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Physical activity and diet quality in relation to non-alcoholic fatty liver disease: a cross-sectional study in a representative sample of U.S. adults using NHANES 2017–2018

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Abstract

The association of physical activity (PA) and dietary factors with non-alcoholic fatty liver disease (NAFLD) and NAFLD-related fibrosis have never been examined in a representative sample of U.S. adults using a more precise form of measuring NAFLD. The purpose of this study was to assess the associations of PA and diet quality (Healthy Eating Index [HEI]-2015) with

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NAFLD and a subset with advanced fibrosis (F3-4) as assessed by vibration-controlled transient elastography with controlled attenuation parameter in a representative sample of U.S. adults. This cross-sectional analysis uses data from 2017–2018 National Health and Nutrition Examination Survey. NAFLD was defined as controlled attenuation parameter ≥285 dB/m, and high likelihood of advanced fibrosis as liver stiffness measurements ≥8.6 kPa. Associations of HEI-2015 from 24-hour dietary recalls and self-reported PA and sedentary behavior were estimated in multivariable-adjusted logistic regression models of NAFLD and advanced fibrosis. In 2,892 adults, the prevalence of NAFLD and advanced fibrosis was 35.6% and 5.6%, respectively. We found that high adherence to U.S. dietary recommendations (highest vs. lowest HEI-2015 tertile) and more PA (middle tertile vs. lowest) were associated with reduced odds of NAFLD (Adjusted OR and 95% CI; 0.60 (0.44, 0.84) and 0.65 (0.42, 0.99), respectively). More PA was inversely associated with advanced fibrosis (Adjusted OR=0.35, 95%CI 0.16, 0.75). Diet quality and PA are associated with reduced odds of NAFLD, and PA may be critical even for those with advanced liver disease. These behaviors should be the focus of targeted public health interventions.

Keywords

physical activity; sedentary behavior; Diet quality; Diet; Non-alcoholic fatty liver disease; fatty liver; fibroscan; fibrosis; advanced fibrosis; National Health and Nutrition Examination Survey

Introduction

Non-alcoholic fatty liver disease (NAFLD) is a highly prevalent liver complication closely associated with obesity,[1,2] soon to become the top reason for liver transplants in the U.S.[3] Currently, NAFLD prevalence is estimated between 34.1–56.7% among U.S. adults.[4] Metabolic dysfunction-associated liver disease (MAFLD) has recently emerged as an alternative nomenclature for this condition. MAFLD is clinically similar to NAFLD and thus they have very similar prevalence estimates in the U.S.[5]

NAFLD is a spectrum of disease ranging from simple steatosis to nonalcoholic steatohepatitis (NASH) with progressive fibrosis that can culminate in cirrhosis and its complications. Among patients with NAFLD, those with advanced liver fibrosis are at highest risk for succumbing to adverse outcomes, including cardiovascular disease,[6] chronic liver failure,[6] and hepatocellular carcinoma.[7,8] Pharmacologic treatments for NAFLD do not exist. Lifestyle modifications are recommended as the first line treatment for NAFLD.[9] This is based on data showing that physical inactivity and poor dietary habits may be associated with progressive NASH fibrosis and changes in these behaviors can lead to improvements in hepatic fat.[10,11]

Existing research on the association between physical activity and diet with NAFLD and NAFLD progression in the U.S. population has shown an association, but the studies relied on imprecise methods for case definition or did not use representative samples.[12–16] The cross-sectional association of physical activity and diet with NAFLD and a subset of those with fibrosis has been previously assessed in a representative sample of U.S. adults using liver enzymes[13,14] or ultrasound[12] to define NAFLD. However, use of liver enzymes and ultrasound data to define NAFLD may potentially result in misclassification bias:

liver enzymes are normal among a large proportion of NAFLD cases and ultrasound can miss mild steatosis[17,18] Furthermore, neither is a reliable measure of fibrosis.[19] Vibration controlled transient elastography (VCTE) with controlled attenuation, a non-invasive method for quantifying liver fat and stiffness, shows good specificity and sensitivity compared to liver biopsy,[20,21] and is a potentially more accurate measure of NAFLD than liver enzymes or ultrasound.[22,23] Additional research on lifestyle behaviors associated with NAFLD and advanced fibrosis using this more precise measurement by VCTE measured in a large, population-based in the U.S. could provide data to support clinical management recommendations for liver disease prevention.

