Original Article

Exploratory analysis of the association between dietary niacin intakes and nonalcoholic fatty liver disease among US adults: 1999–2018 data analysis from the National Health and Nutrition Examination Survey (NHANES)

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Background: Previous researches have revealed the potential association between dietary niacin intakes and several diseases, but studies assessing the association between dietary niacin intakes and nonalcoholic fatty liver disease (NAFLD) is limited and remains unclear. This study was performed to explore the association. Methods: In this study, 10,528 participants (male: 5,257) in the 10 National Health and Nutrition Examination Survey (NHANES) cycles (1999–2018) from the NHANES database were selected for the analyses. We built three logistic regression models to explore the independent association between dietary niacin intakes and NAFLD and to explore whether such association exists. Finally, a restricted cubic spline model was applied to simulate the potential nonlinear association between dietary niacin intakes and the occurrence of NAFLD. Results: The result of the fully-adjusted model suggested that ln-transformed dietary niacin intakes were significantly associated with the reduced occurrence of NAFLD. The odd ratio (OR) of the model and its 95% confidence interval (CI) were 0.81 (0.73, 0.90). When taking the lowest quartile as a reference, the level of niacin in the highest quartile was associated with decreased prevalence of NAFLD (OR: 0.76, 95% CI: 0.63, 0.91). The restricted cubic spline plot presented a negative dose-response association between levels of daily niacin consumption and the occurrence of NAFLD (*p* for nonlinearity = 0.762). Conclusion: According to the results of this study, dietary niacin intakes may have a negative association with NAFLD, and more well-designed cohort studies are required in the future to confirm the obtained finding.

***Key Words*: niacin, nonalcoholic fatty liver disease, NHANES, cross-sectional study**

Nonalcoholic fatty liver disease (NAFLD) is a complex lesion that results from the interaction between genetic susceptibility, environmental factors, and host metabolic disorders.[1] NAFLD refers to greater than 5% hepatocellular lipid accumulation and excludes diseases that lead to secondary hepatic lipid accumulation, such as excessive alcohol consumption and chronic viral liver disease, etc.[2] NAFLD has become a growing public health problem worldwide as the quality of life has improved and the diet has changed.[3] The current global prevalence of NAFLD is 25.24%, and the overall prevalence of NAFLD is expected to continue to increase steadily (0–30%) over the next 10 years.[4] In addition, several studies have found that NAFLD is closely associated not only with the occurrence of cirrhosis and hepatocellular carcinoma,[5] but also with the occurrence of various diseases such as atherosclerosis, cardiovascular disease, diabetes, colorectal cancer in men, and breast cancer in women.[4]

Niacin is involved in many important biochemical reactions within cells and is an essential functional molecule for the organism.[6] It has been recognized that niacin can lower the levels of total blood cholesterol, triglycerides (TG), and low-density lipoprotein (LDL) levels and increase high-density lipoprotein (HDL) levels.[7] Dietary intake of niacin plays an essential role in the regulation of physiological processes, such as the maintenance of genetic stability and the mechanisms regulating the epigenetic control of metabolism and aging.[8] In recent years, the association between dietary niacin intakes and various diseases has been widely noted. For example, a cross-sectional study by Taechameekietichai *et al*.[9] suggested that greater niacin intake may be associated with a lower chance of developing glaucoma. Also, niacin has been shown to reduce the risk of cardiovascular events in current practice.[10] In Ganji's study, they concluded the therapeutic role of niacin in the prevention and regression of hepatic steatosis in rat model of NAFLD.[11] However, the number of epidemiological studies assessing the association between dietary niacin intakes and NAFLD is limited and remains unclear, so it is necessary to evaluate the association between dietary niacin intakes and NAFLD, by a cross-sectional study using the data from the National Health and Nutrition Examination Survey (NHANES).

Materials and methods

Data source. The data for this study were obtained from the 1999–2018 NHANES database, which is an annual cross-

