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RESEARCH ARTICLE

Food Insecurity and Health Care Expenditures in the United States, 2011–2013

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Objective. To determine whether food insecurity, limited or uncertain food access owing to cost, is associated with greater health care expenditures.

Data Source/Study Setting. Nationally representative sample of the civilian noninstitutionalized population of the United States (2011 National Health Interview Survey [NHIS] linked to 2012–2013 Medication Expenditure Panel Survey [MEPS]).

Study Design. Longitudinal retrospective cohort.

Data Collection/Extraction Methods. A total of 16,663 individuals underwent assessment of food insecurity, using the 10-item adult 30-day food security module, in the 2011 NHIS. Their total health care expenditures in 2012 and 2013 were recorded in MEPS. Expenditure data were analyzed using zero-inflated negative binomial regression and adjusted for age, gender, race/ethnicity, education, income, insurance, and residence area.

Principal Findings. Fourteen percent of individuals reported food insecurity, representing 41,616,255 Americans. Mean annualized total expenditures were $4,113 (standard error $115); 9.2 percent of all individuals had no health care expenditures. In multivariable analyses, those with food insecurity had significantly greater estimated mean annualized health care expenditures ($6,072 vs. $4,208, $p < .0001$), an extra $1,863 in health care expenditure per year, or $77.5 billion in additional health care expenditure annually.

Conclusions. Food insecurity was associated with greater subsequent health care expenditures. Future studies should determine whether food insecurity interventions can improve health and reduce health care costs.

Key Words. Food insecurity, health expenditures, socioeconomic status, diabetes, cardiovascular disease, cardiovascular disease, hypertension

In 2014, food insecurity affected approximately 49 million Americans in 17.4 million U.S. households, or 14 percent of the population (Coleman-Jensen et al. 2015). A growing body of evidence links food insecurity—limited

or uncertain access to adequate food (Coleman-Jensen et al. 2015)—with common, costly, and preventable chronic conditions, including obesity, hypertension, and type 2 diabetes (Cook et al. 2004; Seligman et al. 2007, 2010a, 2012; Gundersen and Kreider 2009; Seligman, Laraia, and Kushel 2010b; Castillo et al. 2012; Berkowitz et al. 2013, 2015; Coleman-Jensen Alisha and Nord Mark 2013; Gundersen and Ziliak 2013, 2015; Berkowitz, Gao, and Tucker 2014a; Mayer et al. 2015; Moreno et al. 2015; Wang et al. 2015; Morales and Berkowitz 2016). The relationship between food insecurity and chronic disease is likely bidirectional (Seligman and Schillinger 2010; Berkowitz and Fabreau 2015): Poor health may make it harder to work, leading to lower income and increasing risk of food insecurity; conversely, food insecurity may incentivize purchases of cheaper but less healthy foods, or trade-offs between medications and health care to purchase food (Berkowitz, Seligman, and Choudhry 2014b), leading to chronic disease, poor mental health (Heflin, Siefert, and Williams 2005), and poorer disease self-management.

Interest is growing in addressing social determinants of health as way to achieve the "triple aim" of health care—better health, better patient experience, and lower costs (Berwick, Nolan, and Whittington 2008; Woolf and Purnell 2016). This interest is exemplified by the Accountable Health Communities model recently proposed by the Centers for Medicare & Medicaid Services (CMS), which notes food insecurity as a key area for intervention (Alley et al. 2016). This assumes that alleviating food insecurity—by health care delivery systems, insurers, or social service organizations—would help mitigate the morbidity and costs of many chronic diseases. However, the extent to which food insecurity is associated with excess health expenditures is unknown. In our conceptual model (Seligman and Schillinger 2010), food insecurity may worsen health and increase health care expenditures through several mechanisms, including worse diet, food-medication trade-offs, and reduced "bandwidth" to manage complex chronic conditions. These factors

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may increase both the prevalence of health conditions and their severity when they develop. However, the relationship between food insecurity and health care costs may be confounded by issues of decreased health care access (if those with food insecurity have lower income and are less likely to have health insurance) and age. To help understand these issues, we sought to determine the relationship between food insecurity and health care expenditures in a nationally representative sample. We hypothesized that food insecurity, accounting for potential confounders, would be associated with higher subsequent health care expenditures.

