Food security status and breast cancer screening among women in the United States: Evidence from the Health and Retirement Study and Health Care and Nutrition Study

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Abstract
Purpose To assess the impact of food insecurity on biennial breast cancer screenings (i.e., mammography or breast X-ray) among older women in the United States (US).

Methods Data from the 2014 and 2016 waves of the Health and Retirement Study and the 2013 Health Care and Nutrition Study were used. The analyses were limited to a nationally representative sample of 2,861 women between 50 and 74 years of age, residing in the US. We employed a propensity score weighting method to balance observed confounders between food-secure and food-insecure women and fit a binary logistic regression to investigate population-level estimates for the association between food security and breast cancer screening.

Results Food insecurity was significantly associated with failure to obtain a mammogram or breast X-ray within the past two years. Food-insecure women had 54% lower odds of reporting breast cancer screening in the past 2 years (adjusted OR = 0.46; 95% CI 0.30–0.70, p-value < 0.001) as compared to food-secure women. Additional factors associated with a higher likelihood of receiving breast cancer screenings included greater educational attainment, higher household income, regular access to health care/advice, not smoking, and not being physically disabled or experiencing depressive symptoms.

Conclusion Results demonstrate a socioeconomic gradient existing in regard to the utilization of regular breast cancer screenings among women. Those who tend to have lower education, lower income, and lack of reliable healthcare access are more likely to be food insecure. Thus, more likely to face the financial, logistical, or environmental barriers in obtaining screening services that accompany food insecurity.

Keywords Food insecurity · Breast cancer screening · Mammography · Social determinants of health · Cancer prevention · Older women

Introduction

With an average lifetime risk of over 13%, breast cancer is the most common cancer diagnosis among women in the United States (US) [1]. This trend is expected to continue, as an estimated 287,850 invasive and 51,400 non-invasive (in situ) new breast cancer diagnoses are projected to occur during 2022 [2]. Furthermore, although noteworthy advancements in early detection and treatment have led to gradual declines in breast cancer mortality [3], an estimated 43,250 women will die of breast cancer in 2022 [2].
Early detection reduces breast cancer mortality rates and increases the likelihood of better treatment options [4–6]. With evidence indicating that mammography is the most effective method for early diagnosis [4, 5], the US preventive services task force (USPSTF) recommends biennial screening mammography for women aged 50 to 74 [7]. Despite this recommendation, many women are unaware of the significance of regular mammograms as well as how or when to schedule them. One of the main objectives of Healthy People 2020 in the US was to increase the proportion of women aged 50 to 74 years who receive breast cancer screening to 81.1%. However, these rates stood at 72.8% in 2018, similar to screening rates in 2008 [8].

Social determinants of health play a crucial role in not only how many women access breast cancer screening services but also their awareness of these preventative services. The social determinants can delay or prevent disadvantaged women from receiving timely mammograms or breast X-rays and reduce the likelihood of diagnosing early enough for medical intervention to be effective [9–11]. Although Black and Hispanic women are screened for breast cancer at similar rates as White women, the breast cancer mortality rate is much higher among minority women—in fact, it is the leading cause of cancer death for Black and Hispanic women in the US [12]. Furthermore, women from racial and ethnic minority populations are less likely to be diagnosed with early “localized” stage of breast cancer than their White counterparts [2, 12]. These disparities are partially attributed to inequities in access and quality of breast cancer screening, delays in follow-up care, and reduced access to high-quality treatment after an abnormal mammogram [2, 12–14]. In particular, Black women are more likely to have longer intervals between mammograms with abnormal findings and follow-up care; they are also more likely to be screened at non-accredited, lower-resourced facilities [12].

Barriers to breast cancer screening have been extensively reported in the literature [11, 15–21]. Education, household income, and a lack of health insurance are frequently identified as some of the barriers women face in obtaining these discretionary health services. However, less emphasis has been placed on individual and family food insecurity. Food insecurity is related to economic instability, which is considered one of the key social determinants of health [22]. Generally, food security is construed as someone with access to enough quality food at all times to be able to live an active and healthy life [23]. Food insecurity, on the other hand, occurs when people experience uncertain or limited access to adequate or nutritious food due to a lack of financial or other resources [24, 25]. Food insecurity persists along racial/ethnic lines and disproportionately affects those from non-Hispanic Black and Hispanic backgrounds. For example, a recent study found that in 2015, both Black and Hispanic households experienced food insecurity at substantially higher rates (21.5% and 19.1%, respectively), compared to the national rate of 12.7% [26].

Beyond socioeconomic differences, members of minority populations are more likely to live in impoverished areas that are classified as food deserts. A food desert is an area with limited access to affordable and nutritious food compared to an area with higher access to supermarkets or vegetable shops with fresh foods [27]. Residents of low-income and/or predominantly racial/ethnic minority neighborhoods often have less access to supermarkets and quality foods, travel greater distances to obtain fresh foods and have fewer healthy food options than affluent and/or predominantly White neighborhoods [27]. Food security, access to good nutrition, and high-quality diets are essential to prevent and reduce disease incidences, chronic medical conditions, disease burdens, and precursors for a better quality of life [24, 25]. In 2018, an estimated 11.1% of US households (14.3 million) were food-insecure at some point; a higher than average proportion of these households were adults living alone and people who identified as racial/ethnic minorities [23].

Food insecurity is associated with higher utilization rates of emergency departments and hospitalizations and higher healthcare expenditures [24, 28, 29]. Food insecurity results in significant healthcare burdens, as evidenced by findings that a lack of access to adequate, nutritious food was associated with increased odds of being in the top decile, 5%, and 2% healthcare expenditures [28]. Studies focusing on the associations between food insecurity and preventive healthcare services, including cancer screening services, are scarce. Previous studies have attempted to investigate the associations between food insecurity and other services—such as the uptake of recommended vaccines among adult populations [30]. However, to our knowledge, no study to date has provided empirical evidence based on a national survey sample for the association between food insecurity and breast cancer screening rates among women.

