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Assessing the relationship between food insecurity and mortality among U.S. adults

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ABSTRACT

Purpose: Significant evidence supports a relationship between food insecurity and health, but little work has investigated its relationship on all-cause mortality within a high resource country, such as the United States.

Methods: Data from the 2003–2010 National Health and Nutrition Examination Survey was matched to National Death Index information. Cox models were used to study the relationship between mortality and food insecurity, adjusting for relevant covariates in a sequential manner (demographics, comorbidities, lifestyle variables, body mass index). Food insecurity was used as dichotomous and as four categories.

Results: Of 20,918 participants, 11.6% (representing 208,789,244 U.S. residents) were food insecure. When food insecurity was dichotomized, there was 49% higher odds of mortality after adjusting for demographics (HR, 1.49; 95% CI, 1.19–1.87). After adjusting for comorbidities, the HR remained significant, but lost significance with adjustment for lifestyle factors and body mass index (HR, 1.15; 95% CI, 0.94–1.42). However, marginal food security lost significance after adjustment for lifestyle variables.

Conclusions: Food insecurity significantly impacts all-cause mortality in the United States; however, lifestyle may explain this relationship. Interventions should account for level of severity when creating targeted programs.

Introduction

There is a growing recognition that social determinants, defined as the social and economic conditions in which individuals live, learn, work, and play, have a wide and far-reaching impact on health-related outcomes [1–4]. One of the strongest social determinants of health is poverty, as it has been associated with specific disease outcomes, health behaviors, and access to care [5–7]. In addition, factors often associated with poverty, such as food insecurity, social assistance, and low education, have been linked to clinically important changes in health-related quality of life and necessitate decisions between spending money on food, medications, housing, or other needs [8–10]. These factors, more directly related to health behaviors and health outcomes, have been focused on in an attempt to understand how poverty influences health [2,4,6,7]. In fact, food insecurity was shown to more strongly predict health outcomes than income in a recent investigation of working-age adults in the United States [11].

Food insecurity is defined by the U.S. Department of Agriculture as the "limited or uncertain availability of nutritionally adequate food or limited or uncertain ability to acquire acceptable foods" [12]. It is a cyclic and a dynamic condition, with those who reported food insecurity at any time in the prior year generally food insecure for

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seven of the 12 months during that year [13]. Food insecurity in the United States increased from an age-standardized rate of 9.06% in 2005 to 18.3% in 2012, and an even steeper increase for those with cardiovascular risk profiles [14,15]. Although more recent estimates have decreased to 11.8%, rates are still higher than prerecession levels [16]. Significant evidence supports a relationship between food security and poorer overall health, more comorbid conditions, greater psychological distress, and poor health behaviors, including low physical activity and low consumption of fruits and vegetables [9,17–20]. In addition, evidence suggests food insecurity increases disease risk including an approximately 50% higher risk of diabetes, 21% higher risk of hypertension, worse glycemic control, poor lipid control, and increased likelihood of hypoglycemia [21–25].

Although research in developing countries indicates hunger and household food insecurity exerts an impact on overall mortality through malnutrition, little exists on whether food insecurity impacts mortality in high-income countries [9,26–28]. Differences in dietary quality and health behaviors for food insecure individuals in high resource settings may result in metabolic processes and cardiovascular risk that similarly influences mortality [14,29–32]. A recent study by Gundersen et al. conducted in Canada found that food insecurity was associated with increased mortality after adjusting for age, gender, education, and income [33]. However, this analysis was based on data matched to health administrative data in Canada and may not generalize to a population-based national survey in the United States.

Given the growing awareness of the impact of social determinants of health and the prevalence of food insecurity in the United States, the aim of this project was to investigate the relationship between food insecurity and mortality and understand factors that help explain the relationship.