The purpose of this study was to assess the association of physical activity, sedentary behavior and diet quality with NAFLD and a subset with advanced fibrosis as measured by VCTE with controlled attenuation, in a representative sample of U.S. adults.

Methods

Study Design and Population

We used data extracted from the 2017–2018 cycle of National Health and Nutrition Examination Survey (NHANES), a stratified, multistage probability sample representative of the civilian non-institutionalized U.S. population.[24] A total of 5,265 adults completed both the survey and medical examination (Figure 1). Of these, we included participants with valid VCTE, and excluded those with hepatitis B surface antigen positivity, hepatitis C antibody positivity, significant alcohol consumption (>21 drinks/week in men and >14 drinks/week in women on average),[9] or missing diet and/or physical activity data. The final analytic sample included 2,892 participants. Participants provided written consent. NHANES procedures were approved by the National Center for Health Statistics review board and this study was approved by the Institutional Review Board (IRB) of The University of Texas MD Anderson Cancer Center.

Data Collection and Measures

NHANES interviews use a combination of computer-assisted personal interviewing and audio computer-assisted self-interviewing surveys to elicit sociodemographic and behavioral characteristics.[24] The examination component consists of medical, dental, and physiological measurements, as well as laboratory tests administered by trained medical personnel.

NAFLD and fibrosis.—Hepatic steatosis and advanced fibrosis were assessed using FibroScan®, which uses the controlled attenuation parameter (CAP) value and VCTE with controlled attenuation to derive liver stiffness measurements (LSM), respectively.[25] Exams were considered complete if participants fasted at least 3 hours prior to the exam, there were 10 or more complete LSM, and the liver stiffness IQR/median <30%.[25] CAP values range from 100–400 dB/m, with higher values indicating higher amounts of fat in the liver. LSM range from 1.5 kPa to 75 kPa, with higher values indicating a higher probability of advanced fibrosis. We defined NAFLD as a CAP score ≥285 dB/m among the included study population; a high likelihood of advanced fibrosis (F3-4) was defined as LSM ≥ 8.6 kPa.[21]

Physical activity, sedentary behavior and diet.—The NHANES survey included the Global Physical Activity Questionnaire,[26] which assesses time spent sitting and time spent engaged in typical physical activity over the past week. Questions captured time spent doing physical activity in various domains and by intensity, including vigorous and moderate activity at work, transport activity, and vigorous and moderate activity during leisure time. We calculated metabolic equivalent of task (MET) minutes using NHANES-recommended conversions. We defined total physical activity as total MET hours per week, summed across all physical activity questions. Sedentary behavior was defined as total time spent sitting, in hours per day.

Participants completed a 24-hour recall of all food and drink consumed during the day prior to the interview (midnight to midnight), as well as a second follow-up 24-hour recall 3–10 days later. Using the United States Department of Agriculture Food Patterns Equivalents Database, we calculated the Health Eating Index (HEI)-2015.[27] When two dietary recalls were available (n=2,530, approximately 87% of our sample,), HEI-2015 scores calculated from each assessment were averaged, otherwise data from one recall was used (n=362; approximately 13% of our sample). HEI-2015 measures overall diet quality and alignment with the current Dietary Guidelines for Americans 2015–2020,[28] with higher scores indicating higher diet quality. HEI-2015 includes 13 components, assessing the adequacy of the consumption of foods recommended as part of a healthy diet, including total fruits, whole fruits, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant protein, as well the consumption of foods that should be moderated or consumed sparingly, including refined grains, sodium, and added sugars. Fatty acids are represented as a ratio of monounsaturated and polyunsaturated fatty acids to saturated fatty acids. Each component is assigned points, with the overall HEI-2015 score having a possible range of zero to 100. Higher HEI-2015 scores have been associated with lower risk of NAFLD,[15] as well as lower risk of all-cause, cardiovascular disease and cancer-related mortality.[29]

