Food Insecurity Is Inversely Associated with Diet Quality of Lower-Income Adults

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ABSTRACT

Food insecurity acts as a chronic stressor independent of poverty. Food-insecure adults may consume more highly palatable foods as a coping mechanism, leading to poorer diet quality and increased risks of chronic disease over time. Using data from the 1999-2008 National Health and Nutrition Examination Surveys, this study aimed to examine the cross-sectional differences in dietary intake and diet quality by household food security among 8,129 lower-income adults (≤300% of the federal poverty level). Food insecurity was assessed using the 18-item US Household Food Security Survey Module. Dietary intake was assessed from 24-hour recalls and diet quality was measured using the Healthy Eating Index-2005 and the Alternate Healthy Eating Index-2010. Relative mean differences in dietary outcomes by household food security were estimated using linear regression models, adjusting for sociodemographic characteristics. Lower-income food-insecure adults reported higher consumption of some highly palatable foods, including high-fat dairy products (P trend<0.0001) and salty snacks (P trend=0.01) compared with lower-income food-secure adults. Food insecurity was also associated with more sugar-sweetened beverages (P trend=0.003); more red/processed meat (P trend=0.005); more nuts, seeds, and legumes (P trend=0.0006); fewer vegetables (P trend<0.0001); and fewer sweets and bakery desserts (P trend=0.0002). No differences were observed for intakes of total energy and macronutrients. Food insecurity was significantly associated with lower Healthy Eating Index-2005 (P trend<0.0001) and Alternate Healthy Eating Index-2010 scores (P trend<0.0001). Despite no macronutrient differences, food insecurity was associated with characteristics of poor diet quality known to increase chronic disease risk.
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FOOD INSECURITY IS A HOUSEHOLD-LEVEL SOCIAL and economic condition of perceived inadequate food availability. A recent estimate suggests that 17.6 million US households (14.5%) were food insecure in 2012.[1] Approximately 7.0 million households (5.7%) had very low food security, meaning individuals reported disrupted eating patterns and reduced food intake due to insufficient resources.

Food insecurity has been associated with diet-sensitive chronic disease in low-income adults, including cardiovascular disease, type 2 diabetes, gestational diabetes, and overweight and obesity, particularly among women.[2-7] Because the current questions that assess household food security include reductions in the quantity or quality of food intake, it is hypothesized that food insecurity would be adversely associated with dietary intake and diet quality. However, the studies so far have been inconsistent with respect to differences in nutrient intakes, foods, and dietary quality scores.[8-17] To date, most studies suggest that food insecurity is associated with some, but not all, characteristics of a nutrient-poor diet.

The objective of the current study was to conduct a comprehensive analysis of how household food security was associated with intake of foods, nutrients, and overall dietary quality using large nationally representative samples of lower-income adults. This study aimed to build on the work of previous studies by describing the absolute levels of consumption of foods and nutrients by lower-income Americans as they relate to national dietary guidelines and examining relative differences in consumption by household food-security status independent of poverty and other sociodemographic characteristics.

For two reasons, it was hypothesized that food insecurity would be associated with poorer dietary quality. First, nutrient-dense foods, such as fruits and vegetables, are often more expensive and less available in lower-income neighborhoods when compared with processed foods,[18,19] although evidence for this is mixed.[20,21] Second, processed foods are generally inexpensive and highly accessible. They are energy-dense, high in added fats, sugar, or salt, and often considered highly palatable with addictive potential.[22] Under

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conditions of chronic stress, some individuals cope by eating less and losing weight.[23] However, many individuals cope by eating more, specifically more highly palatable foods,[24,25] which can ameliorate the negative effects of stress on the brain.[24,26,27] Food insecurity is a chronic stressor, it threatens survival and is closely tied to high levels of perceived life stress, even after controlling for poverty.[28] Food-insecure individuals may be compelled to consume highly palatable foods, which, over time, can result in increased total energy intake, visceral fat accumulation, and subsequent chronic disease outcomes.

MATERIALS AND METHODS

Study Population

The National Health and Nutrition Examination Survey (NHANES) is a program of studies administered by the National Center for Health Statistics and approved by the National Center for Health Statistics Research Ethics Review Board.[29] NHANES is designed to be representative of the civilian, noninstitutionalized US population and collects health information from an in-home questionnaire and a physical examination in mobile examination centers.[29] This analysis combined data from 1999-2008 NHANES. The analytic sample was restricted to 8,129 adults, aged 20 to 65 years, not pregnant at the time of the survey, and with a household income $\leq$300% of the federal poverty level (FPL). A household income threshold was applied to exclude higher-income households unlikely to experience food insecurity and to provide a more appropriate comparison of food insecurity among households of similar socioeconomic status.[2]

Household Food Security

Household food security was assessed in all survey cycles during the past 12 months in the household interview using the 18-item US Household Food Security Survey Module questions.[30] Questions are ordered by range of severity of food insecurity and attribute-related experiences, behaviors, and frequencies of insufficient resources to buy food. Responses of "sometimes true," "often true," "almost every month," "some months but not every month," and "yes" were coded as affirmative, and the affirmative responses were summed according to guidelines from the US Department of Agriculture (USDA). Food-security categories were assigned as follows: 0, full food security; 1 to 2, marginal food security; 3 to 7, low food security; and 8 to 18, very low food security. Food insecurity refers to households reporting low or very low food security.[31]

Dietary Intake

From 1999 to 2008, NHANES administered one 24-hour dietary recall in-person to study participants.[29] From 2003 to 2008, a second recall was administered over the phone. Individuals with an incomplete dietary recall (n=70) or with implausible total energy intakes (<500 kcal/day or >5,000 kcal/day) (n=438) were excluded from the analytic sample.