Methods

Data source and study population

The National Health and Nutrition Examination Survey (NHANES) is a part of the National Center for Health Statistics (NCHS) and is used to estimate the health and nutritional status of individuals in the United States [34]. This study used four cycles of continuous NHANES data between the years 2003 and 2010. The latest survey available with linked mortality from the National Death Index (NDI) is 2010 and, therefore, was chosen as the final year of data in this study. Participants who were aged 20 years and older completed both survey interview and physical examination and who had mortality follow-up information were selected for the analysis. Survey participants are defined as ineligible for mortality linkage if they had insufficient identifying data to create an NDI submission record. In total, 21,249 participants were eligible for inclusion. Three hundred thirty-one participants were missing food insecurity responses and, therefore, were excluded from the final analysis to result in a final sample size of 20,918.

Mortality outcome

NCHS has linked various surveys with death certificate records from NDI [35]. NCHS uses multiple sources of information to determine the final mortality status of a survey participant. Mortality sources include NDI match, Social Security Administration Information, Center for Medicare and Medicaid Services Information, and death certification match. All survey participants were followed from interview date through December 31, 2011. Mortality outcome of interest in this analysis includes all-cause death.

Food insecurity measures

Eighteen questions regarding food insecurity were asked of households with children aged younger than 18 years, and 10 questions were asked of households without children [11]. Four response levels result based on the number of affirmative responses for those questions:

1. Household full food security: no affirmative response in any of these items.
2. Household marginal food security: one to two affirmative responses.
3. Household low food security: three to five affirmative responses for household without children aged younger than 18 years; three to seven affirmative responses for household with children.
4. Household very low food security: 6–10 affirmative responses for household without children aged younger than 18 years; 8–18 affirmative responses for household with children.

Models were developed for food insecurity as a categorical variable with all four categories, as well as using a dichotomized variable where full food security and marginal food security were categorized into food security, whereas low food security and very low food security were dichotomized into food insecurity.

Demographic variables

Demographic variables included gender, age (as a continuous variable), race or ethnicity (grouped as non-Hispanic white, non-Hispanic black, Hispanic, and other minority), education (dichotomized as high school or below and college or above), marital status (dichotomized as married or not married), and ratio of family income to poverty (dichotomized as 130% and less of poverty level and above 130% of poverty level based on levels that can qualify households for the Supplemental Nutrition Assistance Program).

Lifestyle variables

Physical activity was based on the individual's self-reported level of engagement in work and recreational activities. Respondents reported type of activity and intensity, which was categorized as vigorous, moderate, and none based on NHANES documentation [36]. Smoking was also based on self-reported history of smoking and grouped as never, former, or current smoker. Dietary intake was incorporated based on energy intake and total fat intake, as calculated by NHANES based on responses to the interviewer-administered 24-hour dietary recall survey [34, 37]. Overall energy intake and total fat intake were based on the daily aggregates from the first dietary recall interview and were broken into quartiles with the lowest quartiles indicating low overall energy (kilocalories) and low total fat intake (grams), respectively. Body mass index (BMI; kilogram per square meter) was calculated from physical examined weight and height and categorized as underweight (<18.5), normal weight (18.5 to <25), overweight (25 to <30), and obesity (≥30).

Comorbidities

Survey participants were asked to self-report diagnosed medical conditions, including diabetes, cancer, hypertension, heart disease, and stroke. Diabetes diagnosis was determined through two self-report questions: first, whether the participant had diabetes diagnosed by a health professional, and second, whether the participant was taking insulin or antidiabetic oral medications. All other diagnoses were based on individual questions asking for self-report of diagnosis by a health professional.

