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Food insecurity, food environments, and disparities in diet quality and obesity in a nationally representative sample of community-dwelling older Americans

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ABSTRACT

Food insecurity, reflecting a household's low ability to purchase healthy food, is a public health concern that is associated with poor diet and obesity. Poor food environments, characterized as a neighborhood with low access to healthy, affordable food, may amplify the negative impact of food insecurity on diet and obesity. This study aims to investigate whether food insecurity and food environments are jointly associated with an increased risk of poor diet quality and obesity. We used data from a nationally representative sample of community-dwelling older adults in the Health and Retirement Study Health Care and Nutrition Survey and the National Neighborhood Data Archive to investigate the role of household and neighborhood characteristics on diet and obesity. Weighted regression models were estimated to examine the relationship between food insecurity and food environments as well as their interaction with diet quality and obesity. Food insecure respondents had lower Healthy Eating Index scores and were more likely to be obese than food secure respondents. Living in a poor food environment was associated with lower Healthy Eating Index scores, but not with obesity. We did not find any interaction between food insecurity and food environment in determining either healthy eating or obesity. Reducing food insecurity and increasing access to healthy food environments may encourage healthier eating among older adults, while alleviating food-related hardship may also reduce their obesity risk.

1. Introduction

Poor diet is a leading cause of disability and death. In 2016, it accounted for 11 % of disability-adjusted life-years lost and 529,299 deaths in the United States (US Burden of Disease Collaborators, 2018). Obesity is a related additional risk factor for morbidity and mortality (US Burden of Disease Collaborators, 2018). Both poor diet and obesity are highly prevalent in the population; 89.1 % of older Americans had a poor or suboptimal quality diet in 2013 and 42.8 % were classified as obese in 2017–2018 (Choi et al., 2021; Hales et al., 2020). Poor diet and obesity are more common in certain populations, including low-income populations and racial and ethnic minority groups (Choi et al., 2021; Hales et al., 2020; Vadiveloo et al., 2019). There are also neighborhood inequalities in diet quality and obesity (Lagström et al., 2019; Mohammed et al., 2019). Several studies have identified social and environmental factors influencing diet and obesity, including limited access to healthy food due to individual- or household-level financial difficulties (e.g., poverty and food insecurity), and poor neighborhood food environments (Choi et al., 2021; Cooksey-Stowers et al., 2017; Leung et al., 2020; Testa & Jackson, 2019).

Food insecurity – "a household-level economic and social condition of limited or uncertain access to adequate food" (U.S. Department of Agriculture Economic Research Service, 2020) or "the disruption of food intake or eating patterns because of lack of money and other resources" (Nord et al., 2005) – is a leading public health challenge in the United States. In 2010, healthcare costs from health issues caused by food insecurity were estimated to total $130.5 billion (Shepard et al., 2011). Previous studies have reported that food insecurity is associated with increased risk for a variety of negative health outcomes and health disparities, including obesity, cardiovascular disease, poor metabolic control, and mobility limitations (Berkowitz et al., 2013; Bishop & Wang, 2018; Lee and Frongillo, 2001a; Lee and Frongillo, 2001b; Leung et al., 2020; Seligman et al., 2010). Food insecurity has negative health consequences because it is often associated with unhealthy dietary behaviors such as skipping meals (Bhattacharya et al., 2004) as well as a suboptimal diet, including a high intake of sugar and low consumption

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of core food groups and nutrients (Keenan et al., 2021; Lee and Frongillo, 2001a; Lee and Frongillo, 2001b; Leung et al., 2014; Robaina & Martin, 2013). Due to their more limited financial resources, older adults are at particularly increased risk for food insecurity (Fernandes et al., 2018).