In this study, data from the USDA Food and Nutrient Database for Dietary Studies were used to identify and estimate servings of foods and food groups from the NHANES individual food files.[32] Foods directly corresponding to the food group of interest were given full weight; mixtures (eg, mixed dishes, soups) were given half weight to account for the other constituents in the mixed food.[33] Servings were estimated by calculating the grams of intake of each food, and applying common serving sizes. Food groupings were created using guidelines from the annual American Heart Association report on Heart Disease and Stroke Statistics[34] and to make comparisons with the 2010 Dietary Guidelines for Americans[35] and the 2006 American Heart Association dietary guidelines for foods and food groups.[36] Intakes of nutrients and water (plain, tap, carbonated, bottled) were derived from the NHANES nutrient files. Nutrient intakes were compared with the Institute of Medicine's age- and sex-appropriate Estimated Average Requirements or the Adequate Intakes.[37]

Overall dietary quality was assessed using the Healthy Eating Index-2005 (HEI-2005) and the Alternate Healthy Eating Index-2010 (AHEI-2010). The HEI-2005 was developed by the USDA Center for Nutrition Policy and Promotion as a tool to measure compliance with the 2005 Dietary Guidelines for Americans.[38] HEI-2005 scores were calculated using the MyPyramid Equivalents Database.[39] The AHEI-2010 was developed by researchers at the Harvard School of Public Health as an updated measure of diet quality for chronic disease risk reduction, and calculated using the calculations of foods, food groups, and nutrients.[40] Each score was chosen for a different objective: the HEI-2005, to measure compliance with national dietary guidelines, and the AHEI-2010, to identify future risks of diet-related chronic disease.

Study Covariates

Covariates of interest included age, sex, race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, other/multi-race/ethnicity), education (<12 years, high school diploma, some college, college graduate), marital status (married/ living with partner, never married, separated/divorced/widowed), poverty income ratio (0 to 50%, 50.1% to 100%, 100.1% to 130%, 130.1% to 185%, and 185.1% to 300%), household size, smoking status (nonsmoker, former smoker, current smoker), and survey year. Models for dietary outcomes also adjusted for total energy intake. A missing indicator was used to account for participants with missing information for educational level (n=5) and marital status (n=171).

Statistical Analysis

Weights for complex surveys were developed by the National Center for Health Statistics and recalculated to account for different sampling probabilities and participation rates across the 10-year period. Differences in sociodemographic characteristics by household food security were estimated using univariate linear regression models (for continuous variables) and χ^2 tests (for categorical variables).

In order to estimate usual dietary intake, a statistical method developed by the National Cancer Institute was used, which accounts for the within-person variation of dietary intake while preserving the complex NHANES survey weighting scheme.[41] Relative mean differences in foods, food groups, nutrients, and dietary quality scores by household food-security status were estimated from linear regression models fit for log-transformed outcomes. Relative mean differences are interpreted as the difference in the means of dietary intake (ie, percentage difference) between individuals of one food-security category and individuals of full food security (reference). Models were first adjusted for

Table 1. Characteristics of adults with household incomes ≤300% federal poverty level by household food-security status from National Health and Nutrition Examination Survey 1999-2008

Characteristics	Full food security (n=4,952)	Marginal food security (n=1,046)	Low food security (n=1,401)	Very low food security (n=730)	*P* value[a]
	←——————*mean±standard error*——————→				
Age (y)	39.4±0.4	37.7±0.4	37.7±0.5	39.7±0.6	0.001
Household size (n)	3.4±0.05	3.6±0.09	3.9±0.09	3.4±0.13	<0.0001
	←——————*n (weighted %)*——————→				
Female	2,527 (66.3)	576 (11.9)	706 (13.3)	391 (8.5)	0.01
Race/ethnicity					<0.0001
Non-Hispanic white	2,009 (74.0)	258 (8.1)	368 (10.7)	257 (7.3)	
Non-Hispanic black	1,179 (60.0)	288 (15.6)	286 (14.6)	186 (9.8)	
Hispanic	1,572 (52.6)	469 (16.5)	705 (22.2)	255 (8.7)	
Other/multirace/ethnicity	192 (70.3)	31 (9.9)	42 (10.8)	32 (9.0)	
Education					<0.0001
<12 y	1,683 (55.5)	429 (12.9)	724 (19.7)	359 (11.9)	
High school diploma	1,331 (68.4)	284 (11.3)	328 (13.0)	169 (7.2)	
Some college	1,392 (70.6)	263 (10.7)	287 (11.5)	174 (7.3)	
College graduate	544 (82.6)	69 (7.4)	61 (7.0)	27 (2.9)	
Marital status					<0.0001
Married or living with partner	2,802 (68.5)	582 (11.3)	792 (13.3)	344 (6.9)	
Never married	1,118 (68.8)	226 (10.1)	295 (13.6)	163 (7.5)	
Separated, widowed, divorced	914 (59.5)	216 (12.0)	292 (15.7)	214 (12.8)	
Poverty level					<0.0001
0%-50% federal poverty level	392 (53.3)	120 (11.6)	205 (19.8)	149 (15.3)	
50.1%-100% federal poverty level	832 (51.0)	288 (14.8)	469 (21.4)	230 (12.8)	
100.1%-130% federal poverty level	662 (56.1)	166 (11.8)	273 (20.1)	145 (12.0)	
130.1%-185% federal poverty level	1,128 (69.9)	219 (11.7)	245 (12.2)	122 (6.1)	
185.1%-300% federal poverty level	1,938 (81.3)	253 (8.5)	209 (6.8)	84 (3.5)	
Smoking status					<0.0001
Nonsmoker	2,559 (70.1)	529 (11.0)	660 (12.5)	299 (6.3)	
Former smoker	960 (71.1)	172 (9.7)	243 (12.8)	111 (6.3)	
Current smoker	1,429 (60.8)	343 (11.9)	496 (15.9)	320 (11.4)	

[a]From χ^2 tests and univariate linear regression models.

age, sex, survey year, and total energy intake, and second for these variables plus race/ethnicity, education, marital status, poverty income ratio, household size, and smoking status. Models for dietary quality were further examined for heterogeneity by sex and race/ethnicity by testing two-way cross-product terms between sex or race/ethnicity and food-security categories in fully adjusted models. Because of the number of dietary outcomes, the results are focused on dietary trends across levels of food insecurity, and the comparison between very low food-secure households to food-secure households.

