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Food Insecurity is associated with chronic liver disease among US adults

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Abstract

Background: Food insecurity is associated with many poor health outcomes. Most contemporary liver disease is metabolic and impacted by nutritional status. Data regarding the association between food insecurity and chronic liver disease are limited. We evaluated the linkage between food insecurity and liver stiffness measurements (LSM), a key measure of liver health.

Methods: A Cross-sectional analysis of 3,502 subjects aged ≥20 years from the 2017–2018 National Health and Nutrition Examination Survey. Food security was measured using the US Department of Agriculture's Core Food Security Module. Models were adjusted using age, sex, race/ethnicity, education, poverty-income ratio, smoking, physical activity, alcohol intake, sugary beverage intake, Healthy Eating Inex-2015 score. All subjects underwent vibration controlled transient elastography which provides liver stiffness measurements (LSM, kPa) and a measure of hepatic steatosis (controlled attenuation parameter, CAP, dB/m). LSM was stratified: <7, 7–9.49, 9.5–12.49 (advanced fibrosis) and ≥12.5 (cirrhosis) in the whole study population and stratified by age (20–49 years and ≥50 years)

Results: There were no significant differences in mean CAP, ALT, or AST values by food security status. However, food insecurity was associated with a higher mean LSM (6.89±0.40 kPa vs 5.77±0.14 kPa, p=0.02) for adults ≥50 years. After multivariate adjustment, food insecurity was associated with higher LSM across all risk stratifications for adults ≥50 years: LSM≥7 kPa (OR 2.06, 95% CI(1.06–4.02)); LSM≥9.5 kPa (OR 2.50, 95% CI (1.11–5.64)); LSM≥12.5 kPa (OR 3.07, 95% CI (1.21–7.80)).

Conclusion: Food insecurity is associated with liver fibrosis and an increased risk of advanced fibrosis and cirrhosis in older adults.

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Keywords

NAFLD; cirrhosis; obesity; malnutrition

Introduction

Chronic liver disease (CLD) is a major threat to our public health. Roughly 60,000 people die from CLD annually.[1] CLD accounts for >1 million outpatient visits and CLD-related hospitalizations have risen every year, overtaking hospitalization-rates for heart failure and lung disease.[2,3] Annual CLD healthcare costs exceed $29.9 billion.[4] Increasingly, the most common etiology of CLD is nonalcoholic fatty liver disease (NAFLD) which, in turn, most closely associates with obesity, insulin resistance, and, above all, malnutrition. Optimal nutrition is the cornerstone of NAFLD management. Our approach to nutritional interventions for NAFLD, however, requires additional data to elucidate the specific needs of afflicted persons and their capacity to execute nutritional guidance.

A healthy diet presupposes accessibility and affordability of foods consistent with evidence-based diet patterns. Unfortunately, food insecurity is common, impacting 10.5% of households prior to the COVID-19 pandemic.[5,6] Food insecurity, a lack of consistent access to sufficient food for an active life, is associated with obesity, diabetes, and cardiovascular disease.[7,8] A recent study showed that food insecurity is also associated with NAFLD risk factors and an elevated NAFLD risk score, an indirect noninvasive assessment of liver fibrosis.[9] Data are limited, however, regarding the association of food insecurity with both liver steatosis and specific measures of liver fibrosis such as transient elastography.

In the 2017–2018 National Health and Nutrition Examination Survey (NHANES), vibration controlled transient elastography (VCTE) was added to the NHANES examination study procedures for the first time to better understand population-level distributions and predictors of hepatic steatosis and hepatic fibrosis. Using this data, we examine the primary associations between food insecurity and liver stiffness in a large, nationally representative cohort of adults.

Methods

Study population

NHANES is a nationally representative cross-sectional study conducted continuously since 1999 by the National Center for Health Statistics (NCHS) at the Centers for Disease Control and Prevention. NHANES enrolls participants using a stratified multistage probability with an oversampling design of certain age and racial/ethnic groups to allow weighted analysis to infer the epidemiology of the civilian non-institutionalized US population.[10] All participants are interviewed for demographic, socioeconomic, dietary, and health information, and physical examinations and laboratory tests are conducted on most study participants. The analytic sample was comprised of 3,502 adults, aged 20 years and older with non-missing data on household food security, LSM measurements, and sociodemographic characteristics.