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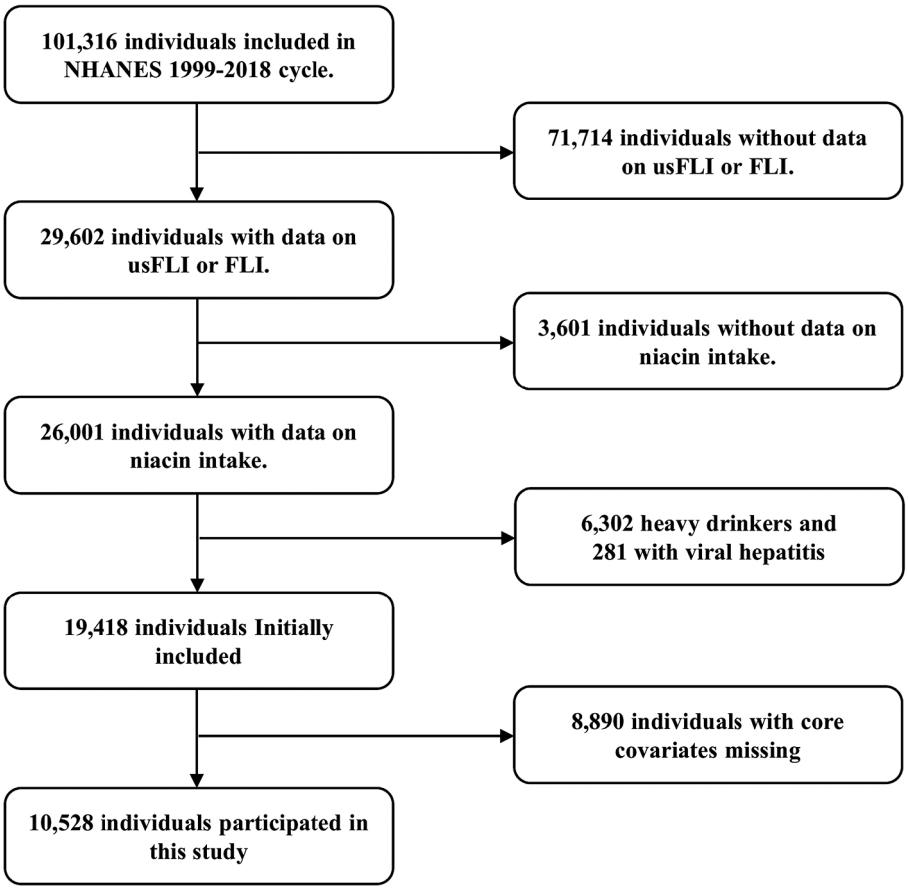

Fig. 1. Flow chart of population included in the final analysis, NHANES 1999–2018.

sectional series of interviews and physical examinations conducted by the National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention (CDC). The survey data has been published on the official website every two years since 1999 and all of them can be publicly available at https://www.cdc.gov/nchs/nhanes/.[12] In this study, ten cycles (1999–2000, 2001–2002, 2003–2004, 2005–2006, 2007–2008, 2009–2010, 2011–2012, 2013–2014, 2015–2016, 2017–2018) of data (including demographic, dietary, somatometric, laboratory, and questionnaire data) from the NHANES database was downloaded and analyzed to explore the association between dietary niacin intakes and NAFLD among US adults. Since the database uses a multi-stage stratified probability design, these samples are representative of the entire population of US citizens without institutionalization. Ethical approval and more detailed information can be viewed on the Review Board's website (https://www.cdc.gov/nchs/nhanes/irba98.htm).[13]

Study design and population. We extracted the data from the NHANES database to conduct this cross-sectional study. The target independent variable was dietary niacin intakes when the participants were tested, and the dependent variable was whether the participants were diagnosed with NAFLD. In the current study, participants over 20 years old who completed interviews and exams at the Mobile Examination Center (MEC) between 1999 and 2018 were enrolled. Participants were regarded as ineligible if they met the following criteria.[1] Participants missing data on dietary niacin intakes. (2) Participants without data on the United States Fatty Liver Index (US-FLI) or Fatty Liver Index (FLI). (3) Participants missing data or information in analytical covariates. (4) Participants with viral hepatitis infection (tested positive for hepatitis B surface antigen, hepatitis C antibody). (5) Participants self-reported significant alcohol consumption (more than 2 drinks per day for men or more than 1 drink per day for women). The detailed process of participant enrollment is shown in Fig. 1.

Measurements of dietary niacin intakes. The dietary niacin intakes were available in the "Dietary Interview-Total Nutrient Intakes dataset". The data on dietary niacin intakes were evaluated by the 24-h recall reviews. Specifically, niacin intake was determined by multiplying the niacin concentration data by the corresponding weight of each reported food by referring to the food code. Notably, two dietary reviews were conducted to collect the data. At MEC, participants were interviewed in person for the first dietary recall interview and, 3 to 10 days later, the second interview was collected by telephone. The intakes of dietary niacin were obtained by calculating the average of intakes of niacin from two 24-h dietary diets and supplements.[14]

