Environmental Exposure to Cooking Oil Fume and Fatty Liver Disease

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Abstract

Background: Evidence on effect of cooking oil fume, which contains numerous carcinogens, on development of fatty liver disease is limited. The present study aims to investigate the association between exposure to cooking oil fume and the risk of fatty liver disease.

Method: A total of 55959 participants aged between 40 and 75 years old participated in a community-based survey in Ningbo, China. Information on exposure to cooking oil fume and fatty liver disease were collected by face-to-face interview. Stratified analysis was used with participants being divided into two groups according to gender. Multiple logistic regression analyses were conducted to investigate the association between cooking oil fume exposure and fatty liver risk. Furthermore, ordered logistic regression was conducted to investigate the association between cooking oil fume exposure and the severity of fatty liver disease.

Results: Fatty liver disease prevalence was 8.79% in none oil fume exposure group, 10.52% in light oil fume exposure group, 23.47% in moderate oil fume exposure group and 41.45% in heavy oil fume exposure group. After adjusting for confounding factors, participants in the light, moderate and heavy cooking oil fume exposure groups all had significantly higher odds ratios as compared with participants in the none oil fume exposure group. In addition, an interaction effect between cooking oil fume exposure and gender on the prevalence and severity of fatty liver disease was observed. Females with heavyoil fume exposure had the highest odds ratios of fatty liver disease and severer disease extent. In the stratified analysis, compared to participants in the smokeless group, males and females in light, moderate and heavy cooking oil fume exposure groups all had significantly higher risk of fatty liver disease and severer disease extent, while participants with heavier cooking oil fume exposure tended to have higher risk of fatty liver disease and severer disease extent.

Conclusion: Exposure to cooking oil fume is associated with incident and severity of fatty liver disease in 40-75 years old Chinese. The associations might be dose-responsive. In addition, heavy oil fume exposure and female sex might have a synergistic effecton incident and severity of fatty liver disease.

1. Background

Fatty liver disease is characterized by fat deposits in liver cells and encompasses a broad array of liver pathology, ranging from asymptomatic steatosis to steatohepatitis, fibrosis, and cirrhosis[1]. It has placed a heavy economic burden on health care systems globally[1]. With changes of lifestyles, the prevalence of fatty liver in Asia area grows sharply in recent years, with the mean prevalence in China reaching 15% in 2009[2]. Thus, it is important to seek related risk factors of fatty liver disease and effective strategies to prevent it.

Cooking is an essential part of daily life. Chinese-style cooking including stir-frying and deep-frying which need preheated about 25–100 ml of cooking oil to approximately 280 °C and produce large quantities of cooking oil fume. [3]Cooking oil fume contains lots of carcinogens, such as polycyclic aromatic hydrocarbons (PAH), fine particulate matter (PM), etc. [4, 5]It is reported that the annual emission rate of total PAH was 2038 kg/year in Chinese restaurants, which was approximately 8-fold higher than that at restaurants of western. [6]Another study reported that the proportion of PM2.5 emissions from cooking fuels was about 12% of total global PM2.5 emissions.[7] Several epidemiologic studies have related cooking oil fume to lung cancer and cardiovascular disease.[8, 9] Recently, Jian etc. found that environmental exposure to cooking oil fume is also associated with diabetes.[10] However, few studies has analyzed the association between cooking oil fume and fatty liver although Ames test and the SOS chromotest have found that cooking oil fume contains genotoxicity which related to fatty deposition[11, 12].

Therefore, the present study is conducted to investigate whether exposure to cooking oil fume is related to incident and severity of fatty liver disease.

2. Methods

2.1 Participants

We performed a cross-sectional study base on Ningbo database of the Cancer Screening Program in Urban China (CanSPUC)[13]. CanSPUC is a national ongoing national cancer screening program which was initiated in October 2012. After obtaining signed written informed consent, all the eligible participants were interviewed face-to-face by trained staffs to collect information about their exposure to risk factors. Cancer screening program in Ningbo, Zhejiang began at 2013 and a total of 55959 participants (male = 24961, female = 30998) aged 40–75 years were included during 2013–2017. Participants with incomplete data on cooking oil fume (n = 1), fat liver disease (n = 899), menopausal status (n = 1) were excluded. Finally, 55058 participants (male = 24551, female = 30507) were included in our analyses.