Food environment (i.e., presence and location of food outlets) is a neighborhood-level factor that plays an important role in food access and may impact diet quality and obesity. Poor food environments are characterized as having limited access to healthy food outlets (food desert) and an abundance of unhealthy food outlets which outnumber healthy food options (food swamp). Previous studies have reported that poor food environments are associated with food insufficiency, encourage unhealthy diets, and result in poor health (Fitzpatrick et al., 2016; Kelli et al., 2019; Moore et al., 2008). On the other hand, healthy food environments, such as those with high supermarket density and limited access to fast-food restaurants, have been associated with healthier diets (Larson et al., 2009; Moore et al., 2008). Although there is no consensus (Black & Macinko, 2008; Chen et al., 2016), a link between food environments and weight and obesity also has been reported (Cooksey-Stowers et al., 2017; Larson et al., 2009; Morland et al., 2002; Paulitsch & Dumith, 2021; Pruchno et al., 2014). For older adults, acquiring healthy food in poor food environments may be more challenging because of reduced mobility, problems with physical functioning, and reduced ability to drive (Schwartz et al., 2019).

Food insecure older adults often have limited economic and social resources which make them more vulnerable to food access barriers (Fitzpatrick et al., 2016; Lee and Frongillo, 2001a; Lee and Frongillo, 2001b). Therefore, poor food environments may amplify the negative effect of food insecurity on diet quality and obesity. Surprisingly, however, the joint association of food insecurity and food environments with diet quality and obesity among older adults has not been documented. To fill the gap in knowledge, this study aims to investigate whether food insecurity and food environments are jointly associated with diet quality and obesity using a nationally representative sample of community-dwelling older adults in the United States.

2. Methods

2.1. Data and sample

We used data from the Health and Retirement Study (HRS), which is a publicly available longitudinal panel study that surveys a nationally representative sample of approximately 20,000 Americans over the age of 50 and their spouses (see Supplementary Material Table S1). The HRS has been biennially collecting a rich array of data on sociodemographic characteristics and health since 1992, with new cohorts added every-six years. For this study, we used the 2012 HRS Core and the RAND Core for sociodemographic information, the 2013 HRS Health Care and Nutrition Survey (HCNS) for food access and consumption, and the 2014 RAND for obesity. The HRS HCNS collected healthcare access, food purchases, food consumption and nutrition information from a subsample of the HRS respondents and their spouses/partners. Information about food consumption over the past 12 months was collected using a modified version of the Harvard Food Frequency Questionnaire (Health and Retirement Study, 2018; Willett et al., 1985), and the HRS team at the University of Michigan calculated average daily servings for each food item using nutrient tables provided by the Harvard School of Public Health (Harvard, 2020; Health and Retirement Study, 2018).

The HRS geocoded respondents' residential addresses to a U.S. census tract. Using the respondent census tract identifiers, we linked the HRS HCNS with tract-level food environment data from the 2013 National Neighborhood Data Archive (NaNDA) (i.e., fast-food restaurants, convenience stores, supermarkets/grocery stores, specialty food stores, and warehouse clubs/supercenters). The NaNDA is a publicly available data archive containing nationwide measures of the physical and social environment (e.g., walkability, crime, housing, fast food) that can be linked to existing survey data (National Neighborhood Data Archive, 2020).

For this study, we limited our sample to community-dwelling, age-eligible respondents (ages 53 and older) who were part of the 2010 HRS sample and completed the 2013 HCNS. The HRS includes both older adults who live in community settings and institutional settings. Respondents who lived in a nursing home in 2012 were excluded as the influence of food insecurity and food environments would be minimal for nursing home residents. Among 7,383 community-dwelling, age-eligible respondents in the HRS HCNS, approximately 16 % of the sample had missing data on at least 1 key variable or covariate. Item nonresponse ranged from < 1 % (physical activity) to 6.18 % (food insecurity). To address item nonresponse, we employed multiple imputation with chained equations. The analytic sample included 6,969 respondents. Sample inclusion criteria and sample characteristics of the full HRS HCNS and imputed data are provided in Supplementary Material (see Figure S1 and Table S2).

2.2. Measures

2.2.1. Diet quality

Diet quality was assessed using the Healthy Eating Index 2015 (HEI-2015) based on dietary guidelines and the nutrition information reported by respondents in 2013 (Krebs-Smith et al., 2018). The index contains 13 dietary components. Maximum scores for each component range from 0 to 5 for total fruits, whole fruits, total vegetables, greens and beans, total protein foods, and seafood and plant proteins, and 0 to 10 for whole grains, dairy, fatty acids, refined grains, sodium, added sugars, and saturated fats. The total maximum score of the HEI-2015 is 100 points; HEI scores below 51 indicate a poor quality diet, scores between 51 and 80 reflect a diet that needs improvement, and scores above 81 are considered a good quality diet (Kennedy et al., 1995).