METHODS

Data Source and Study Sample

Data for this study come from the National Health Interview Survey (NHIS) linked to the Medical Expenditure Panel Survey (MEPS). NHIS is a cross-sectional, nationally representative survey used for epidemiologic surveillance, conducted by the Centers for Disease Control and Prevention's National Center for Health Statistics (Centers for Disease Control and Prevention). In 2011, NHIS first asked questions about food insecurity. A nationally representative subset of NHIS participants are selected to participate, for the 2 years after their NHIS participation, in MEPS, a longitudinal survey conducted by the Agency for Healthcare Research and Quality to gather national health care expenditure data (Agency for Healthcare Research and Quality). We included all NHIS participants with food insecurity assessment in 2011 who participated in MEPS in 2012 and 2013 ($N = 16{,}663$).

The Human Research Committee at Partners Health care exempted this analysis of deidentified data from human subjects review.

Measures

Individuals were categorized as food insecure using a validated 10-item questionnaire with a 30-day look-back period, which the USDA sponsored for inclusion in the NHIS to help understand the relationship between food insecurity and health (Coleman-Jensen et al. 2015; United States Department of Agriculture Food and Nutrition Service 2015; Centers for Disease Control and Prevention). As examples, items queried, "if the family was worried about food running out before there was money to buy more" or "if the food purchased just didn't last until there was money to buy more" (full questionnaire

available at ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Survey_Questionnaires/NHIS/2011/English/qfamily.pdf) (Centers for Disease Control and Prevention). Using standard scoring, those who answered affirmatively to two or more items were considered food insecure (Centers for Disease Control and Prevention). The NHIS and MEPS were administered by trained interviewers in English or Spanish (Agency for Healthcare Research and Quality; Centers for Disease Control and Prevention).

Outcomes

Our primary outcome was total health care expenditure from 2012 through 2013, converted to 2015 U.S. dollars using the Consumer Price Index (http://data.bls.gov/cgi-bin/cpicalc.pl). Total health care expenditure is defined as the actual amount spent by individuals or paid by third parties on their behalf: "expenditures in MEPS are comprised of direct payments for care provided during the year, including out-of-pocket payments and payments by private insurance, Medicaid, Medicare, and other sources"(Agency for Healthcare Research and Quality). Secondary outcomes included expenditures within the following MEPS categories: outpatient expenditures (both office-based and hospital-based outpatient), emergency department expenditures (excluding those resulting in an inpatient admission), inpatient expenditures (including emergency department spending for that admission), and prescription medication expenditures (Agency for Healthcare Research and Quality).

Demographic, Socioeconomic, and Clinical Variables

We included several potential confounders in our multivariable regressions of food insecurity and health care expenditures to account for factors potentially associated with food insecurity, health care expenditures, or both, and to try to isolate, to the extent possible, the role of food insecurity (rather than poverty more broadly). In particular, differences in age and insurance status are strong negative confounders (Berkowitz et al. 2013; Berkowitz, Seligman, and Choudhry 2014b) that need to be accounted for to accurately understand the relationship between food insecurity and health care expenditures. Age, in years as a continuous variable, was taken from NHIS data; because health and health care expenditures may have a curvilinear relationship with age (Lehnert et al. 2011), we also included an age-squared term. Other covariates collected from the NHIS dataset included gender (male or female),

race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and Asian/multiracial/other), educational attainment (less than high school diploma, high school diploma, greater than high school diploma), and household income (expressed as a percentage of the federal poverty level, which accounts for household size), and health insurance categorized as private, Medicare (not including Medicare–Medicaid "dual eligibles"), other public (including Medicaid, "dual eligibles," and coverage through the Department of Veterans Affairs), and uninsured. Because place of residence is associated with variation in health care spending (Sutherland, Fisher, and Skinner 2009), we also included an indicator of living in a rural versus urban area (defined by living in a Metropolitan Statistical Area).

