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ORIGINAL PAPER

US urban–rural disparities in breast cancer-screening practices at the national, regional, and state level, 2012–2016

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Abstract

Purpose Previous studies suggesting that rural US women may be less likely to have a recent mammogram than urban women are limited in either scope or granularity. This study explored urban–rural disparities in US breast cancer-screening practices at the national, regional, and state levels.

Methods We used data from the 2012, 2014, and 2016 Behavioral Risk Factor Surveillance Systems surveys. Logistic models were utilized to examine the impact of living in an urban/rural area on mammogram screening at three geographic levels while adjusting for covariates. We then calculated average adjusted predictions (AAPs) and average marginal effects (AMEs) to isolate the association between breast cancer screening and the urban/rural factor.

Results At all geographic levels, AAPs of breast cancer screening were similar among urban, suburban, and rural residents. Regarding "ever having a mammogram" and "having a recent mammogram," urban women had small but significantly higher adjusted probabilities (AAP: 94.6%, 81.1%) compared to rural women (AAP: 93.5%, 80.2%).

Conclusions While urban–rural differences in breast cancer screening are small, they can translate into tens of thousands of rural women not receiving mammograms. Hence, there is a need to continue screening initiatives in these areas to reduce the number of breast cancer deaths.

Keywords Breast cancer screening · Mammogram · Average adjusted predictions · Average marginal effects · Urban–rural disparity

Introduction

Breast cancer remains one of the most common types of cancer in the US with respect to incidence and mortality [1, 2]. In 2018, more than 265,000 American women were diagnosed with new cases of breast cancer, adding to the 3.4 million US women currently living with the disease [3]. Detection of cancerous breast growths early through screening improves the 5-year survival rate to over 98% if the cancer was localized at diagnosis compared to just 27% if it had metastasized [4, 5]. Although there is continued debate about the net benefit of mammograms, they are still recognized as the gold standard of breast cancer detection and the American Cancer Society (ACS) recommends mammograms for women ≥ 45 years and that women 40–44 years have the option of having a mammogram [6–8].

Lower levels of breast cancer screening in rural compared to urban areas have been reported in multiple US studies [9–21]. However, few studies have looked at whether this disparity persists at multiple geographic levels [10, 11, 13, 14]. Existing studies that compare urban/rural breast cancer-screening levels between urban and rural areas at multiple geographic levels are either limited by non-contemporaneous data, did not include women from the many age groups that the ACS recommends receive breast cancer screenings, or did not adjust for health-seeking behavioral factors associated with breast cancer screening. This leaves a gap for a large contemporary US study that examines whether urban–rural disparities in breast cancer screening remain at the national, regional, and state levels after adjustment for demographic, socioeconomic, and health-seeking behavioral factors for all the age groups that the ACS recommends mammograms for.

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In this study, we assessed US urban–rural disparities in breast cancer screening at the national, regional, and state levels in all age groups the ACS recommends to receive mammograms while taking into account various demographic, socioeconomic, and health-seeking behavioral factors. Using nationally representative CDC surveys from 2012, 2014, and 2016, we explored the association between living in an urban/rural area and breast cancer-screening levels and recency through multivariate logistic regressions and marginal probabilities which can be thought of as an adjusted prevalence. This study's results allowed for the identification of urban/rural areas in the US where breast cancer screening is low and comparisons of breast cancer screening at the national, regional, and state level.

Methods

Study sample

This study used data from the 2012, 2014, and 2016 Behavioral Risk Factor Surveillance System surveys (BRFSS) [22–24]. Initiated in 1984, the BRFSS is the Centers for Disease Control and Prevention's (CDC) national landline and cell phone conducted survey that collects health-related data about US residents in all 50 states and the District of Columbia [25]. Potential BRFSS participants are sampled via random digit dialing from commercially available phone lists [26]. Once these individuals agree to participate in the survey, they complete computer-assisted interviews [24]. In the BRFSS, some racial/ethnic groups and/or geographic areas are oversampled to assure representative estimates at the local level [27]. To maximize the sample size used in the analysis, the study combined data from the three BRFSS years (2012, 2014, and 2016) in which the Breast and Cervical Cancer-Screening module was completed in all states [22–24]. BRFSS surveys from 2011 and earlier were not used because the post-stratification weighting in these surveys is incompatible with that of the 2012, 2014, and 2016 surveys [22–24].