2.2.2. Obesity

Obesity was defined based on participants' body mass index (BMI), which has been widely used for obesity screening. BMI was calculated based on self-reported weights and heights collected in 2014. BMI greater than or equal to 30 kg per meter squared was defined as obesity (Center for Disease Control and Prevention, 2021).

2.2.3. Food insecurity

Food insecurity status was assessed based on the short form of the U. S. Household Food Security Survey Module (U.S. Department of Agriculture Economic Research Service, 2012), which includes six questions capturing self-perceived nutritional inadequacy, household food depletion, disrupted eating patterns, and a repetitive pattern of reduced food intake due to financial constraints (Blumberg et al., 1999). Respondents were asked whether the following two statements were often, sometimes, or never true for their household: "the food that we bought just didn't last and we didn't have enough money to get more" and "we couldn't afford to eat balanced meals" (0 = never true, 1 = often true or sometimes true). Respondents were also asked if anyone in the household ever cut meal size or skipped meals over the last 12 months because there wasn't enough money for food (0 = no, 1 = yes) and if yes, how often it happened (0 = no or yes, only 1 or 2 months, 1 = yes, some months but not every month or almost every month). Lastly, respondents were asked if they ever ate less than they felt they should over the last 12 months because there wasn't enough money for food (0 = no, 1 = yes) and were they ever hungry but didn't eat because there wasn't enough money for food (0 = no, 1 = yes). Responses to the items were summed (range: 0–6); scores of 0 to 1 were categorized as having food security and 2 to 6 as having food insecurity (U.S. Department of Agriculture Economic Research Service, 2012) [Exact wording of questions shown in Supplementary Material Table S3].

2.2.4. Food environments

The Retail Food Environment Index (RFEI) is calculated as the ratio of unhealthy food outlets (e.g., convenience stores, fast-food restaurants) to healthy food outlets (e.g., grocery stores, supermarkets, specialty stores) (Babey et al., 2008; Cooksey-Stowers et al., 2017; Spence et al., 2009). The RFEI in this sample ranged from 0 to 15. Scores of 0 to 1 indicate that residents have the same or a greater access to healthy food outlets as unhealthy food outlets and scores greater than 1 indicate residents have greater access to unhealthy food outlets than healthy food outlets. We created a binary indicator for the food environment where 1 = scores of 0–1 and 0 = scores greater than 1.

2.2.5. Covariates

Several measures collected in the 2012 interview were included as covariates in models predicting HEI-2015 scores and obesity. These included age (in years; range: 53–101), sex (male; female), race/ethnicity (White/other, non-Hispanic; Black, non-Hispanic; Hispanic), marital status (married or partnered; separated, divorced, or widowed; never married), education (less than high school education; high school diploma; more than high school education), household poverty (household income above poverty threshold; household income below the poverty threshold), household assets (in 1,000 dollars; range: −42.8–21,514), Supplemental Nutrition Assistance Program (SNAP) enrollment (not enrolled; enrolled), self-rated health (range: 0–4; higher values indicate better health), and cognitive function related to memory. Poverty thresholds are based on U.S. Census definitions and calculated using the total household income from all resident family members (including earnings, pensions, social security, supplemental security income, and government transfer income) minus the value of food stamps. Household assets are the sum of non-housing assets, including real estate, vehicles, businesses, stocks, bonds, and savings, minus any debts. The memory component of cognitive function was assessed using a summed score of immediate and delayed word recall (range: 0–20), with higher values indicating better cognitive function. To better account for sources of differences in obesity, we also controlled for physical activity (physically inactive; vigorous or moderate activity in the past month) and smoking status (never smoked; former smoker; current smoker).

2.3. Analysis plan

We imputed data on the key independent variables and covariates using the *mi impute* command with chained equations in Stata 17. Following recommended practices, we created 20 imputed data sets (Graham et al., 2007).