Covariates.—NHANES interviews elicit sociodemographic and behavioral characteristics, including age, sex, race/ethnicity, education, household income, smoking, and alcohol use.[24] After excluding significant alcohol consumers from the sample to remove patients at risk for alcohol-related fatty liver,[9] we created a categorical variable representing the average daily use of alcohol over the past year. Alcohol use was categorized no past year use (no alcoholic drink ever or in the past year), light to-moderate (≤2 drinks/day for men and ≤1 drink/day for women, on average during the past year) and heavy (>2 drinks/day for men and >1 drink/day for women, on average during the past year). Trained NHANES staff assessed weight, height and waist circumference. We calculated body mass index (BMI) as weight divided by height squared (kg/m^2) and categorized into underweight and normal (BMI< <25 kg/m^2), overweight (BMI 25–29.9 kg/m^2) and Class 1 obesity (BMI ≥ 30 kg/m^2), Class 2 obesity (35–39.9 kg/m^2) and Class 3 obesity (>40 kg/m^2). Metabolic syndrome was determined by the presence of three of the five Adult Treatment Panel (ATP) III criteria,[30] including abdominal obesity (waist circumference >102 cm in men and >88 cm in women); high blood pressure/hypertension (systolic blood pressure ≥ 130, diastolic blood pressure ≥ 85); high triglycerides (≥150 mg/dl), low HDL cholesterol (<40 mg/dl in men and <50 mg/dl in women); and high fasting glucose (≥110 mg/dl). Type 2 diabetes was categorized as normal (HgbA1C <5.7% and no self-reported diabetes), pre-diabetes (HgbA1C 5.7–6.4% and no self-report diabetes), and diabetes (HgbA1C ≥6.5% or self-report diabetes).

Statistical Analyses

Primary exposure variables were stratified into tertiles based on the distribution in disease-free individuals (i.e., those without NAFLD). We used Chi-Square test or Fisher's exact test for categorical variables to examine for differences between participants with and without NAFLD and advanced fibrosis. We used multivariable (MV)-adjusted logistic regression models to estimate the associations of physical activity, sedentary behavior, and dietary variables with the presence of NAFLD or advanced fibrosis, in a series of models controlling for potential confounders. We first controlled for sex, age, and race/ethnicity (Model 1). We then added covariates significantly associated ($p<0.05$) with the outcomes in univariate analyses. However, given issues of multicollinearity between metabolic syndrome, BMI and type 2 diabetes, we controlled only for metabolic syndrome, given the overlap in its definition. Thus, in Model 2 for NAFLD, we controlled for metabolic syndrome, while in Model 2 for advanced fibrosis we controlled for metabolic syndrome and smoking status. In the fully adjusted model (Model 3), we additionally controlled for total energy intake in physical activity and sedentary behavior models, and total energy intake, physical activity and alcohol use in HEI models. Lastly, we stratified by type 2 diabetes status and tested an interaction term between each behavior and type 2 diabetes. Weighted analyses were carried out using survey weights, which is fundamental to NHANES. These weights are used to account for the complex survey design, survey non-response, post-stratification, and oversampling. The NHANES methodology for weighting is applied to ensure the sample is representative of the U.S. non-institutionalized population.[31] SAS 9.4 (SAS Institute INC, Cary, NC) was used for all analyses (conducted in 2021) with a p-value of less than 0.05 indicative of statistical significance.

Results

Table 1 presents characteristics of the overall sample, as well as characteristics by NAFLD classification (absence vs. presence) and advanced NAFLD fibrosis classification (no/mild fibrosis vs. advanced fibrosis). The overall sample was n=2,892, with 1,082 (weighted %, 35.6%) classified as having NAFLD and 173 (weighted %, 5.6%) classified as having advanced fibrosis related to NAFLD. As compared to those without NAFLD, those with NAFLD has a significantly higher proportion of individuals who were 40 years of age or older (72.1% vs. 52.1%), male (55.7% vs. 47%), and Hispanic (20.3 vs. 15.7%). As expected, those with NAFLD had a higher BMI, less physical activity, and were more likely to have diabetes and metabolic syndrome than those without NAFLD. Among the subset of people with NAFLD, those with advanced fibrosis were more likely to be male, nonsmokers or former smokers, and have a higher BMI, type 2 diabetes, and metabolic syndrome than those with no or mild NAFLD fibrosis. As compared to those with NAFLD and none or mild fibrosis, those with advanced fibrosis had a significantly higher proportion of individuals with type 2 diabetes (47.5% vs 21.8%, respectively) and metabolic syndrome (64.8% vs. 45.6%, respectively).