A flowchart for the inclusion of subjects is provided in Supplementary Figure 1. This study was exempt from IRB review.

Outcomes: Elastographic Measures

During the 2017–2018 survey, NHANES performed VCTE of the liver via FibroScan® on all subjects aged 12 years and over. Details of the procedures are described elsewhere. Only individuals with a “complete” elastography exam, as determined by NCHS staff, were included in the present study. Excluded participants included those who were unable to lie down on the exam table, were pregnant, had an implanted electronic medical device, wore a bandage, had lesions on the right flank where FibroScan measurements were to be made, fasted for <3 hours, unable to provide 10 valid measures, or had IQR/M >30%.

FibroScan® captured liver stiffness measurement (LSM) to estimate liver fibrosis and controlled attenuation parameter (CAP) for hepatic steatosis. In the present study, we analyzed LSM and CAP both continuously. For LSM, we also evaluated the risk of LSM ≥7 kPa to classify the population who was not low-risk for advanced fibrosis,[11] LSM ≥9.5 kPa to classify the population who was at higher risk for advanced fibrosis,[11] and LSM ≥12.5 kPa to classify those at risk for cirrhosis. In addition to LSM and CAP, we also examined alanine aminotransferase (ALT) and aspartate aminotransferase (AST) extracted from the standard biochemistry profile.

Food security status

Household food security was assessed using the US Department of Agriculture’s (USDA) Core Food Security Module. This module assesses experiences or behaviors related to insufficient resources to purchase food over the past 12 months. A score ranging from 0–18 was created by summing the affirmative responses, with a higher score denoting greater food insecurity.[9] According to USDA guidelines, the score was categorized into full food security (0), marginal food security (1, 2), low food security (3–7), and very low food security (8–18). Modified cutpoints are used for households without children. Food insecurity was defined as both low and very low food security groups.[12] The items in the module for adults are provided in Supplementary Table 1, each focusing on hunger, food rationing, ability to buy food (and balanced meals), and weight loss for inability to buy food.

Covariates

Sociodemographic characteristics of interest included age, sex, race/ethnicity, education level, and poverty income ratio. Poverty income ratio was calculated by dividing each family’s total annual income by its corresponding poverty threshold. Health characteristics of interest included comorbidities, smoking status, physical activity, and alcohol intake frequency. We also included a measure of overall diet quality and intake of sugar-sweetened beverages (SSBs).

Dietary intake data were derived from the mean of two 24-hour dietary recalls per participant. Diet quality was measured by the Healthy Eating Index (HEI-2015), a tool developed by the USDA to measure compliance with national dietary guidelines.[13] The HEI-2015, scored with a maximum of 100 is a composite of 12 scores denoting favorable intake of total vegetables, total fruit, whole fruit, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, fatty acids, refined grains, sodium, and empty calories (solid fats, alcohol, and added sugars). SSBs were converted to 8-ounce servings and included sweetened soft drinks, sweetened fruit drinks, sweetened coffee and tea drinks, sport and energy drinks, and sweetened bottled water. All dietary covariates were estimated per day and then averaged across the 2 days.

We also examined the presence of any of the following chronic medical conditions: diabetes, heart failure, coronary heart disease, angina, myocardial infarction, stroke, emphysema, thyroid conditions, liver conditions, and cancer. A missing indicator was used to handle missing data for alcohol consumption (n=154).[14]

Statistical analysis

All statistical analyses were performed using SAS, version 9.4. NHANES mobile examination center (MEC) and dietary two-day sampling weights were used for analyses to account for differential selection probabilities, nonresponse, and to make nationally representative estimates. Bivariate comparisons were conducted using chi-squared tests for categorical variables and univariate linear regression for continuous variables. Univariate linear regression was used to examine mean differences in ALT, AST, CAP and LSM by food security groups. Next, multivariate logistic regression was used to examine associations between food insecurity and LSM categories. Three models were fit for each outcome: model 1 adjusted for age and sex; model 2 additionally adjusted for race/ethnicity, education, and poverty income ratio; and model 3 additionally adjusted for smoking status, vigorous physical activity, moderate physical activity, alcohol intake, sugar-sweetened beverage intake, and HEI-2015 score. In addition, a sensitivity analysis was conducted by including the presence of any chronic medical condition in the fully adjusted multivariate model.