Statistical analysis

Statistical analysis was performed with SAS version 9.4 (SAS Institute), using SURVEYFREQ, SURVEYMEANS, and SURVEYPHREG procedures to account for the complex survey design. Survey Cox proportional hazards regression models were used to calculate all-cause mortality. We first ran a univariate Cox model for food insecurity, as a dichotomous, and then as categorical variable. Second, we ran a Cox model for the impact of food insecurity on mortality, accounting for diabetes, and an interaction between food insecurity and diabetes to investigate whether metabolic processes linking the two are related. The interaction was not significant in either the model ran with food insecurity as dichotomous ($P = .43$) or food insecurity as a categorical variable ($P = .29$); therefore, a series of adjusted models were run in hierarchical sequence. Cox models were (1) adjusted with all demographic variables, (2) adjusted with demographic and comorbidity variables, (3) adjusted with demographic, comorbidity, and lifestyle variables (physical activity, dietary intake, and smoking), and (4) adjusted with demographic, comorbidity, lifestyle, and BMI. Each set of models was run with food insecurity as a dichotomous and a categorical variable. $P < .05$ was considered significant.

Results

A total of 20,918 participants (representing 208,789,244 U.S. noninstitutionalized residents) aged older than 20 years answered food insecurity questions and had mortality data available through 2010. Averaged across all cycles, 81.2% reported full food security, 7.1% reporting marginal food security, 7.5% reporting low food security, and 4.2% reporting very low food security. Sample demographics are presented in Table 1 for the weighted population dichotomized by food secure and food insecure. Differences existed across all demographic, comorbidity, and lifestyle variables. For example, 58.75% of those who were food secure earned below the poverty level based on 130% or less ratio of family income to the poverty line. Comparatively, 84.78% of individuals who were food secure were above the poverty line.

Table 2 shows the results of the Cox proportional hazard models for the relationship between food insecurity and mortality adjusted for demographic, comorbidity, and lifestyle when food insecurity was dichotomized. When adjusted for demographics, individuals reporting food insecurity had a 49% higher mortality compared with food secure individuals (hazard ratio [HR], 1.49; 95% confidence interval [CI], 1.19–1.87). After adjusting for comorbidities, the HR decreased slightly to 1.40 (95% 1.13–1.74) and decreased further but remained at the $P = .05$ level after adjustment for physical activity, dietary intake, and smoking (HR = 1.24, 95% 1.00–1.53). Once BMI was incorporated into the model, the relationship was no longer significant (HR, 1.15; 95% CI, 0.94–1.42).

Table 3 shows the results of the Cox proportional hazard models for the relationship between food insecurity and mortality when food security status was categorized as four categories. When adjusted for demographics, the risk of death for those with marginal food security was 35% higher (HR, 1.35; 95% CI, 1.04–1.77), whereas the risk of death for those with very low food security was twice that of food secure individuals (HR, 2.05; 95% CI, 1.44–2.91). The relationship between low food insecurity and mortality compared with food secure individuals was not significant. The relationship between food insecurity and mortality lost significance for those with marginal food security after lifestyle variables were included in the model (HR, 1.15; 95% CI, 0.85–1.55); however, for those with very low food security, the relationship remained significant after adjustment for comorbidities, lifestyle variables, and BMI (HR, 1.46; 95% CI, 1.04–2.04).

Table 1
Weighted sample demographics by food security status ($n = 20,918$, $n = 208,789,244$)

