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Household Food Security Status and Allostatic Load Among US Adults: National Health and Nutrition Examination Survey 2015–2020

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Abstract

Background: Household food insecurity has been linked to adverse health outcomes, but pathways driving these associations are not well understood. The stress experienced by those in food insecure households and having to prioritize between food and other essential needs could lead to physiological dysregulations (i.e., allostatic load [AL]) and, as a result, adversely impact their health.

Objective: To assess the association between household food security status and AL and differences by gender, race and ethnicity, and Supplemental Nutrition Assistance Program (SNAP) participation.

Methods: We used data from 7640 US adults in the 2015–2016 and 2017–March 2020 National Health and Nutrition Examination Survey to estimate means and prevalence ratios (PR) for AL scores (based on cardiovascular, metabolic, and immune biomarkers) associated with self-reported household food security status from multivariable linear and logistic regression models.

Results: Adults in marginally food secure (mean = 3.09, SE = 0.10) and food insecure households (mean = 3.05, SE = 0.08) had higher mean AL than those in food secure households (mean = 2.70, SE = 0.05). Compared to adults in food secure households in the same category, those more likely to have an elevated AL included: SNAP participants (PR = 1.12; 95% confidence interval, CI = 1.03, 1.22) and Hispanic women (PR = 1.20; 95% CI = 1.05, 1.37) in marginally food secure households; and non-Hispanic Black women (PR = 1.14; 95% CI = 1.03, 1.26), men (PR =

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Conflicts of Interest
The authors declare no competing interests.

1.13; 95% CI = 1.02, 1.26), and non-SNAP non-Hispanic White adults (PR = 1.22; 95% CI = 1.08, 1.39) in food insecure households.

Conclusions: AL may be one pathway by which household food insecurity affects health and may vary by gender, race and ethnicity, and SNAP participation.

Keywords

food insecurity; allostatic load; race and ethnicity; gender; supplemental nutrition assistance program

Background

Household food insecurity, defined by the US Department of Agriculture as "a household-level economic and social condition of limited or uncertain access to adequate food," remains a national public health issue (1). In 2021, approximately 10.2% of, or 13.5 million, US households were food insecure (2). There are racial and ethnic disparities in the prevalence of household food insecurity, with 19.8% of non-Hispanic Black (NHB) and 16.2% of Hispanic households reporting household food insecurity compared to 7.0% of non-Hispanic White (NHW) households (2). Numerous studies have linked household food insecurity to poor health outcomes such as type 2 diabetes, dyslipidemia, and obesity (3–6). The pathways driving the association between household food insecurity and adverse health outcomes are not well understood.

Emerging literature suggests that allostatic load (AL) may be a physiologic pathway by which household food insecurity affects health. AL refers to cumulative physiologic wear and tear on the body due to repeated exposure and response to stress (7). Chronic stress exposure results in excess secretion of hormones that result in physiologic dysregulation, hindering the body's ability to maintain homeostasis (7). AL is generally operationalized with a summary score of high-risk biomarkers related to cardiovascular health, metabolic functioning, and immune response (8). The stress of being food insecure and making trade-offs between food and other necessities may result in these physiologic dysregulations and, consequently, worse health (9). Prior studies have found that household food insecurity was associated with greater AL among US adults, but few studies have investigated whether this association varies by gender, race and ethnicity, and Supplemental Nutrition Assistance Program (SNAP) participation (10, 11).

Racial and ethnic minority groups may experience greater social disadvantage due to historic and current discriminatory policies and practices restricting their access to health-promoting resources that buffer against the impact of household food insecurity (12). This may result in greater AL. Additionally, a prior nationally representative study found that household food insecurity was associated with lower diet quality among NHW adults but not among NHB or Hispanic adults (13), which offers another explanation that the relationship between household food insecurity and AL may vary by race and ethnicity as poor diet is related to various adverse metabolic outcomes (14). Better understanding of whether the relationship between household food insecurity and AL differs by race and ethnicity may clarify the contribution of food insecurity to racial and ethnic disparities in health.

Furthermore, research suggests that the relationship between household food insecurity and AL load may differ by gender. A nationally representative study found that women experiencing household food insecurity had elevated AL, but this association was not found among men (15). Women may be more likely to experience and be impacted by household food insecurity than men (16, 17). For example, women in food insecure households may allocate more nutritious foods to others before themselves, and therefore consume less healthy foods. Previous studies have reported that women who experience household food insecurity have lower intake of some food groups (e.g., fruits and vegetables) and nutrients (e.g., proteins and vitamin C) and are at greater risk for overweight and obesity compared to men (18, 19).

Moreover, the association between household food insecurity and AL may also vary by SNAP participation. A study among Puerto Rican adults aged 45–75 years living in the Greater Boston area revealed that household food insecurity was associated with dysregulation of the inflammatory and neuroendocrine systems and was stronger for SNAP nonparticipants (10). Additionally, research conducted among adults aged 50 years or older from the Health and Retirement Study found a reduction in AL among those in moderate and severe food insecure households who were enrolled in SNAP (11). SNAP participation may play a protective role as it may help to reduce household food insecurity and psychological distress (20, 21).

The purpose of this study is to examine the association between household food security status and AL, and to determine if this association varies by race and ethnicity, gender, and SNAP participation among US adults. Since the operationalization of AL has varied across studies, we included a range of biomarkers used in prior studies relating to cardiovascular, immune, and metabolic systems (8).