Our study was comprised of female survey participants ≥ 40 years who responded to questions in the Breast and Cervical Cancer-Screening module of the BRFSS (section 16 of the 2016 survey and section 15 of the 2012 and 2014 surveys) [22–24]. In particular, we used data on two questions: "A mammogram is an X-ray of each breast to look for breast cancer. Have you ever had a mammogram?" ($n = 482{,}360$), and "How long has it been since you had your last mammogram?" ($n = 449{,}427$) [22–24]. In this study, we classified women who had received a mammogram in the past two years as "recent" (within past year/2 years) while those who did not were classified as "not recent" (within 3 years/5 years/5 or more years) [28]. Responses to these two questions allowed us to separate the sample of female respondents into those who had never received a mammogram (27,472), those who had received a mammogram but had not kept up regular screenings (last mammogram more than 2 years ago) (356,185), and those who maintain a regular screening schedule (93,242). As is typically done in CDC analyses of BRFSS data, we excluded respondents who answered "don't know/not sure" or refused to answer for both questions [29–31].

Covariates

We chose to include and adjust for specific demographic, socioeconomic, and health-seeking behavioral covariates in our analyses that are associated with breast cancer or breast cancer screening in literature [32–48]. All demographic and socioeconomic factors included in this study were categorical. The covariates were age (40–< 45, 45–< 50, 50–< 55, 55–< 60, 60–< 65, ≤ 65), race (White, Black, Hispanic, Other (Asian, American Indian or Alaskan Native, Native Hawaiian or other Pacific Islander, other race, multiracial)), marital status (Married, Divorced, Widowed, Separated, Never married, A member of an unmarried couple), household income (< $15,000, $15,000–< $25,000, $25,000–< $35,000, $35,000–< $50,000, $50,000 or more), education (Never attended school or only kindergarten, Elementary, Some high school, High school graduate, Some college or technical school, College graduate), health care coverage (Yes, No), and have professional doctor or health care provider (Yes, only one, More than one, No).

Definition of urban, suburban, and rural areas

We classified urban, suburban, and rural areas in our study using the metropolitan statistical area (MSA) that is included in the BRFSS's Metropolitan Status Codes (MSCODE) variable and is the sole variable in the BRFSS that can be used to define rurality [15–18]. Created by the US Office of Management and Budget, the MSA classification system is utilized by the US Census Bureau and other government agencies for statistical data analysis purposes [40]. Rural women were defined as those who lived outside an MSA (MSCODE 5), and non-rural women included all those who resided in MSCODE 1, 2, 3, and 4 [40]. Among non-rural women, those who lived inside a suburban county of the MSA (MSCODE 3) or outside the center city of an MSA but inside the county containing the center city (MSCODE 2) were classified as suburban, and urban residents were women who lived in the center city of an MSA (MSCODE 1) [40]. As living in an MSA that has no center city (MSCODE 4) was only available in the 2012 and 2013 BRFSS surveys and was very small compared to other categories in the same survey and the overall study sample, results concerning

MSCODE 4 are not discussed although it was included in the analysis [22, 49]. To determine the association between living in an urban/rural area and breast cancer-screening levels and recency, we included MSCODE as a covariate in our analyses.

Statistical models

We created two logistic models, one for "Have you ever had a mammogram?" (HADMAM) and the other for "How long has it been since you had your last mammogram?" (HOWLONG). Both models were binary with "Yes" being modeled for "Have you ever had a mammogram?" and "Within 2 years" being modeled for "How long has it been since you had your last mammogram?" We included MSCODE, age, race, marital status, household income, education, health care coverage, and have professional doctor or health care provider in both models. To account for the complex survey design and unequal weighting of the BRFSS, we used survey weights in our two logistic regression models. The logistic models were run in SAS 9.4 [50].

Marginal probabilities

Using the results of the logistic regression models, we fit average adjusted predictions (AAPs), which are a specific type of marginal probability that can be thought of as an adjusted prevalence [51, 52]. AAPs control for the other demographic and socioeconomic factors by simulating a hypothetical respondent population with no variation in these factors [51, 52]. AAPs over a covariate are predictions from an adjusted logistic regression model in which the covariate profile of other covariates was held constant either at original or representative values. For example, the rural AAP for HADMAM is the predicted marginal probability of having ever had a mammogram where the survey population was hypothetically all rural residents [51, 52]. Using AAPs, we are able to isolate the association between living in an urban/rural area, each demographic and socioeconomic factor, and breast cancer screening when all other factors are held constant in the logistic regression models for urban, suburban, and rural areas [51, 52]. In addition, the urban/suburban vs. rural AAP differences, known as average marginal effects (AMEs), were also calculated for having ever had a mammogram and recency of last mammogram [51, 52]. In our study, the AME for HADMAM is the difference in the probability of people who have ever had a mammogram between a hypothetically all suburban or urban survey population and a hypothetically all rural one [51, 52]. AAPs and AMEs for having ever had a mammogram and recency of last mammogram were calculated using Stata 15 [53].

Regional and national level analyses

To calculate regional level AAPs, we used the US Census regions defined by the U.S. Census Bureau [54]. The four regions were the Northeast (Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont), the Midwest (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin), the South (Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, West Virginia), and the West (Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming) [54]. In order to obtain regional level estimates of breast cancer screening for each MSCODE, we averaged together the unweighted AAP for each of the states in the respective region. National level AAPs of having ever had a mammogram and recency of last mammogram for rural, suburban, and urban areas were calculated by using all study participants who met the study's eligibility criteria from the 2012, 2014, and 2016 BRFSS surveys.