	Food secure	Food insecure	*P*
Unweighted sample	$n = 17,490$	$n = 3428$	
Weighted sample	$n = 184,436,063$	$n = 24,353,181$	
Demographics			
Gender			.04
Male	48.27%	46.48%	
Female	51.73%	53.52%	
Age group			<.0001
20–34	26.57%	38.81%	
35–49	30.03%	35.27%	
50–64	24.88%	18.38%	
65+	18.51%	7.54%	
Race/ethnicity			<.0001
Non-Hispanic white	73.65%	45.41%	
Non-Hispanic black	10.21%	19.97%	
Hispanic	10.19%	28.48%	
Other minorities	5.94%	6.14%	
Education level			<.0001
High school or below	40.82%	67.46%	
College or above	59.18%	32.54%	
Marital status			<.0001
Married	59.15%	38.78%	
Not married	40.85%	61.22%	
Ratio of family income to poverty			<.0001
130% or less	15.22%	58.75%	
Above 130%	84.78%	41.25%	
Lifestyle and BMI			
Physical activity			<.0001
None	30.57%	40.51%	
Moderate	33.16%	27.62%	
Vigorous	36.27%	31.87%	
Smoking status			<.0001
Never	53.53%	42.65%	
Former	25.69%	16.73%	
Current	20.78%	40.61%	
Energy intake (kcal)			<.0001
Lowest quartile	21.3%	24.4%	
Second quartile	24.6%	21.0%	
Third quartile	26.0%	24.5%	
Highest quartile	28.1%	30.1%	
Total fat intake (g)			<.0001
Lowest quartile	21.1%	25.9%	
Second quartile	23.8%	22.9%	
Third quartile	26.0%	24.9%	
Highest quartile	29.1%	26.3%	
BMI			<.0001
Underweight	1.70%	2.30%	
Normal weight	30.89%	28.26%	
Overweight	34.01%	30.85%	
Obesity	33.41%	38.59%	
Presence of comorbidities			
Cancer	9.53%	5.07%	<.001
Hypertension	30.35%	28.42%	.13
Heart disease	6.86%	7.54%	.25
Stroke	2.77%	3.54%	.06
Diabetes	8.34%	9.61%	.06
Mortality (not adjusted for age)			
Mortality			.2528
Alive	95.38%	95.93%	
Deceased	4.62%	4.07%	

Discussion

Using a nationally representative sample of adults in the United States, this study found that food insecurity is associated with higher mortality after adjusting for demographic variables, comorbidities, smoking, dietary intake, and physical activity. The relationship was only marginally diminished by accounting for sociodemographics and comorbidities. When the measure of food insecurity was dichotomized, the relationship lost significance after adjustment for BMI. When food insecurity was categorized into full,

Table 2
Adjusted Cox proportional hazard models for relationship between dichotomous food insecurity variable and mortality

	Model 1 HR (95% CI)	Model 2 HR (95% CI)	Model 3 HR (95% CI)	Model 4 HR (95% CI)
Food insecurity	**1.49 (1.19–1.87)**	**1.40 (1.13–1.74)**	**1.24 (1.00–1.53)**	1.15 (0.94–1.42)
Gender				
Female	**0.51 (0.44–0.59)**	**0.54 (0.46–0.63)**	**0.53 (0.44–0.63)**	**0.51 (0.42–0.61)**
Age	**1.09 (1.08–1.10)**	**1.08 (1.07–1.09)**	**1.08 (1.07–1.09)**	**1.08 (1.07–1.09)**
Race/ethnicity				
Non-Hispanic black	1.12 (0.95–1.33)	1.14 (0.95–1.36)	1.10 (0.93–1.30)	1.08 (0.90–1.30)
Hispanic	**0.76 (0.61–0.94)**	0.84 (0.68–1.03)	0.84 (0.67–1.06)	0.91 (0.72–1.15)
Other minorities	0.98 (0.61–1.58)	0.89 (0.56–1.44)	0.78 (0.46–1.32)	0.82 (0.47–1.42)
Education level				
College or above	**0.82 (0.71–0.94)**	**0.83 (0.72–0.95)**	0.97 (0.85–1.10)	0.92 (0.82–1.03)
Marital status				
Not married	**1.90 (1.57–2.28)**	**1.92 (1.61–2.30)**	**1.82 (1.52–2.19)**	**1.87 (1.54–2.26)**
Family income to poverty ratio				
Above 130%	**0.76 (0.63–0.90)**	**0.79 (0.66–0.94)**	**0.83 (0.70–1.00)**	0.85 (0.71–1.02)
Diabetes	—	**1.46 (1.24–1.71)**	**1.37 (1.16–1.61)**	**1.42 (1.21–1.67)**
Cancer	—	**1.36 (1.17–1.58)**	**1.37 (1.16–1.62)**	**1.41 (1.19–1.67)**
Hypertension	—	1.07 (0.90–1.26)	1.10 (0.93–1.31)	1.19 (0.99–1.42)
Heart disease	—	**1.72 (1.48–1.99)**	**1.66 (1.43–1.94)**	**1.61 (1.39–1.86)**
Stroke	—	**1.83 (1.51–2.21)**	**1.73 (1.39–2.16)**	**1.69 (1.32–2.16)**
Physical activity				
Vigorous	—	—	**0.50 (0.35–0.73)**	**0.54 (0.38–0.79)**
Moderate	—	—	**0.60 (0.50–0.72)**	**0.64 (0.54–0.75)**
Smoking status				
Current smoker	—	—	**1.99 (1.59–2.50)**	**2.00 (1.62–2.48)**
Former smoker	—	—	1.19 (0.94–1.50)	1.23 (0.98–1.55)
Energy intake				
Second quartile	—	—	1.02 (0.86–1.22)	0.94 (0.76–1.15)
Third quartile	—	—	0.82 (0.63–1.05)	0.77 (0.58–1.01)
Highest quartile	—	—	1.01 (0.70–1.47)	0.92 (0.59–1.41)
Total fat				
Second quartile	—	—	1.07 (0.91–1.26)	1.11 (0.92–1.33)
Third quartile	—	—	0.98 (0.77–1.24)	1.04 (0.80–1.36)
Highest quartile	—	—	0.81 (0.62–1.05)	0.90 (0.67–1.21)
BMI categories				
Underweight	—	—	—	**2.41 (1.47–3.95)**
Overweight	—	—	—	**0.78 (0.63–0.96)**
Obese	—	—	—	0.86 (0.70–1.05)