2.2 Questionnaires

Fatty liver disease, environmental exposure to cooking oil fume, gender, age, menopausal status, weight, height, waist, education, active and passive smoke, alcohol drinking, dietary fat intake, physical activity, and metabolic disease (hypertension, hyperlipemia and type 2 diabetes) were collected through face-to-face interview. Participants who had self-reported fatty liver disease were further grouped as light fatty liver, moderate fatty liver and heavy fatty liver by asking “how severer is the disease?”. Cooking oil fume exposure was leveled as smokeless, light, moderate and heavy. Body mass index (BMI) is calculated by dividing body weight in kilograms by the square of height in meters. Education was classified as illiteracy, primary or middle school, high school and college or above. Information on active smoking was obtained by asking current and lifetime smoking habits and classed as smoker (current or former smoker) or nonsmoker. Passive smoking was defined by asking “Are there smokers living in the participants’ family or at their workplace”. Alcohol drinking was classified as never, regular and quit. Dietary fat intake was leveled as high fat diet, moderate fat diet and low-fat diet. Regular exercise was defined according to whether participants do exercises at least 3 times a week and 30 minutes every time.

2.3 Statistical analysis

The characteristics of the participants were summarized as mean ± standard deviation (SD) for continuous variables and as frequency (percentages) for the categorical variables. Analyses of variance (ANOVA) and Bonferroni test were used to compare continuous variables, and chi-squared tests were used to compare categorical variables across different cooking oil fume exposure groups.

Multiple logistic regression analyses were conducted to investigate the association between cooking oil fume exposure and fatty liver risk after adjusting for gender, age, BMI, waist, education, active and passive smoke, alcohol drinking, dietary fat intake, regular exercise and metabolic disease.

Interactive analysis was used to evaluate the interaction between cooking oil fume exposure and gender. And then participants were divided into two groups as significant interaction was observed. Multiple logistic regression models were respectively rerun in males and females, and models in females were additionally adjusted for menopausal status. Furthermore, multiple ordinal logistic regression analyses were used to examine the association between cooking oil fume exposure and the severity of fatty liver disease with same confounders adjusted in the multiple logistic regression analyses (P value of proportional odds assumption < 0.001). A value of $p < 0.05$ (two sided) was considered statistically significant unless otherwise indicated. Stata version 13 was used for data analyses (Stata Corporation, College Station, TX).

3. Results

The characteristics of participants are shown in Table 1. Participants who were exposed to heavier cooking oil fume were more likely to develop fatty liver disease (all $p < 0.001$). Significant differences were found in waist, education, alcohol use, active and passive smoke, dietary fat intake, physical activity (all $p < 0.001$). Participants in the heavy cooking fume exposure group had the highest risk of metabolic disease (hypertension, dyslipidemia and type 2 diabetes, all $p < 0.05$). There were no significant differences in age, menopausal status and waist across cooking oil fume exposure groups ($p > 0.05$).

Table 1
Descriptive characteristics of study participants.