Assessment of NAFLD. According to the American Association for the Study of Liver Diseases (AASLD) guidelines for NAFLD,[15] the following criteria are required for the diagnosis of NAFLD. (1) FLI or US-FLI was used to determine hepatic steatosis. The requirement is FLI $\geq$60 or US-FLI $\geq$30.[16,17] (2) Lack of substantial alcohol consumption. Heavy drinking was defined as more than one drink per day for females and more than two drinks per day for males.[18]

Definition of other variables. Based on the previous literature, the following covariates were extracted, which included demographics [age, sex, ethnicity, education levels, marital status, and family poverty-income ratio (PIR)], anthropometric measurements [body mass index (BMI)], health-related behaviors

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(smoking status, alcohol usage, and physical activity), medical history [hypertension, hyperlipidemia, and diabetes mellitus (DM)], and blood biochemical indexes [alanine aminotransferase (AST), aspartate transaminase (AST), albumin, and globulin].

We categorized the participants into the following 3 age groups: 20–39 years, 40–59 years, and 60 years or above. The participants were divided into 4 ethnicities, which included Mexican American, Non-Hispanic Black, Non-Hispanic White, and other races. Educational level was classified into 3 groups (including Lower than high school, High school or equivalent, or College or above). Marital status was divided into 3 groups (married/cohabiting, widowed/divorced/separated, and never married).

The following 3 levels of the PIR were coded: low income (≤1.3), middle income (>1.3 to 3.5), and high income (>3.5). BMI was calculated based on height and weight. The formula for BMI is: BMI = weight (kg)/height $(m)^2$, which was divided into underweight or normal weight (<25 kg/m^2), overweight (25–30 kg/m^2), and obesity (≥30 kg/m^2). Participants who smoked <100 cigarettes in the past were described as non-smokers. Drinking status was dichotomized into alcohol users and non-alcohol users (at least 12 alcoholic drinks per year or not). Physical activity was referred as none, moderate, and vigorous according to the self-reported questionnaire items. As to hypertension, the International Society of Hypertension (ISH) 2020 International Hypertension Practice Guidelines and commonly used clinical criteria published by ISH are used as the basis for the diagnosis of hypertension.[19] (1) Systolic blood pressure >130 mmHg or diastolic blood pressure >90 mmHg. (2) Subjects are taking antihypertensive medication. (3) Self-reported diagnosis of hypertension. Diabetes was diagnosed according to the standards of the American Diabetes Association and participants' self-reported questionnaires.[20] Each of the following conditions was diagnosed as diabetes: (1) fasting plasma glucose ≥7 mmol/L, self-reported physician diagnosis of diabetes, or (2) current use of diabetes medication to lower blood glucose level. The hyperlipidemia status was assessed based on the National Cholesterol Education Program (NCEP) in adults (Adult Treatment Panel III, ATP 3). The hyperlipidemia was defined as TG ≥150 mg/dl, total cholesterol (TC) ≥200 mg/dl, LDL ≥130 mg/dl, or HDL ≤40 mg/dl in males and ≤50 mg/dl in females.[21] Also, participants reporting the use of cholesterol-lowering medications were also defined as having hyperlipidemia.

Statistical analysis. Categorical variables were presented by the number of cases (*n*) and percentages (%). Normal distributions were described by the mid-values and SD, while Skewd distributions were described based on the medians and Q1–Q3. Continuous variables were compared between groups using the Student *t* test or Mann–Whitney *U* test based on the normality of the distribution. Three logistic regression models were conducted to estimate the ORs with the corresponding confidence intervals (CIs) for the risk of NAFLD associated with dietary niacin intakes. Model 1 was not adjusted for any covariates. Model 2 was adjusted for age, sex, ethnicity, education level, marital status, BMI level, and PIR. Model 3 was further adjusted for smoking status, alcohol usage, physical activity, hypertension, diabetes, hyperlipidemia, AST, ALT, albumin, and globulin. Moreover, subgroup analyses were performed according to age, sex, ethnicity, education level, marital status, BMI level, PIR, smoking status, alcohol usage, physical activity, hypertension, diabetes, and hyperlipidemia. Finally, a restricted cubic spline model was applied to simulate the potential nonlinear association between dietary niacin intakes and the occurrence of NAFLD. All the above analyses were based on R software (ver. 4.1.1), and *p* values less than 0.05 were considered statistically significant.