Results

Descriptive characteristics

As detailed in Table 1, we included a total sample of 3,502 adults ≥20 years. Overall, participants were aged an average of 46.8 ± 0.8 years, 51% were female, 64.2% identified as Non-Hispanic White, 31.8% had a college degree or more years of education, and 52.9% had an average family income at or above 300% of the federal poverty level. Few (200) subjects had known chronic liver disease – 45 with hepatitis B and 15 with hepatitis C. Of the total participants, 23.8% were food-insecure. Compared to food-secure adults, food-insecure adults were younger in age, more likely to identify as non-White, have fewer years of education, have lower household incomes, be a current smoker, engage in less vigorous and moderate physical activity, report lower alcohol intake, consume more sugar-sweetened beverages and have a lower HEI-2015 score (Ps<0.05).

Bivariate associations between food insecurity and liver enzymes and steatosis

We first assessed the bivariate relationships between food insecurity with markers of liver inflammation and steatosis (Table 2). There was no significant association between food insecurity and the hepatic inflammatory markers (ALT, AST) and hepatosteatosis (CAP). When stratifying the sample by age, food insecurity was associated with higher LSM, for adults ≥50 years, with a mean of 6.89±0.40 kPa vs 5.77±0.14k Pa, p=0.02. However, there were no bivariate associations between food insecurity and markers of liver inflammation and steatosis among younger adults.

Multivariate-adjusted associations between food insecurity and liver stiffness

In Table 3 we examined the relationship between food insecurity and liver stiffness in the overall analytic population and stratified by age group. In the overall population, food insecurity was associated with LSM≥7 kPa (OR 1.41, 95% CI (1.07 – 1.86)) and LSM≥12.5 kPa (OR 2.14, 95%CI (1.08 – 4.25)) when adjusting for age and sex but not after adjusting for other sociodemographic factors. These associations were significantly modified by age (P-interaction=0.03 for LSM≥7 kPa, P-interaction=0.04 for LSM≥9.5 kPa, P-interaction=0.08 for LSM ≥12.5 kPA). In adults ages 20–49, there was no significant associations between food insecurity and any of the stratified LSM categories. In contrast, among adults aged ≥50 years, food insecurity was significantly associated with all stratified liver stiffness levels: 7–9.49 kPa (OR 2.06, 95%CI (1.06 – 4.02)); 9.5–12.49 kPa (OR 2.50, 95%CI (1.11 – 5.64)); ≥12.5 kPa (OR 3.07, 95%CI (1.21 – 7.80)), after adjusting for sociodemographic factors.

To account for the effect of potential comorbidities, we further evaluated the associations between liver stiffness and food insecurity while additionally adjusting for the presence of any chronic medical condition (Supplementary Table 2). Associations remained significant among adults aged ≥50 years for all stratified LSM categories: 7–9.49 kPa (OR 2.05, 95%CI (1.03 – 4.11)); 9.5–12.49 kPa (OR 2.55, 95%CI (1.12 – 5.80)); ≥12.5 kPa (OR 3.09, 95%CI (1.23 – 7.78)). Similarly, associations for the younger age adults remained non-significant.

Discussion

Liver disease is a large and growing public health problem. After identifying liver disease, to prevent progression to cirrhosis and its complications, first-line therapy is dietary modification. Common recommendations include the Mediterranean Diet and eliminating excess carbohydrates in favor of whole foods.[15] Our data highlights a major barrier to the effectiveness of interventions to improve liver health at the population level. Patients with prevalent liver disease may be food insecure and as such interventions based solely on dietary education may be insufficient to forestall the growth of liver disease's population burden.