Methods

Data Source

We used data from the 2015–2016 (51.0% interview response rate) and 2017–March 2020 pre–COVID-19 pandemic (46.9% interview response rate cycles of the National Health and Nutrition Examination Survey (NHANES). NHANES is a nationally representative sample of the noninstitutionalized civilian US population and collects information on various demographic and health indicators via interviews, examinations, and laboratory testing. In-depth details of the study design and procedures have been previously published elsewhere (22, 23). The population was restricted to 10 ,122 adults (≥ 18 years of age) with a household income of ≤ 400% of the federal poverty level—to reduce confounding by socioeconomic status (SES), and because food insecurity was sparse among those with a household income > 400% (excluded n=3,406). Since many of the indicators used to measure AL—body mass index, hemoglobin A1C (HbA1c), blood pressure, and high-density lipoprotein (HDL) cholesterol—tend to change during pregnancy, pregnant women were excluded (n = 112) (24–27). We also excluded those with missing information on household food security (n = 1), SNAP participation (n = 53), and AL biomarkers (n = 2351). The final analytic sample included 7640 participants. Compared to those in the sample, those excluded due to missing data were more likely to be: age ≥ 75 years, women, NHW people; those with < 12 years of education, public health insurance, a household poverty-to-income ratio of ≤ 130%; and those less likely to have none/minimal for their depression score, less likely to be a smoker, and more likely to be taking prescription medication for diabetes, hypertension, or cholesterol. NHANES is approved by the Research Ethics Review Board of the National Center for Health Statistics, and written consent was obtained from all participants.

Household Food Security

Household food security in the previous 12 months was measured with the Household Food Security Scale, consisting of 18 and 10 items for households with and without children, respectively (28). The scale assessed how frequently people went without food or had to consume less food, not by choice, with greater number of affirmative answers representing greater food insecurity. Based on participants' responses, food insecurity is classified as full food security (no affirmative responses), marginal food security (1–2 affirmative responses), low food security (3–7 and 3–5 affirmative responses for households with and without children, respectively), and very low food security (8–18 and 6–10 affirmative responses for households with and without children, respectively) (29). To improve the robustness of our models, household food security was recategorized as food secure, marginally food secure, and food insecure (combination of low and very low food security).

Allostatic Load

AL was calculated from 11 biomarkers related to the following systems: cardiovascular (diastolic blood pressure [DBP], systolic blood pressure [SBP], total cholesterol, and HDL cholesterol); metabolic (HbA1c, body mass index [BMI], waist circumference, estimated glomerular filtration rate [eGFR] calculated from creatinine blood test based on the 2021 equations (30) without race, and albuminuria based on the albumin-to-creatinine ratio collected from urine samples); and immune (high-sensitivity C-reactive protein [hs-CRP], and white blood cell [WBC] count).

We created a binary indicator for each biomarker based on clinical cutoffs in the literature except for WBC count, which was based on whether individuals exceeded the sample's 75th percentile (31–38). The cutoffs for each biomarker were: ≥ 80 mm Hg for DBP, ≥ 130 mm Hg for SBP (based on 2017 American College of Cardiology/American Heart Association guidelines(31)), ≥ 240 mg/dL for total cholesterol, < 40 mg/dL for men or < 50 mg/dL for women for HDL cholesterol, ≥ 6.5% for HbA1c, ≥ 30 kg/m^2 for BMI, > 102 cm for men or > 88 cm for women for waist circumference, < 60 ml/min/1.73 m^2 for eGFR, > 30 mg/g for albuminuria, > 3.0 mg/L for hs-CRP, and > 8.5× 10^9 cells/L WBC count. A summary score was based on summing the number of binary indicators that exceeded the clinical cutoff, resulting in a score of 0–11 with a higher score representing greater AL. Based on previous studies using NHANES data, an AL score ≥ 3 represented elevated AL (15, 39, 40).

Covariates

Covariates were selected based on their potential to be confounders in the association between household food security status and AL. Sociodemographic characteristics included self-reported age, gender (men and women), race and ethnicity (Hispanic, NHB, NHW, and non-Hispanic Other race [e.g., includes Asian persons and persons reporting multiple races]), educational attainment (< 12 years, high school graduate or equivalent, some college/associates degree, or college graduate), health insurance status (private, public, and uninsured), income-to-poverty ratio (≤ 130%, 131%–199%, 200%–400%), marital status (married or living with a partner; separated, divorced, or widowed; and never married), and SNAP participation in the previous 12 months (yes/no). Health characteristics included self-reported Patient Health Questionnaire (PHQ)-9 depression score (none/minimal, mild, moderate, moderately severe, and severe), and current smoking status (self-reported and serum cotinine levels > 10 ng/mL). Self-reported current use (yes/no) of prescription diabetes, hypertension, and cholesterol medication was also included in sensitivity analyses.

Statistical Analysis

To examine differences in population characteristics and the distribution of biomarkers by household food security status, statistical tests were conducted using analysis of variance for continuous variables and chi-square for categorical variables. Linear regression models were used to calculate predictive margins (covariate-adjusted means) for the AL continuous score across household food security status categories. Predictive margins from multivariable logistic regression models were used to estimate adjusted prevalence ratios (PR) and 95% confidence intervals (CI) of elevated AL and each of the biomarkers in relation to household food security status (with food security as the reference group) Additionally, race, gender, and SNAP specific estimates were calculated based on two- and three-way interactions included in the model. All models adjusted for the sociodemographic and health characteristics. Sensitivity analyses were also conducted that adjusted for self-reported use of diabetes, hypertension, and cholesterol prescription medication. Another sensitivity analysis examined the association between household food insecurity status categorized as a 2-level variable (food secure vs. less than food secure) and AL.

