

RESEARCH ARTICLE

People with diabetes, respiratory, liver or mental disorders, higher urinary antimony, bisphenol A, or pesticides had higher food insecurity: USA NHANES, 2005–2006

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Abstract This study was aimed to examine the prevalence of food insecurity and what social, health, and environmental characteristics could constitute such situation in a national and population-based setting. Data was retrieved from the National Health and Nutrition Examination Survey, 2005–2006. Information on demographics, lifestyle factors, self-reported ever medical conditions in the past and self-reported food security conditions in the last 12 months calculated on the household level was obtained by household interview. Bloods and urines (subsample) were collected at the interview as well. Only adults aged 20 years and above ($n=4979$) were included for statistical analysis in the present study. Chi-square test, t test, and survey-weighted logistic regression modeling were performed. Three thousand eight hundred thirty-four (77.9 %) people were with full food security, 466 (9.5 %) people were with marginal food security and 624 (12.7 %) people were with low or very low food security. Being younger, having higher ratios of family income to poverty thresholds (due to low level of education or lack of financial support), having prior asthma, arthritis, chronic bronchitis, depression, diabetes, eczema, emphysema or liver problems, having higher levels of serum cotinine, urinary antimony, bisphenol A, pesticides, or having lower levels of urinary Benzophenone-3 were associated with food insecurity. In addition to socioeconomic and smoking conditions, evidence on

people with several prior health conditions and being exposed to environmental chemicals and food insecurity is further provided. Future social, health and environmental policy, and programs protecting people from food insecurity by considering both health and environmental factors mentioned above would be suggested.

Keywords Food security · Poverty · Chemicals · Chronic disease · Adult health

Introduction

Evidence before this study

Low household income and food insufficiency (as part of food insecurity) have been observed in American children and the elderly for years (Alaimo, et al 2001; Guthrie and Lin 2002). In particular, immigrants with lower levels of education and skills, improper knowledge and learning on social integration, and consequently low income could be at risk. These have been putting them into a situation where their health and nutritional conditions could be deteriorated along the life course. While there have also been quite a few public health and nutrition programs trying to improve the suffering, individuals with physical and/or mental limitations could contribute to food insecurity due in part to the increased health expenses and the shortage of economic income as well (Brewer, et al 2010; Álvarez-Hernández, et al 2012). For example, in the USA, several chronic illnesses among patients have been recently found being associated with food affordability (perceived as part of food insecurity) (Alaimo, et al 2001; Berkowitz 2014).

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Knowledge gap

Previous studies only focused on how food insecurity could affect personal health conditions with an implication on the lack of nutrition. However, what specific social, health, and environmental characteristics of individuals have put people into the situation of food insecurity that could lead to a vicious circle of poor health and therefore premature death is unknown. Following this context, therefore, the aims of the present study were to examine the prevalence of food insecurity in the general population and to understand what social, health, and environmental characteristics could be associated with food insecurity in American adults in a national and population-based setting.

Methods

Study sample

The United States National Health and Nutrition Examination Surveys (NHANES) has been a national, population-based, multi-year, cross-sectional study since the 1980s. The sampling method was a complex, multistage probability sampling design that was used to select a sample representative of the civilian non-institutionalized household population of the USA (more details via http://www.cdc.gov/nchs/data/series/sr_01/sr01_056.pdf). It started from selecting counties or small groups of contiguous counties and then went down to a block or group of blocks containing a cluster of households. After identifying eligible households within segments, individuals within households were invited for surveying. Information on demographics, lifestyle factors, self-reported ever medical conditions in the past, and self-reported food security condition in the last 12 months calculated on the household level was obtained by household interview using questionnaires (more details via http://www.n.cdc.gov/nchs/nhanes/2005-2006/FSQ_D.htm#FSDAD). In the current analysis, the 2005–2006 cohort, being the most recent cohort with all the relevant information, was selected and included for the statistical analysis. Other later study cohorts without any of the required data were excluded (e.g., Vitamin D is available in this study cohort but not in later cohorts). Informed consents were obtained from participants by the NHANES researchers.

