consumptions and NAFLD

Variable	Crude OR (95%CI)	Adjusted OR (95%CI) ^a
Redmeat		
Continuous variable		
Per 50 g/day increase	1.152(1.037-1.281)	1.128(1.003-1.269)
Categorical variables		
Q ₁ (<28.97 g/day)	1 (Reference)	1 (Reference)
Q ₂ (28.97-49.74 g/day)	1.215(0.890 -1.659)	1.405(0.995-1.984)
Q ₃ (49.75-73.94 g/day)	1.164(0.851-1.592)	1.058(0.745-1.501)
Q ₄ (>73.94 g/day)	1.451(1.068-1.971)	1.466(1.039-2.069)
P for trend	0.030	0.119
Processedmeat		
Continuous variable		
Per 50 g/day increase	1.045(0.863-1.266)	1.040(0.835-1.295)
Categorical variables		
Q ₁ (<2.50 g/day)	1 (Reference)	1 (Reference)
Q ₂ (2.50-4.62 g/day)	1.108(0.809-1.517)	1.223(0.865-1.730)
Q ₃ (4.63-6.59 g/day)	2.188(1.605-2.984)	1.500(1.047-2.151)
Q ₄ (>6.59 g/day)	1.447(1.061-1.974)	1.302(0.923-1.838)
P for trend	<0.001	0.095
Poultry		
Continuous variable		
Per 50 g/day increase	0.961(0.691-1.336)	1.089(0.749-1.582)
Categorical variables		
Q ₁ (<7.00 g/day)	1 (Reference)	1 (Reference)
Q ₂ (7.00-9.00 g/day)	1.052(0.762-1.453)	1.296(0.907-1.852)
Q ₃ (9.01-14.00 g/day)	1.444(1.060-1.967)	1.240(0.875-1.756)
Q ₄ (>14.00 g/day)	1.107(0.805-1.520)	1.228(0.862-1.750)
P for trend	0.230	0.344
Fish		
Continuous variable		
Per 50 g/day increase	0.968(0.875-1.071)	1.000(0.894-1.119)
Categorical variables		
Q ₁ (<11.01 g/day)	1 (Reference)	1 (Reference)
Q ₂ (11.01-25.15 g/day)	1.060(0.780-1.440)	1.203(0.854-1.697)
Q ₃ (25.16-50.42 g/day)	1.058(0.782-1.430)	1.203(0.858-1.686)
Q ₄ (>50.42 g/day)	1.035(0.765-1.401)	1.126(0.802-1.580)
P for trend	0.828	0.515

NAFLD, non-alcoholic fatty liver diseases.

^a Adjusted by BMI, smoking status, alcohol intake status, weekly hours of physical activity and the presence of hypertension, dyslipidemia and diabetes. Q = quartile.

Table 3. Stratified analysis of association between meat subtypes intakes and NAFLD risk