All statistical analyses accounted for the complex sampling weights of NHANES using a 5.2 year exam sample weight that was created (22) and were conducted using SAS-callable SUDAAN v11.0. Significance levels were set at $p < 0.05$ for descriptive analyses while we focused on the magnitude of association and 95% CIs to determine whether the differences were meaningful in regression models.

Results

Selected characteristics by household food security status among US adults aged ≥ 18 years with income-to-poverty ratio ≤ 400% are shown in Table 1. The largest proportion: were aged 18–44 years (50.1%), female (52.8%), NHW (57.5%), married or living with a partner (55.1%), not currently smoking (69.8%), not currently taking diabetes (89.4%), hypertension (71.5%), or cholesterol (82.8%) medications; had some college/associates degree education (34.4%), public health insurance (45.8%), none/minimal depression (68.1%); household income 200%–400% of the federal poverty level (47.4%); and did not participate in SNAP (74.0%). Those in marginally food secure and food insecure households had a higher proportion of adults represented as: aged 18–44 years, Hispanic and NHB adults, with a high school diploma and/or < 12 years of education, uninsured, lower household income, never married, SNAP participants, with none/minimal depression scores, current smokers, and not currently taking prescription cholesterol medication.

Comparisons of biomarkers by household food security status are reported in Table 2. Adults in marginally food secure (mean = 3.1; median = 2.46) and food insecure (mean = 3.0; median = 2.47) households had a higher mean and median AL score and were more likely to have elevated AL than those in food secure households (mean = 2.7; median = 1.90). Mean and binary indicators revealed higher BMI, hs-CRP, elevated WBC count, and lower HDL cholesterol among those in marginally food secure and food insecure households than those in food secure households. In addition, those in marginally food secure and food insecure households had higher mean waist circumference and eGFR and were more likely to have HbA1c ≥ 6.5%. In contrast, those in food secure households had a higher mean SBP than the other 2 groups.

The associations between household food insecurity status with the continuous AL score and elevated AL are in Table 3. Overall, adults in marginally food secure (mean 3.09; 95% CI = 2.89, 3.28; PR = 1.13; 95% CI = 1.05, 1.20) and food insecure (mean 3.05; 95% CI = 2.89, 3.21; PR = 1.13; 95% CI = 1.07, 1.20) households had a significantly higher mean AL and were more likely to have elevated AL than those in food secure households (mean 2.70; 95% CI = 2.60, 2.79). Hispanic adults in marginally food secure households (PR = 1.15; 95% CI = 1.03, 1.28), NHB adults in food insecure households (PR = 1.09; 95% CI = 1.00, 1.18), and NHW adults in marginally food secure (PR = 1.14; 95% CI = 1.01, 1.28) or food insecure (PR = 1.12; 95% CI = 1.01, 1.25) households were more likely to have elevated AL than those in food secure households. Overall, women in marginally food secure (PR = 1.15; 95% CI = 1.05, 1.26) and food insecure (PR = 1.14; 95% CI = 1.04, 1.25) households were significantly more likely to have elevated AL than those in food secure households. Furthermore, among men overall, those in food insecure households were more likely to have elevated AL than those in food secure households (PR = 1.13; 95% CI = 1.02, 1.26). Among women, Hispanic women in marginally food secure households (PR = 1.20; 95% CI = 1.05, 1.37) were significantly more likely to have elevated AL than those in food secure households, while NHB women in food insecure households (PR = 1.14; 95% CI = 1.03, 1.26) were more likely to have elevated AL. SNAP nonparticipants in marginally food secure (PR = 1.12; 95% CI = 1.03, 1.22) or food insecure (PR = 1.17; 95% CI = 1.07, 1.28) households were significantly more likely to have elevated AL than those in food secure households; a significant association was found only among SNAP participants in marginally food secure households (PR = 1.12; 95% CI = 1.03, 1.22). Among SNAP nonparticipants, only NHW adults in food insecure households (PR = 1.22; 95% CI = 1.08, 1.39) were significantly more likely to have elevated AL than those who in food secure households. In sensitivity analysis, those in households less than food secure were significantly more likely to have elevated AL than those in food secure households in the overall population, for both men and women, and among NHW adults who were not SNAP participants (data not shown here).

The associations between household food security status and each biomarker as a binary indicator are in Figure 1. Overall, adults in marginally food secure households were significantly more likely to have low HDL cholesterol (PR = 1.20; 95% CI = 1.05, 1.37), HbA1c ≥ 6.5% (PR = 1.55; 95% CI = 1.21, 1.98), obesity (PR = 1.19; 95% CI = 1.06, 1.27), greater waist circumference (PR = 1.08; 95% CI = 1.00, 1.16), and hs-CRP > 3.0 mg/L (PR = 1.21; 95% CI = 1.05, 1.39) than those in food secure households. In addition, compared to adults in food secure households, those in food insecure households were more likely to have elevated SBP (PR = 1.13; 95% CI = 1.02, 1.25), elevated DBP (PR = 1.13; 95% CI = 1.00, 1.27), low HDL cholesterol (PR = 1.21; 95% CI = 1.06, 1.39), obesity (PR = 1.17; 95% CI = 1.08, 1.28), greater waist circumference (PR = 1.11; 95% CI = 1.05, 1.17), microalbuminuria (PR = 1.25; 95% CI = 1.04, 1.51), and hs-CRP (PR = 1.14; 95% CI = 1.02, 1.27). In sensitivity analysis, those who were in food secure households were more likely to have elevated SBP, elevated DBP, low HDL cholesterol, HbA1c ≥ 6.5%, obesity, greater waist circumference, microalbuminuria, and hs-CRP > 3.0 mg/L (Supplemental Figure 1).