Biomarkers and biomonitoring

Bloods were collected in participants aged 1 year and above to measure biomarkers including vitamin D, vitamin C, serum folate (vitamin B12), serum cotinine (a marker of smoking

conditions), proteins, cholesterol, hepatitis C, glucose, and parathyroid hormone with detectable level and normal and abnormal values identified, respectively. Laboratory procedure manuals for each of these biomarkers mentioned above could be found publicly online (more details via http://www.cdc.gov/nchs/data/nhanes/nhanes_05_06/lab_d.pdf). Blood pressure (BP) was measured on all examinees 8 years and older at the household interview and for three times (more details via http://www.cdc.gov/nchs/nhanes/nhanes2009-2010/BPX_F.htm). The standard measuring protocol can be found online as well (more details via http://www.cdc.gov/nchs/nhanes/nhanes20092010/BPX_F.htm#Protocol_and_Procedure). Participants with any of the following on both arms were excluded from the exam according to the standard protocol: rashes, gauze dressings, casts, edema, paralysis, tubes, open sores or wounds, withered arms, a-v shunts, and radical mastectomy or if BP cuff does not fit on the arm. The measurements took three times. In the present study, the second BP measurement was taken when humans were at the stable state. People with ≥ 140 mmHg systolic BP and ≥ 90 mmHg diastolic BP were classified as high BP.

On the other hand, urines were only collected in a subsample (more details via http://www.cdc.gov/nchs/data/nhanes/nhanes_subsample_notes.pdf), being one third of the whole cohort (still representative), to measure environmental chemical concentrations among people aged 6 years and above. Therefore, survey weights are to be applied in the statistical modeling. Urine specimens were processed, stored under appropriate frozen (-20°C) conditions, and shipped to the Division of Environmental Health Laboratory Sciences, National Center for Environmental Health, Centers for Disease Control and Prevention for analysis. Urine specimens were processed, stored and shipped to Division of Laboratory Sciences, National Center for Environmental Health, National Centers for Disease Control and Prevention, Atlanta, Georgia.

Liquid samples are introduced into the inductively coupled-plasma mass spectrometry, a multi-element analytical technique, through a nebulizer and spray chamber carried by a flowing argon stream to detect heavy metals (Date and Gray 1989; Mulligan, et al 1990). High performance liquid chromatography-electrospray ionization-tandem mass spectrometry was used for the quantitative detection in urine of phthalate metabolites (Silva, et al 2007; Westgard, et al 1981). A sensitive method for measuring bisphenol A (BPA), Benzophenone 3 (BP-3), triclosan, parabens, and pesticides was developed to use on-line solid-phase extraction coupled to HPLC and tandem mass spectrometry (Ye, et al 2005; Ye, et al 2006). With the use of isotopically labeled internal standards, the detection limits in 100 μL of urine are 0.1–2.3 nanograms per milliliter (ng/mL), sufficient for measuring urinary levels of phenols in non-occupationally exposed subjects. Arsenic is measured through the use of inductively coupled-plasma dynamic

reaction cell-mass spectrometry (more details via http://wwwn.cdc.gov/Nchs/Nhanes/2005-2006/UAS_D.htm).

Statistical analysis

Adults aged 20 years and above were included in the current statistical analysis since chronic diseases were commonly reported in adults. In the first step, associations of social factors and food security conditions were examined by using chi-square test and survey-weighted logistic regression models. In the second step, associations of bio-markers and common listed chronic diseases and food security conditions were assessed also by performing chi-square test and survey-weighted logistic regression models. In the third step, associations of urinary environmental chemical concentrations and food insecurity

conditions were examined by employing *t* test and survey-weighted logistic regression modeling. Covariates found in the first step were included for modeling adjustment in the second and third steps. In addition, urinary concentrations were also categorized into quartile (i.e., at 25th, 50th, 75th percentile) in the subsequent modeling. All statistical effects were presented with odds ratios (OR) and with $P < 0.05$ considered statistically significant. The statistical software STATA version 13.0 (STATA, College Station, Texas, USA; more details via <http://www.stata.com/>) was used to perform all the analyses.