All statistical tests were two-tailed. Significance was considered at $P<0.05$. Statistical analyses were performed using SAS 9.3 software (2011, SAS Institute Inc).

RESULTS AND DISCUSSION

During the study period (1999 to 2008), 4,952 adults (weighted to the national population: 67.1%) reported their households were fully food secure, 1,046 adults (11.1%) reported their households were marginally food secure, 1,401 adults (13.7%) reported their households experienced low

Table 2. Consumption of servings of selected foods and food groups by household food-security status among 8,129 adults with household incomes ≤300% federal poverty level from National Health and Nutrition Examination Survey 1999-2008

	Mean	Median	10th, 90th percentile	% Meeting guideline	Model 1[a]		Model 2[b]		
					RD[c]	95% CI	RD	95% CI	*P* trend[d]
Whole grains									
Full food security	0.9	0.5	0.1, 2.0	3.7	Ref		Ref		0.13
Marginal food security	1.0	0.6	0.1, 2.2	4.9	1.15***	1.08-1.21	1.01	0.96-1.05	
Low food security	1.0	0.6	0.1, 2.3	5.4	1.15***	1.08-1.23	1.04	0.99-1.09	
Very low food security	1.0	0.6	0.1, 2.3	5.0	1.06	0.99-1.13	1.02	0.97-1.07	
Refined grains									
Full food security	4.9	4.4	2.2, 8.3	77.5	Ref		Ref		0.22
Marginal food security	4.9	4.3	2.1, 8.5	75.9	1.01	0.99-1.02	0.99	0.98-1.01	
Low food security	4.9	4.4	2.1, 8.5	76.1	1.00	0.98-1.02	0.99	0.97-1.01	
Very low food security	4.8	4.2	2.0, 8.3	73.7	0.99	0.96-1.01	0.99	0.96-1.01	
Fruits									
Full food security	0.8	0.4	0.0, 2.2	1.6	Ref		Ref		0.77
Marginal food security	0.8	0.4	0.0, 2.2	1.6	1.03	0.95-1.11	0.95	0.89-1.02	
Low food security	0.8	0.4	0.0, 2.3	1.8	1.10*	1.02-1.19	1.05	0.99-1.13	
Very low food security	0.9	0.4	0.0, 2.3	1.8	0.92*	0.86-0.98	0.94	0.88-1.00	
100% fruit juice									
Full food security	0.6	0.2	0.0, 1.7	—	Ref		Ref		0.66
Marginal food security	0.7	0.3	0.0, 1.9	—	1.09*	1.01-1.17	0.96	0.90-1.03	
Low food security	0.7	0.3	0.0, 2.0	—	1.13**	1.04-1.23	1.04	0.95-1.13	
Very low food security	0.7	0.2	0.0, 1.9	—	1.05	0.96-1.16	1.01	0.90-1.12	
Vegetables									
Full food security	1.2	0.9	0.2, 2.5	0.0	Ref		Ref		<0.0001
Marginal food security	1.1	0.9	0.2, 2.4	0.0	0.92**	0.88-0.96	0.94**	0.90-0.98	
Low food security	1.1	0.8	0.2, 2.4	0.0	0.91***	0.88-0.94	0.94**	0.91-0.97	
Very low food security	1.1	0.8	0.2, 2.3	0.0	0.85***	0.81-0.88	0.88***	0.85-0.91	
White potatoes									
Full food security	0.8	0.6	0.2, 1.4	—	Ref		Ref		<0.0001
Marginal food security	0.7	0.6	0.2, 1.4	—	0.95**	0.93-0.98	0.98	0.95-1.01	
Low food security	0.7	0.6	0.2, 1.4	—	0.93***	0.91-0.96	0.95**	0.92-0.97	
Very low food security	0.7	0.6	0.2, 1.3	—	0.92***	0.89-0.95	0.93***	0.90-0.96	
Nuts, seeds, and legumes									
Full food security	0.5	0.3	0.0, 1.3	27.9	Ref		Ref		0.0006
Marginal food security	0.6	0.3	0.1, 1.5	33.2	1.21***	1.14-1.30	1.00	0.96-1.04	
Low food security	0.6	0.3	0.1, 1.5	34.3	1.26***	1.18-1.34	1.07**	1.03-1.11	
Very low food security	0.6	0.3	0.1, 1.5	32.9	1.19***	1.11-1.28	1.10**	1.03-1.17	
Fish/shellfish									
Full food security	0.2	0.1	0.0, 0.4	20.7	Ref		Ref		0.36
Marginal food security	0.2	0.1	0.0, 0.4	21.6	1.09***	1.05-1.13	1.02	0.98-1.05	
Low food security	0.2	0.1	0.0, 0.4	22.2	1.05**	1.01-1.09	1.00	0.97-1.03	
Very low food security	0.2	0.1	0.0, 0.4	21.4	1.05**	1.01-1.09	1.03	0.99-1.06	
Red/processed meat									
Full food security	0.9	0.8	0.3, 1.7	—	Ref		Ref		0.005
Marginal food security	0.9	0.8	0.3, 1.7	—	1.02	1.00-1.05	1.03*	1.00-1.06	

(*continued on next page*)

Table 2. Consumption of servings of selected foods and food groups by household food-security status among 8,129 adults with household incomes ≤300% federal poverty level from National Health and Nutrition Examination Survey 1999-2008 (*continued*)