Results

Characteristics of study participants. Eventually, 10,528 participants were enrolled in the subsequent analysis, including 6,415 NAFLD patients and 4,113 subjects without NAFLD. The detailed characteristics of the NAFLD and non-NAFLD participants in the NHANES database was presented in Table 1. In the overall dataset, the proportion of males and female was almost the same (49.93% for female and 50.07% for male). The majority of individuals were over 60 years old (43.97%) and were Non-Hispanic White (49.73%). Of the participants, 5,538 (52.60%) received college education or above, and 2,371 (22.52%) have high school or equivalent education. Individuals in good marital status accounted for the largest proportion (64.95%). Approximately 78.56% of the participants were overweight or obese. The proportion of low-income family, middle-income family, and high-income family were 27.06%, 39.18%, and 33.76%, respectively. Compared with non-NAFLD group, the NAFLD group was older, more likely to be male, more likely to be Non-Hispanic White, and had a higher proportion of educated less, overweight or obese, lower income, former smoking, more alcohol usage, less physical activity, hypertension, and diabetes and hyperlipidemia (All $p<0.001$). Besides, the levels of ALT and AST in NAFLD patients were significantly higher than that in the control group (All $p<0.001$).

Association between dietary niacin intakes and NAFLD. In the total populations, the results of the univariate logistic regression model suggested no association between ln-transformed niacin and NAFLD (OR: 0.99, 95% CI: 0.92, 1.05). In model 2, After adjusted for age, sex, ethnicity, education level, marital status, BMI level, and PIR, the OR of NAFLD was negatively associated with ln-transformed niacin (OR: 0.83, 95% CI: 0.76, 0.92). Besides, the result of model 3 (further adjusted for smoking status, alcohol usage, physical activity, hypertension, diabetes, hyperlipidemia, AST, ALT, albumin, and globulin) suggested that ln-transformed niacin intakes were significantly associated with the reduced occurrence of NAFLD. The OR of the model and its 95% CI were 0.81 (0.73, 0.90). The effect value of the model can be interpreted as a corresponding 19% decrease in the probability of developing NAFLD with increasing 1 unit of ln-transformed dietary niacin intakes.

When taking the lowest quartile as a reference, the level of niacin in the highest quartile was not associated with decreased prevalence of NAFLD in model 1 (OR: 0.99, 95% CI: 0.88, 1.10). However, in the adjusted model 2, we identified that subjects with niacin intakes in the fourth quartile are the least likely to have NAFLD (OR: 0.79, 95% CI: 0.67, 0.93). Similarly, this association persisted even after further adjustment in model 3 (OR: 0.76, 95% CI: 0.63, 0.91). We also conducted trend analyses and the results showed that the odds of NAFLD were reduced with more daily niacin consumption in both adjusted models (model 2: p for trend = 0.005; model 3: p for trend = 0.004) (Table 2).

We conducted further stratified analyses to evaluate the association between dietary niacin intakes and the risk of NAFLD in different subgroups. After adjusting all the covariate factors, Table 3 demonstrated that the negative association between the highest dietary niacin intake category and occurrence of NAFLD appeared stronger among males, Non-Hispanic White, and participants with age over 60 years. The odds ratios of these groups both had an obvious decreasing trend (All p for trend <0.05).

In addition, a restricted cubic spline model was applied to simulate the potential nonlinear association between dietary niacin intakes and the occurrence of NAFLD. Figure 2 describes a negative dose-response association between levels of daily niacin consumption and the occurrence of NAFLD (p for nonlinearity = 0.762), suggesting that the risk of NAFLD decreased with the consumption of niacin.

Table 1. Characteristics of the NAFLD and non-NAFLD participants in the NHANES database