Ethics considerations

Since there are only secondary data analyses employed without any participant personal information identified by

Table 1 Associations between social factors and food security conditions in American adults

	Full security (<i>n</i> =3834, 77.9 %)	Marginal security (<i>n</i> =466, 9.5 %)	Low security (<i>n</i> =624, 12.7 %)	OR (95%CI)*	<i>p</i> value
Sex					
Male	1865 (79.0 %)	199 (8.4 %)	296 (12.5 %)	1.00	
Female	1969 (76.8 %)	267 (10.4 %)	328 (12.8 %)	1.14 (0.94–1.38)	0.176
Age (20–85 years)					
20–39	1341 (71.0 %)	244 (12.9 %)	305 (16.1 %)	1.00	
40–69	1708 (79.2 %)	175 (8.1 %)	275 (12.7 %)	0.68 (0.55–0.83)	0.001
70–84	628 (88.2 %)	44 (6.2 %)	40 (5.6 %)	0.37 (0.22–0.65)	0.002
85	160 (95.8 %)	3 (1.8 %)	4 (2.4 %)	0.12 (0.05–0.26)	<0.001
BMI					
<18.5	61 (77.2 %)	7 (8.9 %)	11 (13.9 %)	0.90 (0.37–2.14)	0.790
18.5–24.9	1052 (78.8 %)	112 (8.4 %)	171 (12.8 %)	1.00	
25.0–29.9	1243 (78.5 %)	150 (9.5 %)	190 (12.0 %)	0.91 (0.67–1.25)	0.546
30+	1478 (76.7 %)	197 (10.2 %)	22 (13.1 %)	1.01 (0.73–1.39)	0.962
Education					
Degree+	912 (94.0 %)	27 (2.8 %)	31 (3.2 %)	1.00	
AA degree	1131 (80.1 %)	120 (8.5 %)	161 (11.4 %)	2.54 (1.52–4.26)	0.002
High school	902 (77.4 %)	126 (10.8 %)	137 (11.8 %)	2.83 (1.82–4.39)	<0.001
9–11th grade	522 (69.4 %)	88 (11.7 %)	142 (18.9 %)	3.75 (2.45–5.74)	<0.001
<9th grade	361 (58.5 %)	105 (17.0 %)	151 (24.5 %)	5.78 (3.35–9.96)	<0.001
Ethnicity					
White	2183 (87.9 %)	133 (5.4 %)	167 (6.7 %)	1.00	
Mexican	558 (57.6 %)	188 (19.4 %)	223 (23.0 %)	3.39 (2.35–4.88)	<0.001
Black	833 (74.2 %)	114 (10.2 %)	175 (15.6 %)	2.47 (1.74–3.51)	<0.001
Other Hispanic	101 (67.8 %)	26 (17.5 %)	22 (14.8 %)	1.94 (1.18–3.20)	0.013
Other	159 (79.1 %)	5 (2.5 %)	37 (18.4 %)	1.82 (1.04–3.16)	0.036
Family PIR**					
5	1049 (94.6 %)	33 (3.0 %)	27 (2.4 %)	1.00	
0–4.99	2785 (73.0 %)	433 (11.4 %)	597 (15.7 %)	6.35 (3.32–12.17)	<0.001

*Adjusted for all the variables shown in the table and survey weighting. ORs were made in groups of non-full food security (marginal and low) compared to full food security

**A ratio of family income to poverty threshold. When removing “education” and “ethnicity” from the model, OR for family PIR became 9.58 (95%CI 5.06–18.16)

extracting statistical data from the US NHANES website in the present study, no further ethics approval for conducting the present study is required (more details via <http://www.ethicsguidebook.ac.uk/Secondary-analysis-106>).