Table 2 shows MV-adjusted associations for diet and physical activity with NAFLD and advanced fibrosis. Higher adherence to current U.S. dietary recommendations, as defined by the HEI-2015 diet quality score, was significantly associated with NAFLD. In fully adjusted models considering demographics, metabolic syndrome and other lifestyle behaviors, the highest vs lowest tertile of the HEI-2015 score was associated with 40% lower odds of NAFLD (adjusted OR=0.60, 95% CI 0.44, 0.84). We found some evidence that the association of HEI with NAFLD is modified by type 2 diabetes (Supplementary Table 1). There was no clear linear association of increased physical activity with NAFLD. As compared to participants in the lowest tertile of physical activity, participants in the middle tertile had statistically significant lower odds of NAFLD (adjusted OR=0.65, 95% CI 0.42, 0.99), while there was no association with individuals in the highest tertile (adjusted OR=0.98, 95%CI 0.66, 1.47). In the subset of the sample with NAFLD, the HEI-2015 diet quality score was not associated with advanced fibrosis, while participants in the highest tertile of physical activity had 65% lower odds of advanced fibrosis (adjusted OR=0.35, 95%CI 0.16, 0.75). No significant associations were observed for sedentary behavior.

Discussion

In this representative sample of U.S. adults, we assessed the association of physical activity, sedentary behavior, and diet quality with the presence of NAFLD and advanced fibrosis using VCTE with controlled attenuation. We found that higher diet quality scores and moderate levels of physical activity were associated with lower odds of NAFLD, while, among patients with NAFLD, physical activity was inversely associated with advanced fibrosis.

Our results indicate that higher diet quality, as represented by increased adherence to the current Dietary Guidelines for Americans (higher HEI-2015 score) was associated with lower odds of NAFLD. These findings align with a previous NHANES 1998–1994 analysis using ultrasound to define NAFLD and a prior version of the HEI.[12] Similarly, in the Multiethnic Cohort, diet quality was inversely associated with NAFLD (ascertained through Medicare claims).[15] Although it did not reach statistical significance, our findings indicate that HEI may be more strongly associated with lower odds of NAFLD in those without type 2 diabetes, although the reasons for this are unclear. We did not find an association of HEI with advanced fibrosis, in contrast to previous studies.[15] Higher diet quality does not hinge on any single component in the diet, but rather indicates a greater conformity with overall healthful eating patterns emphasizing that American's fill their plates with a variety of fiber-rich plant foods and lean protein while limiting intake of added sugars and fats from processed foods and sugar-sweetened beverages.

We found that moderate amounts of physical activity (middle tertile; between 4.67 and 60 MET hours/week) was associated with lower odds of NAFLD, though there was no protective effect among those in the highest tertile who had ≥60 MET hours/week. These findings are similar to a previous NHANES paper that used noninvasive panels to define NAFLD.[14] We also found that the highest levels of physical activity were associated with significantly lower odds of advanced fibrosis. Again, these findings align with previous NHANES findings using noninvasive panels to define fibrosis,[14] as well as findings using biopsy-ascertained fibrosis in non-representative samples.[16] Physical activity has been identified as an important method for preventing progression of NAFLD.[10] Importantly, our findings show that it may be important to promote physical activity both for those with early disease, i.e. NAFLD-only, as well as those with more advanced liver disease. We did not find an association between sedentary behavior and NAFLD. This finding is in contrast to previous NHANES work where sedentary behavior was significantly predictive of NAFLD.[14] More research is needed on the association of domain-specific physical activity with NAFLD, as well as to establish a prospective association of sedentary behavior and NAFLD.