Although many of the persistent disparities across the cancer continuum are attributed to social determinants of health [9, 31], it is not known how food insecurity status influences utilization of recommended cancer screening services independent of other social determinants. With health systems across the US shifting towards value-based care models, which emphasize prevention and multidimensional population health, the significance of addressing social determinants of health in ameliorating health disparities among underserved and disadvantaged populations becomes evident [11]. Identifying social determinants that substantially contribute to the gaps in cancer screening services would benefit narrowing these disparities in healthcare access by informing the development of public health interventions and clinical practice guidelines in this area [9, 11].
In the present study, we examine the effect of food insecurity on the utilization of recommended mammography screening services among US women aged 50 to 74 years. More specifically, we employed data from the health and retirement study (HRS) and the health care and nutrition study (HCNS) to test the hypothesis that food insecurity is a potential barrier to breast cancer screening among this population.

**Methods**

**Data sources, study settings, and the sample**

In this study, we utilized data from the 2014 and 2016 waves of the HRS and the 2013 HCNS. The HRS is an ongoing, nationally representative, longitudinal survey that focuses on health, employment, income, and family structure among US residents aged 50 years and older. The HRS is conducted biennially by the institute for social research (ISR) at the University of Michigan [32]. The survey data and documents regarding its design and methodology can be accessed online at https://hrs.isr.umich.edu/. The HRS has several off-year studies, such as HCNS, on a variety of topics. The HCNS was fielded between November 2013 and May 2014. It included a random subsample \((n = 12,418)\) of HRS core respondents who were invited to participate in a mail-out questionnaire. The HCNS provides information about respondents’ healthcare access, food purchases, food consumption, and nutrition; its response rate was 65% \((n = 8,073)\) [33].

We merged HCNS and HRS data on unique respondent identifiers. The final sample included 2,861 female respondents aged 50 to 74 years in 2014. Figure 1 is a flowchart displaying the inclusionary and exclusionary criteria for the final sample. Both the HRS and HCNS are supported by the National Institute on Aging (grant number: NIA U01AG009740) and the Social Security Administration [33]. The HRS protocol was approved by the University of Michigan’s Institutional Review Board. Prior to each wave’s new interviews or re-interviews, participants are provided with a written informed consent information document; they are then read a confidentiality statement and provide oral consent. For the HCNS, consent was inferred by completion and return of the questionnaire; respondents were informed that their participation was voluntary in the study invitation letter [34]. The present study followed the strengthening the reporting of observational studies in epidemiology (STROBE) guidelines.

![Fig. 1 A flowchart showing inclusion/exclusion criteria](image)

**Main study measures**

Information on breast cancer screening was obtained from the 2016 wave of HRS. Participants were asked if they had a mammogram or x-ray of the breast to screen for cancer in the last two years; response options were ‘yes’ or ‘no’. The 2016 question on breast cancer screening was used to preserve the temporal sequence between the exposure and the outcome, and for the outcome to follow food security status assessment and baseline covariates in 2014. Data on food security were extracted from a portion of the HCNS, which assessed food insecurity using the six-item short form of the US Household Food Security Survey Module [35]. The assessment starts by asking the respondents whether the following two statements were often true, sometimes true, or never true for their households in the last 12 months: ‘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.’ The responses for each statement were scored as ‘1 = often true or sometimes true, 0 = never...’
true.’ Then, they were asked if they, or other adults in the household, ever cut meal size or skip meals because there was not enough money for food: ‘yes’ or ‘no.’ Respondents who answered ‘yes’ were further asked about the frequencies of cutting portions or skipping meals ‘1 = almost every month or some months but not every month, 0 = only 1 or 2 months or no.’ The last two questions evaluate if, in the last 12 months, the respondent ever ate less than they felt they should because there was not enough money for food (‘yes’ or ‘no’) and whether the respondent ever went hungry but did not eat because there was not enough money for food (‘yes’ or ‘no’). The affirmative responses to all six questions were summed to develop the food security status scale score. Respondents with a raw score of 0 or 1 were considered ‘food-secure’ while those with raw scores ranging from 2 to 6 were considered ‘food-insecure’ [35].

**Covariates**

We followed the extant literature and the Behavioral Model of Health Services Utilization, developed and modified by Andersen and colleagues [36–39], as a conceptual framework to identify covariates and related factors that could contribute to the associations between food security status and breast cancer screening (see Fig. 2). This behavioral model posits that individuals’ use of health and healthcare services is a function of their predispositions to use health services, factors that enable or impede such use, and their need for care [36–39]. The model includes predisposing factors such as demographic factors, social structural factors, and belief factors (e.g., attitudes, values, and knowledge); individual- and family level enabling factors (e.g., having a regular provider, household income, urban or rural location); and need factors, including perceived (e.g., self-rated health status), and evaluated (e.g., chronic medical conditions), needs.

Guided by the framework and literature, covariates were extracted from the 2014 wave of the HRS and considered baseline characteristics for survey respondents. Predisposing characteristics included participants’ age, and race and ethnicity: ‘non-Hispanic White,’ ‘non-Hispanic Black,’ ‘Hispanic,’ or ‘non-Hispanic others.’ Enabling characteristics included education level (‘less than high school or GED,’ ‘high-school graduate,’ ‘some college,’ or ‘college and above’), annual household income (‘< $20,000,’ ‘$20,000–$35,000,’ ‘$35,001–$50,000,’ ‘$50,001–$75,000,’ and ‘> $75,000’), whether working for pay (‘yes’ or ‘no’), and census region (‘Northeast,’ ‘Midwest,’ ‘South,’ and ‘West’). Other enabling factors included whether the respondent was covered by a government health insurance

[Fig. 2] A conceptual framework adopted from Andersen’s Behavioral Model of Health Services Utilization to investigate associations between food security status and breast cancer screening among women aged 50–74 years in the United States

Abbreviations: BMI, Body Mass Index; ADL, Activities of Daily Living; IADL, Instrumental Activities of Daily Living; CES-D, Center for Epidemiologic Studies Depression Scale. The initial model and subsequent revisions of the Andersen’s Behavioral Model of Health Services Utilization suggest that the use of health care services by individuals is a function of their predispositions to use health services, factors that enable or impede such use, and people’s need for care.