Variables	Cooking oil fumes exposure				P value
N (%) or mean (SD)	Smokeless (n = 10643)	Light (n = 39895)	Moderate (n = 4175)	Heavy (n = 345)	
Age, y	57.13 ± 7.71	57.02 ± 7.97	57.23 ± 7.80	56.48 ± 8.13	0.124
Male [b, d]	4805 (45.15)	17852 (44.75)	1740 (41.68)	154 (44.64)	0.001
BMI, kg/m^2	23.75 ± 5.54	23.67 ± 6.35	23.81 ± 4.95	23.69 ± 3.00	0.348
Waist, cm [a, d]	81.92 ± 9.80	80.90 ± 9.71	81.73 ± 9.97	82.03 ± 9.73	< 0.001
Education [a, d]					< 0.001
Illiteracy	340 (3.19)	1341 (3.36)	180 (4.31)	19 (5.51)	
Primary or secondary	7069 (66.42)	23839 (59.75)	2683 (64.26)	205 (59.42)	
High School	2826 (26.55)	12456 (31.22)	1123 (26.90)	99 (28.70)	
College or above	408 (3.83)	2259 (5.66)	189 (4.53)	22 (6.38)	
Alcohol user [a, b, c, d, e, f]	2646 (24.86)	8418 (21.10)	1366 (32.72)	139 (40.29)	< 0.001
Smoker [a, b, c, d, e, f]	2879 (27.05)	8964 (22.47)	1403 (33.60)	146 (42.32)	< 0.001
Passive smoker [a, b, c, d, e, f]	3215 (30.21)	12994 (32.57)	2941 (70.44)	310 (89.86)	< 0.001
Fat intake [b, c, d, e, f]					< 0.001
Low	1239 (11.64)	4990 (12.51)	271 (6.49)	18 (5.22)	
Middle	8678 (81.54)	31400 (78.71)	2136 (51.16)	131 (37.97)	
High	726 (6.82)	3505 (8.79)	1768 (42.35)	196 (56.81)	
Regular exercise [a, b, c, d, e, f]	5572 (52.35)	23023 (57.71)	1262 (3023)	56 (16.23)	< 0.001
Hypertension [a, b, c, d, e, f]	3214 (30.20)	11188 (28.04)	1416 (33.92)	144 (41.74)	< 0.001

Variables	Cooking oil fumes exposure				P value
N (%) or mean (SD)	Smokeless (n = 10643)	Light (n = 39895)	Moderate (n = 4175)	Heavy (n = 345)	
Dyslipidemia [b, c, d, e, f]	1712 (16.09)	6847 (17.16)	1149 (27.52)	146 (42.32)	< 0.001
Diabetes [a, c, d, e, f]	1014 (9.53)	3282 (8.23)	436 (10.44)	53 (15.36)	< 0.001
Fatty liver disease [a, b, c, d, e, f]					< 0.001
Normal	9708 (91.21)	35699 (89.48)	3195 (76.53)	202 (58.55)	
Light	650 (6.11)	3017 (7.56)	501 (12.00)	42 (12.17)	
Moderate	239 (2.25)	967 (2.42)	372 (8.91)	63 (18.26)	
Heavy	56 (0.43)	212 (0.53)	107 (2.56)	38 (11.01)	
Abbreviations: BMI, body mass index; SD, standard deviation.					
Analysis of variance (ANOVA) for continuous variables and chi^2 test for categorical.					
a $p < 0.05$ Significant difference between participants in none and low cooking oil fumes exposure group.					
b $p < 0.05$ Significant difference between participants in none and middle cooking oil fumes exposure group.					
c $p < 0.05$ Significant difference between participants in none and high cooking oil fumes exposure group.					
d $p < 0.05$ Significant difference between participants in low and middle cooking oil fumes exposure group.					
e $p < 0.05$ Significant difference between participants in low and high cooking oil fumes exposure group.					
f $p < 0.05$ Significant difference between participants in middle and high cooking oil fumes exposure group.					

Associations between cooking oil fume exposure and prevalence of fatty liver disease are shown in Table 2. Compared with participants in smokeless group, the adjusted ORs for fatty liver disease among participants in light, moderate and heavy cooking oil fume exposure groups were 1.24 (95%CI 1.15–1.35, P < 0.001), 1.64 (95%CI 1.46–1.84, P < 0.001), 2.60 (95%CI 1.99–3.39, P < 0.001), respectively. Participants with heavier cooking oil fume exposure tended to have higher risk of fatty liver disease (P < 0.001).

Table 2
The association between cooking oil fumes exposure and fatty liver disease

Cooking oil fumes exposure	OR (95%CI)	P value
Smokeless	1.00	
Light	1.24 (1.15,1.35)	< 0.001
Moderate	1.64 (1.46, 1.84)	< 0.001
Heavy	2.60 (1.99, 3.39)	< 0.001
P for trend	< 0.001	
Models were adjusted for age, gender, body mass index, waist, education level, smoking, passive smoker, alcohol assumption, regular exercise, fat intake habits, hypertension, dyslipidemia and diabetes.		