	Mean	Median	10th, 90th percentile	% Meeting guideline	Model 1[a]		Model 2[b]		
					RD[c]	95% CI	RD	95% CI	*P* trend[d]
Low food security	1.0	0.8	0.3, 1.8	—	1.02	0.99-1.04	1.02	0.99-1.05	
Very low food security	0.9	0.8	0.3, 1.8	—	1.05**	1.01-1.09	1.05**	1.01-1.09	
High-fat dairy products									
Full food security	0.8	0.6	0.1, 1.9	—	Ref		Ref		<0.0001
Marginal food security	0.8	0.6	0.1, 1.9	—	1.02	0.98-1.07	1.02	0.98-1.07	
Low food security	0.9	0.6	0.1, 2.0	—	1.08***	1.05-1.12	1.08**	1.04-1.12	
Very low food security	0.9	0.6	0.1, 2.0	—	1.07**	1.03-1.11	1.08**	1.03-1.13	
Low-fat dairy products									
Full food security	0.2	0.0	0.0, 0.7	—	Ref		Ref		0.03
Marginal food security	0.2	0.0	0.0, 0.6	—	0.70***	0.60-0.82	0.92	0.81-1.04	
Low food security	0.2	0.0	0.0, 0.6	—	0.72***	0.64-0.82	0.92	0.84-1.02	
Very low food security	0.2	0.0	0.0, 0.7	—	0.69***	0.57-0.82	0.87	0.74-1.01	
Salty snacks									
Full food security	0.4	0.3	0.1, 0.8	—	Ref		Ref		0.01
Marginal food security	0.3	0.3	0.0, 0.8	—	0.93**	0.89-0.97	1.02	0.98-1.05	
Low food security	0.4	0.3	0.1, 0.8	—	0.97	0.93-1.00	1.04	1.00-1.08	
Very low food security	0.4	0.3	0.1, 0.8	—	0.99	0.94-1.05	1.04*	1.00-1.09	
Sweets and bakery desserts									
Full food security	1.0	0.8	0.2, 2.1	21.2	Ref		Ref		0.0002
Marginal food security	1.0	0.7	0.2, 2.1	24.8	0.92**	0.88-0.96	0.97	0.93-1.01	
Low food security	1.0	0.7	0.2, 2.1	24.7	0.90***	0.87-0.93	0.95**	0.92-0.98	
Very low food security	1.0	0.7	0.2, 2.1	25.2	0.90**	0.86-0.95	0.94*	0.90-0.99	
Sugar-sweetened beverages									
Full food security	2.6	2.0	0.2, 5.7	21.7	Ref		Ref		0.003
Marginal food security	2.7	2.1	0.2, 5.9	20.3	1.12**	1.05-1.20	1.06	0.99-1.13	
Low food security	2.8	2.3	0.2, 6.1	18.9	1.16***	1.10-1.22	1.08**	1.02-1.14	
Very low food security	2.7	2.0	0.2, 6.0	21.4	1.21***	1.12-1.31	1.12**	1.03-1.21	
Water									
Full food security	9.3	7.4	1.1, 19.6	—	Ref		Ref		0.25
Marginal food security	9.1	7.3	1.1, 19.1	—	0.94	0.88-1.01	0.97	0.91-1.04	
Low food security	9.2	7.3	1.1, 19.5	—	0.93*	0.88-0.98	0.98	0.92-1.04	
Very low food security	9.1	7.3	1.1, 19.2	—	0.90**	0.83-0.97	0.96	0.88-1.04	
Alcoholic beverages									
Full food security	1.0	0.1	0.0, 3.1	79.7	Ref		Ref		0.15
Marginal food security	0.9	0.1	0.0, 3.0	80.5	0.97	0.88-1.07	0.99	0.91-1.09	
Low food security	1.0	0.1	0.0, 3.4	78.9	1.01	0.94-1.08	1.03	0.96-1.12	
Very low food security	1.0	0.1	0.0, 3.3	78.8	1.12	0.99-1.26	1.10	0.97-1.25	

[a]Model 1 adjusted for age, sex, survey year, and total energy intake. Associations are comparing marginal, low, and very low food security groups to the full food security group (reference).
[b]Model 2 adjusted for age, sex, survey year, total energy intake, race/ethnicity, education level, marital status, household size, poverty income ratio, and smoking status. Associations are comparing marginal, low, and very low food security groups to the full food security group (reference).
[c]RD=relative difference.
[d]Trend test from Model 2.
*$P<0.05$.
**$P<0.01$.
***$P<0.0001$.

Table 3. Consumption of nutrients by household food-security status among 8,129 adults with household incomes ≤300% federal poverty level from National Health and Nutrition Examination Survey 1999-2008