Food Insecurity and Liver Disease

In this study utilizing nationally representative data from NHANES, we show that food insecurity is associated with liver stiffness, including at levels suggestive of cirrhosis, for persons aged ≥50 years old. The mechanisms for this finding are likely multifold including unhealthy dietary choices, micronutrient deficiency, proinflammatory diet, and associated behavioral patterns including increased alcohol consumption. First, food insecurity is associated with inadequate dietary intake. A previous study in NHANES has found inverse associations between food insecurity and healthful diet patterns.[5] Food insecurity is associated with higher consumption of carbohydrates, prioritization of fast food for lack of time, and higher BMI.[16,17] In addition, there is evidence suggesting that food insecurity is associated with increased alcohol consumption and binge drinking as well as smoking across the lifespan.[18,19] Compared to food-secure persons, food-insecure individuals may also be associated with reduced intake a critical micronutrients such as vitamins A, B-6, and E, niacin, riboflavin, calcium, magnesium, and zinc.[20,21] Second, food insecurity has also been associated with gut dysbiosis favoring the predominance of pro-inflammatory bacterial species,[22,23] and fibrotic liver disease, in turn, is associated with dysbiosis.[24] Our data extends prior findings by Tamargo et al where food insecurity was associated with liver stiffness using magnetic resonance elastography in a cohort of 600 subjects from one region, most of whom where living with HIV or hepatitis C.[25] In contrast, however, our study utilized a nationally representative sample of adults, markedly increasing the generalizability of the association between food insecurity and liver stiffness.

Although the associations between food security and liver stiffness were less consistent after adjusting for potential confounders among younger subjects, it is unclear if these data apply exclusively to those aged ≥50 years. Instead, it may be likely that one's cumulative exposure to food insecurity in younger years results in a higher risk of advanced liver disease in middle-age. Kardashian recently showed that food insecurity was associated with a high risk of death for patients with likely NAFLD and advanced fibrosis.[26] In sum, these data highlight an association between food insecurity and liver disease that should spur further evaluation into the linkage of diet quality and liver disease.

Food insecurity is not associated with steatosis or hepatic inflammation

Our data demonstrate no difference in CAP, ALT, or AST by food security status. These data confirm and extend the findings from Tamargo et al who also found no association between food security and steatosis defined by MRI proton density fat fraction.[25] Two potential reasons underlie the reproducibly differential associations where food insecurity is linked with fibrosis but not steatosis or inflammation. First, it is important to recognize that many of the factors included as covariates for adjustment in our models are associated with liver fat accumulation. These include sugary beverages and alcohol.[15,27] There is evidence, however, that food insecurity is associated with increased sugar consumption in the first instance.[5] Second, in addition to adverse changes in gut microbiota,[22,23] food insecurity may be associated with a pro-inflammatory diet,[28] increased circulating inflammatory cytokines,[29] and micronutrient deficiencies[20,21] that could uniquely compound fibrogenesis. Future mechanistic data may be necessary to elucidate the pathophysiology of these observations.

Contextual factors

These data must be understood in the context of the study design. First, elevated LSM is not always caused by advanced liver fibrosis. Biopsy data, though often unreliable, is not available in NHANES.[30] Second, missing data in NHANES impacts the accuracy of the population size estimate, although the proportion among LSM strata is impacted to a lesser extent. Third, those with failed VCTE exams (including high IQR/m) were not captured in the study and could represent a significant at-risk group. Fourth, the conclusions here are extrapolated from 3,502 subjects using sampling weights in only one cycle of NHANES and the accuracy of the population estimate will benefit from a continuation of VCTE inclusion in future NHANES waves. Fifth, as a cross-sectional study, causality cannot be inferred as prior food security is unknown. However, present food security remains critical to the management of CLD. Finally, although our model adjusts for confounders such as poverty income ratio, smoking, physical activity, alcohol intake, sugary beverage intake, and HEI-2015 score, there may be unmeasured confounders such as remote alcohol intake or prior behaviors or health status measures such as body mass index.

Implications

Given that patients with prevalent liver disease may be food insecure, educational interventions to improve diet may lack effectiveness should we not also address food security. Patients with liver disease and food insecurity would benefit from social work consultation to initiate US Supplement Nutrition and Assistance Program (SNAP).[31] As argued in a white paper from the National Committee for Quality Assurance (NCQA),[32] dietary advice for patients with liver disease must be sensitive to their specific needs and that requires first assessing their ability to pay for or access the foods recommended.