In the interactive analysis, we observed significant interaction between cooking oil fume exposure and gender on the risk of fatty liver disease (OR for interaction = 0.858, P for interaction = 0.001). Compared with males in the smokeless group, females in the heavy cooking oil fume exposure group had the highest risk of fatty liver disease and severest disease extent among all participants (OR = 4.36, P < 0.001, Figure a.; OR = 6.08, P < 0.001, Figure b.).

Thus, models were rerun with participants being divided into two groups according to gender (Table 3). Compared to participants in the smokeless group, males and females in light, moderate and heavy cooking oil fume exposure groups all had significantly higher risk of fatty liver disease, while participants with heavier cooking oil fume exposure tended to have higher risk of fatty liver disease (all P < 0.001).

Table 3
The association between cooking oil fumes exposure and fatty liver disease by gender

Cooking oil fumes exposure	Male	Female
	OR (95%CI)	OR (95%CI)
Smokeless	1.00	1.00
Light	1.22 (1.08,1.37) ***	1.27 (1.14, 1.42) ***
Moderate	2.01 (1.69, 2.38) ***	1.41 (1.20, 1.65) ***
Heavy	2.69 (1.80, 4.01) ***	2.56 (1.79, 3.67) ***
P for trend	< 0.001	< 0.001
Models were adjusted for age, gender, body mass index, waist, education level, smoking, passive smoker, alcohol assumption, regular exercise, fat intake habits, hypertension, dyslipidemia and diabetes. Females were additionally adjusted for menopausal status.		
*** P < 0.001		

Associations between cooking oil fume exposure and severity of fatty liver disease were further analyzed in males and females, respectively (Table 4). Compared to participants in the smokeless group, males and females in light, moderate and heavy cooking oil fume exposure groups all had significantly higher risk of severer fatty liver disease (all $P < 0.001$). Besides, participants with heavier cooking oil fume exposure tended to have higher risk of severer fatty liver disease.

Table 4
The association between cooking oil fumes exposure and severity of fatty liver disease by gender.

Cooking oil fumes exposure	Male	Female
	OR (95%CI)	OR (95%CI)
Smokeless	1.00	1.00
Light	1.21 (1.08, 1.36) ***	1.24 (1.11, 1.38) ***
Moderate	2.10 (1.78, 2.48) ***	1.46 (1.25, 1.70) ***
Heavy	3.45 (2.41, 4.93) ***	3.37 (2.41, 4.71) ***
P for trend	< 0.001	< 0.001

Models were adjusted for age, gender, body mass index, waist, education level, smoking, passive smoker, alcohol assumption, regular exercise, fat intake habits, hypertension, dyslipidemia and diabetes. Females were additionally adjusted for menopausal status.

*** P < 0.001

Figure. a. Combined effect of cooking oil fumes exposure and gender on risk of fatty liver disease (FLD).

b. Combined effect of cooking oil fumes exposure and gender on severity of FLD.

Odds ratios were all adjusted for age, gender, body mass index, waist, education level, smoking, passive smoker, alcohol assumption, regular exercise, fat intake habits, hypertension, dyslipidemia and diabetes.

All P < 0.001.

4. Discussion

In the present study, we found a positive association between cooking oil fume exposure and fatty liver disease after adjusting for various potential confounders in Chinese adults. Participants who exposure to heavier cooking oil fume tended to have higher risk of fatty liver disease and severer disease extent. In addition, we observed significant interaction between cooking oil fume exposure and gender on the risk of fatty liver disease. Female with heavy cooking oil fume exposure was associated with the highest observed odds ratio of fatty liver disease and severer disease extent.