The text and constructs in the gray boxes are the selected variables of interest in the current study.
plan (‘yes’ or ‘no’), had at least one private health insurance plan (‘yes’ or ‘no’), and had a usual place for health care/advice (‘yes’ or ‘no’). Need characteristics included respondent’s body mass index (BMI) (kg/m²) (‘Normal or underweight [< 25.0],’ ‘Overweight [25–29.9],’ and ‘Obese [≥ 30.0]’), smoking status (‘current,’ ‘former,’ or ‘never’), number of comorbid medical conditions (‘none,’ ‘one,’ ‘two and more’), having activities of daily living (ADL) limitations (i.e., ‘yes’ or ‘no’), having instrumental activities of daily living (IADL) limitations (‘yes’ or ‘no’), and their center for epidemiologic studies depression evaluation (CES-D) scale score (‘elevated depressive symptoms [CES-D ≥ 3]’ or ‘normal [CES-D < 3]’).

Statistical analysis

We first calculated the respondents’ general characteristics and then estimated weighted proportions in crosstabulations of food security status and respondent characteristics. The design-adjusted Satterthwaite Rao-Scott Chi-square test was used to assess the significance of cross-tabulated associations and t-test was used to evaluate continuous variables (Table 1). To properly adjust for confounding factors and reduce selection bias associated with food security status that could distort the estimated effects on breast cancer screening among women, we employed the propensity score (PS) method using the PROC PSMATCH procedure [40–42]. PS is generally calculated as the probability of treatment assignment conditional on the baseline covariates [43]. It usually balances the observed baseline covariates between treatment (food-insecure) and control (food-secure) groups, which could mimic some of the characteristics of a randomized controlled trial design [43]. Among different PS methods—such as matching, stratification, and weighting [41, 42, 44]—we applied the propensity score weighting method to create an output dataset in which the distributions of the variables are balanced between the food-insecure and food-secure subgroups. The procedure was performed using the baseline covariates as a set of potential confounding variables with potential correlations to food security status and breast cancer screening. These variables were used to fit a logistic regression model, using food security status as the outcome, to compute the propensity scores through inverse probability of treatment weighting. In this step, original survey weights were incorporated as a predictor variable along with other covariates to enhance the estimates’ external validity [45]. Then the output PS weights were multiplied by the original survey weights to form a new weight. The computed new weights were later applied in cross-tabulations between food security status and the baseline covariates (see Table 2) to investigate the significance of differences in characteristics between food security status subgroups post-PS weighting. Conventional regression models were used to output crude odds ratios (ORs) of breast cancer screening for baseline characteristics (Table 3), and crude and adjusted ORs for food security status (Table 4, Models I and II).

Lastly, by applying the PS weights, a binary logistic regression model was fitted for breast cancer screening as an outcome to obtain the population average treatment effect (PATE) and to generate the population-average ORs of screening among food-insecure women (Table 4, Model III). This model generated the main result of interest in the current study; in addition to PS weights, it incorporated the baseline covariates (doubly robust method) to increase the accuracy of the outcome estimations and control for residual confounding [46]. Other complex survey sampling design elements, such as clustering and stratification, were properly accounted for in analyses [40, 45] to obtain accurate variance and population-level estimates. All analyses were conducted using SAS 9.4 statistical software (SAS Institute Inc., Cary, NC, USA), and the significance threshold was set at $p$-value $\leq 0.05$.

Results

Our sample represented nearly 32.4 million women aged 50 to 74 residing in the US during 2014. Within this population, 21% were deemed food-insecure, and 76.5% reported receiving breast cancer screening in the past 2 years. The sample’s mean ($\pm$ standard error (SE)) age was 61.6 $\pm$ 0.18 years. About 60.8% of respondents were white (75.8%) of respondents. More than half of the respondents (53.3%) had some college or college and above education. Respondents had an annual household income of $>75,000 (35.7%), were not working for pay (53.8%), and were from the southern regions of the US (38.5%). Over half (53.3%) of respondents were covered by government health insurance plans, had at least one private health insurance plan (63.1%), and had a usual place for health care/advice (92%). The proportion of respondents who reported being obese, never-smokers, and those with two and more comorbid conditions, any ADL limitation, any IADL limitations, and elevated depressive symptoms were (48.1%), (51.0%), (59.4%), (63.1%), and (13.1%), (11.2%), and (14.3%), respectively (see Table 1).

Among the food-insecure, about two-thirds (67.3%) reported receiving breast cancer screening in the past two years. Food-insecure women had a mean ($\pm$ SE) age of 59.6 $\pm$ 0.26 years; they were predominantly non-Hispanic Whites (50.3%), had less than high school or GED education (36.4%), had an annual household income of < $20,000 (48.8%), were not working for pay (62.6%), and were from the southern regions of the US (45.0%). About 60.8% of food-insecure women reported having government health insurance coverage, 67.2% reported having no private health insurance plan, and 87.1% reported having a usual place for...
Table 1  Respondent characteristics (HRS & HCNS, n=2,861 women, ages 50–74 years, the United States, 2014–2016)