Notably, our study is based on cross-sectional analyses, and therefore we cannot determine causality. More specifically, we cannot determine if prevalent disease impacts lifestyle behaviors, that is, if those with impaired liver function are able to do engage in sufficient physical activity and/or eat a healthy and diverse diet, or whether have already changed their behavior based on symptoms or a diagnosis. We were limited to the data available from NHANES 2017–2018, which does not currently include accelerometry-based physical activity. Therefore, physical activity was assessed with self-report, which is subject to measurement error and bias,[32] including social desirability and recall bias, though we used a well-validated measure of self-reported physical activity. Similarly, the interviewer-administered 24-hour dietary recall was the basis for our HEI calculation, a form of dietary assessment where underreporting can be an issue.[33] However, interviewer-administered 24-hour dietary recalls are considered a gold-standard method, as compared to food frequency questionnaires;[34,35] and their validity is strengthened with the use of multiple recalls and vast majority (87%) of our sample completed two recalls.[36] Measurement error for HEI-2015 scores based on 24-hour dietary recalls is generally small and use of a single recall is an acceptable estimate of mean dietary intake at the population-level.[37] Furthermore, because case-control status was unknown at the time of survey administration, any recall bias would likely be non-differential between those with and without NAFLD. While VCTE is more accurate than liver enzymes and ultrasound, there are no well-established cut-offs for LSM or CAP values. However, we relied on previous studies that compared VCTE with liver biopsy to identify acceptable cut-off values.[21] We excluded participants for this study without complete data on primary predictor and outcome variables, as well as those who may have had elevated CAP or LSM due to other clinical reasons. These exclusions may have created selection bias. We performed sensitivity analyses to assess differences between our final sample and those from the overall NHANES 2017–2018 sample that were excluded from our study. We found that our analytic sample was significantly younger (46 years of age for included vs.51 years of age in excluded sample), included a larger proportion of males (50% of the sample in included vs. 46% in excluded sample), and included a smaller proportion of non-Hispanic white participants (61% included vs. 64% excluded). While not a primary focus of this study and limited by small numbers of persons who smoke and have advanced fibrosis, we found an inverse relationship with smoking and advanced fibrosis, which has been found in prior analyses of NHANES.[38–40] While this finding is contrary to the expected relationship, future studies are needed as data from prospective studies provide strong evidence that smoking is a risk factor for NAFLD and advanced fibrosis.[41,42]"

Lastly, there may be residual confounders if there were factors associated with diet, physical activity and NAFLD that remained uncontrolled in this sample. The strengths of this study include the use of well-validated questionnaires and physiological assessments collected by trained personnel using a large cohort of participants representative of the non-institutionalized U.S. population. This is also one of the largest studies to date using VCTE to assess the association of lifestyle behaviors with NAFLD.

Conclusion

Our findings point to the important association of diet quality and physical activity with NAFLD in a representative sample of U.S. adults. Furthermore, physical activity was the only behavior associated with reduced odds for NAFLD-associated advanced fibrosis, pointing to the need to focus on this behavior as part of NAFLD treatment. These findings help identify aspects of lifestyle that need to be targeted among the general population to potentially prevent NAFLD and advanced fibrosis.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Conflict of interest statement

The authors report that they have received funding from the Prevent Cancer Foundation, National Institutes of Health, Cancer Prevention and Research Institute of Texas, and Merck.

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Highlights

- High adherence to U.S. dietary recommendations associated with reduced odds of non-alcoholic fatty liver disease (NAFLD)
- More physical activity associated with reduced odds of NAFLD
- More physical activity inversely associated with advanced fibrosis