We first present sample characteristics. We then tested whether food insecurity status and food environments were associated with HEI-2015 scores and obesity using ordinary least squares (OLS) regression and logistic regression. In Model 1, we tested the independent associations of food insecurity and food environment with HEI-2015 scores and obesity. In Model 2, we included the interactive effect of food insecurity and food environment on the outcomes. In models predicting HEI-2015 scores, we controlled for sociodemographic characteristics. Models predicting obesity additionally controlled for health behaviors (i.e., physical activity, smoking, diet quality). Sample weights provided by the HRS were applied in all analyses to account for the complex survey design and sample composition. Analyses were conducted using Stata 17.

Ethical approval

This study used secondary data that include non-identifiable information. The study was approved by the Institutional Review Board (UP-18–00229) at the University of Southern California.

3. Results

3.1. Sample characteristics

Table 1 presents sample characteristics. The mean HEI-2015 score for the sample was 66.76 (SD = 11.40). About 35 % of the sample were obese. The majority of the sample were food secure (82.9 %) and were living in neighborhoods with a healthy food environment (70.9 %). The sample was more than half female (54.7 %), primarily non-Hispanic White or other (85.1 %), and mostly married or partnered (63.6 %). Most respondents were physically active (84.4 %), nearly half never smoked (45.4 %), more than half had more than high school education (54.2 %), and most had a household income above the poverty threshold (90.4 %), and were not enrolled in the SNAP (91.4 %). The mean age was 65.10 (SD = 9.61), the mean household assets were 354,860 dollars (SD = 1,132,960), the mean self-rated health was 2.29 (SD = 1.07), and the mean total word recall score was 10.18 (SD = 3.31).

Table 1
Sociodemographic characteristics of the 2013 HRS HCNS sample (N = 6,203).

	Weighted M (SD)/%	Unweighted N
HEI-2015 (range:0–100)	66.76(11.40)	
Obesity		
BMI below 30	64.5	4,021
BMI 30+	35.5	2,182
Food security status		
Food secure	82.9	5,082
Food insecure	17.1	1,121
Food environment		
Healthy food environment	70.9	4,496
Poor food environment	29.1	1,707
Age (in years; range: 53–100)	65.10(9.61)	
Sex		
Male	45.8	2,589
Female	54.2	3,614
Race/Ethnicity		
White/Other, non-Hispanic	82.4	4,533
Black, non-Hispanic	9.9	1,013
Hispanic	7.8	657
Marital Status		
Married/Partnered	65.1	3,928
Separated/Divorced/Widowed	29.0	1,985
Never married	6.0	290
Education		
Less than high school	13.6	1,011
High school education	31.6	2,027
More than high school	54.8	3,165
Household poverty		
Not in poverty	90.4	5,529
In poverty	9.6	674
Household assets (in 1,000 dollars; range: −42.8–21514)	354.86(1132.96)	
SNAP enrollment status		
Not enrolled	91.4	5,621
Enrolled	8.6	582
Self-rated health (range: 0–4 better health)	2.29(1.07)	
Cognitive function (range: 0–20 better cognitive function)	10.18(3.31)	
Physical Activity		
Physically inactive	15.1	1,001
Physically active	84.9	5,202
Smoking status		
Never smoked	45.3	2,786
Former smoker	41.2	2,685
Current smoker	13.5	732

HEI = Healthy Eating Index; Poor food environment = Greater access to unhealthy food outlets than healthy food outlets; Physically active = Moderate to vigorous activities.
Note. Unimputed data of respondents with complete data were used for descriptive statistics. See Supplemental Material S2 for imputed data sample characteristics.

3.2. Association between food insecurity Status, food Environments, and diet quality

Table 2 presents the results of the OLS regression model for the association between food insecurity status, food environments, and HEI-2015 scores. In Model 1, food insecure respondents had a significantly lower HEI-2015 score indicating less healthy eating (b = -1.21, 95 % CI: −2.19, −0.22) than food secure respondents. Living in a poor food environment was also negatively associated with HEI-2015 scores (b = -1.35, 95 % CI: −2.06, −0.63). When the interaction term between food insecurity and food environments was introduced (Model 2), the main effect of both food insecurity (b = -1.18, 95 % CI: −2.29, −0.06) and food environment (b = -1.33, 95 % CI: −2.11, −0.55) remained significant with little change. The interaction term between food insecurity and food environments was not statistically significant (b = -0.10, 95 % CI: −2.07, 1.88).