Characteristics	Participants (*n* = 10,528)	Without NAFLD (*n* = 6,415)	NAFLD (*n* = 4,113)	*p* value
Age, *n* (%)				**<0.001**
20–39	2,561 (24.33)	1,847 (28.79)	714 (17.36)	
40–59	3,338 (31.71)	1,928 (30.05)	1,410 (34.28)	
≥60	4,629 (43.97)	2,640 (41.15)	1,989 (48.36)	
Sex, *n* (%)				**<0.001**
Male	5,257 (49.93)	2,984 (46.52)	2,273 (55.26)	
Female	5,271 (50.07)	3,431 (53.48)	1,840 (44.74)	
Ethnicity, *n* (%)				**<0.001**
Mexican American	1,636 (15.54)	906 (14.12)	730 (17.75)	
Non-Hispanic Black	2,037 (19.35)	1,626 (25.35)	411 (9.99)	
Non-Hispanic White	5,236 (49.73)	2,832 (44.15)	2,404 (58.45)	
Other race	1,619 (15.38)	1,051 (16.38)	568 (13.81)	
Education, *n* (%)				**<0.001**
Lower than high school	2,619 (24.88)	1,473 (22.96)	1,146 (27.86)	
High school or equivalent	2,371 (22.52)	1,381 (21.53)	990 (24.07)	
College or above	5,538 (52.60)	3,561 (55.51)	1,977 (48.07)	
Marital status, *n* (%)				**<0.001**
Married/cohabiting	6,838 (64.95)	4,037 (62.93)	2,801 (68.10)	
Widowed/divorced/separated	2,351 (22.33)	1,419 (22.12)	932 (22.66)	
Never married	1,339 (12.72)	9,59 (14.95)	380 (9.24)	
BMI, *n* (%)				**<0.001**
Underweight or normal	2,257 (21.44)	2,226 (34.70)	31 (0.75)	
Overweight	2,966 (28.17)	2,511 (39.14)	455 (11.06)	
Obesity	5,305 (50.39)	1,678 (26.16)	3,627 (88.18)	
PIR, *n* (%)				**<0.001**
<1.3	2,849 (27.06)	1,642 (25.60)	1,207 (29.35)	
1–3.5	4,125 (39.18)	2,514 (39.19)	1,611 (39.17)	
>3.5	3,554 (33.76)	2,259 (35.21)	1,295 (31.49)	
Smoking status, *n* (%)				**<0.001**
No	6,200 (58.89)	3,977 (62.00)	2,223 (54.05)	
Yes	4,328 (41.11)	2,438 (38.00)	1,890 (45.95)	
Alcohol usage, *n* (%)				**0.003**
No	2,094 (19.89)	1,335 (20.81)	759 (18.45)	
Yes	8,434 (80.11)	5,080 (79.19)	3,354 (81.55)	
Physical activity, *n* (%)				**<0.001**
No	3,864 (36.70)	2,182 (34.01)	1,682 (40.89)	
Moderate	3,413 (32.42)	2,055 (32.03)	1,358 (33.02)	
Vigorous	3,251 (30.88)	2,178 (33.95)	1,073 (26.09)	
Hypertension, *n* (%)				**<0.001**
No	5,386 (51.16)	3,815 (59.47)	1,571 (38.20)	
Yes	5,142 (48.84)	2,600 (40.53)	2,542 (61.80)	
Diabetes				**<0.001**
No	6,581 (62.51)	4,705 (73.34)	1,876 (45.61)	
Yes	3,947 (37.49)	1,710 (26.66)	2,237 (54.39)	
Hyperlipidemia, *n* (%)				**<0.001**
No	2,497 (23.72)	2,044 (31.86)	453 (11.01)	
Yes	8,031 (76.28)	4,371 (68.14)	3,660 (88.99)	
ALT (U/L)*	21.0 [16.0, 27.0]	19.0 [15.0, 24.0]	24.0 [19.0, 32.0]	**<0.001**
AST (U/L)*	22.0 [19.0, 27.0]	22.0 [19.0, 26.0]	23.0 [20.0, 28.0]	**<0.001**
Albumin (g/dl)*	4.20 [4.00, 4.40]	4.30 [4.00, 4.50]	4.20 [4.00, 4.40]	**<0.001**
Globulin (g/dl)*	2.90 [2.70, 3.20]	2.90 [2.60, 3.20]	3.00 [2.70, 3.30]	**<0.001**

The bold values mean statistical significance. *Values were presented as median (interquartile range). NAFLD, nonalcoholic fatty liver disease; NHANES, the National Health and Nutrition Examination Survey; BMI, body mass index; PIR, family poverty-income ratio; ALT, alanine aminotransferase; AST, aspartate transaminase.

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Table 2. Association between niacin intake and NAFLD in the US adults

	Model 1	Model 2	Model 3
Ln	0.99 (0.92, 1.05)	**0.83 (0.76, 0.92)**	**0.81 (0.73, 0.90)**
Q1	1	1	1
Q2	0.97 (0.86, 1.08)	0.89 (0.76, 1.04)	**0.85 (0.72, 1.00)**
Q3	1.00 (0.90, 1.12)	0.87 (0.74, 1.01)	**0.85 (0.72, 1.00)**
Q4	0.99 (0.88, 1.10)	**0.79 (0.67, 0.93)**	**0.76 (0.63, 0.91)**
p for trend	0.993	**0.005**	**0.004**

Ln means ln-transformed niacin. Model 1 was not adjusted. Model 2 was adjusted for age, sex, ethnicity, education level, marital status, BMI level, and PIR. Model 3 was further adjusted for smoking status, alcohol usage, physical activity, hypertension, diabetes, hyperlipidemia, AST, ALT, albumin, and globulin. The bold values mean statistical significance.