Conclusion

Interventions to address food insecurity may be needed to address the burden of chronic liver disease. These data demonstrate that food insecurity is strongly associated with chronic liver disease for persons older than 50. In order to understand the sources of and how to mitigate the public health burden of chronic liver disease, additional research is needed to address the role of food insecurity and how to overcome this barrier to promote optimal liver health.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1:

Cohort Demographics and Characteristics

Characteristic		Overall	Food Secure	Food Insecure	p-value
n		3502	2668	834	
Age, mean (SE)		46.8 (0.8)	47.7 (0.8)	43.1 (0.9)	0.0002
Female		1794 (51.0)	1357 (50.4)	437 (53.5)	0.07
Weight (kg)		84.3 (0.7)	84.2 (0.8)	84.7 (1.4)	*0.75*
BMI (kg/m2)		29.6 (0.3)	29.5 (0.3)	30.2 (0.5)	*0.19*
Race	White	1198 (64.2)	929 (67.1)	269 (51.0)	<0.0001
	Black	773 (10.2)	577 (9.4)	196 (13.5)	<0.0001
	Hispanic	814 (15.1)	550 (12.9)	264 (25.1)	<0.0001
	Other	717 (10.5)	612 (10.5)	105 (10.4)	<0.0001
Education	< High school	621 (9.9)	377 (7.4)	244 (20.9)	<0.0001
	High school	820 (26.7)	580 (24.2)	240 (37.6)	<0.0001
	Some college	1178 (31.7)	894 (31.1)	284 (34.1)	<0.0001
	≥ College	883 (31.8)	817 (37.2)	66 (7.4)	<0.0001
Poverty income ratio (%Federal Poverty Level)	<100%	647 (12.2)	332 (7.2)	315 (34.4)	<0.0001
	100-<200%	952 (19.8)	625(16.1)	327 (36.2)	<0.0001
	200-<300%	562 (15.1)	448 (14.9)	114 (16.0)	<0.0001
	300-<400%	406 (13.9)	362 (15.3)	44 (8.0)	<0.0001
	≥400%	935 (39.0)	901 (46.5)	34 (5.4)	<0.0001
Smoking	Never	2039 (58.2)	1624 (61.3)	415 (44.5)	<0.0001
	Former	815 (24.5)	635 (25.3)	180 (20.7)	<0.0001
	Current	648 (17.3)	409 (13.4)	239 (34.9)	<0.0001
Vigorous activity	Yes	889 (30.0)	745 (32.7)	144 (18.2)	<0.0001
Moderate activity	Yes	1497 (49.1)	1219 (51.5)	278 (37.9)	<0.0001
Alcohol intake frequency	Non-drinker/none in last year	944 (21.3)	667 (19.6)	277 (28.6)	0.0008
	< once a week	1522 (44.8)	1185 (45.4)	337 (42.1)	0.0008
	≥ once a week	882 (30.8)	695 (31.8)	187 (26.2)	0.0008
	Missing	154 (3.2)	121 (3.3)	33 (3.0)	0.0008
Sugar-sweetened beverage intake	0 servings	1270 (44.9)	1028 (47.5)	242 (33.4)	0.0008
	>0–1 serving	538 (18.3)	403 (17.4)	135 (22.2)	0.0008
	>1–2 servings	469 (16.6)	354 (16.5)	115 (17.2)	0.0008
	>2 servings	618 (20.2)	416 (18.6)	202 (27.2)	0.0008
Healthy Eating Index, mean (SE)		52.4 (0.8)	52.9 (0.7)	49.8 (1.5)	0.02
Chronic Medical Conditions	Any	1224 (31.6)	900 (31.2)	324 (33.3)	0.46
	Diabetes	508 (10.2)	368 (10.1)	140 (11.0)	0.59
	Heart Failure	82 (1.5)	52 (1.3)	30 (2.6)	0.02
	Coronary Heart Disease	114 (3.1)	80 (3.1)	34 (2.9)	0.86
	Angina	72 (1.9)	43 (1.8)	29 (2.5)	0.38