Results

Our study consisted of 789,681 respondents to the question "Have you ever had a mammogram?" and 621,710 respondents to "How long has it been since you had your last mammogram?" in the 2012, 2014, and 2016 BRFSS. The population was predominantly 65 years or older (42.4%–51.8%), non-Hispanic White (75.4%–91.0%), married (42.8%–53.1%), had an income $\geq$ \$25,000 (51.1%–65.2%), and had at least a high school education (90.2%–96.2%) (Table 1). Furthermore, respondents mostly had health care coverage (93.6%-95.3%) and a personal doctor/health care provider (91.6%–94.5%). The study population mainly lived in the center city of an MSA (157,255) or not in an MSA at all (162,566) and there were no significant differences in the covariates by MSCODE. In addition, the magnitude of the difference among the population percentage values for one level of any covariate across all MSCODEs was never > 16%.

At the national level, age, race, household income, education, and healthcare coverage were found to be significantly associated with ever having a mammogram (HADMAM) at $\alpha = 0.05$ (Table 2). We observed that people $\geq$ 65 years had the highest odds of ever having mammograms compared to those 40–< 45 years, Hispanics had the highest odds compared to Blacks, people with household incomes of \$50,000 or more had higher odds compared to all other household income categories, college graduates had higher odds

Table 1 Demographic, socioeconomic, and health risk factors among participants in the behavioral risk factor surveillance survey (2012, 2014, and 2016) used in the study ($n = 482{,}360$)

	In the center city of an MSA (MSCODE 1)		Outside the center city of an MSA but inside the county containing the center city (MSCODE 2)		Inside a suburban county of the MSA (MSCODE 3)		In an MSA that has no center city (MSCODE 4)		Not in an MSA (MSCODE 5)	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Age groups										
40–< 45	9,268	5.9	5,907	6.6	4,733	6.6	85	7.6	8,316	5.1
45–< 50	11,029	7.0	7,165	8.0	5,890	8.2	128	11.5	10,571	6.5
50–< 55	15,175	9.7	9,688	10.8	7,611	10.6	129	11.5	15,849	9.8
55–< 60	18,569	11.8	11,052	12.4	8,784	12.2	145	13.0	20,103	12.4
60–< 65	21,686	13.8	12,267	13.7	9,993	13.9	157	14.0	22,940	14.1
≥ 65	80,613	51.3	42,936	48.0	34,614	48.1	474	42.4	84,225	51.8
Refused/not asked or missing	915	0.6	429	0.5	352	0.5	0	0	562	0.4
Race										
White	118,500	75.4	75,523	84.5	61,125	84.9	1,017	91.0	140,281	86.3
Black	20,834	13.3	5,473	6.1	5,881	8.2	22	2.0	8,535	5.3
Hispanic	8,643	5.5	4,014	4.5	2,038	2.8	32	2.9	4,049	2.5
Other (e.g., Asian, American Indian or Alaskan Native, Native Hawaiian or other Pacific Islander, other race, multiracial)	7,051	4.5	3,309	3.7	2,054	2.9	22	2.0	7,925	4.9
Refused/not asked or missing	2,201	1.4	1,106	1.2	873	1.2	25	2.2	1,769	1.1
Marital status										
Married	67,369	42.8	45,469	50.8	36,895	51.3	594	53.1	82,269	50.6
Divorced	28,774	18.3	13,908	15.6	10,797	15.0	194	17.4	22,761	14.0
Widowed	39,417	25.1	20,921	23.4	17,481	24.3	238	21.3	44,127	27.1
Separated	2,919	1.9	1,432	1.6	1,205	1.7	13	1.2	2,675	1.7
Never married	15,671	10.0	6,132	6.9	4,487	6.2	63	5.6	8,394	5.2
A member of an unmarried couple	2,146	1.4	1,121	1.3	798	1.1	14	1.3	1,782	1.1
Refused/not asked or missing	955	0.6	460	0.5	314	0.4	2	0.2	557	0.3
Household income										
< $15,000	15,539	9.9	7,435	8.3	6,188	8.6	75	6.7	20,379	12.5
$15,000–< $25,000	24,367	15.5	12,694	14.2	10,905	15.2	129	11.5	30,203	18.6
$25,000–< $35,000	15,760	10.0	8,265	9.2	7,025	9.8	115	10.3	18,176	11.2
$35,000–< $50,000	19,086	12.1	10,534	11.8	8,690	12.1	139	12.4	20,675	12.7
$50,000 or more	54,877	34.9	34,941	39.1	26,551	36.9	475	42.5	44,249	27.2
Refused/not asked or missing	27,626	17.6	15,575	17.4	12,618	17.5	185	16.6	28,884	17.8
Education										
Never attended school or only kindergarten	235	0.2	103	0.1	59	0.1	0	0	153	0.1
Elementary	3,729	2.8	1,872	2.1	1,464	2.0	21	1.9	4,999	3.1
Some high school	7,719	4.9	3,982	4.5	3,779	5.3	21	1.9	10,645	6.6
High school graduate	41,776	26.6	25,417	28.4	22,952	31.9	351	31.4	57,638	35.5
Some college or technical school	43,226	27.5	24,780	27.7	19,885	27.6	317	28.4	46,110	28.4
College graduate	60,098	38.2	33,073	37.0	23,648	32.9	407	36.4	42,697	26.3
Refused/not asked or missing	472	0.3	216	0.2	190	0.3	1	0.1	324	0.2
Health care coverage										
Yes	149,326	95.0	85,217	95.3	68,388	95.0	1,055	94.4	152,110	93.6
No	7,565	4.8	4,036	4.5	3,433	4.8	62	5.6	10,041	6.2