Being older, female, non-Hispanic black, Hispanic and having higher education, greater household assets, better self-rated health and cognitive function were associated with higher HEI-2015 scores, while being enrolled in SNAP was negatively associated with HEI-2015 scores when other controls were included.

3.3. Association between food insecurity Status, food Environments, and obesity

Table 3 presents the results of the logistic regression predicting obesity. In Model 1, food insecurity is associated with greater odds of being obese (odds ratio [OR] = 1.25, 95 % CI: 1.03, 1.52). However, living in a poor food environment was not significantly associated with obesity (OR = 1.10, 95 % CI: 0.96, 1.27). In Model 2, the association of food insecurity (OR = 1.22, 95 % CI: 0.98, 1.51) and food environment (OR = 1.09, 95 % CI: 0.93, 1.27) with obesity showed similar patterns. The interaction term was not statistically significantly associated with the outcome (OR = 1.09, 95 % CI: 0.74, 1.60).

Being older, being physically active, smoking, better self-rated health, and higher HEI-2015 scores were negatively associated with obesity, while respondents who were non-Hispanic black and former smokers were more likely to have a higher BMI.

3.4. Sensitivity analysis

We conducted an additional analysis using non-imputed data. Overall, similar patterns were observed. Food insecure respondents were more likely to have lower HEI-2015 scores and had greater odds of being obese. Living in a poor food environment was significantly associated with lower HEI-2015 scores and marginally significantly associated with obesity.

Since self-reported measures of height and weight can be less accurate than direct measurements, we also examined models with obesity calculated from measured height and weight that were collected from a random half of the 2014 sample. The results were similar regardless of whether we used obesity derived from self-reported or measured data.

Lastly, we examined whether the results were sensitive to including food insecurity and food environments as continuous variables. Regardless of the measurement level, the pattern of results for HEI-2015 scores was similar. Food insecurity and food environment were marginally statistically significantly associated with obesity. The results of the sensitivity analyses are provided in the Supplementary Material Sensitivity Analysis section.

4. Discussion

This is the first study that uses a nationally representative sample of community-dwelling older Americans to examine the relationship between food insecurity and food environments with diet and obesity, an important indicator of health. Food insecure respondents were more likely to have a poor quality diet and were more likely to be obese. This is in line with previous studies that reported an association between food insecurity and a less diverse, unhealthy diet (Keenan et al., 2021; Lee and Frongillo, 2001a; Lee and Frongillo, 2001b; Leung et al., 2014; Nettle & Bateson, 2019; Robaina & Martin, 2013). Lower HEI scores and higher obesity risk among food insecure older adults compared to food

Table 2
Coefficients and 95 % confidence intervals (CI) from ordinary least squares regression predicting Healthy Eating Index 2015 Score (N = 6,969).

	Model 1				Model 2			
	Coefficient		95 % CI		Coefficient		95 % CI	
Food insecurity status (ref: food secure)								
Food insecure	−1.21	*	−2.19	−0.22	−1.18	*	−2.29	−0.06
Food environment (ref: healthy food environment)								
Poor food environment	−1.35	***	−2.06	−0.63	−1.33	***	−2.11	−0.55
Food insecurity X Food environment					−0.10		−2.07	1.88
Age (in years; range: 52–100)	0.11	***	0.08	0.15	0.11	***	0.08	0.15
Sex (ref: male)								
Female	2.71	***	2.05	3.38	2.71	***	2.05	3.38
Race/Ethnicity (ref: white/other, non-Hispanic)								
Black, non-Hispanic	1.97	***	0.99	2.96	1.97	***	0.99	2.96
Hispanic	5.59	***	4.47	6.70	5.58	***	4.47	6.70
Marital Status (ref: married/partnered)								
Separated/Divorced/Widowed	−0.41		−1.17	0.35	−0.41		−1.17	0.35
Never married	−0.11		−1.69	1.47	−0.11		−1.69	1.47
Education (ref: less than high school)								
High school education	0.94	†	−0.08	1.97	0.94	†	−0.08	1.97
More than high school	3.59	***	2.56	4.62	3.59	***	2.56	4.62
Household poverty (ref: not in poverty)								
In poverty	−0.81		−2.01	0.39	−0.81		−2.01	0.39
Household assets (in 1,000 dollars; range: −42.8–21514)	0.00	***	0.00	0.00	0.00	***	0.00	0.00
SNAP enrollment status (ref: not enrolled)								
Enrolled	−1.66	**	−2.88	−0.44	−1.65	**	−2.87	−0.44
Self-rated health (range: 0–4 better health)	1.33	***	0.99	1.66	1.33	***	0.99	1.66
Cognitive function (range: 0–20 better cognitive function)	0.23	***	0.12	0.34	0.23	***	0.12	0.34
Constant	50.26	***	47.07	53.45	50.25	***	47.06	53.45