*Model 1 adjusted for demographics, Model 2 adjusted for demographics and comorbidities, Model 3 adjusted for demographics, comorbidities, and lifestyle variables, and Model 4 adjusted for all factors including BMI.
†Reference groups = food security, male, non-Hispanic white, high school or below education, married, 130% or less poverty level, no diabetes, cancer, hypertension, heart disease, or stroke, no physical activity, never smoked, lowest energy intake and total fat intake quartiles, and normal BMI.
‡Bold type represents hazard ratios significant at $P < .05$ level.

marginal, low, and very low food security levels, the relationship lost significance for marginal food security after adjustment for lifestyle variables, and the relationship remained significant for those with very low food security even after adjustment for BMI. Therefore, the severity of food security may be an important factor in intervention development, and efforts to improve lifestyle decisions, such as increasing physical activity, decreasing smoking, and having a healthy BMI, may be important targets to address for individuals with marginal food security, but not those with very low food security.

To our knowledge, this is the first study to investigate the influence of food insecurity on mortality in the United States. The findings indicate that food insecurity should be considered a strong predictor of health outcomes, and that lifestyle factors may be a modifiable aspect of the relationship amenable to interventions in populations with marginal food security. Studies outside the United States have shown the impact of food insecurity within the context of malnutrition and extreme poverty, and a recent study in Canada found a relationship between food insecurity and mortality in another high-income country [26,27,33]. Estimates of the increased odds were similar when comparing these results to Canada, with this analysis incorporating additional covariates to better understand possible areas for intervention [33]. Although the relationship between very low food security and mortality remained after adjustment for comorbidities and lifestyle behaviors, the relationship between less severe categories of food insecurity and mortality was explained by lifestyle behaviors.

The specific mechanisms linking food insecurity to an increased prevalence of morbidity and mortality are an important area for future research to inform clinical practice and policy development [20]. Seligman et al. found a significant relationship between food insecurity and higher prevalence of diabetes, independent from BMI and waist circumference [12]. Based on their findings, the authors suggested that in times of famine, peripheral insulin resistance may serve as a survival advantage in some individuals, and that repeated episodes of inadequate access to food could exacerbate this tendency toward developing insulin resistance and diabetes [12]. Insulin resistance, even in the absence of diabetes, has been shown to be an independent predictor of cardiovascular mortality [38]. However, our results found that comorbidities, such as diabetes and cardiovascular disease, did not explain the relationship between food insecurity and mortality, and that no interaction existed between food insecurity and diabetes in its relationship on mortality. Although a large body of literature exists highlighting the importance of food insecurity particularly in individuals with diabetes, this finding suggests attention should not be focused solely on those with chronic disease. Another possible explanation as to how food insecurity may lead to increased mortality is through health behaviors known to influence health outcomes, such as smoking and exercise. Using a modeling technique