| Respondent characteristics | Total sample (n=2,861) | Food-secure (n=2,177) | Food-insecure (n=684) | p-valuea |
|----------------------------|------------------------|------------------------|-----------------------|----------|
|                            | Frequency (Weighted %) | Frequency (Weighted %) | Frequency (Weighted %) |          |
| Food security status       |                        |                        |                        |          |
| Food-secure                | 2,177 (79.0)           | 1,706 (79.0)           | 478 (67.3)            | <0.001   |
| Food-insecure              | 684 (21.0)             | 467 (21.0)             | 205 (32.7)            |          |
| Had a mammogram or breast x-ray in past 2 years |                        |                        |                        |          |
| Yes                       | 2,184 (76.5)           | 1,706 (79.0)           | 478 (67.3)            | <0.001   |
| No                        | 672 (23.5)             | 467 (21.0)             | 205 (32.7)            |          |
| Predisposing characteristics |                       |                        |                        |          |
| Age (years), mean (± SE)   | 61.6 (± .18)           | 62.2 (± .20)           | 59.6 (± .26)          | <0.001   |
| Race and ethnicity         |                        |                        |                        |          |
| Non-Hispanic white         | 1,790 (75.8)           | 1,536 (82.5)           | 254 (50.3)            | <0.001   |
| Non-Hispanic black         | 570 (11.2)             | 357 (8.6)              | 213 (21.1)            |          |
| Hispanic                   | 384 (9.1)              | 208 (6.0)              | 176 (21.0)            |          |
| Non-Hispanic others        | 110 (3.9)              | 72 (2.9)               | 38 (7.6)              |          |
| Enabling characteristics   |                        |                        |                        |          |
| Level of education         |                        |                        |                        |          |
| Less than high school or GED | 566 (16.5)           | 307 (11.1)             | 259 (36.4)            | <.001    |
| High-school graduate       | 862 (28.6)             | 657 (27.9)             | 205 (31.6)            |          |
| Some college               | 785 (27.8)             | 613 (29.0)             | 172 (23.3)            |          |
| College and above          | 647 (27.1)             | 599 (32.0)             | 48 (8.7)              |          |
| Annual household income    |                        |                        |                        |          |
| <$20,000                   | 666 (18.9)             | 319 (10.9)             | 347 (48.8)            | <0.001   |
| $20,000–$35,000            | 483 (14.3)             | 330 (12.5)             | 153 (21.0)            |          |
| $35,001–$50,000            | 409 (14.2)             | 328 (14.3)             | 81 (13.9)             |          |
| $50,001–$75,000            | 469 (16.9)             | 395 (18.2)             | 74 (12.2)             |          |
| > $75,000                  | 834 (35.7)             | 805 (44.1)             | 29 (4.1)              |          |
| Working for pay            |                        |                        |                        |          |
| Yes                       | 1,214 (46.2)           | 966 (48.5)             | 248 (37.4)            | <0.001   |
| No                        | 1,645 (53.8)           | 1,209 (51.5)           | 436 (62.6)            |          |
| Census region              |                        |                        |                        |          |
| Northeast                  | 397 (15.9)             | 304 (16.1)             | 93 (15.1)             | 0.07     |
| Midwest                    | 633 (25.6)             | 513 (26.9)             | 120 (20.5)            |          |
| South                      | 1,237 (38.5)           | 901 (36.8)             | 336 (45.0)            |          |
| West                       | 590 (20.0)             | 456 (20.2)             | 134 (19.4)            |          |
| Covered by government health insurance plan |            |                        |                        |          |
| Yes                       | 1,623 (53.3)           | 1,220 (51.4)           | 403 (60.8)            | <0.01    |
| No                        | 1,225 (46.7)           | 946 (48.6)             | 279 (39.2)            |          |
| Have at least one private health insurance plan |                  |                        |                        |          |
| Yes                       | 1,648 (63.1)           | 1,429 (71.2)           | 219 (32.8)            | <0.001   |
| No                        | 1,202 (36.9)           | 737 (28.8)             | 465 (67.2)            |          |
| Have a usual place for health care/advice |            |                        |                        |          |
| Yes                       | 2,580 (92.0)           | 2,002 (93.4)           | 578 (87.1)            | <0.001   |
| No                        | 279 (8.0)              | 173 (6.6)              | 106 (12.9)            |          |
| Need characteristics       |                        |                        |                        |          |
| BMI (kg/m²)                |                        |                        |                        |          |
| Normal or underweight (< 25) | 596 (22.8)           | 498 (24.9)             | 98 (14.8)             | <0.001   |
| Overweight (25–29.9)       | 822 (29.1)             | 646 (30.3)             | 176 (24.7)            |          |
| Obese (≥ 30)               | 1,441 (48.1)           | 1,032 (44.8)           | 409 (60.5)            |          |
| Smoking status             |                        |                        |                        |          |
| Current                    | 347 (12.6)             | 215 (10.3)             | 132 (21.4)            | <0.001   |

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health care/advice. The proportions of women who were obese, never-smokers, those with two and more comorbid conditions, any ADL and IADL limitations, and those with elevated depressive symptoms among the food-insecure group were (60.5%), (42.2%), (73.3%), (29.1%), (25.2%), and (34.6%), respectively (see Table 1).

Table 2 shows an improved covariate balance between food-secure and food-insecure subgroups after applying the PS weights. The weighted proportion of food-insecure women now stands at (46.0%) not significantly different (p-value = 0.15) than food-secure women. The two groups are substantially balanced on all characteristics, except for the outcome, when we compare them to the pre-PS weighting distributions in Table 1. This relatively balanced distribution facilitated an unbiased estimate of the odds of breast cancer screening in our final model, where the PS weights were applied.

We analyzed crude associations between respondents’ reports of a breast cancer screening in the past 2 years and their predisposing, enabling, and need characteristics (see Table 3). The likelihood of reporting a screening was positively associated with respondents’ education level; women with a college education or higher were more than twice as likely to have received a screening compared to those who had not completed high school (OR = 2.16; 95% CI 1.54–3.02; p-value < 0.001). The odds of screening increased nearly threefold for women reporting a yearly income greater than $75,000 (OR = 2.50; 95% CI 1.78–3.50; p-value < 0.001; vs. <$20,000) and over 33% for women who reported working for pay (OR = 1.33; 95% CI 1.05–1.68; p-value = 0.02; vs. no). Furthermore, those who reported at least one private health insurance plan (OR = 2.02; 95% CI 1.60–2.55; p-value < 0.001) and those having a regular place for health care/advice (OR = 2.14; 95% CI 1.53–2.99; p-value < 0.001) were both twice as likely to have received screenings compared to their counterparts.