Table 1 (continued)

	In the center city of an MSA (MSCODE 1)		Outside the center city of an MSA but inside the county containing the center city (MSCODE 2)		Inside a suburban county of the MSA (MSCODE 3)		In an MSA that has no center city (MSCODE 4)		Not in an MSA (MSCODE 5)	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Don't know/not sure	161	0.1	75	0.1	58	0.1	0	0	157	0.1
Refused/not asked or missing	203	0.1	116	0.1	98	0.1	1	0.1	258	0.2
Have personal doctor or health care provider										
Yes, only one	133,135	84.7	76,948	86.0	60,569	84.2	985	88.1	135,313	83.2
More than one	13,190	8.4	6,989	7.8	6,665	9.3	72	6.4	13,584	8.4
No	10,473	6.7	5,291	5.9	4,562	6.3	60	5.4	13,152	8.1
Don't know/not sure	283	0.2	142	0.2	106	0.2	1	0.1	326	0.2
Refused/not asked or missing	174	0.1	74	0.1	75	0.1	0	0	190	0.1
Have you ever had a mammogram										
Yes	149,567	95.1	84,973	95.0	67,807	94.2	1,074	96.1	151,447	93.2
No	7,688	4.9	4,471	5.0	4,170	5.8	44	3.9	11,119	6.8
How long since last mammogram										
2 years or more	28,883	19.5	15,501	18.4	13,576	20.3	159	14.9	35,123	23.5
Within 2 years	118,919	80.5	68,631	81.6	53,478	79.8	910	85.1	114,247	76.5

compared to all other education categories, and those with health care coverage had higher odds than those without health care coverage. There was a pattern of increased odds of having a mammogram with increasing age, education, and household income. For having a recent mammogram (HOWLONG), race, marital status, household income, healthcare coverage, and personal doctor/health care provider were significantly associated with having a recent mammogram at $\alpha = 0.05$. Our results show that people 60–< 65 had the highest odds of having a recent mammogram compared to people 40–< 45, Blacks had the highest odds compared to Whites, people who were married had higher odds compared to all the marital status categories, people with household incomes of $50,000 or more had higher odds compared to all other household income categories, those with health care coverage had higher odds than those without health care coverage, and people with one health care provider had higher odds compared to the other personal doctor/health care provider categories. Increasing age and household income corresponded with increasing odds of having a recent mammogram. Although not statistically significant, people who lived in urban (MSCODE1) and suburban areas (MSCODE 2 and MSCODE 3) had higher odds of ever having a mammogram and having a recent mammogram than people living in rural areas (MSCODE5).

Overall, the probabilities of ever having a mammogram and having a recent mammogram were high (AAP > 79%) across the US (Table 3). People who lived in urban (MSCODE1) and suburban areas (MSCODE 2 and 3) had higher probabilities of ever having a mammogram [AAPs: MSCODE 1: 94.6% (95% CI 94.4–94.9%); MSCODE 2: 94.4% (95% CI 94.2–94.7%); and MSCODE 3: 93.8% (95% CI 93.5–94.2%)] compared to people who lived in rural areas [AAP MSCODE 5: 93.5% (95% CI 93.3–93.7%)]. Similar to the probability of ever having a mammogram, the probability of having a recent mammogram was higher among urban and suburban residents [AAPs: MSCODE 1: 81.1% (95% CI 80.7–81.4%); MSCODE 2: 81.3% (95% CI 80.8–81.7%); and MSCODE 3: 80.6% (95% CI 80.1–81.1%)] compared to rural residents [AAP MSCODE 5: 80.2% (95% CI 79.8–80.6%)]. The greatest difference in probabilities of having a recent mammogram was between those in the center city of an MSA (MSCODE 1) and those not in an MSA (MSCODE 5) (AME: 1.1%) and the smallest was between those inside a suburban county of the MSA (MSCODE 3) and those not in an MSA (MSCODE 5) (AME: 0.3%). For recency of last mammogram, the greatest difference in probabilities was between those outside the center city of an MSA but inside the county containing the center city (MSCODE 2) and those not in an MSA (MSCODE 5) (AME: 1.1%) and the smallest was between those inside a suburban county of the MSA (MSCODE 3) and those not in an MSA (MSCODE 5) (AME: 0.4%).