Compared to those in food secure households, only NHW adults in marginally food secure households were significantly more likely to have low HDL cholesterol, HbA1c ≥ 6.5%, obesity, higher waist circumference, and hs-CRP > 3.0 mg/L—with similar findings for those in food insecure households, except for nonsignificant findings for HbA1c ≥ 6.5% (Supplemental Table 1). Women in marginally food secure households were less likely to have elevated total cholesterol levels, but were significantly more likely to have HbA1c ≥ 6.5%, obesity, higher waist circumference, and hs-CRP > 3.0 mg/L. Findings were similar for women in food insecure households, except for nonsignificant results for elevated total cholesterol, and these women were more likely to have elevated SBP and low HDL cholesterol (Supplemental Table 2). Furthermore, only men in food insecure households were significantly more likely to have microalbuminuria. SNAP participants in marginally food secure households were less likely to have elevated total cholesterol levels, while those in food insecure households were significantly more likely to have elevated SBP (Supplemental Table 3). SNAP nonparticipants in marginally food secure households were more likely to have low HDL cholesterol, HbA1c ≥ 6.5%, obesity, greater waist circumference, and hs-CRP > 3.0 mg/L. There were similar findings for those in food insecure households apart from nonsignificant HbA1c ≥ 6.5% results, and they were more likely to have microalbuminuria. Results were similar but attenuated after adjusting for medication use (data not shown).

Discussion

In this nationally representative study, different patterns of associations between household food security status and AL were observed according to gender, race and ethnicity, and SNAP participation status. The associations between household food security status and individual biomarkers may have largely been driven by NHW adults, women, and SNAP nonparticipants.

Our primary findings were inconsistent with previous studies. A previous study using 2007–2010 NHANES data found that household food insecurity was associated with higher AL among women only (15), while our study found significant associations for both genders. We also observed significant differences in AL when comparing women from food secure households to those from both marginal food secure and food insecure households. The variation in results between our study and the previous study may be attributed to differences in NHANES survey cycles (2007–2010 vs. 2015–2020 pre-pandemic), the duration of included data (4 years vs. 5.2 years), and the threshold for household income (≤300% vs. ≤400%). Changes in NHANES survey methodology between the 2007–2010 and 2015–2020 pre-pandemic cycles, along with varying economic circumstances between time periods, coupled with differing sample sizes due to incorporating more years and a less stringent threshold for household income, may have contributed to the differences in findings. Additionally, our study used 10 biomarkers with different cutoffs which may also explain the differing results from the previous study. In another study among Puerto Rican adults aged 45–75 years living in the Greater Boston area, from the Boston Puerto Rican Health Study, household food insecurity was associated with dysregulation of the inflammatory and neuroendocrine systems and was more pronounced for SNAP nonparticipants, but household food insecurity was not associated with overall AL irrespective of SNAP participation (10). The contrasting findings from this prior study may be due to its older population, for whom chronic disease and disability are more common regardless of household food security status. Furthermore, a study among adults aged 50 years or older from the Health and Retirement Study found that moderate and severe household food insecurity was associated with higher AL, and that SNAP enrollment mitigated these associations (11). Our study findings differed in that SNAP participation did not change differences in the prevalence of elevated AL between those in marginally food secure and food secure households. These differing results may be due to varying categorizations and measurement of household food insecurity because the previous study used a modified 2-item version of the survey we used.

The findings that household food security status is associated with some, but not all, of the individual biomarkers may suggest specific physiologic pathways in which household food insecurity could influence health. This could be important for designing effective interventions or policies to reduce the impact of household food insecurity. As previously described by Pak et al., these physiologic parameters (1) can capture immediate health responses to interventions/policies aimed at reducing the impact of household food insecurity, and (2) may be important performance indicators for modifying interventions and policies that are failing to achieve goals (11). In addition, identifying specific biomarkers associated with household food insecurity may be important for selecting the type of interventions or policies that would help buffer the effects of household food insecurity on health. For instance, since diet quality and physical activity are associated with the identified biomarkers, interventions focused on improving diet and physical activity among those in food insecure households may help limit the negative effects of household food insecurity on health. Interventions to improve diet may include produce prescription programs and community supported agriculture while physical activity interventions may include implementation of community-based physical activity programs and developing partnerships to leverage resources to increase access to physical activity opportunities (41, 42).

Results from this study should be interpreted in the context of its limitations. Although this study included a comprehensive set of biomarkers for measuring AL, there may be other important biomarkers such as cortisol, homocysteine, and epinephrine that were unavailable for our analysis (12). In addition, the summary AL score gave equal weighting to each biomarker, yet some biomarkers may have stronger associations with household food insecurity. Future studies could explore this using machine learning techniques such as random forest models and shapely values (43). Another limitation was that any household food insecurity was assessed over the previous 12 months in NHANES, which prevented us from examining whether episodic (i.e., few times throughout the 12 months) or persistent (i.e., all throughout the 12 months) food insecurity may have a greater influence on AL. Also, food insecurity was assessed at the household level, perhaps not representing food insecurity at the individual level. Moreover, there may be unmeasured and residual confounding variables related to SES. Furthermore, this study was cross-sectional, which precluded establishing causality—given that there may be reverse causation where higher AL may result in increased health care costs, and subsequently household food insecurity.