Results

Descriptive statistics

Of all the included adult participants ($N=4979$), 3834 (77.9 %) people reported full food security. Four hundred sixty-six (9.5 %) people reported marginal food security and 624 (12.7 %) people reported low or very low food security. Associated social factors of food security conditions in

American adults are shown in Table 1. Clearly, a ratio of family income to poverty threshold, being linked with education level and ethnicity, was significantly associated with food security conditions. Interestingly, older adults seemed to have better food security, compared to other age groups. This might attribute to previous successful food programs for older adults over years.

Analytical statistics

In Table 2, associations between biomarkers and food security conditions in American adults are presented. After the full adjustment (see the footnote in Table 2), no clear significant associations were observed, except for serum cotinine (OR 1.67, 95%CI 1.25–2.24, $P=0.002$), a marker of smoking. Table 3 displays associations between health factors and food

Table 2 Associations between biomarkers and food security conditions in American adults

	Full security ($n=3834$, 77.9 %)	Marginal security ($n=466$, 9.5 %)	Low security ($n=624$, 12.7 %)	OR (95%CI)*	<i>p</i> value
Vitamin D					
<30 ng/mL	2777 (76.0 %)	384 (10.5 %)	494 (13.5 %)	1.00	
≥30 ng/mL	675 (84.3 %)	53 (6.6 %)	73 (9.1 %)	0.97 (0.72–1.31)	0.826
Serum cotinine					
<10 ng/mL	2630 (79.6 %)	315 (9.5 %)	360 (10.9 %)	1.00	
≥10 ng/mL	811 (71.1 %)	121 (10.6 %)	208 (18.3 %)	1.67 (1.25–2.24)	0.002
Vitamin C					
<2.16 ng/dL	3360 (77.2 %)	434 (10.0 %)	559 (12.8 %)	1.00	
≥2.16 ng/dL	53 (85.5 %)	2 (3.2 %)	7 (11.3 %)	1.02 (0.31–3.39)	0.973
Hepatitis C					
Positive	3379 (77.6 %)	422 (9.7 %)	552 (12.7 %)	1.00	
Negative	51 (68.0 %)	11 (14.7 %)	13 (17.3 %)	1.63 (0.86–3.08)	0.126
HDL cholesterol					
20–85 mg/dL	3238 (77.3 %)	406 (9.7 %)	545 (13.0 %)	1.00	
Abnormal	200 (79.1 %)	30 (11.9 %)	23 (9.1 %)	0.89 (0.61–1.31)	0.532
Total cholesterol					
140–400 mg/dL	3238 (78.0 %)	400 (9.6 %)	512 (12.3 %)	1.00	
Abnormal	200 (68.5 %)	36 (12.3 %)	56 (19.2 %)	1.26 (0.82–1.93)	0.263
C-reactive protein					
0–1 mg/dL	3046 (78.0 %)	374 (9.6 %)	487 (12.5 %)	1.00	
Abnormal	403 (73.8 %)	62 (11.4 %)	81 (14.8 %)	1.25 (0.86–1.81)	0.218
Apolipoprotein					
65–145/165 m mg/dL	1447 (77.1 %)	190 (10.1 %)	239 (12.7 %)	1.00	
Abnormal	178 (69.0 %)	39 (15.1 %)	41 (15.9 %)	1.16 (0.81–1.65)	0.396
Fasting glucose					
60–100 mg/dL	976 (76.4 %)	141 (11.0 %)	161 (12.6 %)	1.00	
Abnormal	662 (76.1 %)	89 (12.3 %)	119 (13.7 %)	1.26 (0.88–1.81)	0.191
Serum folate					
165–1600 pg/mL	3276 (77.9 %)	395 (9.4 %)	537 (12.8 %)	1.00	
Abnormal	106 (73.1 %)	21 (14.5 %)	18 (12.4 %)	1.06 (0.70–1.61)	0.757
Parathyroid Hormone					
18–74 pg/mL	2981 (77.2 %)	384 (10.0 %)	496 (12.9 %)	1.00	
Abnormal	453 (78.5 %)	52 (9.0 %)	72 (12.5 %)	0.91 (0.62–1.33)	0.591

*Adjusted for age, sex, education, ethnicity, and family PIR. ORs were made in groups of non-full food security (marginal and low) compared to full food security