Health-related practices and health status were also associated with breast cancer screening. Both never (OR = 2.41; 95% CI 1.67–3.48; p-value < 0.001) and former smokers (OR = 2.43; 95% CI 1.68–3.52; p-value < 0.001) were twice as likely to report screening than current smokers. Health status was negatively associated with breast cancer screening; those with any ADL (OR = 0.46; 95% CI 0.34–0.64; p-value < 0.001; vs. no ADL limitations) or any IADL limitations (OR = 0.49; 95% CI 0.33–0.72; p-value < 0.001; vs. no IADL limitations) were half as likely to receive these screenings. Those evaluated as having elevated depressive symptoms were 45% less likely to receive a screening (OR = 0.55; 95% CI 0.42–0.71; p-value < 0.001) compared to those without a clinically significant CES-D score.

Without any adjustments for confounding and selection bias, the crude associations show that (Model I; see Table 4) food-insecure women had 45% lower odds of reporting breast cancer screening in the past two years (OR = 0.55; 95% CI 0.42–0.71, p-value < 0.001) when compared to food-secure women. The conventional multivariable logistic regression model (Model II; see Table 4) indicates that, after adjusting for baseline predisposing, enabling, and

Table 1 (continued)

| Respondent characteristics | Total sample (n=2,861) | Food-secure (n=2,177) | Food-insecure (n=684) | p-value* |
|---------------------------|-----------------------|-----------------------|----------------------|----------|
|                           | Frequency (Weighted %)| Frequency (Weighted %)| Frequency (Weighted %)|          |
| Former                    | 1,046 (36.4)          | 813 (36.3)            | 233 (36.4)           |          |
| Never                     | 1,456 (51.0)          | 1,142 (53.4)          | 314 (42.2)           |          |
| Comorbid medical conditions|                       |                       |                      |          |
| None                      | 418 (15.5)            | 357 (17.2)            | 61 (9.4)             | < 0.001  |
| One                       | 663 (25.1)            | 547 (27.2)            | 116 (17.2)           |          |
| Two and more              | 1,780 (59.4)          | 1,273 (55.6)          | 507 (73.3)           |          |
| ADL limitations           |                       |                       |                      |          |
| Yes                       | 396 (13.1)            | 203 (8.8)             | 193 (29.1)           | < 0.001  |
| No                        | 2,465 (86.9)          | 1,974 (91.2)          | 491 (70.9)           |          |
| IADL limitations          |                       |                       |                      |          |
| Yes                       | 347 (11.2)            | 178 (7.4)             | 169 (25.2)           | < 0.001  |
| No                        | 2,514 (88.8)          | 1,999 (92.6)          | 515 (74.8)           |          |
| CES-D scale               |                       |                       |                      |          |
| Elevated depressive symptoms (CES-D ≥ 3) | 442 (14.3) | 210 (8.9)             | 232 (34.6)           | < 0.001  |
| Normal (CES-D < 3)        | 2,419 (85.7)          | 1,967 (91.1)          | 452 (65.4)           |          |

SE standard error, GED general educational development, BMI body mass index, ADL activities of daily living, IADL instrumental activities of daily living, CES-D center for epidemiologic studies depression scale

*a The design-Adjusted Rio-Scott Chi-square test or the t-test
| Respondent characteristics                              | Food-secure Weighted % | Food-insecure Weighted % | p-value |
|--------------------------------------------------------|------------------------|--------------------------|---------|
| Food security status                                   | 54.0                   | 46.0                     | 0.15    |
| Had a mammogram or breast x-ray in past 2 years        |                        |                          |         |
| Yes                                                    | 77.6                   | 61.3                     | <0.01   |
| No                                                     | 22.4                   | 38.7                     |         |
| Predisposing characteristics                           |                        |                          |         |
| Age (years), mean                                      | 61.7                   | 61.2                     | 0.41    |
| Race and ethnicity                                     |                        |                          |         |
| Non-Hispanic white                                     | 76.6                   | 66.4                     | 0.13    |
| Non-Hispanic black                                     | 11.2                   | 15.4                     |         |
| Hispanic                                               | 8.6                    | 12.6                     |         |
| Non-Hispanic others                                    | 3.6                    | 5.6                      |         |
| Enabling characteristics                               |                        |                          |         |
| Level of education                                     |                        |                          |         |
| Less than high school or GED                           | 15.9                   | 17.6                     | 0.78    |
| High-school graduate                                   | 28.3                   | 29.7                     |         |
| Some college                                           | 28.3                   | 29.2                     |         |
| College and above                                      | 27.5                   | 23.5                     |         |
| Annual household income                                |                        |                          |         |
| < $20,000                                              | 18.8                   | 23.1                     | 0.53    |
| $20,000–$35,000                                        | 14.1                   | 16.6                     |         |
| $35,001–$50,000                                        | 14.0                   | 13.9                     |         |
| $50,001–$75,000                                        | 16.9                   | 16.0                     |         |
| > $75,000                                              | 36.2                   | 30.4                     |         |
| Working for pay                                        |                        |                          |         |
| Yes                                                    | 46.1                   | 49.0                     | 0.58    |
| No                                                     | 53.9                   | 51.0                     |         |
| Census region                                          |                        |                          |         |
| Northeast                                              | 15.7                   | 13.8                     | 0.91    |
| Midwest                                                | 26.4                   | 25.0                     |         |
| South                                                  | 37.7                   | 38.5                     |         |
| West                                                   | 20.2                   | 22.7                     |         |
| Covered by government health insurance plan            |                        |                          |         |
| Yes                                                    | 53.3                   | 49.9                     | 0.56    |
| No                                                     | 46.7                   | 50.1                     |         |
| Have at least one private health insurance plan        |                        |                          |         |
| Yes                                                    | 63.7                   | 62.2                     | 0.76    |
| No                                                     | 36.3                   | 37.8                     |         |
| Have a usual place for health care/advice              |                        |                          |         |
| Yes                                                    | 92.4                   | 86.1                     | 0.22    |
| No                                                     | 7.6                    | 13.9                     |         |
| Need characteristics                                   |                        |                          |         |
| BMI (kg/m2)                                            |                        |                          |         |
| Normal or underweight (< 25)                           | 22.7                   | 18.7                     | 0.45    |
| Overweight (25–29.9)                                   | 29.4                   | 27.0                     |         |
| Obese (≥ 30)                                           | 47.9                   | 54.3                     |         |
| Smoking status                                         |                        |                          |         |
| Current                                                | 13.4                   | 16.3                     | 0.63    |
| Former                                                 | 35.5                   | 33.3                     |         |
| Never                                                  | 51.1                   | 50.4                     |         |
| Comorbid medical conditions                            |                        |                          |         |
need factors of the respondents, the odds of reporting breast cancer screening in the past two years were still 21% lower among food-insecure women (adjusted OR = 0.79; 95% CI 0.56–1.12) compared to those food-secure; however, the differences were nonsignificant. Model III, the main finding of interest (see Table 4), shows the average estimated effect of food insecurity on breast cancer screening among women when the PS weights were applied. In this model, food-insecure women had 54% lower odds of reporting screening in the past two years (adjusted OR = 0.46; 95% CI 0.30–0.70, p-value < 0.001) when compared to food-secure women. The results from Model III show more precision with less potentiality for confounding and selection bias.