†p <.10, *p <.05, **p <.01, ***p <.001.
Note. Model 1 tested the independent association of food insecurity and food environment with HEI-2015 score. In Model 2, the interaction term, food insecurity X food environment, was introduced.

Table 3
Odds ratios and 95 % confidence intervals (CI) from logistic regression predicting obesity (N = 6,969).

	Model 1				Model 2			
	Odds Ratio		95 % CI		Odds Ratio		95 % CI	
Food insecurity status (ref: food secure)								
Food insecure	1.25	*	1.03	1.52	1.22	†	0.98	1.51
Food environment (ref: healthy food environment)								
Poor food environment	1.10		0.96	1.27	1.09		0.93	1.27
Food insecurity X Food environment					1.09		0.74	1.6
Age (in years; range: 52–100)	0.96	***	0.95	0.96	0.96	***	0.95	0.96
Sex (ref: male)								
Female	1.06		0.93	1.22	1.06		0.93	1.22
Race/Ethnicity (ref: white/ other, non-Hispanic)								
Black, non-Hispanic	1.48	***	1.23	1.77	1.48	***	1.23	1.77
Hispanic	1.13		0.89	1.44	1.13		0.89	1.44
Marital Status (ref: married/ partnered)								
Separated/ Divorced/ Widowed	0.93		0.8	1.09	0.93		0.8	1.09
Never married	1.06		0.79	1.43	1.06		0.79	1.43
Education (ref: less than high school)								
High school education	1.07		0.88	1.32	1.07		0.88	1.32
More than high school	0.96		0.78	1.19	0.96		0.78	1.19
Household poverty (ref: not in poverty)								
In poverty	0.93		0.74	1.18	0.93		0.74	1.18
Household assets (in 1,000 dollars; range: −42.8–21514)	1.00	†	1.00	1.00	1.00	†	1.00	1.00
SNAP enrollment status (ref: not enrolled)								
Enrolled	0.91		0.71	1.16	0.91		0.71	1.16
Self-rated health (range: 0–4 better health)	0.74	***	0.69	0.79	0.74	***	0.69	0.79
Cognitive function (range: 0–20 better cognitive function)	1.01		0.99	1.04	1.01		0.99	1.04
Physical Activity (ref: physically inactive)								
Physically active	0.68	***	0.57	0.81	0.68	***	0.57	0.81
Smoking status (ref: never smoked)								
Former smoker	1.17	*	1.02	1.34	1.16	*	1.02	1.34
Current smoker	0.41	***	0.33	0.52	0.41	***	0.33	0.52
HEI-2015 (range: 0–100 better quality diet)	0.99	**	0.99	1.00	0.99	**	0.99	1.00

†p <.10, *p <.05, **p <.01, ***p <.001.
HEI = Healthy Eating Index.
Note. Model 1 tested the independent association of food insecurity and food environment with obesity. In Model 2, the interaction term, food insecurity X food environment, was introduced.

secure older adults have also been frequently reported (Keenan et al., 2021; Leung et al., 2014; Leung & Wolfson, 2021). This may be because of the limited ability to acquire healthy food. Healthier food is often more expensive than less healthy options (Rao et al., 2013), and food insecure older adults, who may have a more limited budget for food purchases, cannot afford healthy food. Previous studies have reported positive effects from congregate or delivered meals and food donations in reducing food insecurity and diet quality (Mabli et al.; Miewald et al., 2012; Mousa & Freeland-Graves, 2019). Therefore, providing information on the available resources and encouraging the use of charitable food sources (e.g., food banks and pantries at community organizations) may alleviate food-related hardship and promote healthy eating.