Table 3 Associations between health factors and food security conditions in American adults

	Full security (<i>n</i> =3834, 77.9 %)	Marginal security (<i>n</i> =466, 9.5 %)	Low security (<i>n</i> =624, 12.7 %)	OR (95%CI)*	<i>p</i> value
Hypertension					
No	2936 (78.2 %)	351 (9.4 %)	467 (12.4 %)	1.00	
Yes	117 (72.7 %)	11 (6.8 %)	33 (20.5 %)	1.26 (0.80–1.99)	0.301
Asthma					
No	3344 (78.3 %)	408 (9.6 %)	517 (12.1 %)	1.00	
Yes	486 (75.0 %)	57 (8.8 %)	105 (16.2 %)	1.57 (1.21–2.04)	0.002
Eczema					
No	3587 (77.9 %)	438 (9.5 %)	582 (12.6 %)	1.00	
Yes	241 (77.4 %)	28 (9.0 %)	41 (13.2 %)	1.69 (1.28–2.22)	0.001
Cancer					
No	3479 (77.2 %)	436 (9.7 %)	592 (13.1 %)	1.00	
Yes	351 (85.0 %)	30 (7.3 %)	32 (7.8 %)	1.31 (0.96–1.79)	0.083
Chronic bronchitis					
No	3615 (78.2 %)	443 (9.6 %)	565 (12.2 %)	1.00	
Yes	211 (73.0 %)	20 (6.9 %)	58 (20.1 %)	2.01 (1.43–2.81)	0.001
Arthritis					
No	2816 (76.7 %)	372 (10.1 %)	486 (13.6 %)	1.00	
Yes	1013 (81.6 %)	92 (7.4 %)	137 (11.0 %)	1.29 (1.00–1.66)	0.051
Heart failure					
No	3679 (77.8 %)	451 (9.5 %)	598 (12.7 %)	1.00	
Yes	140 (78.2 %)	15 (8.4 %)	24 (13.4 %)	1.59 (0.71–3.54)	0.237
CHD					
No	3650 (77.6 %)	454 (9.7 %)	597 (12.7 %)	1.00	
Yes	162 (82.2 %)	10 (5.1 %)	25 (12.7 %)	0.86 (0.35–2.09)	0.726
Angina					
No	3700 (77.8 %)	449 (9.4 %)	605 (12.7 %)	1.00	
Yes	119 (77.3 %)	17 (11.0 %)	18 (11.7 %)	1.66 (0.89–3.09)	0.101
Heart attack					
No	3658 (77.8 %)	449 (9.6 %)	597 (12.7 %)	1.00	
Yes	169 (79.7 %)	16 (7.6 %)	27 (12.7 %)	1.18 (0.75–1.86)	0.441
Stroke					
No	3680 (77.9 %)	451 (9.5 %)	594 (12.6 %)	1.00	
Yes	149 (78.0 %)	14 (7.3 %)	28 (14.7 %)	1.52 (0.85–2.72)	0.141
Depression					
No	1903 (77.9 %)	245 (10.0 %)	294 (12.0 %)	1.00	
Yes	201 (56.3 %)	45 (12.6 %)	111 (31.1 %)	2.57 (1.84–3.57)	<0.001
Diabetes					
No	3378 (77.1 %)	412 (9.5 %)	537 (12.4 %)	1.00	
Yes	382 (75.4 %)	48 (9.5 %)	77 (15.2 %)	1.32 (1.01–1.72)	0.042
Emphysema					
No	3755 (78.0 %)	454 (9.4 %)	608 (12.6 %)	1.00	
Yes	71 (72.5 %)	12 (12.2 %)	15 (15.3 %)	2.38 (1.24–4.58)	0.013
Liver problem					
No	3708 (78.0 %)	447 (9.4 %)	598 (12.6 %)	1.00	
Yes	119 (73.9 %)	17 (10.6 %)	25 (15.5 %)	2.06 (1.13–3.79)	0.022
Thyroid					
No	3449 (77.4 %)	432 (9.7 %)	577 (12.9 %)	1.00	
Yes	375 (82.4 %)	34 (7.5 %)	46 (10.1 %)	1.13 (0.75–1.70)	0.532