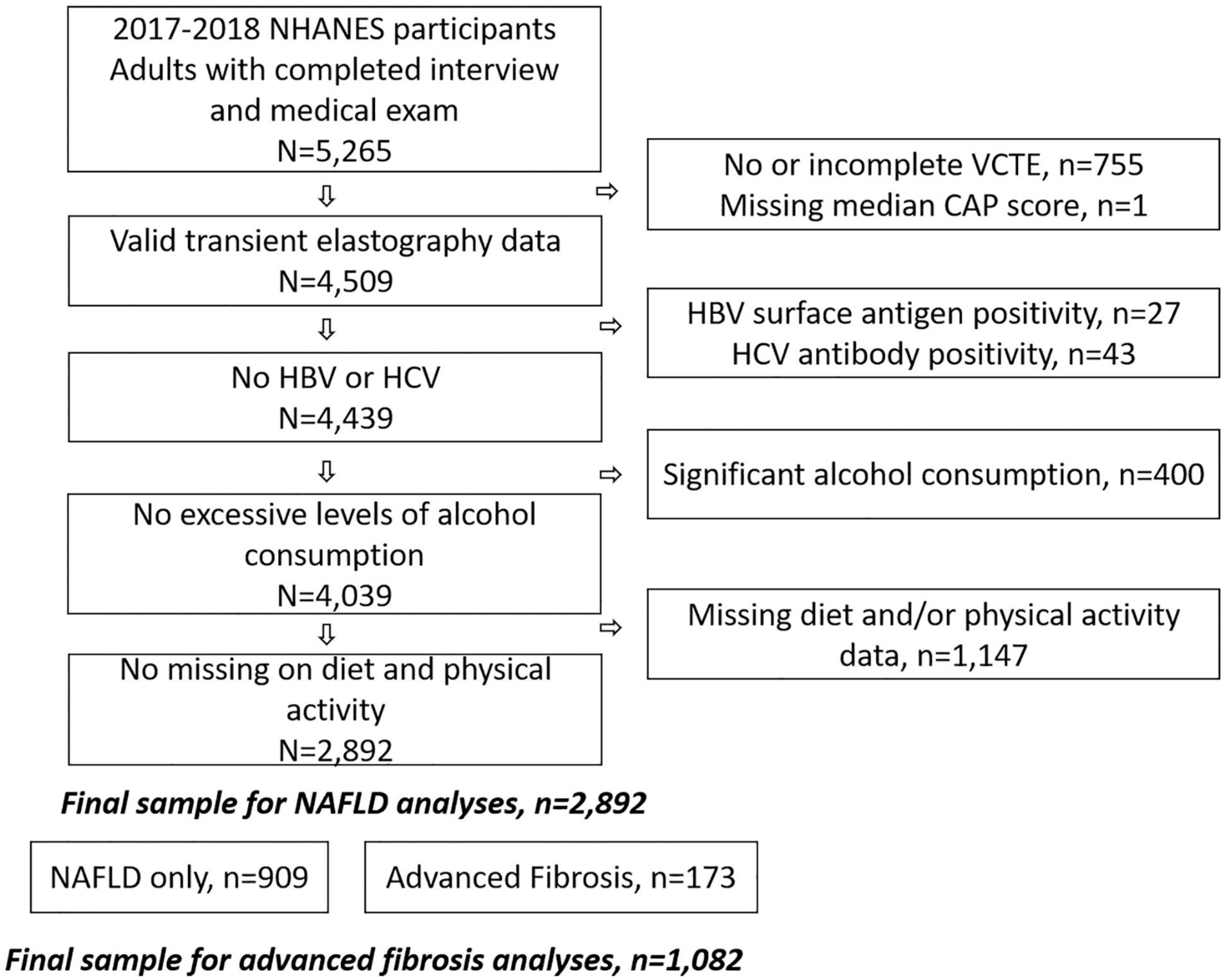

Figure 1.
Study Population

Table 1.

Characteristics for total sample, and by non-alcoholic fatty liver disease (NAFLD) and subset with advanced fibrosis

Variables	Total n=2892			NAFLD (CAP score ≥285 dB/m)							Advanced fibrosis (LSM≥ 8.6 kPa)						
				Yes n=1082			No=1810			p-value	Yes n=173			No n=909			p-value
		Weighted % ± SE			Weighted % ± SE			Weighted % ± SE				Weighted % ± SE			Weighted % ± SE		
Age																	
20–39	68	0.8	.0	48	7.9	.0	20	7.9	.3	< 0.0001	0	3.6	.4	08	6.8	.0	0.23
40–59	06	4.3	.7	89	0.1	.7	17	1.1	.8		8	9.9	.0	31	1.2	.8	
60–89	018	4.9	.6	45	2.0	.3	73	1.0	.6		5	6.5	.8	70	3.0	.4	
Sex																	
Male	444	0.1	.3	08	5.7	2.8	36	7.0	.4	< 0.001	09	6.4	.8	99	3.8	.9	0.01
Female	448	9.9	.3	74	4.3	2.8	74	3.0	.4		4	3.6	.8	10	6.2	.9	
Race/Ethnicity																	
Non-Hispanic White	59	0.9	.6	86	1.9	2.8	73	0.4	.0	< 0.0001	4	0.6	.8	22	2.1	.0	0.90
Non-Hispanic Black	88	1.9	.8	90	.3	1.5	98	3.8	.0		7	.4	.8	63	.5	.4	
Hispanic	20	7.4	.1	19	0.3	2.7	01	5.7	.9		4	2.2	.6	65	9.9	.0	
Other	25	.9	.4	87	.6	1.6	38	0.0	.6		8	.8	.8	59	.5	.6	
Education																	
<12th grade	55	1.1	.0	13	1.6	.5	42	0.8	.0	0.33	78	1.0	.6	5	4.6	.7	0.30
High school +	333	8.9	.0	66	8.4	.5	467	9.2	.0		28	9.0	.6	38	5.4	.7	
Household income																	
<$55,000	417	2.2	1.6	32	1.8	.9	85	2.4	.8	0.85	7	2.9	.3	45	1.6	.1	0.80
≥$55,000	244	7.8	1.6	63	8.2	.9	81	7.6	.8		5	7.1	.3	88	8.4	.1	
Smoking																	
Nonsmoker	724	9.6	.0	04	9.4	.3	120	9.9	.3	0.61	01	3.0	.2	03	8.7	.0	0.02
Former smoker	08	.8	.6	6	.9	.7	2	.3	.9			0.0	.1	0	.1	.5	
Current smoker	82	5.4	.7	20	4.8	.3	62	5.8	.1		3	.0	.7	07	6.2	.7	
Alcohol Use																	
No past year use	02	9.9	.0	61	5.7	.6	41	2.9	.5	0.28	0	6.7	.7	01	5.5	.9	0.52
Light-to-Moderate	078	0.6	.7	17	2.2	.0	61	9.7	.9		1	7.2	.9	46	3.1	.8	
Heavy Use	11	5.5	.7	04	2.1	.5	07	7.3	.7		2	6.0	.8	62	1.4	.3	
Body Mass Index																	