	Mean	Median	10th, 90th percentile	% Meeting guideline	Model 1[a]		Model 2[b]		*P* trend[d]
					RD[c]	95% CI	RD	95% CI	
Total energy (kcal/day)									
Full food security	2,312	2,253	1,440, 3,264	—	Ref		Ref		0.57
Marginal food security	2,263	2,201	1,406, 3,213	—	0.99	0.97-1.01	1.01	0.99-1.03	
Low food security	2,312	2,250	1,444, 3,265	—	0.99	0.97-1.00	1.01	0.99-1.03	
Very low food security	2,270	2,206	1,403, 3,233	—	0.98	0.96-1.01	1.00	0.98-1.03	
Energy density (kcal/g)									
Full food security	2.2	2.1	1.7, 2.7	—	Ref		Ref		0.69
Marginal food security	2.1	2.1	1.6, 2.6	—	1.00	0.98-1.01	1.01	1.00-1.03	
Low food security	2.1	2.1	1.6, 2.7	—	0.99	0.97-1.00	1.00	0.99-1.01	
Very low food security	2.1	2.1	1.6, 2.7	—	1.00	0.98-1.01	1.00	0.98-1.01	
Carbohydrates (% energy)									
Full food security	50.7	50.7	41.4, 60.1	—	Ref		Ref		0.39
Marginal food security	51.3	51.3	42.0, 60.7	—	1.00	0.99-1.01	1.00	0.99-1.01	
Low food security	51.2	51.2	41.8, 60.6	—	1.02**	1.01-1.02	1.01	1.00-1.02	
Very low food security	51.0	51.0	41.7, 60.4	—	1.01	0.99-1.02	1.00	0.99-1.01	
Protein (% energy)									
Full food security	14.3	14.2	10.9, 17.9	—	Ref		Ref		0.33
Marginal food security	14.4	14.3	11.0, 18.0	—	1.01	0.99-1.02	1.00	0.99-1.01	
Low food security	14.4	14.2	11.0, 18.0	—	1.00	0.99-1.01	1.00	0.99-1.01	
Very low food security	14.4	14.2	11.0, 18.0	—	0.99	0.97-1.00	0.99	0.98-1.01	
Total fat (% energy)									
Full food security	33.2	33.2	26.5, 39.8	62.9	Ref		Ref		0.28
Marginal food security	32.5	32.5	25.8, 39.2	67.0	0.99*	0.98-1.00	1.01	1.00-1.01	
Low food security	32.7	32.7	26.0, 39.3	66.5	0.98**	0.97-0.99	1.00	0.99-1.00	
Very low food security	33.0	33.0	26.3, 39.6	64.6	0.98*	0.97-1.00	0.99	0.98-1.01	
Saturated fat (% energy)									
Full food security	11.0	10.9	8.2, 13.8	2.9	Ref		Ref		0.70
Marginal food security	10.7	10.6	7.9, 13.5	3.9	0.99	0.98-1.00	1.01*	1.00-1.02	
Low food security	10.8	10.7	8.0, 13.6	3.6	0.98**	0.97-0.99	1.00	0.99-1.01	
Very low food security	10.9	10.8	8.1, 13.7	3.3	0.98*	0.96-1.00	0.99	0.97-1.01	
Dietary cholesterol (mg/day)									
Full food security	293	272	143, 470	58.3	Ref		Ref		0.45
Marginal food security	289	269	140, 465	59.7	1.04**	1.02-1.07	1.02	1.00-1.04	
Low food security	294	273	143, 471	58.0	1.00	0.99-1.02	0.99	0.97-1.01	
Very low food security	290	270	142, 467	59.1	1.00	0.97-1.03	0.99	0.96-1.02	
Carotenoids (μg/day)									
Full food security	5,194	3,999	1,218, 10,599	—	Ref		Ref		0.05
Marginal food security	5,138	3,947	1,199, 10,532	—	0.97	0.93-1.01	0.97	0.93-1.01	
Low food security	5,212	4,005	1,228, 10,661	—	0.99	0.96-1.02	1.00	0.96-1.03	
Very low food security	5,178	3,986	1,224, 10,584	—	0.92**	0.87-0.96	0.94*	0.90-0.99	

(*continued on next page*)

Table 3. Consumption of nutrients by household food-security status among 8,129 adults with household incomes ≤300% federal poverty level from National Health and Nutrition Examination Survey 1999-2008 (*continued*)

	Mean	Median	10th, 90th percentile	% Meeting guideline	Model 1[a] RD[c]	Model 1[a] 95% CI	Model 2[b] RD	Model 2[b] 95% CI	*P* trend[d]
Vitamin E (mg/day)									
Full food security	7.5	7.1	4.2, 11.4	7.8	Ref		Ref		0.02
Marginal food security	7.3	6.9	4.0, 11.2	7.0	0.98*	0.96-1.00	0.99	0.97-1.01	
Low food security	7.5	7.0	4.1, 11.3	7.4	0.97**	0.95-0.99	0.99	0.97-1.01	
Very low food security	7.4	7.0	4.1, 11.3	7.5	0.94***	0.92-0.97	0.97*	0.94-0.99	
Vitamin C (mg/day)									
Full food security	78.3	67.0	26.1, 144.8	50.0	Ref		Ref		0.51
Marginal food security	82.1	70.4	27.7, 151.0	53.6	1.02	0.98-1.06	0.97	0.94-1.01	
Low food security	81.7	69.8	27.7, 150.9	52.4	1.06**	1.02-1.10	1.03	1.00-1.07	
Very low food security	80.3	68.6	27.1, 148.8	51.9	0.94*	0.90-0.99	0.95	0.91-1.00	
EPA[e] and DHA[f] (g/day)									
Full food security	0.08	0.06	0.02, 0.16	0.0	Ref		Ref		<0.0001
Marginal food security	0.08	0.06	0.02, 0.17	0.0	1.07**	1.03-1.11	0.96**	0.94-0.99	
Low food security	0.08	0.06	0.02, 0.16	0.0	0.99	0.95-1.03	0.92***	0.90-0.94	
Very low food security	0.07	0.05	0.01, 0.15	0.0	0.94***	0.91-0.97	0.90***	0.87-0.92	
Dietary fiber (g/day)									
Full food security	14.6	13.8	7.5, 22.7	4.4	Ref		Ref		0.30
Marginal food security	14.6	13.8	7.5, 22.7	4.5	0.99	0.97-1.01	0.98*	0.96-1.00	
Low food security	14.7	13.9	7.6, 22.9	4.2	1.01	0.99-1.04	1.01	0.99-1.03	
Very low food security	14.6	13.8	7.5, 22.7	4.5	0.95**	0.92-0.98	0.97	0.95-1.00	
Folate (μg/day)									
Full food security	379	361	218, 561	62.8	Ref		Ref		0.47
Marginal food security	373	356	215, 555	61.3	0.98	0.97-1.00	0.99	0.97-1.00	
Low food security	379	361	219, 562	62.9	0.99	0.98-1.01	1.00	0.99-1.02	
Very low food security	375	357	216, 559	61.7	0.97**	0.95-0.98	0.99	0.97-1.01	
Sodium (mg/day)									
Full food security	3483	3371	2,104, 5,009	12.9	Ref		Ref		0.007
Marginal food security	3397	3286	2,047, 4,906	14.6	0.99*	0.98-1.00	1.00	0.99-1.01	
Low food security	3469	3355	2,098, 4,995	13.1	0.97***	0.96-0.98	0.99*	0.98-1.00	
Very low food security	3419	3305	2,053, 4,964	14.1	0.97**	0.95-0.98	0.98	0.96-1.00	
Potassium (mg/day)									
Full food security	2623	2541	1,579, 3,772	1.7	Ref		Ref		0.14
Marginal food security	2556	2474	1,528, 3,685	1.4	0.98**	0.96-0.99	0.98*	0.97-1.00	
Low food security	2595	2511	1,562, 3,734	1.6	0.99	0.98-1.01	1.00	0.98-1.01	
Very low food security	2591	2507	1,564, 3,741	1.6	0.97**	0.95-0.98	0.98	0.97-1.00	
Calcium (mg/day)									
Full food security	868	814	456, 1,351	49.0	Ref		Ref		0.16
Marginal food security	841	787	439, 1,315	46.0	0.96**	0.94-0.99	0.99	0.96-1.01	
Low food security	859	802	450, 1,337	48.3	0.98	0.97-1.00	1.01	0.99-1.03	
Very low food security	852	796	443, 1,332	47.2	0.94***	0.92-0.97	0.97*	0.94-1.00	