Medication Expenditure Panel Survey includes detailed questions regarding several "priority" health conditions, including diabetes, hypertension, and heart disease (Agency for Healthcare Research and Quality). Because these conditions are thought to be closely related to food insecurity (Seligman, Laraia, and Kushel 2010b), we conducted prespecified subgroup analyses focusing on individuals who reported these conditions using validated self-report items in MEPS (Agency for Healthcare Research and Quality). Diabetes was defined as self-report of having been diagnosed with diabetes by a doctor. Hypertension was defined as self-report of having been diagnosed with high blood pressure by a doctor. Heart disease was defined as having been diagnosed with coronary heart disease, angina, myocardial infarction, or other unspecified heart disease by a doctor. Owing to issues of age penetrance, MEPS only asks these questions of respondents aged >17 years, so analyses of these conditions were restricted to adults.

Statistical Analysis

We first conducted descriptive statistics, applying sampling weights to estimate population-representative numbers. Differences in health care expenditures between individuals who did and did not report food insecurity were examined using chi-square testing for dichotomous variables and Wilcoxon testing for continuous variables.

A major concern when attempting to answer the question of whether food insecurity is associated with greater health care expenditures is that conditions associated with food insecurity, such as lack of health insurance and low income, may lessen the ability of those with food insecurity to access health care and thus generate expenditures. Therefore, we conducted multivariable regression analyses that adjusted for income, health insurance, age,

age-squared, race/ethnicity, education, and rural residence, in order to obtain a more accurate understanding of the independent association between health care expenditures and food insecurity. There are many options for analyzing expenditure data, which is often highly skewed, overdispersed (i.e., the variance is greater than the mean), and inclusive of a high proportion of individuals with no expenditures. We considered several commonly used options, including generalized linear models with Poisson, negative binomial, or gamma distributions, ordinary least-squares regression, and a two-part model with an initial logistic model to predict any occurrence of expenditures, followed by least-squares regression of log-transformation of expenditures, conditional on having expenditures (Manning and Mullahy 2001; Basu and Manning 2009). We examined model residuals and conducted a modified Park test to aid in model selection (Manning and Mullahy 2001). Ultimately, we used zero-inflated negative binomial regression for our main analyses (Austin, Ghali, and Tu 2003; Cameron and Trivedi 2010; Akbarzadeh Baghban et al. 2013). This modeling approach considers that two processes may be occurring simultaneously: one that generates expenditures, including zero expenditures in some cases (e.g., illness requiring medical care, or lack thereof), and a separate process that can reduce the likelihood of expenditures even if they would otherwise occur, leading to what is sometimes called "excess zero" expenditures (e.g., inability to access health care). An advantage of this approach, compared with estimating expenditure contingent on having greater than zero spending, is that observations with true zero expenditures are still analyzed. Zero-inflated negative binomial regression models estimate the probability of having "excess zero" health care expenditures (using a logistic model) and the expenditure count (using a negative binomial model). The logistic regression part of the zero-inflated negative binomial model allows us to test, after adjustment, whether "excess zero" expenditures, that is, zero expenditure observations that occur with greater frequency than would be expected based on the distribution of the data, are more likely to occur in those with versus without food insecurity. A nonsignificant difference in the odds of "excess zero" expenditures indicates that, after adjustment, both groups are similarly able to generate health care expenditures.

Our primary focus when constructing our models was to adjust for factors that may confound the relationship between food insecurity and health care expenditures. Therefore, we included, as covariates, potentially confounding factors, in order to reduce bias in the estimates of the association between food insecurity and health care expenditures. The model coefficients for these potential confounders may remain biased. For example, health

insurance, which was included to adjust for confounding introduced by health insurance status (both through its direct effect on health care expenditures and as a proxy indicator for being "sicker" in some way), may remain biased. Since estimating the association between these other factors and health care expenditures was not our main goal, we viewed this as an acceptable trade-off in order to obtain less biased estimates of the association between food insecurity and health care expenditures.