Variables	Total n=2892			NAFLD (CAP score ≥285 dB/m)							Advanced fibrosis (LSM≥ 8.6 kPa)						
				Yes n=1082			No=1810			p-value	Yes n=173			No n=909			p-value
		Weighted % ± SE			Weighted % ± SE			Weighted % ± SE				Weighted % ± SE			Weighted % ± SE		
Under weight/ Normal (<25kg/m²)	44	6.4	1.5	5	.8	0.8	79	8.9	.0	< 0.0001		.6	.8	1	.2	.9	< 0.0001
Overweight (2529.9kg/m²)	29	1.3	1.8	01	4.7	3.0	28	4.9	.9		2	.8	.0	79	7.5	.3	
Class 1 obesity (3034.9 kg/m²)	34	1.6	1.8	12	8.5	2.7	22	7.7	.8		4	5.1	.7	76	1.0	.1	
Class 2 obesity (3539.9 kg/m²)	14	1.4	1.0	03	2.1	2.0	11	.4	.9		7	0.7	.0	66	2.4	.3	
Class 3 obesity (>40 kg/m²)	55	.4	1.1	97	0.8	2.6	8	.0	.5		6	2.9	.6	21	4.9	.2	
Diabetes																	
Normal	535	6.6	.2	00	6.7	.9	135	7.5	.6	< 0.0001	0	6.0	.3	60	8.6	.9	< 0.0001
Pre-diabetes	88	0.4	.1	10	7.6	.9	78	6.4	.2		4	6.5	.7	76	9.6	.0	
Diabetes	09	3	.9	17	5.6	.3	92	.1	.7		8	7.5	.6	29	1.8	.9	
Metabolic Syndrome																	
Yes	47	6.2	.6	89	8.6	.7	58	3.6	.9	< 0.001	5	4.8	.9	94	5.6	.8	< 0.0001
No	867	3.8	.6	97	1.4	.7	370	6.4	.9		0	5.2	.9	37	4.4	.8	
Total energy intake																	
T1 (<1591 kcal)	11	0.1	.3	90	8.8	.7	21	0.8	.5	0.82	6	5.4	.6	44	9.4	.7	0.35
T2 (1591–2273 kcal)	78	4.9	.3	50	5.6	.7	28	4.5	.6		4	9.3	.3	06	6.6	.0	
T3 (≥2273 kcal)	41	5.0	.4	06	5.6	.9	35	4.6	.4		7	5.3	.1	49	4.0	.8	
Physical activity																	
T1 (<4.67 MET hours/ week)	050	0.3	.2	46	5.7	.3	04	7.3	.5	< 0.01	7	5.5	.3	79	5.8	.8	0.79
T2 (4.67 – 60 MET hours/week)	17	5.1	.7	19	4.0	.7	98	5.8	.1		3	7.9	.4	56	3.2	.2	
T3 (≥60 MET hours/ week)	25	4.5	.6 ±	17	0.3	.8	08	6.9	.5		3	6.6	.9	74	0.9	.6	
Sedentary Behavior																	
T1 (<4 hours/day)	06	6.4	.7	13	3.5	.5	93	8.1	.9	0.11	2	1.9	.6	71	3.8	.5	0.18
T2 (4–6 hours/day)	59	6.0	.3	79	5.9	.9	80	6.1	.4		4	8.7	.4	45	7.3	.8	