Nevertheless, to our knowledge, this is one of the few nationally representative studies to examine the association between household food insecurity and AL, and to determine whether this association differed by race and ethnicity, gender, and SNAP participation. Another strength of this study was including a comprehensive set of measures for AL and controlling for various confounders. Furthermore, biomarkers in NHANES are collected objectively, using standard procedures, which helps reduce measurement error that often appears with self-reported data.

These findings, that those in marginally food secure or food insecure households have higher AL, contribute to the growing evidence that AL is one way in which household food insecurity can adversely influence health outcomes. Our findings—and those of previous studies that assessed the association between household food security status and AL by differences in race and ethnicity, gender, and SNAP participation—may warrant further research to better understand which pathways contribute to differential associations. Future studies could also investigate whether chronic stress from household food insecurity influences health through modifiable health behaviors (e.g., diet and physical activity) and community characteristics (e.g., access to healthy foods and recreational areas) in order to design effective interventions to buffer the impact of household food insecurity.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

RS and KMB designed research; RS conducted research and analyzed data; RS, DSA, SO, GI, and KMB wrote the paper. RS had primary responsibility for final content. All authors read and approved the final manuscript.

Abbreviations:

AL	allostatic load
BMI	body mass index
CI	confidence interval
DBP	diastolic blood pressure

eGFR	estimated glomerular filtration rate
HbA1c	hemoglobin A1C
HDL	high-density lipoprotein
hs-CRP	high-sensitivity C-reactive protein
NHANES	National Health and Nutrition Examination Survey
NHB	non-Hispanic Black
NHW	non-Hispanic White
PHQ	patient health questionnaire
PR	prevalence ratio
SBP	systolic blood pressure
SE	standard error
SES	socioeconomic status
SNAP	supplemental nutrition assistance program
WBC	white blood cell

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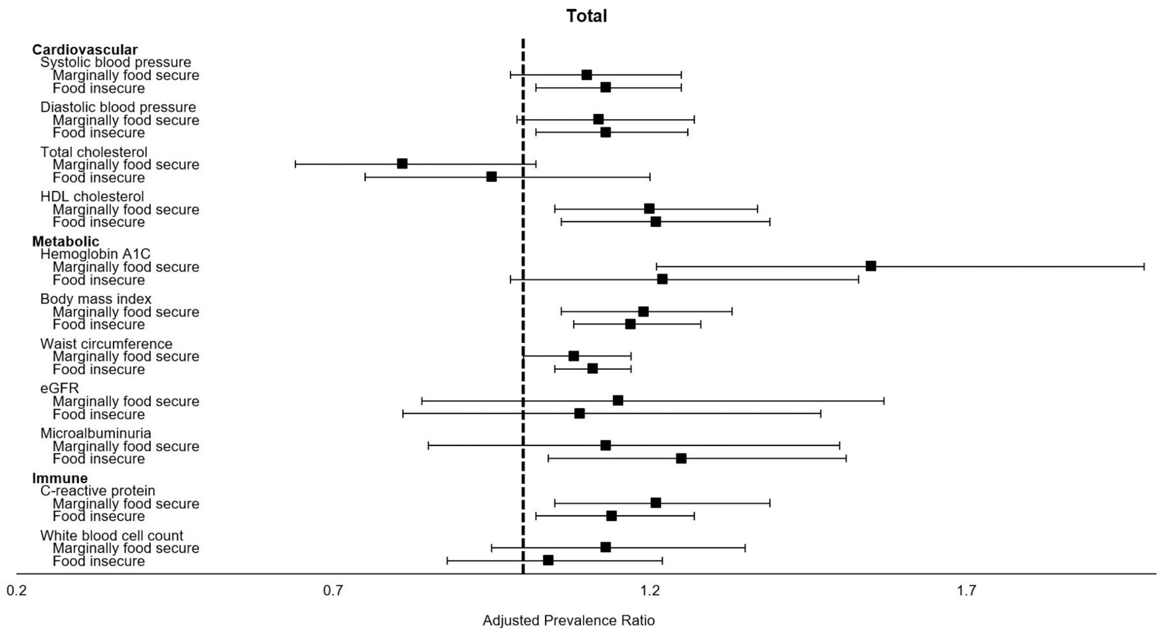

Figure 1.

Associations[a] Between Household Food Security and Elevated Allostatic Load Biomarkers[b] Among Adults With Household Incomes ≤ 400% of the Federal Poverty Level, National Health and Nutrition Examination Surveys 2015–2020

[a]Based on multivariable logistic regression models adjusted for age, race and ethnicity, gender, educational attainment, household income, marital status, health insurance, depression score, current smoking status, and SNAP participation. Food secure was the reference group. *Note*. eGFR = estimated glomerular filtration rate.

[b] Models included elevated biomarkers except for HDL cholesterol which was measured as low HDL cholesterol.

Table 1.