Subgroup	Red meat (per 50 g/day)	<i>P</i> for interaction	Processed meat (per 50 g/day)	<i>P</i> for interaction	Poultry (per 50 g/day)	<i>P</i> for interaction	Fish (per 50 g/day)	<i>P</i> for interaction
	OR (95%CI)		OR (95%CI)		OR (95%CI)		OR (95%CI)	
Gender		0.259		0.759		0.565		0.844
Male	1.177(1.013-1.368)		0.991(0.798-1.231)		1.156(0.737-1.838)		0.962(0.820-1.128)	
Female	1.097(0.883-1.364)		1.165(0.619-2.193)		0.896(0.397-2.018)		1.009(0.857-1.188)	
Age		0.503		0.208		0.121		0.220
<60 years	1.112(0.969-1.276)		1.004(0.812-1.243)		0.990(0.649-1.510)		0.956(0.841-1.087)	
≥60 years	1.255(0.956-1.649)		3.397(0.657-17.567)		2.134(0.686-6.636)		1.201(0.870-1.657)	
BMI		0.543		0.346		0.391		0.947
<24 kg/m ²	1.141(0.906-1.438)		0.856(0.508-1.441)		1.124(0.624-2.024)		1.025(0.873-1.205)	
≥24 kg/m ²	1.195(1.029-1.387)		1.196(0.789-1.811)		1.542(0.880-2.704)		1.002(0.855-1.175)	
Smoking status		0.425		0.811		0.746		0.732
Never	1.079(0.916-1.271)		1.195(0.685-2.082)		1.332(0.747-2.376)		1.018(0.888-1.168)	
Former	1.560(0.908-2.680)		1.422(0.052-39.060)		1.246(0.228-6.818)		1.047(0.697-1.573)	
Current	1.176(0.959-1.442)		1.006(0.798-1.269)		0.936(0.535-1.638)		0.919(0.726-1.164)	
Tea intake status		0.095		0.842		0.201		0.745
No	1.014(0.832-1.235)		1.006(0.808-1.253)		0.822(0.430-1.570)		0.965(0.726-1.281)	
Yes	1.229(1.048-1.442)		1.037(0.499-2.155)		1.413(0.838-2.385)		0.994(0.875-1.131)	
Hypertension		0.166		0.195		0.363		0.094
No	1.037(0.884-1.216)		1.269(0.870-1.852)		0.935(0.568-1.537)		0.905(0.760-1.079)	
Yes	1.304(1.063-1.598)		0.766(0.389-1.508)		1.440(0.752-2.757)		1.138(0.945-1.369)	
Dyslipidemia		0.245		0.118		0.607		0.709
No	1.203(1.017-1.424)		1.686(0.806-3.526)		1.208(0.709-2.056)		0.999(0.860-1.159)	
Yes	1.072(0.898-1.278)		0.958(0.759-1.211)		1.037(0.594-1.812)		0.975(0.811-1.172)	
Diabetes		0.973		0.852		0.112		0.110
No	1.129(0.988-1.290)		1.001(0.810-1.237)		0.978(0.631-1.518)		0.936(0.813-1.076)	
Yes	1.272(0.923-1.753)		1.206(0.357-4.073)		2.816(0.990-8.008)		1.447(1.017-2.059)	
Physical activity		0.745		0.730		0.653		0.736
<9.0 hours/week	1.135(0.949-1.356)		0.800(0.346-1.851)		1.211(0.716-2.046)		1.001(0.828-1.211)	
≥9.0 hours/week	1.134(0.957-1.344)		1.024(0.829-1.266)		1.070(0.600-1.908)		0.986(0.851-1.142)	

NAFLD, non-alcoholic fatty liver diseases; BMI, body mass index.

* Adjusted for age, gender, BMI, smoking status, tea intake status, weekly hours of physical activity and the presence of hypertension, dyslipidemia and diabetes.

Figures

Figure 1

Flowchart of the study population. NAFLD, non-alcoholic fatty liver disease.

Figure 2

Restricted cubic spline model of the odds ratios of non-alcoholic fatty liver diseases (NAFLD) with intakes of (A) red meat (Pnonlinearity=0.63), (B) processed meat (Pnonlinearity=0.24), (C) poultry (Pnonlinearity=0.69) and (D) fish (Pnonlinearity=0.55). Gray area, 95% confidence interval. Each model was adjusted for age, gender, body mass index (BMI), smoking status, tea intake status, weekly hours of physical activity and the presence of hypertension, dyslipidemia and diabetes.

Figure 3

Heatmap of associations between meat subtypes intakes and liver-related biochemical indexes. GGT, γ -glutamyl transferase; ALT, alanine aminotransferase; AST, aspartate aminotransferase; FPG, fasting plasma-glucose; TC, total cholesterol; TG, total triglyceride; LDL, low-density lipoprotein; HDL, high-density lipoprotein. * $P < 0.05$.

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