Table 2 Results of logistic regression models on ever having a mammogram (HADMAM) and having a recent mammogram (HOWLONG)

Parameters	Ever had a mammogram				Recent mammogram (< 2 years)			
	Odds ratio	95% CI		*p* value	Odds ratio	95% CI		*p* value
		Lower	Upper			Lower	Upper	
Age groups (ref: 40–< 45)								
45–< 50	3.33	3.05	3.64	< 0.001	1.02	0.93	1.10	0.728
50–< 55	5.91	5.40	6.47	< 0.001	1.06	0.98	1.15	0.152
55–< 60	8.87	8.04	9.78	< 0.001	1.08	1.00	1.17	0.047
60–< 65	10.71	9.70	11.83	< 0.001	1.13	1.04	1.21	0.003
≥ 65	10.79	9.97	11.67	< 0.001	1.02	0.95	1.09	0.650
Race (ref: White)								
Black	1.52	1.38	1.68	< 0.001	2.03	1.91	2.15	< 0.001
Hispanic	1.66	1.43	1.92	< 0.001	1.72	1.56	1.89	< 0.001
Other (e.g., Asian, American Indian or Alaskan Native, Native Hawaiian or other Pacific Islander, other race, multiracial)	0.87	0.77	0.99	0.035	0.92	0.85	0.99	0.035
Marital status (ref: married)								
Divorced	0.93	0.86	1.01	0.081	0.85	0.81	0.88	< 0.001
Widowed	0.81	0.75	0.88	< 0.001	0.67	0.65	0.70	< 0.001
Separated	0.91	0.76	1.08	0.267	0.80	0.71	0.90	< 0.001
Never married	0.68	0.62	0.76	< 0.001	0.85	0.80	0.91	< 0.001
A member of an unmarried couple	0.88	0.73	1.05	0.157	0.76	0.67	0.87	< 0.001
Household income (ref: $50,000 or more)								
< $15,000	0.50	0.46	0.55	< 0.001	0.56	0.53	0.60	< 0.001
$15,000–< $25,000	0.58	0.53	0.63	< 0.001	0.63	0.60	0.66	< 0.001
$25,000–< $35,000	0.65	0.59	0.71	< 0.001	0.72	0.68	0.76	< 0.001
$35,000–< $50,000	0.71	0.66	0.78	< 0.001	0.82	0.79	0.86	< 0.001
Education (ref: College graduate)								
Never attended school or only kindergarten	0.36	0.17	0.78	0.009	1.05	0.59	1.86	0.876
Elementary	0.59	0.49	0.72	< 0.001	0.83	0.73	0.93	0.002
Some high school	0.56	0.50	0.63	< 0.001	0.71	0.67	0.77	< 0.001
High school graduate	0.71	0.66	0.76	< 0.001	0.88	0.84	0.91	< 0.001
Some college or technical school	0.83	0.77	0.89	< 0.001	0.84	0.81	0.88	< 0.001
Health care coverage (ref: yes)								
No	0.56	0.51	0.61	< 0.001	0.45	0.42	0.48	< 0.001
Personal doctor/health care provider (ref: yes, only one)								
More than one	1.03	0.94	1.14	0.518	0.95	0.90	1.00	0.045
No	0.30	0.28	0.32	< 0.001	0.33	0.32	0.35	< 0.001
MSCODE (ref: not in an MSA)								
In the center city of an MSA	1.26	1.18	1.34	< 0.001	1.06	1.02	1.10	0.002
Outside the center city of an MSA but inside the county containing the center city	1.20	1.12	1.30	< 0.001	1.07	1.03	1.12	0.001
Inside a suburban county of the MSA	1.06	0.98	1.15	0.120	1.03	0.98	1.07	0.234

Of all the US regions, the Northeast had the highest probabilities (AAP: 94.3–95.1%) and the West the lowest probabilities (AAP: 93.1–94.3%) for ever having a mammogram for all MSCODEs (Table 4). The low regional probability in the West is primarily driven by the state-level AAPs of Alaska (91.4–92.9%), Nevada (92.3–93.6%), and Idaho (92.5–93.8%) which were 3 of the 4 lowest state AAPs in terms of ever having a mammogram in the nation. Massachusetts was the state with the highest probability of ever having a mammogram (AAP: 94.5–95.5%) and Alaska was the lowest (AAP: 91.4–92.9%). As with the probability of ever having a mammogram, the Northeast (AAP: 81.1–82.1%) and West (AAP: 79.3–80.4%) had the highest and lowest probabilities, respectively, of having a recent mammogram for all MSCODEs. The state with the highest probability of having a recent mammogram