Characteristic		Overall	Food Secure	Food Insecure	p-value
	Myocardial Infarction	135 (2.8)	81 (2.5)	54 (3.8)	0.06
	Stroke	137 (2.4)	87 (1.9)	50 (4.5)	0.0003
	Emphysema	48 (1.0)	26 (0.9)	22 (1.7)	0.03
	Thyroid Conditions	379 (11.4)	290 (11.3)	89 (11.6)	0.84
	Known chronic liver disease	200 (5.1)	134 (4.6)	66 (7.2)	0.15
	Cancer	284 (8.6)	222 (9.0)	62 (7.0)	0.18
Liver stiffness (median Kilopascals)	**<7**	2939 (85.8)	2256 (86.3)	683 (83.3)	0.09
	7–9.49	327 (8.6)	238 (8.4)	89 (9.4)	
	9.5–12.49	123 (2.4)	94 (2.5)	29 (2.3)	
	≥12.5	113 (3.2)	80 (2.8)	33 (5.1)	

Table 2:

Bivariate Comparison associations with Food Security

		Food secure		Food insecure		
		Mean	**SE**	**Mean**	**SE**	**p-value**
Overall (n=3502)	**LSM** [1]	5.62	0.13	5.87	0.2	0.26
	CAP[2]	263.63	1.80	265.65	3.93	0.62
	ALT[3]	23.54	0.45	24.65	1.78	0.58
	AST[4]	22.51	0.33	22.58	1.13	0.95
Ages 20–49 (n=1763)	**LSM** [1]	5.49	0.23	5.29	0.15	0.55
	CAP[2]	253.38	2.55	259.06	4.68	0.32
	ALT[3]	24.37	0.65	24.43	1.79	0.98
	AST[4]	22.63	0.45	21.31	0.91	0.27
Ages ≥50 (n=1739)	**LSM** [1]	5.77	0.14	6.89	0.40	**0.02**
	CAP[2]	275.82	2.39	277.17	6.04	0.84
	ALT[3]	22.56	0.34	25.03	3.60	0.49
	AST[4]	22.37	0.33	24.82	2.86	0.40

[1] LSM: liver stiffness measurement

[2] CAP: controlled attenuation parameter

[3] ALT: alanine aminotransferase

[4] AST: aspartate aminotransferase

Bolded p-values denote statistical significances

Table 3:

Associations between Liver Stiffness and Food Insecurity*

	Overall (n=3502)		Ages 20–49 (n=1763)		Ages ≥50 (n=1739)	
	OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
LSM ≥7 kPa[1]						
Model 1	**1.41**	**1.07, 1.86**	1.12	0.66, 1.89	**1.80**	**1.28, 2.53**
Model 2	1.21	0.85, 1.71	1.00	0.60, 1.68	1.48	0.96, 2.29
Model 3	1.39	0.89, 2.15	0.97	0.54, 1.72	**2.06**	**1.06, 4.02**
LSM ≥9.5 kPa[1]						
Model 1	1.64	0.93, 2.88	0.94	0.31, 2.86	**2.45**	**1.52, 3.95**
Model 2	1.31	0.69, 2.52	0.90	0.29, 2.75	1.59	0.82, 3.08
Model 3	1.90	0.99, 3.63	0.95	0.28, 3.23	**2.50**	**1.11, 5.64**
LSM ≥12.5 kPa[1]						
Model 1	**2.14**	**1.08, 4.25**	1.00	0.19, 5.25	**3.26**	**1.59, 6.67**
Model 2	1.62	0.69, 3.83	0.82	0.15, 4.42	**2.15**	**1.00, 4.62**
Model 3	2.35	0.99, 5.60	0.76	0.14, 4.06	**3.07**	**1.21, 7.80**

*Food Secure used as reference for all models. Bolded values denote statistical significances

[1]LSM: liver stiffness measurement

Model 1 adjusted for age and sex

Model 2 adjusted for age, sex, race/ethnicity, education, poverty income ratio

Model 3 adjusted for age, sex, race/ethnicity, education, poverty income ratio, smoking status, vigorous physical activity, moderate physical activity, alcohol intake, sugary beverage intake, HEI-2015 score