*Adjusted for age, sex, education, ethnicity, and family PIR. ORs were made in groups of non-full food security (marginal and low) compared to full food security

security conditions in American adults. Among all the included common chronic diseases, people who had had asthma, chronic bronchitis, arthritis, depression, diabetes, eczema, emphysema, and liver problems previously were more likely to report non-full food security (marginal or low). This might indicate that people with any of these existing health conditions are more likely to have a lower chance of getting a proper job and consequently receiving appropriate economic income to sustain food security and nutrition.

In Table 4, associations between urinary environmental chemicals and food security conditions were modeled. It was observed that people with higher levels of urinary antimony, BPA, and pesticides concentrations tended to have marginal or low food security. People with lower level of urinary BP3, a chemical mainly used for sun protection, were observed to have low food security as well. There were no other clear significant associations found in other chemicals including arsenic, parabens, and phthalates (data not shown). In the subsequent analysis of categorizing urinary chemical concentrations into quartile, the results are very much similar as shown in Table 4 with continuous values in the modeling (data not shown).

Discussion

Health and food security

Consistent with a previous study using data from NHAENS 1999–2002, smoking is a more apparent associated social factor for food insecurity than physical performance (Xu, et al 2011). Although another previous study using data from NHANES 1999–2004 among participants aged 18–65 years showed hypertension and hyperlipidemia but not diabetes as associated health factors for food insecurity (Seligman, et al 2010), the present study using data from NHANES 2005–2006 among participants aged 20–85 years showed the opposite. The methodological concerns and consequently the bias in results from that study were addressed in another paper (Tayie and Zizza 2010). A later cardiovascular-risk study using data from NHANES 2003–2008 among participants aged 20–85 years presented the consistent results with those in the present study—smoking was related while hypertension, cholesterol, or proteins are not (Ford 2013).

A Canadian study using adult patients observed that patients using diabetes services had a higher risk of food

Table 4 Associations between environmental chemicals and food security conditions in American adults

(ng/mL)	Full security (<i>n</i> =3834, 77.9 %)	Marginal and low security (<i>n</i> =1090, 22.1 %)	OR (95%CI)*	<i>p</i> value
Heavy metals				
Barium	2.27±4.06	2.26±4.27	1.03 (0.87–1.21)	0.745
Beryllium	0.005±0.001	0.005±0.001	5.66 (0.19–171.71)	0.296
Cadmium	0.42±0.46	0.42±0.46	1.19 (0.99–1.42)	0.060
Cobalt	0.54±1.09	0.81±2.70	1.13 (0.89–1.42)	0.290
Cesium	5.80±4.46	5.67±3.50	1.08 (0.86–1.36)	0.459
Molybdenum	58.68±52.20	63.38±54.67	1.07 (0.81–1.40)	0.618
Lead	0.88±0.87	1.21±2.03	1.10 (0.92–1.32)	0.260
Platinum	0.68±20.40	1.43±25.83	0.97 (0.62–1.52)	0.901
Antimony	0.10±0.15	0.14±0.25	1.28 (1.00–1.63)	0.046
Thallium	0.19±0.13	0.20±0.15	1.06 (0.83–1.36)	0.615
Tungsten	0.14±0.31	0.18±0.37	1.13 (0.95–1.35)	0.155
Uranium	0.01±0.02	0.01±0.03	1.16 (0.90–1.49)	0.229
Bisphenols				
4-tert-octylphenol	0.21±2.06	0.15±0.09	0.89 (0.43–1.85)	0.744
Benzophenone-3	320.16±1564.72	161.08±759.47	0.93 (0.87–0.99)	0.021
Bisphenol A	3.78±13.62	3.95±9.96	1.18 (1.01–1.36)	0.034
Triclosan	136.44±388.39	152.38±341.60	0.94 (0.87–1.02)	0.119
Pesticides				
2,5-dichlorophenol	191.17±1122.54	225.36±855.68	1.01 (0.90–1.13)	0.834
O-phenyl phenol	0.21±1.23	0.19±0.80	0.94 (0.70–1.26)	0.651
2,4-dichlorophenol	6.01±32.27	6.69±24.61	1.04 (0.94–1.16)	0.423
2,4,5-trichlorophenol	0.15±0.29	0.16±0.38	1.28 (1.04–1.57)	0.022
2,4,6-trichlorophenol	0.66±2.86	0.86±2.57	1.44 (1.07–1.93)	0.019