Cooking fume exposure has been found to be related with many chronic diseases such as lung cancer, cardiovascular disease and diabetes.[8–10] Previous animal studies also found that carcinogens contained in cigarette smoke, which can also be found in cooking oil fume, might accelerate fat deposition in liver.[14] However, clinical data on the association between environmental exposure to cooking oil fume and fatty liver disease is limited. In the present study, we firstly found that cooking oil fume is significantly associated with fatty liver disease and severer disease extent even after adjusting for possible confounders. In addition, participants with heavier cooking oil fume exposure tended to have higher odds ratios of fatty liver disease and severer disease extent, suggesting a dose-response relationship between cooking oil fume exposure and fatty liver. However, the mechanism underlying the association is still unclear. There is plenty of evidences showed that exposure to environmental PAHs induced oxidative DNA damage and elevated systemic inflammatory marker (C-reactive protein) in general population.[15, 16] Both DNA damage and inflammatory response contribute to decomposition of fatty acid which is involved in the development of fatty liver.[17, 18] Similarly, PM, another important component of cooking oil fume, related to fat redistribution and metabolism as well.[19, 20] Additionally, Tan et al found that PM that reached the liver could induce Kupffer cell cytokine secretion, which then trigger inflammation and hepatic stellate cell collagen synthesis.[21]

In the interaction analyses, we found a synergistic effect between heavy cooking oil fume exposure and female sex on fatty liver disease and severer disease extent. Female with heavy cooking oil fume exposure was associated with highest risk for fatty liver disease and severest disease extent, suggesting female were more likely to be affected by cooking oil fume than male. Consistent with our observation, previous studies reported that female were more susceptible to environmental pollutants in relation to oxidative stress and diabetes than male.[22, 23] A possible explanation is the higher activity of CYP1A1 which can produce higher levels of DNA adducts and lower DNA repair capacity in female than male.[24] In addition, body fat mass and abdominal fat mass have been documented to be associated with increased systemic inflammation and reduced anti-inflammation function and might also have modifying effects on the cross-sectional association between environmental pollutants and metabolic disease.[25] Thus, the different associations between cooking oil fumes and fatty liver among males and females might partly because that females have higher body fat mass and abdominal fat mass than male.[26] However, in the stratified analysis, the associations between cooking oil fume exposure and fatty live disease were found in both males and females. The results indicated that the positive association between cooking oil fume exposure and fatty liver disease should be noted in both males and females.

The present study has several strengths. Our study firstly related cooking oil fume to fatty liver disease and found a dose-response relationship between cooking oil fume exposure and fatty liver. Secondly, the sample size was relatively large, making the statistical significance being robust. Thirdly, a series of important confounders, such as dietary fat intake, social economic factors and metabolic diseases, were taken into consideration in the analysis. Lastly, collapsing environmental exposure of cooking oil fume, severity of fatty liver into four categories separately enabled us to have a better understanding on the associations between cooking oil fume and fatty liver.

Conversely, limitations should also be noted. First, because of the cross-sectional design, a causal relationship between cooking oil fume and fatty liver may not be inferred. Second, the measurement of cooking oil fume exposure and fatty liver were based on self-report only, which may lead to recall bias and misclassification. Prospective and longitudinal studies should be made in the future with more accurate information on cooking oil fume exposure and fatty liver. Third, participants with nonalcoholic fatty liver disease cannot be distinguished from alcoholic fatty liver disease in our study. However, a sensitive analyze included only nondrinker observed similar results (table S1, table S2).

5. Conclusion

In conclusion, our study found that there may be a dose-dependent association between cooking oil fume exposure and fatty liver disease. In addition, heavy cooking oil fume exposure might have a synergistic effect with female sex on fatty liver disease. These findings add to the current understanding regarding fatty liver prevention. Future studies should be conducted to explore the underlying mechanism of this association and whether effective cooking oil fume control means like a fume extractor in home kitchen can reduce the risk of fatty liver.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Cancer Hospital Chinese Academy of Medical Science.

Consent for publication

Not applicable

Availability of data and materials

The data that support the findings of this study are available from Cancer Hospital Chinese Academy of Medical Science but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Cancer Hospital Chinese Academy of Medical Science.