Table 3
Cox proportional hazard model for relationship between relationship between categorical food insecurity variable and mortality

	Model 1 HR (95% CI)	Model 2 HR (95% CI)	Model 3 HR (95% CI)	Model 4 HR (95% CI)
Household food security				
Marginal food security	**1.35 (1.04–1.77)**	**1.32 (1.00–1.74)**	1.15 (0.85–1.55)	1.22 (0.89–1.66)
Low food security	1.29 (0.97–1.71)	1.22 (0.93–1.59)	1.09 (0.84–1.40)	1.03 (0.81–1.32)
Very low food security	**2.05 (1.44–2.91)**	**1.92 (1.37–2.70)**	**1.56 (1.12–2.19)**	**1.46 (1.04–2.04)**
Gender				
Female	**0.51 (0.44–0.59)**	**0.53 (0.45–0.63)**	**0.52 (0.44–0.63)**	**0.51 (0.42–0.61)**
Age	**1.09 (1.08–1.10)**	**1.08 (1.07–1.09)**	**1.08 (1.07–1.09)**	**1.08 (1.07–1.09)**
Race/ethnicity				
Non-Hispanic black	1.10 (0.93–1.29)	1.12 (0.94–1.33)	1.09 (0.93–1.28)	1.07 (0.89–1.29)
Hispanic	**0.74 (0.60–0.92)**	0.81 (0.66–1.01)	0.83 (0.66–1.04)	0.90 (0.71–1.13)
Other minorities	0.97 (0.61–1.56)	0.89 (0.56–1.41)	0.77 (0.46–1.29)	0.81 (0.47–1.39)
Education level				
College or above	**0.82 (0.72–0.94)**	**0.83 (0.72–0.96)**	0.97 (0.85–1.10)	0.93 (0.83–1.04)
Marital status				
Not married	**1.89 (1.56–2.27)**	**1.91 (1.59–2.28)**	**1.81 (1.51–2.17)**	**1.86 (1.54–2.24)**
Family income to poverty ratio				
Above 130%	**0.78 (0.65–0.94)**	**0.81 (0.68–0.97)**	0.84 (0.70–1.02)	0.86 (0.72–1.04)
Diabetes	—	**1.46 (1.24–1.71)**	**1.37 (1.17–1.62)**	**1.43 (1.21–1.67)**
Cancer	—	**1.36 (1.16–1.58)**	**1.37 (1.16–1.62)**	**1.40 (1.18–1.66)**
Hypertension	—	1.06 (0.89–1.26)	1.10 (1.93–1.30)	1.18 (0.99–1.41)
Heart disease	—	**1.71 (1.48–1.99)**	**1.66 (1.42–1.93)**	**1.60 (1.39–1.85)**
Stroke	—	**1.83 (1.52–2.21)**	**1.74 (1.40–2.16)**	**1.69 (1.33–2.15)**
Physical activity				
Vigorous	—	—	**0.50 (0.35–0.73)**	**0.55 (0.38–0.79)**
Moderate	—	—	**0.60 (0.50–0.72)**	**0.64 (0.54–0.75)**
Smoking status				
Current smoker	—	—	**1.97 (1.56–2.48)**	**1.98 (1.59–2.46)**
Former smoker	—	—	1.19 (0.94–1.50)	1.23 (0.98–1.55)
Energy intake				
Second quartile	—	—	1.02 (0.85–1.21)	0.93 (0.76–1.14)
Third quartile	—	—	0.81 (0.63–1.05)	0.76 (0.58–1.01)
Highest quartile	—	—	1.01 (0.70–1.46)	0.91 (0.59–1.41)
Total fat				
Second quartile	—	—	1.07 (0.91–1.26)	1.11 (0.93–1.33)
Third quartile	—	—	0.98 (0.77–1.24)	1.05 (0.81–1.37)
Highest quartile	—	—	0.81 (0.62–1.05)	0.91 (0.68–1.22)
BMI categories				
Underweight	—	—	—	**2.46 (1.49–4.06)**
Overweight	—	—	—	**0.78 (0.63–0.96)**
Obese	—	—	—	0.86 (0.70–1.05)