To aid understanding of the data, we estimated adjusted annualized expenditures and per-year difference in health care expenditures for individuals at different levels of food insecurity using the regression models and the margins command in Stata and estimated total annual excess costs in the USA (Barber and Thompson 2000). The postregression margins command allowed us to estimate the expected expenditure difference between those with and without food insecurity, after potential confounders, including differences in access to health care, have been taken into account. Finally, we evaluated the possibility of an interaction between food insecurity and health insurance, evaluated the relationship between food insecurity and health care expenditures without adjusting for health insurance, given nonrandom selection into health insurance (Nicholson et al. 2004; Deb and Trivedi 2006; Shen et al. 2008; Hackmann, Kolstad, and Kowalski 2012), and conducted sensitivity analyses restricted to adults.

A p-value $<.05$ indicated statistical significance for the primary hypothesis. Analyses were conducted in *SAS* version 9.4 (SAS Institute, Cary, NC, USA) and *Stata/SE* version 14.0 (StataCorp LP, College Station, TX, USA). All analyses incorporated survey design and sampling weights in their estimation of standard errors, confidence intervals, and p-values, in accordance with MEPS documentation (Agency for Healthcare Research and Quality).

RESULTS

Of 16,663 individuals eligible for analysis, 14.0 percent reported food insecurity in the 2011 NHIS, representing approximately 41,616,255 Americans. Food insecurity was more common among younger individuals, racial/ethnic minorities, those with lower education and income, and those with public health insurance or who lacked insurance (Table 1). The mean and median annualized total expenditures among all individuals were $4,113.30 (standard error [SE] $115.36) and $1,108.17 (interquartile range [IQR] $219.09 to

Table 1: Demographics

	Total % (n) or Mean (SE)	*Food Secure* % (n) or Mean (SD)	*Food Insecure* % (n) or Mean (SD)	*p-Value*
Age (years)	37.1 (0.3)	37.9 (0.4)	32.1 (0.6)	<.0001
Age categories				
0–17	23.5 (4,604)	22.9 (3,611)	27.6 (991)	<.0001
18–64	63.8 (10,235)	63.2 (8,335)	66.9 (1,896)	
65 and greater	12.7 (1,551)	13.9 (1,390)	5.5 (160)	
Female	51.5 (8,769)	51.3 (7,068)	52.7 (1,695)	.21
Race/ethnicity				
Non-Hispanic white	64.1 (5,815)	66.1 (5,095)	51.7 (719)	<.0001
Non-Hispanic black	12.4 (3,542)	11.3 (2,665)	18.9 (875)	
Hispanic	16.9 (5,664)	15.4 (4,286)	26.1 (1,374)	
Asian/multi-/other	6.7 (1,612)	7.3 (1,482)	3.3 (130)	
Educational attainment				
< High school diploma	30.5 (5,966)	28.6 (4,490)	42.6 (1,473)	<.0001
High school diploma	21.6 (3,202)	20.9 (2,577)	25.7 (625)	
>High school diploma	47.9 (5,891)	50.4 (5,203)	31.7 (687)	
Income				
<100% FPL	15.1 (3,692)	11.5 (2,327)	36.9 (1,362)	<.0001
100–199% FPL	18.9 (3,462)	16.5 (2,564)	34.0 (898)	
≥200% FPL	66.0 (7,823)	72.1 (7,235)	29.1 (587)	
Census region				
Northeast	17.7 (2,790)	17.7 (2,296)	17.5 (491)	.16
Midwest	21.7 (2,955)	22.0 (2,446)	19.6 (508)	
South	37.2 (6,092)	36.4 (4,809)	42.3 (1,281)	
West	23.4 (4,784)	23.9 (3,967)	20.5 (816)	
Rural residence	14.3 (2,005)	13.9 (1,587)	16.9 (418)	.17
Insurance				
Private	63.0 (7,920)	67.6 (7,226)	34.1 (692)	<.0001
Medicare	7.7 (1,108)	7.7 (880)	8.1 (228)	
Other public	14.1 (3,725)	11.6 (2,592)	29.5 (1,131)	
Uninsured	15.3 (3,317)	13.2 (2,404)	28.3 (911)	
Health conditions[†]				
Diabetes	8.5 (1,160)	7.9 (892)	11.7 (268)	<.0001
Hypertension	35.5 (4,224)	35.1 (3,410)	38.0 (814)	.12
Heart disease	15.7 (1,630)	15.2 (1,302)	18.6 (327)	.02

Note: % presented are weighted, not directly calculable from N.
[†]Restricted to individuals aged > 17 years.
FPL, federal poverty level.