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Table 3. Consumption of nutrients by household food-security status among 8,129 adults with household incomes ≤300% federal poverty level from National Health and Nutrition Examination Survey 1999-2008 (*continued*)

	Mean	Median	10th, 90th percentile	% Meeting guideline	Model 1[a] RD[c]	Model 1[a] 95% CI	Model 2[b] RD	Model 2[b] 95% CI	*P* trend[d]
Iron (mg/day)									
Full food security	14.6	13.9	8.4, 21.7	95.5	Ref		Ref		0.39
Marginal food security	14.3	13.6	8.2, 21.3	94.6	0.99	0.97-1.01	1.00	0.98-1.01	
Low food security	14.6	13.9	8.4, 21.7	95.3	0.99	0.98-1.01	1.00	0.98-1.02	
Very low food security	14.4	13.7	8.2, 21.5	94.8	0.97**	0.95-0.99	0.99	0.97-1.01	

[a]Model 1 adjusted for age, sex, survey year, and total energy intake. Associations are comparing marginal, low, and very low food security groups to the full food security group (reference).
[b]Model 2 adjusted for age, sex, survey year, total energy intake (excluding models for total energy, energy density, and macronutrients), race/ethnicity, education level, marital status, household size, poverty income ratio, and smoking status. Associations are comparing marginal, low, and very low food security groups to the full food security group (reference).
[c]RD=relative difference.
[d]Trend test from Model 2.
[e]EPA=eicosapentaenoic acid.
[f]DHA=docosahexaenoic acid.
*$P<0.05$.
**$P<0.01$.
***$P<0.0001$.

food security, and 730 adults (8.1%) reported their households experienced very low food security during the past 12 months. Characteristics of adults by household food security are shown in Table 1.

Few adults met the national Dietary Guidelines with their intakes of several important foods and food groups (Table 2). For example, only 4% to 5% of adults consumed ≥3 servings/day of whole grains; 2% of adults consumed ≥4 servings/day of fruit (excluding juices); 0% of adults consumed ≥5 servings/day of vegetables (excluding white potatoes, legumes), 28% to 34% of adults consumed ≥4 servings/wk of nuts, seeds and legumes, and 21% to 22% of adults consumed ≥2 servings/wk of fish/shellfish. Conversely, 75% to 79% of adults exceeded the guideline for sweets and bakery desserts (2.5 servings/wk), and 78% to 81% of adults exceeded the guideline for sugar-sweetened beverages (4 servings/wk). Compared to the general population (NHANES 2005-2008), lower-income adults in our study population were less likely to meet important dietary guidelines for several food groups.[34] A comparison of the lower-income population to the higher-income population would likely yield even larger differences in intakes of important foods and food groups.

Compared to full food security, very low food security was significantly associated with higher intakes of some highly palatable foods, including 8% more high-fat dairy products (95% CI 3% to 13%) and 4% more salty snacks (95% CI 0% to 9%). Significant trends were observed for these associations, where lower food security was associated with higher intakes (*P* trend ≤0.01). In addition, very low food security was associated with 12% more sugar-sweetened beverages (95% CI 3% to 21%; *P* trend=0.003), 12% fewer servings of vegetables (95% CI −15% to −9%; *P* trend<0.0001), and 5% more servings of red and processed meat (95% CI 1% to 9%; *P* trend=0.005) compared with full food security. There were a couple aspects of better dietary quality among food-insecure adults, including 6% fewer servings of sweets and bakery desserts (95% CI −10% to −1%; *P* trend=0.0002) and 10% more servings of nuts, seeds, and legumes (95% CI 3% to 17%; *P* trend=0.0006). Although most lower-income adults consumed more sweets and bakery desserts than the current guideline, the inverse association between food insecurity and sweets and bakery desserts was contrary to our initial hypothesis and deserves additional investigation. The higher consumption of nuts, seeds, and legumes among food-insecure adults could also reflect the fact that legumes are inexpensive and high in protein and fiber. No differences were found for other foods (ie, whole grains, refined grains, fruits, 100% fruit juice, fish/shellfish, and low-fat dairy products). For several of these foods, consumption levels were extremely low across levels of food-security status, with few lower-income adults meeting the dietary guidelines.