*Adjusted for age, sex, education, ethnicity, family PIR, and urinary creatinine

insecurity (Galesloot, et al 2012). The 2011 national health interview survey with patients aged 20 years and above showed that self-reported asthma, arthritis, and respiratory conditions were associated with food insecurity (Berkowitz 2014). These observations were consistent with those obtained in the present study. Although there have been numerous studies previously concluded how food insecurity could lead to depression because of the chronic and continuous worries, little attention was paid to adults who had had depression prior to food insecurity condition in real life since they could be less likely to secure jobs to support themselves and their families (Laraia, et al 2009). Apart from those health conditions mentioned above, the present study additionally observed that people with prior emphysema and liver problems were more likely to report food insecurity in the household as well.

Environmental chemicals and food security

The relationship of different sets of urinary chemicals and food insecurity in the general population is the first being explored in the present study. In a previous experimental study, tissue antimony level was observed being associated with liver problems in rats (Poon, et al 1998). Following such observation, the association of urinary antimony and food insecurity found in the present study is likely via liver disorder. In particular, both urinary antimony and liver disorder were associated with food insecurity in the current analysis. The linkage of BPA and food insecurity is not new (Nelson, et al 2012), and it might be due to the wide use in food containers when cheap canned food is mostly purchased and consumed by people with limited finance (Viberg and Lee 2012). Consistently, there was a significant association found in the present study as well that might suggest the similar mechanism. On the other hand, exposure to pesticides was linked to food insecurity in Brazilian temporary farming workers that is also consistent with the finding obtained in the present study (Carneiro, et al 2008). The similar mechanism might be due to low finance in the household and neighborhood and therefore the environmental and occupational exposure at workplace. Apart from those chemicals mentioned above, the present study additionally observed that people with lower urinary BP3 were more likely to report food insecurity in the household as well. The implication might indicate less financial expense to purchase sun protection.

Strengths and limitations

The present study has a few strengths. Firstly, it was conducted in a large study sample from across the USA with different ethnicities and socioeconomic levels. Secondly, it was the first time to examine what specific biomarkers, social, health, and environmental characteristics could be associated with food insecurity in the household. However, there are also a few

limitations worthy of being noted. First, only common health problems and traceable urinary environmental chemicals were included in the current dataset. In other words, other uncommon health conditions and/or unknown environmental chemicals that could also be linked to food insecurity were unable to be examined. Second, food insecurity condition could be passed down over generations within the family tree owing to the similar lifestyle pattern and knowledge learning level. In the current dataset, however, it was not possible to assess this because of the lack of such generational data. Third, the causation cannot be drawn due to the study design being cross-sectional in nature. Taken together, future research keeping the strengths and overcoming the limitations mentioned above with a longitudinal or experimental approach to find out the mechanism would be warranted.

Research, practice, and policy implications

In addition to socioeconomic and smoking conditions that are linked to food insecurity, evidence on prior asthma, arthritis, depression, diabetes, chronic bronchitis, emphysema, liver problems and urinary antimony, BP3, BPA, and pesticides that could also play a role in food insecurity is now further provided. In spite of the pathway from food insecurity to health conditions, the situation where the existing health conditions could further result in loss of adherence to medication making it a vicious circle (Sattler and Lee 2013). These could come together and lead to premature deaths. Future social, health, and environmental policy and programs protecting people from food insecurity by further considering both health and environmental factors mentioned above would be suggested.

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Compliance with ethical standard

Conflict of interest The author declared no conflict of interest.

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