$3,993.07), respectively (Figure S1). Overall, 9.2 percent of individuals had no health care expenditures during the study period (food insecure, 13.2 percent; food secure, 8.6 percent, $p < .0001$). Unadjusted annualized mean and median health care expenditures were $4,382.64 (SE $329.98) and $1,648.19 (IQR $284.12 to $7,050.56) for food insecure individuals versus $4,070.48

(SE $113.24) and $2,296.63 (IQR $523.67 to $8,100.38) for food secure individuals, respectively. Annually, an estimated $182.4 billion in health care spending occurred among individuals with food insecurity.

In multivariable regressions (Table 2, full models in Table S1) adjusted for age, age-squared, race/ethnicity, education, income, rural residence, and health insurance category, those with food insecurity had significantly greater health care expenditures: $6,071.60 (95 percent confidence interval [CI] $5,144.92 to $6,998.28) for those with food insecurity, compared with $4,208.43 (95 percent CI $3,976.07 to $4,437.79) for those without. The adjusted model estimates that food insecurity was associated with an extra $1,863.17 in health care expenditure per person per year ($p < .0001$). This difference in expenditures, multiplied by 41,616,255 food insecure Americans, represents approximately $77.5 billion in additional health care costs, compared with what would be expected for demographically similar individuals without food insecurity, if the relationship between food insecurity and expenditures were causal. We did not observe evidence that food insecure individuals were prevented from generating health care expenditures (OR of "excess zero" expenditures 0.93, 95 percent CI 0.72 to 1.21). Results restricted to adults (age > 18 years) were similar (Tables S2a, b). We found no evidence of an interaction between food insecurity status and health insurance coverage ($p = .84$), but we observed the largest incremental difference by insurance

Table 2: Total Expenditure

	Odds of "Excess Zero" Expenditures		*Incidence Rate of Expenditures*		*Expenditure Estimates*		
	OR	*95% Confidence Interval*	*IRR (95% CI)*	*p-Value*	*Annualized Estimated Expenditures*	*95% Confidence Interval*	*Annualized Difference*
Food insecure	0.93	0.72–1.21	1.44 (1.24–1.67)	<.0001	$6,071.60	$5,144.92 to $6,998.28	$1,863.17
Food secure	ref	–	ref	–	$4,208.43	$3,976.07 to $4,437.79	–

Notes: Estimates adjusted for age, age-squared, gender, race/ethnicity, education, income, rural residence, and insurance. Estimated expenditures in 2015 dollars.
Interpretation note: an odds ratio greater than 1 represents evidence of a process that prevents expenditures (e.g., inability to access health care). An incidence rate ratio greater than 1 represents evidence of greater expenditures in a group, compared with a referent group. Information from both models is used to estimate annual expenditures.
Ref, reference category.

category between food insecure and food secure individuals with regard to health care spending among Medicare beneficiaries (Figure S2).

When examining categories of expenditures, we found significant differences between those with and those without food insecurity (Table 3, full models in Tables S3a–d). Individuals reporting food insecurity had significantly greater expenditures than food secure individuals for inpatient hospitalizations ($493.41 greater per year, $p = .03$) and prescription medications ($779.36 greater per year, $p < .0001$). Expenditure differences for food insecure individuals were not statistically significant for outpatient ($154.34 greater per year, $p = .07$) and emergency department expenditures ($91.46 greater per year, $p = .51$).

Among those with conditions previously associated with food insecurity, food insecure individuals with diabetes had $4,413.61 higher estimated annualized total health care expenditures than food secure individuals with diabetes (annualized total expenditure $13,035.16 vs. $8,621.55, $p = .004$) (Table 4, full models in Tables S4a–c). Similarly, food insecure individuals with hypertension had $2,175.51 higher annualized costs than food secure individuals with hypertension (annualized total expenditure $8,134.71 vs. $5,959.21, $p = .003$), and food insecure individuals with heart disease had $5,144.05 higher annualized costs than food secure individuals with heart disease (annualized total expenditure $12,984.17 vs. $7,840.12, $p = <.0001$).