Few adults across all household food-security categories met the recommendations for saturated fat, eicosapentaenoic acid, docosahexaenoic acid, dietary fiber, vitamin E, potassium, and calcium (Table 3). Most adults exceeded the recommended upper limit for sodium. There were no differences in total energy intake, energy density, or macronutrient densities by household food-security status, which might be attributed to the little variation in macronutrient intake across all levels of household food security. After adjustment for sociodemographic characteristics and total energy intake, lower food security was associated with lower intakes of vitamin E (*P* trend=0.02) and eicosapentaenoic acid and docosahexaenoic acid (*P* trend<0.0001), and marginally associated with lower intakes of carotenoids (*P* trend=0.05). Specifically, very low food security was associated with 10% lower intakes of eicosapentaenoic acid and docosahexaenoic acid (95% CI −13% to −8%), 6% lower intakes of carotenoids (95% CI −10% to −1%), 3% lower intakes of vitamin E (95% CI −6% to −1%), and 3% lower intakes of calcium (95% CI −6% to 0%). There were no other significant associations in micronutrient intake by household food-security status.

Across all household food-security categories, mean HEI-2005 scores ranged from 45.5 to 47.3 out of 100 points (Table 4). For the AHEI-2010, mean scores were between 34.0

Table 4. Associations between household food-security status and dietary quality scores among 8,129 adults with household incomes ≤300% federal poverty level from National Health and Nutrition Examination Survey 1999-2008

	Mean score	Median score	10th, 90th percentile	Model 1[a]		Model 2[b]		*P* trend[d]
				RD[c]	95% CI	RD	95% CI	
Healthy Eating Index-2005 score (100 points)								
Full food security	47.3	47.0	36.4, 58.5	Ref		Ref		<0.0001
Marginal food security	47.1	46.9	36.3, 58.4	0.99*	0.97-1.00	0.98**	0.97-0.99	
Low food security	46.0	45.8	35.4, 57.1	0.99	0.97-1.00	0.99	0.98-1.00	
Very low food security	45.5	45.3	34.8, 56.6	0.95***	0.94-0.97	0.97***	0.96-0.98	
Alternate Healthy Eating Index-2010 score (110 points)								
Full food security	35.5	35.0	24.6, 46.9	Ref		Ref		<0.0001
Marginal food security	35.1	34.7	24.2, 46.6	0.98*	0.97-1.00	0.98**	0.96-0.99	
Low food security	34.1	33.7	23.5, 45.3	0.98*	0.97-1.00	0.98**	0.97-1.00	
Very low food security	34.0	33.5	23.3, 45.4	0.94***	0.92-0.96	0.96***	0.94-0.97	

[a]Model 1 adjusted for age, sex, survey year, and total energy intake. Associations are comparing marginal, low, and very low food security groups to the full food security group (reference).
[b]Model 2 adjusted for age, sex, survey year, total energy intake, race/ethnicity, education level, marital status, household size, poverty income ratio, and smoking status. Associations are comparing marginal, low, and very low food security groups to the full food security group (reference).
[c]RD=relative difference.
[d]Trend test from Model 2.
*$P<0.05$.
**$P<0.01$.
***$P<0.0001$.

and 35.5 out of 110 points. For both indices, a low score corresponds to poor dietary quality. After adjustment for sociodemographic characteristics and total energy intake, lower food security was associated with lower diet-quality scores (P trend<0.0001 for both HEI-2005 and AHEI-2010). Households of very low food security had 3% lower total HEI-2005 scores (95% CI −4% to −2%) and 4% lower total AHEI-2010 scores (95% CI −6% to −3%) compared with households of full food security. Results were similar when stratified by sex and race/ethnicity (Tables 5 and 6, available online at www.andjrnl.org). There was no evidence of significant heterogeneity by sex or race/ethnicity in the associations between food insecurity and dietary quality (P interaction>0.10).

The results of the current study suggest that dietary factors can mediate the associations between food insecurity, overweight and obesity, and diet-sensitive chronic disease in lower-income adults. For example, diets high in red and processed meats, refined grains, and sugar-sweetened beverages, and low in vegetables, have been associated with inflammation and weight gain in longitudinal studies.[42-44] In particular, sugar-sweetened beverage consumption has been linked to increased risks of type 2 diabetes, metabolic syndrome, and cardiovascular disease in all age groups.[45-49] Our results showed that, among food-insecure adults, the mean intake of sugar-sweetened beverage was 2.7 to 2.8 servings (approximately 22 oz) per day, with 10% of adults consuming at least 6 servings (approximately 48 oz) per day. These strikingly high consumption levels deserve special attention for their health and policy implications.[50] Both measures of overall dietary quality, the HEI-2005 and the AHEI-2010, have been shown to predict risk of major chronic disease among healthy adults.[40] In our study, the means for both scores were low, suggesting that poor dietary quality over time might be contributing to the documented health consequences in lower-income adults.

Our results corroborate those of previous studies. For example, Dixon and colleagues found that food-insufficient adults consumed lower intakes of dairy, fruits, juices, salty snacks, sweets and desserts, vegetables, calcium, and vitamin E compared to food-sufficient adults in NHANES III.[10] In the same data set, Bhattacharya and colleagues found that food insufficiency was associated with a 2.4-point lower HEI score, a previous version of the HEI-2005.[9] The one-item measure of food insufficiency used in these studies has since been replaced by the current 18-item US Household Food Security Survey Module.[51] In a recent analysis of the 1999-2002 NHANES using the current USDA Food Security Survey Module, Zizza and colleagues found fewer meal occasions with lower food security.[17] Our results further demonstrate that household food security is associated with higher intakes of some highly palatable foods and lower scores for two measures of overall dietary quality. Together, this growing literature suggests that food insufficiency/insecurity influences multiple dimensions of diet, including consumption of individual foods, food groups, nutrients, dietary quality scores, and meal occasions. Policies and food-assistance programs aimed at improving food insecurity can also have a beneficial impact on dietary intake and diet quality of lower-income adults.[52-54]