Table 3 Average adjusted predictions (AAPs) (%) for different urban–rural categories and average marginal effects (AMEs) of urban/suburban areas versus rural area with respect to ever having a mammogram (HADMAM) and having a recent mammogram (HOWLONG)

Parameters	Ever had a mammogram				Recent mammogram (< 2 years)			
	Estimate	95% CI		*p* value	Estimate	95% CI		*p* value
		Lower	Upper			Lower	Upper	
MSCODE	Average adjusted predictions (AAPs)							
In the center city of an MSA (MSCODE 1)	94.6	94.4	94.9	< 0.001	81.1	80.7	81.4	< 0.001
Outside the center city of an MSA but inside the county containing the center city (MSCODE 2)	94.4	94.2	94.7	< 0.001	81.3	80.8	81.7	< 0.001
Inside a suburban county of the MSA (MSCODE 3)	93.8	93.5	94.2	< 0.001	80.6	80.1	81.1	< 0.001
Not in an MSA (MSCODE 5)	93.5	93.3	93.7	< 0.001	80.2	79.8	80.6	< 0.001
Parameters	Ever had a mammogram				Recent mammogram (< 2 years)			
	Estimate	95% CI		*p* value	Estimate	95% CI		*p* value
		Lower	Upper			Lower	Upper	
MSCODE	Average marginal effects (AMEs) (ref: not in an MSA (MSCODE 5))							
In the center city of an MSA (MSCODE 1)	1.1	0.8	1.5	< 0.001	0.9	0.3	1.4	0.002
Outside the center city of an MSA but inside the county containing the center city (MSCODE 2)	0.9	0.6	1.3	< 0.001	1.1	0.5	1.7	0.001
Inside a suburban county of the MSA (MSCODE 3)	0.3	−0.1	0.007	0.117	0.4	−0.3	1.0	0.233

AAPs are a type of marginal probability that attempt to control for the other demographic, socioeconomic, and health-seeking behavioral factors by considering a hypothetical respondent population with no variation in these factors calculated [40, 41]

AMEs are the differences in AAPs

was Maryland (AAP: 83.3–84.3%) and the state with the lowest probability was West Virginia (AAP: 77.4–78.5%). Urban–rural differences were very small across all US regions ranging from 1.1–1.2% for the probability of ever having a mammogram and 0.8–0.9% for probability of having a recent mammogram. Urban–rural differences at the state level were also small for probability of ever having a mammogram (0.9–1.5%) and probability of having a recent mammogram (0.7–1.0%).

Discussion

We conducted a nationally representative study using data from the 2012, 2014, and 2016 BRFSS to determine if urban–rural disparities in breast cancer screening exist at multiple geographic levels in the US. Nationwide and at the regional and state levels, adjusted probabilities of ever having a mammogram and having a recent mammogram were roughly similar among urban, suburban, and rural residents. However, women living in urban areas (MSCODE 1) had small but significantly higher adjusted probabilities of breast cancer screening compared to rural women (MSCODE 5). We also noted that the Northeast and West, respectively, had the highest and lowest probability of ever having a mammogram and having a recent mammogram. On the other hand, the states with the highest and lowest levels of breast cancer screening differed.

Our findings that rural areas have lower levels of mammogram screening and less recent mammograms at the national, regional, and state level are in line with earlier research on urban/rural disparities in breast cancer-screening practices in the US [10, 11, 13, 14]. In an unadjusted county level analysis of women aged 67–69 years enrolled in Medicare in 2012 and 2013, Heller et al. found that rural counties (44.0–68.4%) had significantly lower mammogram screening levels than urban counties (54.5–74.1%) within these years in 25 out of the 26 states included in the study [10]. Using data from the 1994 U.S. National Health Interview Survey, Zhang et al. showed that mammogram screening levels were significantly lower in rural (61%) compared to urban areas (68%) for women aged 50–69 years [11]. In a national level study using the 2004 BRFSS, Doescher and Jackson found that rural residents (70.8%) still had significantly lower mammogram screening levels than urban residents (75.7%) even after adjustment for age, race, income, education, and employment [14]. The higher mammogram screening levels we report in our study compared to Heller et al.'s, Zhang et al.'s, and Doescher and Jackson's probably stem from our inclusion of women from more age groups that the ACS specifically recommends breast cancer screening to, considering mammogram screening over a lifetime

Table 4 Average adjusted predictions (AAPs) (%) at the state level for different urban–rural categories with respect to having ever had a mammogram and recency of last mammogram in all five metropolitan status areas