Alternative modeling specifications for total expenditures (generalized linear model with gamma distribution, ordinary least squares, or two-part log-transformed modeling) did not differ substantially from our main model (Table S5). Modeling total expenditures without health insurance in the model resulted in an estimate difference of $1681.07 more (95 percent CI $788.78 to $2573.37) health care spending per year in food secure, compared with food insecure, participants (full model in Table S6).

DISCUSSION

In this study of 16,663 individuals in the 2011 NHIS who underwent food insecurity assessment and subsequently enrolled in MEPS, food insecurity was associated with approximately $1,800 higher health care expenditures per year, after adjusting for age, gender, race/ethnicity, education, income, insurance, and residence area. Individuals with food insecurity were particularly more likely to incur expenditures for inpatient hospitalizations and prescription medications. The expenditure difference between those with and

Table 3: Estimated Expenditures by Spending Category

	Outpatient			*Emergency Department*			*Inpatient*			*Prescription Medication*		
	Annualized Estimated Expenditure (95% CI), $	*Annualized Difference, $*	*p-Value*	*Annualized Estimated Expenditure (95% CI), $*	*Annualized Difference, $*	*p-Value*	*Annualized Estimated Expenditure (95% CI), $*	*Annualized Difference, $*	*p-Value*	*Annualized Estimated Expenditure (95% CI), $*	*Annualized Difference, $*	*p-Value*
Food insecure	576.60 (417.22–735.99)	154.34	.07	271.96 (201.74–342.18)	91.46	.512	1587.49 (1149.85–2025.14)	**493.41**	.03	1776.59 (1472.03–2081.15)	**779.36**	<.0001
Food secure	422.26 (377.42–467.10)	–		180.50 (164.58–196.42)	–		1094.09 (958.73–1229.44)	–		997.23 (897.52–1096.95)	–	

Notes: Estimates adjusted for age, age-squared, gender, race/ethnicity, education, income, rural residence, and insurance. Estimated expenditures expressed in 2015 dollars.
Bold indicates significant at $p < .05$.

Table 4: Total Expenditures by Condition

	Odds of "Excess Zero" Expenditures	*Incidence Rate of Expenditures*	*Expenditure Estimates*		
	OR (95% CI)	*IRR (95% CI)*	*Annualized Estimated Expenditure (95% CI)*	*Annualized Difference*	*p-Value*
Diabetes mellitus[†]					
Food insecure	2.69 (0.57–12.73)	1.52 (1.14–2.02)	$13,035.16 ($9,527.01 to $16,543.30)	$4,413.61	.004
Food secure	Ref	Ref	$8,621.55 ($7,274.23 to $9,968.87)	–	–
Hypertension[†]					
Food insecure	0.63 (0.29–1.36)	1.35 (1.11–1.65)	$8,134.71 ($6,596.09 to $9,673.34)	$2,175.50	.003
Food secure	Ref	Ref	$5,959.21 ($5,462.33 to $6,456.09)	–	–
Heart disease[†]					
Food insecure	0.72 (0.26–2.01)	1.65 (1.29–2.10)	$12,984.17 ($9,988.35 to $15,979.99)	$5,144.05	<.0001
Food secure	Ref	Ref	$7,840.12 ($6,813.83 to $8,866.41)	–	–

Notes: Estimates adjusted for age, age-squared, gender, race/ethnicity, education, income, and insurance. Estimated expenditures in 2015 dollars.
Interpretation note: an odds ratio greater than 1 represents evidence of a process that prevents expenditures (e.g., inability to access health care). An incidence rate ratio greater than 1 represents evidence of greater expenditures in a group, compared with a referent group. Information from both models is used to estimate annual expenditures.
[†]Analysis conducted among those reporting the condition.
IRR, incident rate ratio; OR, odds ratio; Ref, reference category.

without food insecurity was even greater in chronic diseases that have been associated with food insecurity: diabetes, hypertension, and heart disease (Seligman, Laraia, and Kushel 2010b). This finding lends support to the idea of a causal relationship between food insecurity and health care expenditures. The difference between the unadjusted and adjusted results suggests that the unadjusted association between food insecurity and health care expenditures is likely confounded, for example, by issues of age and health care access, and the adjusted association more accurately reflects the true relationship.