Competing interests

The authors declare that they have no competing interests

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Contributors

JL, SZ and TC designed the study. JL and SN analyzed the data and drafted the manuscript. JL, SN, QS, ZX, JK, XS, YG, HZ and SL contributed to the discussion and the interpretation of data and results and revised the manuscript. SZ has primary responsibility for the final content. All the authors have read and approved the final manuscript.

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Figures

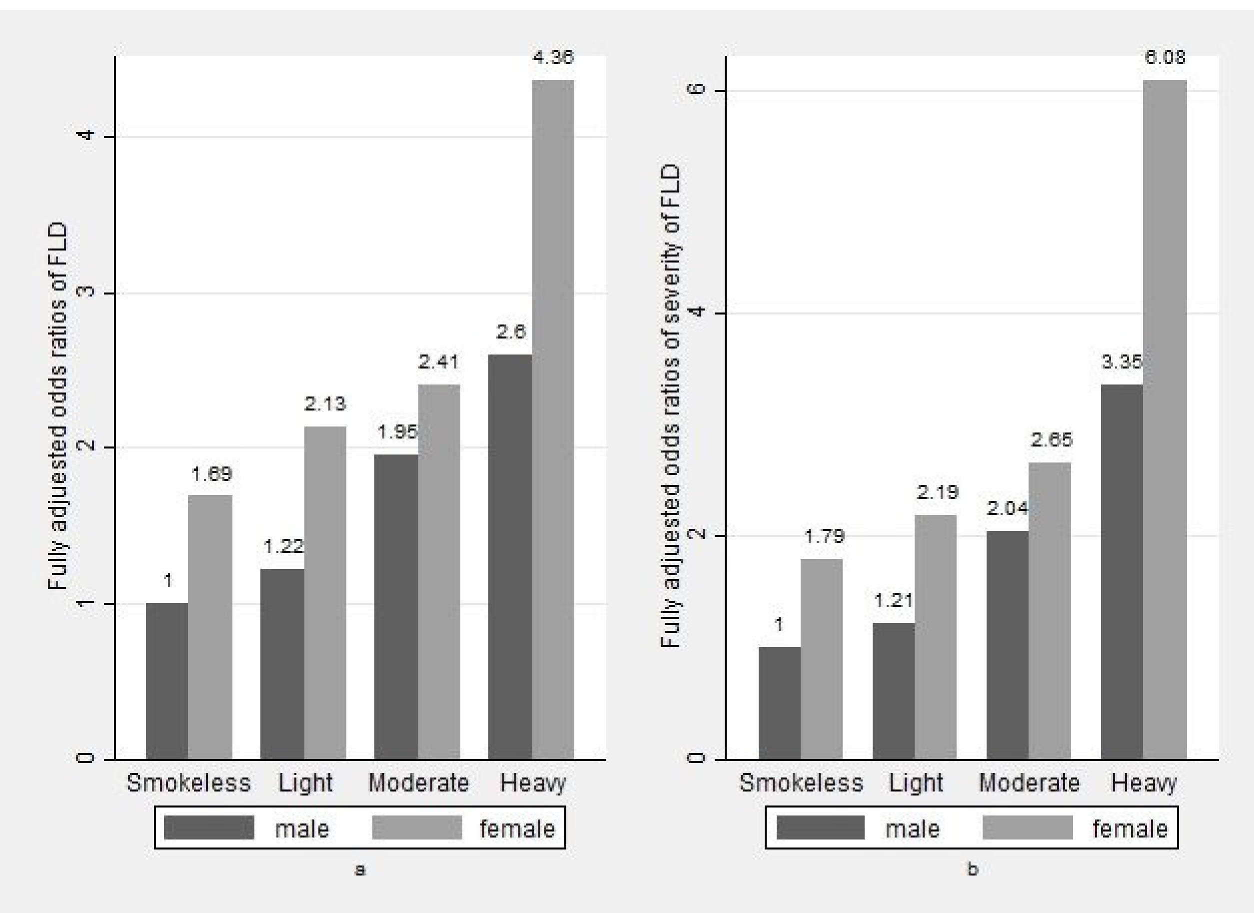

Figure 1

Fully adjusted odds ratios of FLD Fully adjusted odds ratios of severity of FLD

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