Discussion

Drawing from a nationally representative sample of US women aged 50 to 74, the present study revealed that food security status had a substantial effect on subsequent breast cancer screening. Respondents who experienced food insecurity were significantly less likely to report engaging in formal breast cancer screening activities (i.e., mammogram or breast x-ray) within the past 2 years than their food-secure counterparts. This conclusion was drawn after proper adjustments for confounding and selection bias through a PS weighting method utilized to create a balance between food security status subgroups based on a set of observed respondent characteristics, and through redesigning the study to resemble characteristics of a randomized controlled trial in the best practical way.

The present findings align with the existing research suggesting that food insecurity negatively impacts health services access and utilization among US residents. The existing literature suggests that food insecurity is associated with delaying medical care [47], lower treatment adherence [48, 49], and poor chronic disease management [25, 50]. Berkowitz and colleagues (2014) attributed these trends to the ‘treat or eat’ dilemma experienced by those facing food insecurity; in such instances, people are forced to choose between accessing medical services or meeting the basic needs of food and shelter [51]. Our results indicate that women experiencing food insecurity may encounter a similar dilemma when considering whether to engage in breast cancer screening. This is especially relevant for women facing food insecurity who do not have health insurance coverage and, thus, may be responsible for the entire cost of screening. Previous findings have led to calls for cancer care providers to integrate food insecurity screening and resources into cancer care [52]. The present study results suggest that addressing the relationship between food insecurity and cancer prevalence must also involve efforts to promote screening behaviors among those who are food-insecure, especially older women and those at increased risk for breast cancer.

Our findings suggest that women facing food insecurity encounter structural, multilayered, and multi-factorial barriers to breast cancer screening [9, 10]. Any accumulation, or a combination, of factors addressed in our study, in addition to other unmeasured factors, might partially explain the lower screening rates among women experiencing food insecurity. For example, women from racial/ethnic minority populations as well as those living in poverty, those with lower educational attainment, and those with comorbid health conditions and/or disabilities are more likely to be food-insecure; furthermore, they are more likely to face logistical, psychological, and cultural barriers to breast cancer screening [18, 21]. Previous literature identifies several other

### Table 2 (continued)

| Respondent characteristics | Food-secure Weighted % | Food-insecure Weighted % | p-value |
|----------------------------|------------------------|--------------------------|---------|
| None                       | 15.4                   | 18.5                     | 0.66    |
| One                        | 25.0                   | 21.8                     |         |
| Two and more               | 59.6                   | 59.7                     |         |
| ADL limitations            |                        |                          |         |
| Yes                        | 13.7                   | 14.8                     | 0.61    |
| No                         | 86.3                   | 85.2                     |         |
| IADL limitations           |                        |                          |         |
| Yes                        | 12.0                   | 13.4                     | 0.47    |
| No                         | 88.0                   | 86.6                     |         |
| CES-D scale                |                        |                          |         |
| Elevated depressive symptoms (CES-D ≥ 3) | 14.1                   | 16.6                     | 0.32    |
| Normal (CES-D < 3)        | 85.9                   | 83.4                     |         |

GED general educational development, BMI body mass index, ADL activities of daily living, IADL instrumental activities of daily living, CES-D center for epidemiologic studies depression scale
factors—including health literacy, breast cancer screening awareness, lack of physician recommendations, concerns about screening success and efficacy, lack of public or private health insurance, and mistrust of healthcare services—that influence the decision to perform or to utilize breast cancer mammography [1, 18, 21]. There is also evidence that women facing food insecurity may also be impacted by other challenges, such as schedule inflexibility, limited access to transportation, and unavailability of childcare services; these factors could make it difficult to complete breast cancer screenings—even if they are recommended by a health care provider [9]. The misconception that screening is expensive, and that actual costs associated with screening are high, are significant deterrents to screening participation [31].

Other significant barriers for women experiencing food insecurity might include the location of residence and travel times to mammogram centers [9, 19]. In a manner similar to 'treat or eat' dilemma, food-insecure women could be forced to decide whether to use money and other resources on food, medical care, utilities, transportation, or housing [53, 54]. Evidence suggests that such a dilemma may be more pronounced among women from racial/ethnic minority populations and those residing in low-income urban areas because, among other reasons, they are less to have personal transportation and more dependent on public transportation [53]. These facts support the notion that understanding lower breast cancer screening rates, even among women facing food insecurity, cannot merely be analyzed through the lens of socioeconomic status. Instead, it is crucial to understand and account for the full scope of breast cancer screening