Discussion

Overall, our study found that dietary niacin intakes were negatively associated with NAFLD in adults. It is worth noting that participants aged 60 and above, male, overweight and obesity, smoking, drinking, or hypertension were more likely to show such association. Before this study, no similar studies have found a specific association between dietary niacin intakes and NAFLD. Therefore, our study is likely to have an important guiding role in how people can better adjust their diet to avoid the occurrence of NAFLD or inhibit the progression of NAFLD.

Niacin has been considered as one of the first-choice drugs for lowering blood lipids in clinical practice for many years[22,23] and was widely used in the prevention and treatment of cardiovascular diseases such as atherosclerosis.[24] Studies have shown that niacin can reduce low-density lipoprotein cholesterol (LDL), TG, and lipoprotein (a) [Lp (a)].[7,25,26] Compared to statin lipid-lowering drugs, niacin is the only drug that significantly reduces Lp (a) levels and is the only approved drug that increases high-density lipoprotein cholesterol (HDLc) levels, so niacin is also an alternative to statin intolerance in patients with hyperlipidemia.[27] NAFLD is a chronic liver disease associated with metabolic diseases such as obesity, hyperlipidemia, hypertension, and type 2 diabetes. It is increasingly recognized as a major health problem in many parts of the world[28] and is characterized by excessive accumulation of TG (steatosis) in liver cells.[29] Recent studies have found that niacin may contribute to the treatment of NAFLD and its secondary complications, including non-alcoholic steatohepatitis and fibrosis. Animal and cell experiments have found that niacin can inhibit and reverse hepatic steatosis. It prevents liver fibrosis in animals and reduces collagen in cultured human stellate cells.[30] In addition, previous studies have shown that niacin can inhibit fat production in the liver of mice through GPR109A-mediated signaling pathways, indicating its potential for the treatment of NAFLD.[31]

As a vitamin, nicotinic acid is not only a first-line drug for lipid-lowering and treatment-related diseases, but also an essential nutrient for the human body.[32] Although tryptophan can be converted into nicotinic acid in the body, the proportion is very low, so the nicotinic acid in the body is mostly derived from dietary intake.[33,34] However, there has been no epidemiological investigation on the relationship between dietary niacin and NAFLD. Therefore, our study also provides some new insights into the role of dietary niacin intake changes in NAFLD. The study population included multiple factors such as age, gender, education level, region, smoking, drinking, physical activity, hypertension, diabetes, hyperlipidemia, and related indicators reflecting liver function. The results showed that the relative risk of NAFLD decreased with the increase of niacin intake, which was consistent with previous clinical or basic experimental studies. Moreover, we found that participants with one or more conditions such as 60 years of age or older, male, married or cohabiting, BMI showing overweight and obesity, smoking, drinking, hypertension, and hyperlipidemia were more likely to be affected by niacin intake. Previous studies have shown that smoking, obesity and diabetes are common risk factors for NAFLD8. Smoking increases TC, TG, and LDL, while reducing cardiac protective HDL, which indirectly induces metabolic diseases.[35,36] Previous studies have shown that niacin can change serum LDL particle size[37] and increase cardiac protective HDL levels.[38] These may be the mechanism by which nicotinic acid is more likely to reduce the incidence of NAFLD in these populations. Of course, the specific mechanism of action remains to be further studied and proved. More interestingly, although diabetes is a risk factor for NAFLD, our study found that the negative correlation between niacin and NAFLD was more pronounced in non-diabetic subjects. Long-term intake of nicotinic acid may lead to excessive inhibition of lipolysis. When lipolysis recovers or exceeds the baseline value, diabetes will be induced,[39] which may be one of the reasons why the effect of niacin on NAFLD in diabetic population is not obvious. However, the specific mechanism still needs further study.

This study has several inherent limitations. Firstly, as an inherent drawback of cross-sectional studies, the exact causal relationship cannot be determined because of the coexistence of disease and factors. In the future, more well-designed cohort studies will be performed to further investigate such association. Secondly, the data used in this paper are only representative of US adults, and some other national or ethnic groups could not be investigated in depth. Future research in this area is urgently needed. Thirdly, people usually ingest multiple related nutrients at the same time, so it is difficult to exclude the effect of other types of nutrients on NAFLD. Despite the limitations, the advantages of this cross-sectional study should be highlighted. First of all, to our knowledge, it was the first study to explore the association between dietary niacin intakes and NAFLD. Second, the sample size in our study is large and therefore had greater statistical validity and more feasible results.