States/MSCODE	Ever had a mammogram				Recent mammogram (< 2 years)			
	1	2	3	5	1	2	3	5
Northeast								
Connecticut	***95.4***	***95.2***	94.7	94.4	**83.0**	***83.2***	82.6	82.2
Maine	***95.0***	***94.8***	94.3	93.9	**80.5**	***80.7***	80.1	79.6
Massachusetts	***95.5***	***95.3***	94.8	94.5	**83.1**	***83.3***	82.6	82.3
New Hampshire	***95.1***	***95.0***	94.4	94.1	**81.5**	***81.7***	81.0	80.7
New Jersey	***94.8***	***94.6***	94.0	93.6	**82.5**	***82.7***	82.0	81.7
New York	***94.8***	***94.6***	94.0	93.7	**82.3**	***82.5***	81.8	81.4
Pennsylvania	***95.0***	***94.8***	94.2	93.8	**81.1**	***81.3***	80.7	80.3
Rhode Island	***95.1***	***94.9***	94.3	94.0	**81.9**	***82.1***	81.5	81.1
Vermont	***95.1***	***94.9***	94.4	94.1	**81.7**	***81.8***	81.2	80.8
Regional average	95.1	94.9	94.3	94.0	82.0	82.1	81.5	81.1
Midwest								
Illinois	***95.3***	***95.1***	94.5	94.2	**82.1**	***82.3***	81.6	81.2
Indiana	***94.3***	***94.1***	93.5	93.1	**80.2**	***80.4***	79.7	79.3
Iowa	***95.0***	***94.8***	94.2	93.9	**80.8**	***81.0***	80.4	80.0
Kansas	***95.1***	***94.9***	94.3	94.0	**81.2**	***81.4***	80.7	80.3
Michigan	***95.2***	***95.0***	94.4	94.1	**81.4**	***81.6***	81.0	80.6
Minnesota	***94.7***	***94.5***	93.9	93.6	**81.0**	***81.2***	80.5	80.1
Missouri	***94.6***	***94.3***	93.7	93.4	**80.1**	***80.3***	79.7	79.2
Nebraska	***94.9***	***94.7***	94.1	93.8	**81.1**	***81.3***	80.6	80.2
North Dakota	***95.0***	***94.8***	94.2	93.9	**80.5**	***80.7***	80.0	79.6
Ohio	***94.4***	***94.2***	93.6	93.3	**80.6**	***80.8***	80.1	79.7
South Dakota	***95.0***	***94.8***	94.2	93.9	**79.8**	***80.0***	79.3	78.9
Wisconsin	***94.9***	***94.7***	94.1	93.8	**81.3**	***81.5***	80.8	80.4
Regional average	94.9	94.7	94.1	93.8	80.8	81.0	80.4	80.0
South								
Alabama	***94.7***	***94.5***	93.9	93.6	**80.9**	***81.1***	80.4	80.1
Arkansas	***94.8***	***94.6***	94.0	93.7	**79.5**	***79.7***	79.0	78.6
Delaware	***95.3***	***95.1***	94.5	94.2	**82.5**	***82.7***	82.0	81.7
District of Columbia	***96.0***	***95.8***	95.3	95.1	**85.7**	***85.9***	85.3	85.0
Florida	***94.7***	***94.5***	93.9	93.6	**80.1**	***80.3***	79.6	79.2
Georgia	***94.2***	***93.9***	93.3	92.9	**80.9**	***81.1***	80.4	80.0
Kentucky	***94.0***	***93.8***	93.1	92.8	**80.0**	***80.2***	79.5	79.1
Louisiana	***94.3***	***94.0***	93.4	93.0	**80.5**	***80.7***	80.0	79.6
Maryland	***95.3***	***95.1***	94.5	94.2	**84.1**	***84.3***	83.7	83.3
Mississippi	***94.5***	***94.2***	93.6	93.3	**80.8**	***81.0***	80.3	79.9
North Carolina	***94.3***	***94.1***	93.5	93.1	**80.6**	***80.8***	80.2	79.8
Oklahoma	***93.9***	***93.7***	93.0	92.7	**79.0**	***79.2***	78.5	78.1
South Carolina	***94.6***	***94.4***	93.8	93.5	**81.3**	***81.5***	80.9	80.5
Tennessee	***94.0***	***93.8***	93.1	92.8	**79.2**	***79.5***	78.8	78.3
Texas	***94.1***	***93.9***	93.3	92.9	**80.5**	***80.7***	80.0	79.6
Virginia	***94.8***	***94.6***	94.0	93.7	**82.1**	***82.3***	81.7	81.3
West Virginia	***93.7***	***93.4***	92.7	92.4	**78.3**	***78.5***	77.8	77.4
Regional average	94.5	94.3	93.7	93.4	80.9	81.1	80.5	80.1
West								
Alaska	***92.9***	***92.6***	91.8	91.4	**79.3**	***79.5***	78.8	78.4
Arizona	***94.6***	***94.4***	93.8	93.5	**80.3**	***80.5***	79.9	79.5
California	***94.1***	***93.9***	93.3	92.9	**81.1**	***81.3***	80.6	80.3
Colorado	***94.9***	***94.7***	94.1	93.8	**82.0**	***82.2***	81.6	81.2