Distribution of Demographic Characteristics by Food Security Among US Adults With Household Incomes ≤ 400% of the Federal Poverty Level, National Health and Nutrition Examination Surveys 2015–2020

	Total (n = 7640)	Food Secure (n = 3932)	Marginally Food Secure (n = 1307)	Food Insecure (n = 2401)	*P* Value[a]
Age, years, % (SE)					< 0.001
18–44	50.1 (1.2)	45.0 (1.5)	57.1 (2.5)	56.7 (1.7)	
45–64	30.7 (0.9)	29.8 (1.3)	30.2 (1.9)	32.8 (1.4)	
65–74	11.3 (0.7)	13.6 (1.0)	8.1 (1.3)	8.3 (0.9)	
≥ 75	8.0 (0.6)	11.6 (0.9)	4.6 (0.8)	2.3 (0.4)	
Gender, % (SE)					0.93
Women	52.8 (0.7)	52.8 (0.9)	53.2 (1.7)	52.6 (1.0)	
Men	47.2 (0.7)	47.2 (0.9)	46.8 (1.7)	47.4 (1.0)	
Race/ethnicity, % (SE)					< 0.001
Hispanic	19.9 (1.9)	14.4 (1.7)	25.3 (2.9)	28.3 (2.4)	
Non-Hispanic Black	13.1 (1.5)	11.0 (1.5)	16.0 (2.3)	15.7 (1.8)	
Non-Hispanic White	57.5 (2.7)	65.1 (2.6)	47.1 (3.9)	47.4 (2.9)	
NH Other	9.6 (0.8)	9.5 (0.8)	11.7 (1.7)	8.6 (1.0)	
Educational attainment, % (SE)					< 0.001
< 12 years	16.1 (0.9)	11.4 (0.8)	18.8 (1.5)	24.5 (1.4)	
High school diploma or equivalent	30.3 (0.8)	27.7 (1.3)	36.4 (1.9)	32.5 (1.3)	
Some college/associate degree	34.4 (0.8)	35.7 (1.3)	33.3 (1.7)	32.1 (1.5)	
College graduate or higher	17.3 (1.0)	23.3 (1.4)	10.3 (1.5)	8.5 (1.2)	
Health insurance, % (SE)					< 0.001
Private	34.7 (1.2)	40.5 (1.6)	34.9 (2.2)	22.5 (1.7)	
Public	45.8 (1.4)	45.4 (1.5)	42.3 (2.8)	48.5 (2.2)	
Uninsured	18.6 (1.2)	13.5 (1.1)	22.2 (1.9)	27.1 (2.1)	
Household income (as ratio to federal poverty level), % (SE)					< 0.001
≤ 130%	31.5 (1.1)	19.7 (1.0)	36.5 (2.0)	53.4 (2.0)	
131%–199%	21.1 (0.7)	19.1 (0.9)	25.1 (2.4)	23.0 (1.5)	
200%–400%	47.4 (1.2)	61.2 (1.4)	38.5 (2.0)	23.6 (1.6)	
Marital status, % (SE)					< 0.001

	Total (n = 7640)	Food Secure (n = 3932)	Marginally Food Secure (n = 1307)	Food Insecure (n = 2401)	*P* Value[a]
Married or living with partner	55.1 (1.6)	57.3 (1.7)	55.6 (3.1)	50.3 (1.8)	
Separated, divorced, or widowed	21.6 (0.9)	21.7 (1.2)	19.5 (1.8)	22.6 (1.3)	
Never married	20.3 (1.2)	18.3 (1.2)	22.9 (2.2)	23.0 (1.6)	
SNAP participation, % (SE)					< 0.001
Yes	26.0 (1.2)	14.6 (1.1)	30.5 (1.9)	47.4 (1.5)	
No	74.0 (1.2)	85.4 (1.1)	69.5 (1.9)	52.6 (1.5)	
PHQ-9 depression score					< 0.001
None/minimal, 0–4	68.1 (0.9)	75.1 (1.0)	64.8 (2.1)	55.4 (1.7)	
Mild, 5–9	18.4 (0.8)	15.1 (0.8)	20.5 (1.6)	24.1 (1.6)	
Moderate, 10–14	6.2 (0.5)	3.8 (0.5)	7.3 (1.1)	10.6 (1.0)	
Moderately severe, 15–19	2.4 (0.2)	1.5 (0.3)	1.8 (0.5)	4.4 (0.7)	
Severe, 20–27	1.1 (0.1)	0.6 (0.2)	1.2 (0.3)	2.1 (0.3)	
Current smoking status, % (SE)					< 0.001
Yes	30.2 (0.9)	24.3 (1.3)	33.7 (2.0)	40.7 (1.5)	
No	69.8 (0.9)	75.7 (1.2)	66.3 (2.0)	59.3 (1.5)	
Taking diabetes medication, % (SE)					0.40
Yes	10.6 (0.5)	10.2 (0.5)	12.4 (1.7)	10.4 (0.8)	
No	89.4 (0.5)	89.8 (0.5)	87.6 (1.7)	89.6 (0.8)	
Taking hypertension medication, % (SE)					0.08
Yes	28.5 (1.1)	29.5 (1.3)	25.2 (1.7)	28.3 (1.6)	
No	71.5 (1.1)	70.5 (1.3)	74.8 (1.7)	71.7 (1.6)	
Taking cholesterol medication, % (SE)					0.003
Yes	17.2 (0.8)	19.2 (1.1)	16.7 (1.9)	13.3 (1.0)	
No	82.8 (0.8)	80.8 (1.1)	83.3 (1.9)	86.7 (1.0)	

[a] *P* value from chi-square tests.