This study has several strengths. First, data came from large, nationally representative samples of adults surveyed over a recent 10-year period. Second, household food security was assessed using the full 18-item USDA Household Food Security Survey Module, which is currently the most accurate measure. Third, the majority of study participants contributed two 24-hour dietary recalls. Although two 24-hour dietary recalls are limited in capturing long-term diet, a statistical method developed by the National Cancer Institute was used to approximate usual dietary intake. This method has been validated in estimating the population-level distribution of usual intakes of most dietary components using 24-hour dietary recalls.[55,56]

This study is limited by the cross-sectional nature of the data, which makes it difficult to examine how food insecurity affects dietary intake over time and to make causal inferences about the data. In addition, household food security was assessed over the past 12 months, and dietary intake was assessed at the time of the NHANES interview. To better understand the effects of food insecurity on dietary intake, it would have been more useful to measure household food security closer to the time of the interview (ie, within the past month) and to assess the duration of household food security. The analytic population was defined by adults with incomes up to 300% FPL, which may be considered high. However, 17.3% of adults with incomes between 200% to 300% FPL experienced marginal, low, or very low food security during the past year. A sensitivity analysis showed that the results did not change when the analytic population was restricted to adults with incomes $\leq$200% FPL (results not shown). There is also the potential for unmeasured confounding by physical activity, environmental characteristics (eg, neighborhood food environment), psychosocial factors (eg, chronic stress, depression), or other correlates of having less income. Longitudinal studies that include a broad range of environmental, social, and health variables are needed to better understand the effects of prolonged food insecurity on dietary intake and subsequent health outcomes in lower-income populations.

CONCLUSIONS

Although most lower-income adults were far from meeting national guidelines for foods and nutrients important for long-term health and chronic disease prevention, there is evidence to suggest that food-insecure adults consume more of some highly palatable foods and diets of poorer quality than food-secure adults, independent of poverty and other sociodemographic differences. Poorer diet quality may be contributing to the higher risks of diet-sensitive diseases among food-insecure adults. Additional research is needed to better understand the complex interplay between food insecurity, stress, and dietary intake in this vulnerable population.

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Table 5. Associations between household food-security status and dietary quality scores stratified by sex among 8,129 adults with household incomes ≤300% federal poverty level from National Health and Nutrition Examination Survey 1999-2008

	Men				Women				*P* interaction for sex
	Mean	RD[ab]	95% CI	*P* trend[c]	Mean	RD[b]	95% CI	*P* trend[c]	
Healthy Eating Index-2005 score (100 points)									
Full food security	46.7	Ref		0.03	47.8	Ref		<0.0001	0.14
Marginal food security	46.8	0.98	0.97-1.00		47.5	0.98**	0.97-0.99		
Low food security	46.0	1.00	0.98-1.02		46.4	0.98*	0.97-1.00		
Very low food security	45.3	0.97**	0.95-0.98		45.7	0.97**	0.95-0.99		
Alternate Healthy Eating Index-2010 score (110 points)									
Full food security	33.7	Ref		0.005	36.9	Ref		<0.0001	0.25
Marginal food security	33.9	0.98	0.96-1.01		36.1	0.97**	0.96-0.99		
Low food security	33.2	0.99	0.97-1.01		35.1	0.97**	0.96-0.99		
Very low food security	32.9	0.96**	0.93-0.98		34.6	0.96**	0.93-0.98		

[a]RD=relative difference.

[b]Model adjusted for age, survey year, total energy intake, race/ethnicity, education level, marital status, household size, poverty income ratio, and smoking status. Associations are comparing marginal, low and very low food security groups to the full food security group (reference).

[c]Trend test from full multivariate model.

*$P<0.05$.

**$P<0.01$.

Table 6. Associations between household food-security status and dietary quality scores stratified by race/ethnicity among 8,129 adults with household incomes <300% federal poverty level from National Health and Nutrition Examination Survey 1999-2008

	Non-Hispanic White				Non-Hispanic Black				Hispanic				*P* interaction for race/ethnicity
	Mean	RD[ab]	95% CI	*P* trend[c]	Mean	RD[b]	95% CI	*P* trend[c]	Mean	RD[b]	95% CI	*P* trend[c]	
HEI-2005[d] score (100 points)													
Full food security	46.2	Ref		0.005	45.6	Ref		0.004	51.3	Ref		0.06	0.56
Marginal food security	45.2	0.98	0.97-1.00		45.1	0.98*	0.96-1.00		50.8	0.98*	0.97-1.00		
Low food security	43.8	0.99	0.97-1.01		44.8	0.98*	0.96-1.00		50.7	1.00	0.98-1.02		
Very low food security	43.1	0.97**	0.95-0.99		44.5	0.98*	0.95-1.00		51.2	0.97**	0.95-0.99		
AHEI-2010[e] score (110 points)													
Full food security	34.3	Ref		0.02	35.2	Ref		0.005	37.8	Ref		0.007	0.69
Marginal food security	33.6	1.00	0.97-1.02		34.2	0.98*	0.96-1.00		37.2	0.96**	0.93-0.98		
Low food security	32.3	0.99	0.96-1.01		34.0	0.98	0.96-1.00		37.3	0.98	0.96-1.01		
Very low food security	32.1	0.97*	0.94-1.00		33.8	0.95**	0.92-0.98		38.0	0.95**	0.92-0.98		

[a]RD=relative difference.
[b]Model adjusted for age, sex, survey year, total energy intake, education level, marital status, household size, poverty income ratio, and smoking status. Associations are comparing marginal, low, and very low food security groups to the full food security group (reference).
[c]Trend test from full multivariate model.
[d]HEI-2005=Healthy Eating Index-2005.
[e]AHEI-2010=Alternate Healthy Eating Index-2010.
*$P<0.05$.
**$P<0.01$.