This study is consistent with prior work and enhances our understanding of food insecurity and health. A recent cross-sectional study conducted in Ontario, Canada (Tarasuk et al. 2015), found an association between food insecurity and health care costs similar in magnitude to what we observed in this study. Because of universal health care coverage in Ontario, those findings are likely more comparable to an insured U.S. population than the entire U.S.

population. While the data in our study were mainly collected before implementation of the Affordable Care Act's health insurance coverage mandate (Sommers et al. 2015), results from the Canadian study suggest that improvements in health insurance coverage in the United States are unlikely to close the gap in health care expenditures between those with and without food insecurity.

Another recent study (Sonik 2016) found that increases in Medicaid spending for those in Massachusetts with conditions thought to be related to food insecurity, including diabetes and malnutrition, declined after a temporary increase in Supplemental Nutrition Assistance Program (SNAP) benefits, a federal nutrition program known to reduce the depth, breadth, and severity of food insecurity (White House Council of Economic Advisors 2015; United States Department of Agriculture Food and Nutrition Service 2016). Because the study was ecological in nature, however, it is unknown whether the decreased spending occurred in those experiencing food insecurity or enrolled in the SNAP program. Still, these results are consistent with our finding that food insecurity is associated with significant increases in health care expenditures, and they suggest that addressing food insecurity may lead to health care savings.

More individuals with food insecurity had zero expenditures, likely due to younger age in this population, but we did not find evidence of a process that prevented expenditures. However, food insecurity is associated with a different distribution of expenditures: shifted toward costly inpatient and prescription medication spending.

We do not know whether the association between food insecurity and increased health care spending is causal, and we do not know whether improving food insecurity will reduce health care expenditure. However, such a causal connection is plausible, and these results do at least suggest the potential for significant savings if expenditure patterns in those reporting food insecurity could be changed to resemble those without it. Therefore, we believe reduction in health care expenditure should be evaluated in future studies of food insecurity interventions. Further, even if the excess expenditures observed are due solely to underlying conditions that also led to food insecurity, food insecurity would remain an important marker for individuals likely to have high subsequent costs.

The results of this study have significant implications for public health and health policy. With decades of research demonstrating that "social determinants of health," including food insecurity, have a profound influence on health and health care costs, policy makers and health care providers are

increasingly seeking actionable "levers" to help individuals and populations pursue better health, better patient experience, and lower costs (Alley et al. 2016; Woolf and Purnell 2016). The finding that food insecurity is particularly associated with inpatient and prescription medication expenditures is consistent with the idea that people facing food insecurity may defer attending to their health in the presence of pressing immediate needs, which in turn leads their health conditions to worsen. As such, food insecurity interventions have the potential to improve health not only by improving dietary quality, but also by improving mental health, medication adherence, and by freeing up financial and cognitive resources for health maintenance and chronic disease management.

Recent changes in health care financing may permit food insecurity interventions to become part of health care delivery. A recent Internal Revenue Service rule interpreting the Affordable Care Act (Rosenbaum 2015) specifically permits hospitals to count the cost of nutrition-related interventions as community benefit spending when supported by a community needs assessment, and CMS's Accountable Health Communities model (Alley et al. 2016) may lead the way to including food security interventions as covered health insurance benefits.

The mechanisms whereby food insecurity may increase health care costs include dietary intake, medication adherence, and reduce cognitive bandwidth for disease self-management (Seligman and Schillinger 2010; Wright et al. 2015). If these mechanisms only increase costs over a long timeframe, insurers and health care systems that typically cover beneficiaries for short time periods would have little financial incentive to address food insecurity. It is therefore notable that we observed significantly greater health care expenditures in this study over a brief 2-year timeframe. Because we do not yet know whether addressing food insecurity would bring the health care expenditures of food insecure individuals closer to those of food secure individuals, it may still be true that addressing food insecurity does not reduce health care costs. However, with an estimated $77 billion in excess expenditures among those with food insecurity, there is significant potential for a "return on investment" in food insecurity reduction programs.