Note. NH = Non-Hispanic, PHQ = Patient Health Questionnaire; SE = standard error; SNAP = Supplemental Nutrition Assistance Program.

Table 2.

Biomarkers of Allostatic Load by Food Security Status Among US Adults With Household Incomes ≤ 400% of the Federal Poverty Level, National Health and Nutrition Examination Surveys 2015–2020

	Total (n = 7685)	Food Secure (n = 3961)	Marginally Food Secure (n = 1314)	Food Insecure (n = 2410)	*P* value[a]
Allostatic load score, median (IQR)	2.28 (0.70, 3.78)	1.90 (0.55, 3.64)	2.46 (0.85, 4.07)	2.47 (1.01, 3.92)	
Allostatic load score, mean (SE)	2.9 (0.04)	2.7 (0.05)	3.1 (0.10)	3.0 (0.07)	< 0.001
Elevated allostatic load (score ≥ 3), % (SE)	54.4 (1.1)	51.9 (1.2)	57.2 (2.1)	57.9 (1.8)	< 0.001
Cardiovascular					
Systolic blood pressure (mm Hg)					
Mean (SE)	122.4 (0.3)	123.1 (0.3)	121.3 (0.7)	121.7 (0.6)	0.012
≥ 130 mm Hg, % (SE)	27.6 (0.8)	28.5 (1.1)	26.5 (1.7)	26.1 (1.4)	0.35
Diastolic blood pressure (mm Hg)					
Mean (SE)	72.3 (0.2)	72.0 (0.3)	72.7 (0.5)	72.5 (0.4)	0.27
≥ 80 mm Hg, % (SE)	23.6 (0.7)	22.4 (1.1)	25.4 (1.4)	25.2 (1.3)	0.08
Total cholesterol (mg/dL)					
Mean (SE)	186.2 (0.9)	187.0 (1.1)	184.1 (1.8)	185.8 (1.1)	0.26
≥ 240 mg/dL, % (SE)	9.9 (0.5)	10.3 (0.80)	8.3 (0.9)	10.1 (0.8)	0.14
HDL cholesterol (mg/dL)					
Mean (SE)	52.6 (0.3)	54.1 (0.4)	50.6 (0.5)	50.5 (0.5)	< 0.001
< 40 mg/dL for men, < 50 mg/dL for women, % (SE)	32.0 (1.0)	27.9 (1.2)	36.3 (1.9)	38.3 (1.9)	< 0.001
Metabolic					
Hemoglobin A1C (%)					
Mean (SE)	5.7 (0.02)	5.7 (0.03)	5.8 (0.1)	5.7 (0.03)	0.07
≥ 6.5%, % (SE)	10.1 (0.6)	9.3 (0.7)	13.1 (1.8)	10.3 (0.7)	0.0415
Body mass index (kg/m^2)					
Mean (SE)	29.8 (0.2)	29.3 (0.2)	30.5 (0.3)	30.5 (0.3)	< 0.001
≥ 30 kg/m^2, % (SE)	42.8 (1.0)	39.4 (1.3)	47.8 (2.1)	47.0 (1.5)	< 0.001
Waist circumference					
Mean (SE)	100.7 (0.4)	99.8 (0.5)	101.9 (0.8)	101.8 (0.7)	0.003
> 102 cm for men, 88 cm for women, % (SE)	60.5 (1.1)	59.1 (1.5)	61.7 (2.0)	62.6 (1.5)	0.10
eGFR					

	Total (n = 7685)	Food Secure (n = 3961)	Marginally Food Secure (n = 1314)	Food Insecure (n = 2410)	*P* value[a]
Mean (SE)	98.4 (0.6)	96.3 (0.5)	100.9 (1.1)	101.3 (0.6)	< 0.001
< 60 ml/min/1.73 m^2, % (SE)	5.5 (0.4)	6.4 (0.6)	4.9 (0.8)	3.9 (0.4)	0.002
Microalbuminuria					
Geometric mean (SE)	9.4 (0.2)	9.3 (0.2)	9.3 (0.4)	9.8 (0.3)	0.34
> 30 mg/g, % (SE)	11.5 (0.5)	11.0 (0.6)	11.0 (1.4)	12.6 (0.8)	0.14
Immune					
High-sensitivity C-reactive protein (mg/L)					
Geometric mean (SE)	1.9 (0.1)	1.7 (0.1)	2.2 (0.1)	2.1 (0.1)	< 0.001
> 3.0 mg/L, % (SE)	36.2 (0.8)	32.6 (1.1)	41.9 (2.1)	40.4 (1.4)	< 0.001
White blood cell count (cells/μL)					
Geometric mean (SE)	7.2 (0.1)	7.0 (0.1)	7.5 (0.1)	7.3 (0.1)	< 0.001
> 8.5× 10^9 cells/L, % (SE)	25.7 (0.9)	23.8 (0.9)	29.0 (2.3)	28.1 (1.8)	0.038

[a] *P* values from chi-square tests for categorical measures and ANOVA for continuous measures.

Note. eGFR = estimated glomerular filtration rate; HDL = high-density lipoprotein; IQR = interquartile range; SE = standard error.

Table 3.