*Model 1 adjusted for demographics, Model 2 adjusted for demographics and comorbidities, Model 3 adjusted for demographics, comorbidities, and lifestyle variables, and Model 4 adjusted for all factors including BMI.
†Reference groups = full food security, male, non-Hispanic white, high school or below education, married, 130% or less poverty level, no diabetes, cancer, hypertension, heart disease, or stroke, no physical activity, never smoked, lowest energy intake and total fat intake quartiles, and normal BMI.
‡Bold type represents hazard ratios significant at $P < .05$ level.

involving structural demand models, access for low-income households to similar nutritional availability as high-income households only accounted for 9% of the inequality, with the other 91% driven by differences in demand for food with poor nutritional content [39]. Particularly in moderately food insecure households, lifestyle factors explained some of the relationships between food insecurity and mortality. This suggests the need to address preferences and knowledge regarding lifestyle choices, particularly in moderately food secure households in an effort to address health impacts. Qualitative research focused on understanding decisions made by food insecure households is needed to offer insight on the lived experience and inform investigation into additional mechanisms to explain the relationship with mortality.

Finally, as noted in a recent review of the literature, more work is needed to understand the possible influence of food assistance programs and coping mechanisms of food insecure households on the relationship between food insecurity and health [20]. The relationship between individuals with an income to poverty ratio of less than 130% and mortality was significant in adjusted models until lifestyle variables were added. This may suggest the need to pair food assistance programs with training in lifestyle behaviors or coping mechanisms. The Supplemental Nutrition Assistance Program has been shown to play a crucial role in reducing food insecurity levels and improving caloric intake [40–44]; however, more evidence is needed to understand its influence on health outcomes and longer term consequences of food insecurity [20].

Although this is the first analysis to link nationally representative data on food insecurity to mortality information in the United States, there are limitations of the analysis that should be noted. First, data are limited to those responding to the NHANES survey, which limits results to noninstitutionalized adults, and those willing to complete the survey and physical examination. However, surveys conducted by the NCHS are designed as a population-based sample and have been used previously to influence policy, supporting the validity of the survey. Second, additional factors may exist that could explain the relationship between food insecurity and mortality but are not available in the NHANES dataset. Details regarding food choices, health impacts of psychosocial factors such as stress, health behaviors such as medication adherence, and social influences such as access to safe housing may help explain the relationship. In addition, although overall energy intake and total fat intake did not help explain the relationship, a detailed analysis of dietary intake may help further understand specific aspects of diet that could influence the relationship. More longitudinal work should be conducted to understand the trajectory of health for food insecure individuals and explain the mechanisms to guide intervention and policy development. Lifestyle variables and BMI may have a mediating role rather than a confounding role on the relationships and therefore should be investigated using mediation and pathway analysis to better guide future policy and practice. Finally, although mortality data were longitudinal in nature, the remaining variables in the dataset are cross-sectional; therefore, implications of a causal relationship are limited.

Overall, results show an important association between food insecurity and mortality in the United States. Taken in combination with prior work in this area, clinicians, researchers, and policymakers should consider food insecurity an important social determinant of health for consideration in clinical care and inclusion in the design of health interventions and health promotion efforts. Modifiable lifestyle factors and BMI may be important targets for intervention development in moderately food insecure populations, and the level of food insecurity experienced by individuals should be taken into account in intervention design to have the greatest impact attenuating the relationship with mortality.

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