| Table 3 | Crude associations between respondents' predisposing, enabling, need characteristics and reporting breast cancer screening in past two years among women 50–74 years (HRS & HCNS, n = 2,861 women, the United States, 2014–2016) |
| --- | --- |
| Respondent characteristics | Total study sample crude OR (95% CI) |
| Predisposing characteristics |  |
| Age in years | 0.98 (0.97–1.01) |
| Race and ethnicity |  |
| Non-Hispanic white | Reference |
| Non-Hispanic black | 1.23 (0.92–1.64) |
| Hispanic | 1.00 (0.71–1.41) |
| Non-Hispanic others | 0.83 (0.45–1.56) |
| Enabling characteristics |  |
| Level of education |  |
| Less than high school or GED | Reference |
| High-school graduate | 1.26 (0.93–1.70) |
| Some college | 1.44 (1.04–2.00)* |
| College and above | 2.16 (1.54–3.02)** |
| Annual household income |  |
| <$20,000 | Reference |
| $20,000–$35,000 | 1.21 (0.82–1.78) |
| $35,001–$50,000 | 1.64 (1.07–2.51)* |
| $50,001–$75,000 | 2.80 (2.05–3.83)** |
| >$75,000 | 2.50 (1.78–3.50)** |
| Working for pay |  |
| Yes | 1.33 (1.05–1.68)* |
| No | Reference |
| Census region |  |
| Northeast | Reference |
| Midwest | 0.65 (0.48–0.89)** |
| South | 0.84 (0.63–1.13) |
| West | 0.82 (0.59–1.15) |
| Covered by government health insurance plan |  |
| Yes | 0.80 (0.63–1.02) |
| No | Reference |
| Have at least one private health insurance plan |  |
| Yes | 2.02 (1.60–2.55)** |
| No | Reference |
| Have a usual place for health care/advice |  |
| Yes | 2.14 (1.53–2.99)** |
| No | Reference |
| Need characteristics |  |
| BMI (kg/m²) |  |
| Normal or underweight (< 25) | Reference |
| Overweight (25–29.9) | 1.11 (0.83–1.48) |
| Obese (≥ 30) | 1.12 (0.82–1.53) |
| Smoking status |  |
| Current | Reference |
| Former | 2.43 (1.68–3.52)** |
| Never | 2.41 (1.67–3.48)** |

| Table 3 (continued) | Total study sample crude OR (95% CI) |
| --- | --- |
| Respondent characteristics |  |
| None | Reference |
| One | 1.02 (0.71–1.47) |
| Two and more | 0.96 (0.68–1.37) |
| ADL limitations |  |
| Yes | 0.46 (0.34–0.64)** |
| No | Reference |
| IADL limitations |  |
| Yes | 0.49 (0.33–0.72)** |
| No | Reference |
| CES-D scale | Elevated depressive symptoms (CES-D ≥ 3) 0.55 (0.42–0.71)** |
| Normal (CES-D < 3) | Reference |

OR odds ratio, CI confidence interval, GED general educational development, BMI body mass index, ADL activities of daily living, IADL instrumental activities of daily living, CES-D center for epidemiologic studies depression scale

*p-value ≤ 0.05, **p-value < 0.01, ***p-value < 0.001
barriers at the individual, family, community, policy, and health systems levels.

The crude associations between reported breast cancer screenings and respondents’ predisposing, enabling, and need characteristics demonstrated that such screenings were more prevalent among the socioeconomically advantaged—i.e., those with more education, higher incomes, and consistent healthcare access. These findings are consistent with past research suggesting that medical screenings, increased health literacy, and greater perceived control over disease prevention are tied to education level [55, 56]. Similarly, those with higher incomes and reliable healthcare services would be less likely to experience financial, institutional, or environmental barriers in paying for and accessing preventative healthcare such as breast cancer screening services [57]. Conversely, those from socioeconomically disadvantaged groups are more likely to experience food insecurity, which in turn can be a barrier to utilizing preventative health services.

Additional factors that were negatively associated with breast cancer screening in the present study—including smoking and health status—may also be tied to respondents’ socioeconomic status. For example, smoking is most prevalent among lower income people and those with less education [58]; these factors have also been shown to make people less likely to engage in preventative health behaviors [59]. The mediating role of life stressors, which may be more likely to manifest amongst those of lower socioeconomic standing, on cigarette usage and insufficient usage of preventative health services also merits further investigation [60].

Cancer screenings were also less likely among those with physical disabilities and poor mental health status. Existing scholarship suggests that women with disabilities encounter significant barriers to obtain screenings: for example, they may be deterred by factors that include unreliable transportation, lack of preparedness of healthcare providers, undermining or silencing of their questions, scarcity of barrier-free clinics, and the additional effort required to obtain such screenings [61]. Likewise, those experiencing depression often experience limited energy and motivation [62], making it difficult to engage in cancer screening behaviors.

Efforts to address food insecurity among vulnerable populations in the US have shown some promise. For instance, the supplemental nutrition assistance program (SNAP) is one of the primary mechanisms for reducing food insecurity in these vulnerable subgroups. Recent research has linked SNAP participation with improved health outcomes both regarding positive self-assessments and by addressing the ‘treat or eat’ compromise through providing beneficiaries the ability to spend money and resources on their health that otherwise would have been spent on food. Moreover, among older adults (similar to those in our study sample), SNAP participation has led to a reduced likelihood of nursing home or hospital admission compared to non-participating counterparts [63]. Although the association between SNAP participation and breast cancer screening rates has yet to be examined, reducing food insecurity among older women could increase their likelihood of utilizing preventative health services. Targeting social determinants of health, such as food insecurity, could trigger a protective mechanism that would promote health screenings among the most disadvantaged populations.