Living in poor food environments was also associated with a poor quality diet. The negative impact of living in a food desert/swamp or a neighborhood with limited access to healthy food on food insufficiency and unhealthy eating behaviors (i.e., meal skipping) has been frequently reported in previous studies (Cummins & Macintyre, 2006; Fitzpatrick et al., 2016; Moore et al., 2008). Providing incentives and tax credits to supermarket developers and retailers could promote healthy food environments (Lewis et al., 2011; Moore et al., 2009). For example, Philadelphia Fresh Food Financing Initiative financed the development of 88 supermarkets and fresh food outlets in underserved areas and it increased access to healthy foods for nearly half a million Pennsylvania residents (Carpenter et al., 2019; Harries et al., 2014). In neighborhoods where fast-food restaurants have already proliferated, prohibiting the establishment of new fast-food restaurants while increasing healthy food options in fast-food restaurants could be a solution (Ashe et al., 2003; Lewis et al., 2011). In 2017, Los Angeles City Council adopted the South Los Angeles Fast-Food Interim Control Ordinance, which places a moratorium on new stand-alone fast-food restaurants in the area. After the moratorium, South LA's ratio of healthy food retail establishments to total food retail establishments and the number of grocery stores per 10,000 people increased significantly, while unhealthy dietary behaviors (i.e., sugar-sweetened beverage consumption) and death rates due to diet- or obesity-related diseases (i.e., coronary heart disease, diabetes) decreased (Hawkins & Flynn, 2017). The availability of fast-food restaurants, convenience stores, and energy-dense foods has been found to be greater in low-income, minority neighborhoods (Haynes-Maslow & Leone, 2017; Hilmers et al., 2012; Larson et al., 2009; Walker et al., 2010); thus, adoption of regulations and/or urban planning to promote healthy food outlets should prioritize deprived neighborhoods.

The association between food environments and obesity, however, was not significant in our sample. Previous findings on the relationship between food environments and obesity have been inconsistent (Black & Macinko, 2008; Chen et al., 2016). This may be because of different ways of assessing food environments or other confounding factors that are not controlled in our study. Further research is needed to understand mechanisms linking food environments and obesity.

5. Limitations

We recognize several limitations of this study. First, we linked sociodemographic and health behavior information (i.e., marital status, poverty status, wealth, physical activity, smoking) in 2012 with food environment and dietary intake data collected in 2013 and obesity data collected in 2014. Although this information often does not generally change much within a short period of time, there could be a change in sociodemographic characteristics and health behaviors due to the one- to two-year difference. Second, dietary intake was assessed based on the average intake of food and nutrients during the past 12 months, reported by study participants. Although we controlled for cognitive function related to memory (immediate and delayed word recall), this may have introduced recall and/or response bias into this study and the results

may not accurately reflect dietary intake. In addition, the modified version of the Harvard Food Frequency Questionnaire used to calculate average daily servings for each food item was not validated in the HRS sample. There may be potential bias due to residual confounding as well. For instance, we adjusted for self-rated health as a proxy for overall health. However, the variable may be limited in capturing specific aspects of health, such as limited mobility and poor oral health, which may influence diet quality and obesity. Lastly, while it is possible that living in a poor food environment increases the risk for poor diet and obesity, it may also be the case that individuals with a high risk for these outcomes are more likely to move to or stay in poor neighborhoods, where poor food environments are more common. However, because we did not have longitudinal data on dietary intake, we could not assess the directionality of the relationship. Future studies that use longitudinal data are needed to explore the causal relationship of food insecurity and food environment with diet quality and obesity.

6. Conclusions

Our study confirms that food insecurity and poor food environments play an important role in diet and health. Therefore, providing delivery or transportation options and increasing meal programs and charitable food sources may reduce disparities in diet quality and obesity. implementing policies that facilitate changes to food environments also could promote access to healthy food.

7. Submission declaration

The paper has not been published previously and is not under consideration for publication elsewhere. It will not be published elsewhere in the same form.

CRediT authorship contribution statement

Yeon Jin Choi: Conceptualization, Methodology, Formal analysis, Writing – original draft. **Eileen M. Crimmins:** Writing – review & editing, Supervision. **Jennifer A. Ailshire:** Conceptualization, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2022.101912.

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