Variables	Total n=2892			NAFLD (CAP score ≥285 dB/m)							Advanced fibrosis (LSM≥ 8.6 kPa)						
				Yes n=1082			No=1810			p-value	Yes n=173			No n=909			p-value
		Weighted % ± SE			Weighted % ± SE			Weighted % ± SE				Weighted % ± SE			Weighted % ± SE		
T3 (≥ 6 hours/day)	227	7.5	.0	90	0.6	.1	37	5.9	.4		7	9.4	.8	93	9.0	.2	
Healthy Eating Index (HEI)																	
T1 (<45.6)	45	4.4	.4	40	8.2	.0	05	2.4	.4	0.18	7	2.6	.0	83	7.5	.1	0.78
T2 (45.6–58.5)	41	5.5	.7	00	5.3	.8	41	5.6	.9		8	1.6	.9	52	5.9	.0	
T3 (≥58.5)	44	0.1	.4	06	6.5	.4	38	2.1	.9		2	5.8	.6	64	6.6	.5	

Notes:

Abbreviations: NAFLD: non-alcoholic fatty liver disease, CAP: controlled attenuation parameter, LSM: liver stiffness measurements, SE: standard error, T: tertile, kcal: kilocalorie, MET: metabolic equivalent.

Models: Chi-Square test or Fisher’s exact test

Table 2.

Multivariate Analyses for non-alcoholic fatty liver disease (NAFLD) and subset with advanced fibrosis

Adjusted OR (95% CI)	NAFLD (CAP score ≥285 dB/m)			Advanced fibrosis (LSM≥ 8.6 kPa)		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Physical activity						
T1 (Reference)						
T2	0.67 (0.46, 0.98)	0.65 (0.42, 0.99)	0.65 (0.42, 0.99)	0.83 (0.35, 1.96)	1.08 (0.39, 3.02)	1.11 (0.41, 2.98)
T3	0.87 (0.60, 1.26)	0.98 (0.56, 1.47)	0.98 (0.66, 1.47)	0.54 (0.31, 0.95)	0.36 (0.18, 0.72)	0.35 (0.16, 0.75)
Sedentary behavior						
T1 (Reference)						
T2	0.95 (0.65, 1.39)	0.98 (0.65, 1.49)	0.99 (0.65, 1.50)	0.72 (0.29, 1.79)	0.68 (0.26, 1.82)	0.57 (0.24, 1.39)
T3	1.19 (0.87, 1.63)	1.15 (0.81, 1.64)	1.16 (0.82, 1.64)	1.38 (0.57, 3.36)	1.23 (0.53, 2.84)	1.03 (0.47, 2.21)
Health Eating Index (HEI)						
T1 (Reference)						
T2	0.80 (0.49, 1.30)	0.75 (0.50, 1.15)	0.75 (0.50, 1.13)	0.81 (0.29, 2.28)	0.62 (0.20, 1.91)	0.69 (0.20, 2.34)
T3	0.57 (0.40, 0.82)	0.61 (0.43, 0.85)	0.60 (0.44, 0.84)	0.96 (0.37, 2.47)	0.84 (0.28, 2.49)	0.91 (0.29, 2.82)

Notes:

Abbreviations: NAFLD: non-alcoholic fatty liver disease, CAP: controlled attenuation parameter, LSM: liver stiffness measurements, CI: confidence interval, T: tertile

Models: Multivariable-adjusted logistic regression

Model 1: Adjusted for age, sex, race/ethnicity

Model 2 for NAFLD: Model 1 + Metabolic Syndrome

Model 2 for advanced fibrosis: Model 1 + Metabolic Syndrome + smoking

Model 3 for Physical Activity and Sedentary Behavior: Model 2 + total energy

Model 3 for HEI: Model 2 + total energy, physical activity, alcohol use