The results of our study must be interpreted, bearing several limitations in mind. First, a significant portion of data from HRS, and all data from HCNS, specifically the questions on food security and breast cancer screening, are respondent self-reports, which are prone to bias. For example, there might be underreporting or over-reporting of some measures due to social desirability. Second, given that the response rate for HCNS is relatively low (65%), it is plausible that biases associated with survey nonresponse are introduced. Third, we followed the guidelines provided by the USPTSF to define the age limits of the studied population; thus, the results are only generalizable to women of ages 50–74 in the US. Other agencies, such as the American Cancer Society, have slightly different screening guidelines that include younger age groups below age 50 [3]. Their recommendations encourage women with an average risk

Table 4 Logistic regression results for the association between food security status and breast cancer screening among women of ages 50–74 in the United States (HRS & HCNS, n = 2,861, 2014–2016)

| Respondent characteristic | Receipt of a mammogram or breast X-ray in the past 2 years |
|---------------------------|----------------------------------------------------------|
|                           | Model I | Model II<sup>a</sup> | Model III<sup>b</sup> |
|                           | Crude OR (95% CI) | Adjusted OR (95% CI) | Adjusted OR (95% CI) |
| Food security status      |         |                    |                     |
| Food-insecure             | 0.55 (0.42–0.71)* | 0.79 (0.56–1.12) | 0.46 (0.30–0.70)* |
| Food-secure               | Reference | Reference          | Reference           |

OR odds ratio, CI confidence interval

<sup>a</sup>The conventional regression model was adjusted for all baseline characteristics of the respondents

<sup>b</sup>Propensity score weights were applied and all baseline characteristics were adjusted for (doubly robust method)

<sup>c</sup>ORs were statistically significant at p-values < 0.001
of breast cancer to undergo regular screening mammography starting at age 45, and those of ages 45–54 to conduct screening annually. Based on those guidelines, there is no cap on age to perform mammography for women as long as their overall health is good, and they have a life expectancy of 10 years or longer [3].

Lastly, while PS weighting is a powerful method for causal associations, it does not control for unobserved covariates. The PS weighing results are interpreted under the assumption of no unobserved confounding [44]. Despite this assumption, unmeasured confounding might still be present, and the assumption cannot truly be tested outside of an actual randomized study. Hence, we were primarily limited to the information provided in the HRS and HCNS surveys. Those unmeasured covariates could have contributed to breast cancer screening differences between the food-secure and food-insecure subgroups of women.

**Conclusion and public health implications**

Among a nationally representative sample of women aged 50–74 years residing in the US, we found food insecurity to be an additional barrier to breast cancer screening. Since the reasons for lower rates of breast cancer screening among women experiencing food insecurity, compared to those who are food-secure, are multi-faceted, efforts to increase screening rates should address the complex needs of the targeted population. Improving cancer screening rates among this population will ultimately require a multilevel approach embracing a more holistic view of the problem because food insecurity, as an important element of social determinants of health, is a complex issue [9]. Community-level programs or campaigns such as breast cancer awareness and screening, or other health education programs for women, should be designed to incorporate or reflect the sociodemographic profile of women at increased risk for food insecurity.

Generally, interventions to increase cancer screening rates at the community-level could yield more success, with most sustainable change, compared to efforts only in the healthcare settings [31], and they deem to be more cost-effective for underserved, vulnerable populations in the US [31]. The efforts to eliminate the inequitable burden of cancer require more focused attention to substantially reduce cancer-related disparities beyond the continued progress in population health and through community-level initiatives [9].

One established strategy for targeted, community-level intervention to promote cancer screening is the patient navigation model [17, 64, 65]. The first patient navigation program was established at New York’s Harlem Hospital Center in the 1990s as means of addressing barriers to breast cancer screening and treatment among underserved and minority women [64]; building from the success of this initial program, patient navigation has been widely implemented across the US and has been shown to produce measurable improvements in cancer screening rates and in reducing times to diagnostic services [17, 65, 66]. A promising iteration of the patient navigation model that could be expanded or modified to target food-insecure women is the mile square accessible mammogram outreach and engagement (Mi-MAMO) initiative; the Mi-MAMO program’s preliminary results suggest that its combination of community outreach and clinical navigation services has led to increased breast cancer screening utilization and awareness among under-resourced populations at higher risk for breast cancer [17]. An additional strategy for reaching this population is to develop or expand partnerships between healthcare centers and local food banks [67]—which could potentially include offering mobile breast cancer screenings at food bank sites [68, 69].

Further, in efforts to increase screening rates among women experiencing food insecurity, healthcare providers have substantial roles and responsibilities. Healthcare providers and primary care physicians can screen their patients for food insecurity or other social risks and follow up with women to confirm that they are up to date regarding cancer screening recommendations. Perhaps providing financial incentives to healthcare providers can be a motivator to encourage routine assessments of social risks in healthcare settings. [9]. Currently, there are a few ongoing initiatives in which health care providers screen for social risks and connect patients to community-level services. For example, the Every One Project Toolkit [70], by the American Academy of Family Physicians, is a viable comprehensive resource for family physicians to promote health equity, screen for social risks, and use best practices for engaging with communities to address patients’ social determinants of health (including food insecurity) [9, 70].

Our study found that about 87.1% of women experiencing food insecurity had a usual place for health care and health advice. Thus, healthcare providers could screen for food insecurity and communicate the health benefits of routine screening and share the best screening options for insured and uninsured food-insecure women. In the US, under the Affordable Care Act, women’s preventive health care services must be covered with no cost-sharing to consumers [71]. Hence, food-insecure, but insured, women could have free access to screening services regardless of other barriers. Private health insurance plans and the State Medicaid expansion programs must cover mammography at least biennially and as frequently as once a year for women ages 40–74 who are at average risk of breast cancer, without consumer cost-sharing [71]. Other government-sponsored health insurance programs like Medicare Part B cover annual screening mammograms for women over 40 at no cost to consumers [71].
Moreover, programs such as the national breast and cervical cancer early detection program (NBCCEDP) provide an opportunity for uninsured and underinsured women of ages 40–64, who are at or below 250% of the Federal Poverty Level, to gain access to breast cancer screening services [71]. Healthcare providers can also help refer food-insecure women to social workers or case managers to facilitate their enrollment into SNAP and other food assistance programs in local communities to alleviate, at least partially, the financial burdens felt by these individuals [9, 72]. Further studies are needed on this topic, specifically to investigate breast cancer screening barriers among women facing food insecurity.

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Data availability The data analyzed for the current study were obtained from the Health and Retirement Study, publicly available to access and download @ https://hrs.isr.umich.edu/about.

Code availability Code is available upon reasonable request from the corresponding author.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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