The results of this study should be interpreted in light of several limitations. This study relied on self-report of clinical conditions, without laboratory or other clinical confirmation. However, these self-report items are validated and commonly used in epidemiologic surveillance of the conditions of interest (Agency for Healthcare Research and Quality). Secondly, because of the nature of the study, those in the most severe social circumstances, including very

low food security, may have been less likely to enroll in NHIS and be followed in MEPS. Next, the study may have lacked power to evaluate categories of expenditures. While not all observed differences were statistically significant, the direction of difference was consistent across spending categories. Food insecurity was assessed only once, in the 2011 NHIS, and over the preceding 30-day period. Because food insecurity is a dynamic condition, individuals who did not report food insecurity in 2011 may have experienced it during the subsequent period. This may bias estimates of expenditure difference to the null. Finally, because this study used observational data, we used regression modeling to help account for confounding. Our modeling focused on reducing bias in estimating the association between food insecurity and health care expenditures, and for that reason, the coefficients for other terms in the models likely remain biased, as they were included specifically to adjust for confounding rather than to study the association between those factors and health care expenditures. In particular, with regard to health insurance, there is a large literature (Nicholson et al. 2004; Deb and Trivedi 2006; Shen et al. 2008; Hackmann, Kolstad, and Kowalski 2012) documenting that those who enroll in health insurance are often sicker than those who do not and thus may be prone to incurring greater health care expenditures, regardless of any direct role played by insurance itself. Therefore, model coefficients other than for food insecurity, and particularly for health insurance, should be interpreted with caution.

The limitations of this study are balanced by several strengths. The MEPS methodology allows for highly accurate capture of the health care expenditures for a nationally representative sample of individuals, giving a complete picture of costs borne by the individuals themselves or reimbursed on their behalf. Secondly, the longitudinal design provides strong evidence that exposure to food insecurity, for whatever reason, is likely to be associated with excess subsequent health care expenditure.

CONCLUSION

Food insecurity is an all-too-common problem for many Americans. Food insecurity is associated with increased health care spending, particularly in those with common and costly conditions such as diabetes, hypertension, and heart disease. For this reason, we next need to evaluate the potential of food insecurity interventions to improve health and reduce health care costs among vulnerable populations. Ultimately, our success at achieving the triple aim of

health care will depend on our ability to address critical social determinants of health in an evidence-based fashion.

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AUTHOR CONTRIBUTION

Seth A. Berkowitz conceived of the study and drafted the manuscript. Sanjay Basu and Hilary K. Seligman conceived of the study and revised the manuscript critically for important intellectual content. James B. Meigs made substantial contributions to the design of the study and revised the manuscript

critically for important intellectual content. All authors give final approval of the version to be published and agree to accountability. A "working paper" report on the project, not intended for publication or peer review, which included analyses presented into this manuscript, was submitted to the University of Kentucky Poverty Research Center on January 31, 2017, as required by the funding agreement.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the supporting information tab for this article:

Appendix SA1: Author Matrix.

Figure S1: Kernel Density Plot of Expenditures.

Figure S2: Annualized Costs for Individuals, by Insurance Type.

Table S1: Total Expenditures.

Table S2a: Annualized Expenditures, Restricted to Adults (age ≥18 years).

Table S2b: Total Expenditures, Restricted to Adults (age ≥18 years).

Table S3a: Outpatient Expenditures.

Table S3b: Emergency Department Expenditures.

Table S3c: Inpatient Expenditures.

Table S3d: Prescription Medication Expenditures.

Table S4a: Total Expenditures in Individuals with Diabetes.

Table S4b: Total Expenditures in Individuals with Hypertension.

Table S4c: Total Expenditures in Individuals with Heart Disease.

Table S5: Comparison of Different Modeling Strategies for Total Expenditures.

Table S6: Total Expenditures, without Health Insurance.