In conclusion, our study showed that dietary niacin intakes may be negatively associated with NAFLD. This finding offers a new insight for the clinical research. Given the relatively high prevalence of NAFLD, niacin's effect on NAFLD in our study is promising. Further corroboration by larger prospective studies is warranted to confirm these findings and establish causal inference.

Author Contributions

BC conceived and designed the research. YC, XG, and LH designed the research, performed statistical analysis, interpret data, and wrote the manuscript. WY and RL provided critical opinion and revised the manuscript. All authors approved the final manuscript.

Table 3. The results of subgroup analyses

	Q1	Q2	Q3	Q4	*p* for trend
Model 3					
Age					
20–39	1	0.75 (0.49, 1.12)	0.67 (0.45, 1.01)	0.74 (0.49, 1.09)	0.136
40–59	1	**0.69 (0.50, 0.93)**	0.81 (0.60, 1.10)	**0.72 (0.53, 0.99)**	0.121
≥60	1	1.01 (0.80, 1.28)	0.90 (0.71, 1.15)	**0.75 (0.57, 0.99)**	**0.04**
Sex					
Male	1	0.93 (0.71, 1.23)	**0.77 (0.59, 1.00)**	**0.72 (0.56, 0.93)**	**0.004**
Female	1	**0.76 (0.61, 0.94)**	0.93 (0.74, 1.16)	0.81 (0.61, 1.08)	0.268
Ethnicity					
Mexican American	1	0.85 (0.60, 1.22)	0.85 (0.58, 1.25)	0.92 (0.61, 1.39)	0.61
Non-Hispanic Black	1	0.77 (0.53, 1.11)	0.98 (0.68, 1.44)	0.89 (0.58, 1.35)	0.874
Non-Hispanic White	1	0.85 (0.65, 1.10)	0.78 (0.60, 1.01)	**0.68 (0.52, 0.89)**	**0.005**
Other race	1	0.79 (0.50, 1.25)	0.68 (0.42, 1.07)	0.59 (0.36, 0.95)	**0.025**
Education					
Lower than high school	1	**0.66 (0.50, 0.88)**	0.94 (0.69, 1.29)	**0.70 (0.49, 1.00)**	0.129
High school or equivalent	1	0.80 (0.57, 1.13)	**0.67 (0.47, 0.94)**	**0.56 (0.38, 0.82)**	**0.002**
College or above	1	1.05 (0.80, 1.36)	0.92 (0.71, 1.19)	0.90 (0.69, 1.17)	0.277
Marital status					
Married/cohabiting	1	**0.79 (0.64, 0.98)**	**0.76 (0.62, 0.93)**	**0.66 (0.53, 0.83)**	**<0.001**
Widowed/divorced/separated	1	0.94 (0.67, 1.30)	1.18 (0.84, 1.68)	0.77 (0.52, 1.13)	0.509
Never married	1	0.87 (0.49, 1.53)	0.76 (0.43, 1.34)	1.38 (0.77, 2.50)	0.335
BMI					
Underweight or normal	1	**0.24 (0.06, 0.78)**	**0.15 (0.02, 0.60)**	0.50 (0.15, 1.53)	0.087
Overweight	1	0.99 (0.72, 1.35)	**0.70 (0.50, 0.97)**	0.78 (0.56, 1.09)	**0.04**
Obesity	1	0.83 (0.68, 1.01)	0.93 (0.75, 1.14)	**0.75 (0.61, 0.94)**	**0.043**
PIR					
<1.3	1	**0.71 (0.52, 0.95)**	**0.64 (0.46, 0.88)**	**0.49 (0.34, 0.70)**	**<0.0001**
1–3.5	1	0.80 (0.62, 1.04)	1.02 (0.78, 1.33)	0.95 (0.72, 1.26)	0.874
>3.5	1	1.14 (0.82, 1.58)	0.91 (0.66, 1.24)	0.85 (0.61, 1.17)	0.139
Smoking status					
No	1	**0.79 (0.64, 0.99)**	0.89 (0.71, 1.11)	0.88 (0.69, 1.11)	0.431
Yes	1	0.93 (0.72, 1.20)	0.78 (0.60, 1.02)	**0.62 (0.47, 0.81)**	**<0.001**
Alcohol usage					
No	1	0.80 (0.57, 1.14)	1.19 (0.82, 1.72)	1.28 (0.83, 1.98)	0.163
Yes	1	0.84 (0.70, 1.02)	**0.77 (0.63, 0.93)**	**0.68 (0.56, 0.83)**	**<0.001**
Physical activity					
No	1	**0.77 (0.60, 0.99)**	0.92 (0.71, 1.20)	**0.74 (0.55, 1.00)**	0.125
Moderate	1	0.92 (0.68, 1.24)	0.89 (0.66, 1.20)	**0.70 (0.51, 0.97)**	**0.036**
Vigorous	1	0.83 (0.58, 1.18)	**0.67 (0.47, 0.94)**	0.77 (0.55, 1.08)	0.115
Hypertension					
No	1	**0.74 (0.57, 0.96)**	0.82 (0.64, 1.06)	**0.75 (0.58, 0.98)**	0.097
Yes	1	0.94 (0.75, 1.16)	0.84 (0.67, 1.05)	**0.74 (0.58, 0.95)**	**0.014**
Diabetes					
No	1	0.86 (0.69, 1.08)	0.81 (0.65, 1.02)	**0.69 (0.55, 0.88)**	**0.003**
Yes	1	0.83 (0.65, 1.07)	0.86 (0.67, 1.12)	0.83 (0.62, 1.10)	0.242
Hyperlipidemia					
No	1	1.00 (0.64, 1.56)	0.93 (0.59, 1.45)	0.81 (0.51, 1.28)	0.326
Yes	1	**0.82 (0.69, 0.98)**	0.84 (0.70, 1.01)	**0.75 (0.61, 0.91)**	**0.007**