Associations Between Household Food Security and Allostatic Load by Race and Ethnicity, Gender, and SNAP Participation Among US Adults With Household Incomes ≤ 400% of the Federal Poverty Level, National Health and Nutrition Examination Surveys 2015–2020

	Total		Hispanic		Non-Hispanic Black		Non-Hispanic White	
	AL score[a]	Elevated AL[b]	AL score[a]	Elevated AL[b]	AL score[a]	Elevated AL[b]	AL score[a]	Elevated AL[b]
	Mean (95% CI)	PR (95% CI)	Mean (95% CI)	PR (95% CI)	Mean (95% CI)	PR (95% CI)	Mean (95% CI)	PR (95% CI)
Total								
Food secure	2.70 (2.60, 2.79)	Ref.	2.86 (2.65, 3.07)	Ref.	3.01 (2.85, 3.16)	Ref.	2.64 (2.52, 2.76)	Ref.
Marginally food secure	3.09 (2.89, 3.28)	**1.13 (1.05, 1.20)**	3.15 (2.88, 3.42)	**1.15 (1.03, 1.28)**	2.91 (2.69, 3.13)	1.04 (0.92, 1.17)	3.18 (2.92, 3.45)	**1.14 (1.01, 1.28)**
Food insecure	3.05 (2.89, 3.21)	**1.13 (1.07, 1.20)**	3.03 (2.83, 3.22)	1.06 (0.95, 1.20)	3.08 (2.90, 3.25)	**1.09 (1.00, 1.18)**	3.05 (2.80, 3.30)	**1.12 (1.01, 1.25)**
Women								
Food secure	2.84 (2.73, 2.94)	Ref.	2.54 (1.31, 3.76)	Ref.	3.19 (2.70, 3.68)	Ref.	2.89 (2.59, 3.19)	Ref.
Marginally food secure	3.24 (3.04, 3.44)	**1.15 (1.05, 1.26)**	2.36 (0.93, 3.79)	**1.20 (1.05, 1.37)**	3.02 (2.45, 3.60)	1.07 (0.94, 1.21)	3.47 (3.01, 3.93)	1.11 (0.96, 1.29)
Food insecure	3.23 (3.07, 3.39)	**1.14 (1.04, 1.25)**	3.21 (3.02, 3.40)	1.11 (0.97, 1.26)	3.61 (3.39, 3.83)	**1.14 (1.03, 1.26)**	3.13 (2.87, 3.38)	1.09 (0.94, 1.26)
Men								
Food secure	2.54 (2.38, 2.70)	Ref.	2.23 (1.06, 3.41)	Ref.	2.43 (1.95, 2.91)	Ref.	2.63 (2.22, 3.04)	Ref.
Marginally food secure	2.92 (2.60, 3.23)	1.10 (0.96, 1.25)	1.96 (0.50, 3.41)	1.10 (0.92, 1.31)	1.93 (1.26, 2.59)	0.95 (0.75, 1.19)	3.44 (2.88, 4.00)	1.16 (0.94, 1.44)
Food insecure	2.85 (2.64, 3.06)	**1.13 (1.02, 1.26)**	2.83 (2.57, 3.08)	1.02 (0.88, 1.19)	2.48 (2.21, 2.74)	1.01 (0.87, 1.16)	2.98 (2.63, 3.32)	1.18 (0.98, 1.42)
Received SNAP								
Food secure	2.95 (2.74, 3.16)	Ref.	3.07 (2.63, 3.52)	Ref.	3.13 (2.91, 3.35)	Ref.	2.95 (2.60, 3.31)	Ref.
Marginally food secure	3.20 (2.90, 3.49)	**1.12 (1.03, 1.22)**	3.38 (2.91, 3.86)	1.15 (0.96, 1.38)	2.98 (2.67, 3.29)	0.97 (0.84, 1.12)	3.42 (2.95, 3.89)	1.13 (0.97, 1.32)
Food insecure	3.16 (2.95, 3.37)	1.07 (0.95, 1.20)	3.27 (2.96, 3.57)	1.09 (0.92, 1.30)	3.25 (3.03, 3.48)	1.04 (0.90, 1.20)	3.08 (2.75, 3.41)	0.97 (0.80, 1.19)
Did not receive SNAP								
Food secure	2.62 (2.53, 2.72)	Ref.	2.80 (2.57, 3.02)	Ref.	2.97 (2.76, 3.18)	Ref.	2.56 (2.44, 2.69)	Ref.
Marginally food secure	3.05 (2.81, 3.29)	**1.12 (1.03, 1.22)**	3.06 (2.69, 3.44)	1.14 (0.98, 1.33)	2.93 (2.59, 3.27)	1.08 (0.91, 1.29)	3.11 (2.78, 3.43)	1.13 (0.97, 1.30)
Food insecure	3.04 (2.84, 3.23)	**1.17 (1.07, 1.28)**	2.89 (2.69, 3.10)	1.01 (0.90, 1.14)	3.00 (2.69, 3.31)	1.10 (0.96, 1.26)	3.10 (2.77, 3.43)	**1.22 (1.08, 1.39)**

Note. AL = allostatic load; CI = confidence interval; PR = prevalence ratio; Ref = reference group; SNAP = Supplemental Nutrition Assistance Program.

Linear and logistic regression models adjusted for age, race and ethnicity, gender, educational attainment, household income, marital status, health insurance, depression score, current smoking status, and SNAP participation. Models used to estimate race and ethnicity stratified results exclude non-Hispanic Other adults. Bolded prevalence ratios and 95% confidence intervals indicate statistical significance.

[a] Continuous allostatic load score.

[b] Allostatic load score ≥ 3.