Model 3 was adjusted for age, sex, ethnicity, education level, marital status, BMI level, PIR, smoking status, alcohol usage, physical activity, hypertension, diabetes, hyperlipidemia, AST, ALT, albumin, and globulin. Notably, if we performed subgroup analyses on one of the above variables, this variable would not be adjusted in model 3. The bold values mean statistical significance.

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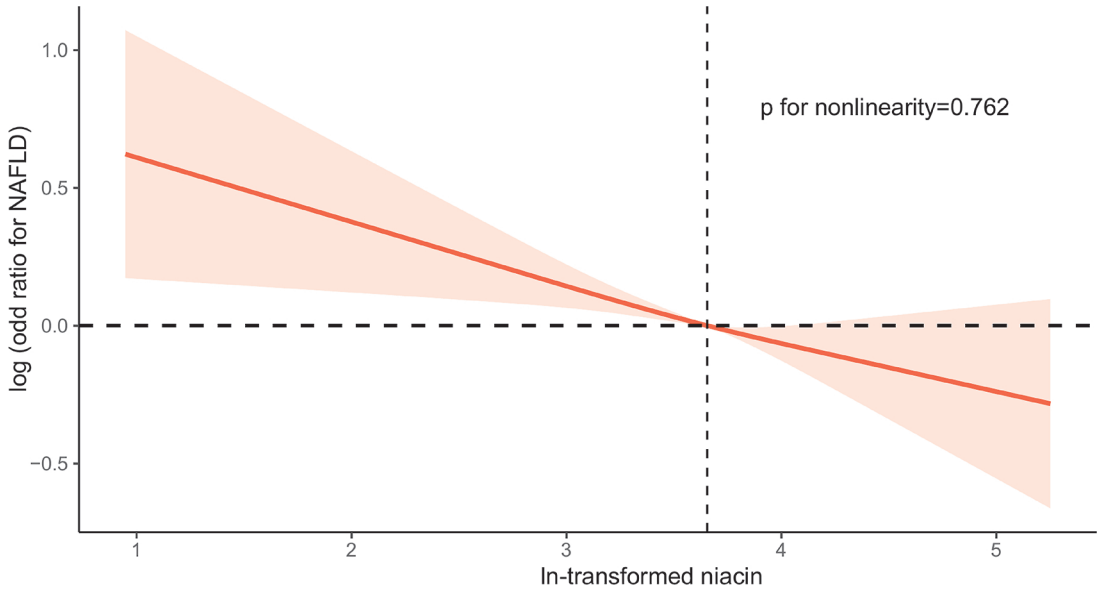

Fig. 2. The restricted cubic spline plot of the association between ln-transformed niacin and nonalcoholic fatty liver disease (NAFLD). The association was adjusted for age, sex, ethnicity, education level, marital status, BMI level, PIR, smoking status, alcohol usage, physical activity, hypertension, diabetes, hyperlipidemia, AST, ALT, albumin, and globulin.

Data Availability Statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

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Conflict of Interest

No potential conflicts of interest were disclosed.

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