Table 4 (continued)

States/MSCODE	Ever had a mammogram				Recent mammogram (< 2 years)			
	1	2	3	5	1	2	3	5
Hawaii	***95.1***	***94.9***	94.4	94.1	**80.5**	***80.7***	80.0	79.6
Idaho	***93.8***	***93.5***	92.9	92.5	**78.8**	***79.0***	78.3	77.9
Montana	***94.1***	***93.9***	93.2	92.9	**78.4**	***78.6***	77.9	77.4
Nevada	***93.6***	***93.4***	92.7	92.3	**79.3**	***79.5***	78.8	78.3
New Mexico	***94.6***	***94.4***	93.7	93.4	**80.9**	***81.1***	80.4	80.0
Oregon	***94.8***	***94.6***	94.0	93.7	**80.4**	***80.6***	79.9	79.5
Utah	***94.2***	***93.9***	93.3	92.9	**81.2**	***81.3***	80.7	80.3
Washington	***95.0***	***94.8***	94.2	93.9	**81.2**	***81.4***	80.8	80.4
Wyoming	***94.6***	***94.4***	93.7	93.4	**79.2**	***79.4***	78.7	78.3
Regional average	94.3	94.1	93.5	93.1	80.2	80.4	79.7	79.3

Statistical significance with respect to differences between AAPs of MSCODE 1, 2, and 3 versus those of MSCODE 5: in bold and italic: sig. at 0.001 level; bold only: sig. at 0.01 level; italic only: sig. at 0.05 level

rather than within a two-year timespan, and more contemporary data [7, 11, 14]. Looking at urban–rural differences at the county, state, and national level, Berkowitz et al. found that the percentage of women > 40 years who had a current mammogram was higher in urban areas (75.4%) than in rural areas (73.0%) in a small-area estimation analysis that controlled for age, race, income, education, and employment [13]. These results were slightly lower than the figures we had for having a recent mammogram in urban (80.2%) and rural areas (81.1%) in our study which could be attributed to differences in the age composition of the study population, the inclusion of newer data in our analyses, and the instability of small-area estimates in terms of bias and precision [55, 56]. However, the Berkowitz et al. study did not adjust for health-seeking behavioral factors that influence preventative health screening and regional level results which may provide a different picture of urban–rural disparities in mammogram screening than are captured by state and national level results were not presented [13].

Although the urban–rural breast cancer-screening difference we report is smaller than that found in earlier studies, it is important to make a distinction between the statistical and clinical significance of the study's results and how this relates to its public health impact [10, 11, 13, 14]. While the differences in the magnitude of AAPs for ever having a mammogram and having a recent mammogram are relatively small between urban and rural areas, their strength and direction are consistent at the national, regional, and state level. Additionally, a 1–2% difference in AAPs still corresponds to tens of thousands of people at the state level, the finest scale in the study. For example, in Illinois, one of the top ten states with the highest age-adjusted rates of new breast cancer cases, the 1.1% difference in AAPs for having ever been screened for MSCODE 1 vs. MSCODE 5 within the state still translates to about 22,000 additional women receiving screening [57, 58].

Several limitations of the study need to be considered. BRFSS data are self-reported which may result in some misclassification of age, race, education, and income [22–24]. However, several BRFSS validation studies have shown that the correlations between in person obesity and diabetes measurements and BRFSS responses ranged from 74–82% [59]. Furthermore, a study that compared Massachusetts electronic health records (EHR) to the Massachusetts BRFSS found very similar prevalences of diabetes (EHR: 9.4%, BRFSS: 9.7%), smoking (EHR: 13.5%, BRFSS: 14.7%), hypertension (EHR: 26.3%, BRFSS: 29.6%), and obesity (EHR: 22.8%, BRFSS: 23.8%) [60]. As a result, we feel that the BRFSS is quite reliable and issues related to self-report are minor. Small errors due to self-report will likely cause minimal non-differential misclassification bias [61]. Some residual confounding may still exist even after controlling for demographic, socioeconomic, and health-seeking behavioral factors. To mitigate the influence of residual confounding on our estimates, we adjusted for all covariates included in other studies on rurality and breast cancer screening that the BRFSS had information on [10, 11, 13, 14].

Conclusion

In this study, we aimed to establish whether disparities existed between urban and rural women for breast cancer screening and whether any disparity was consistent across the US. Our study shows that a disparity between urban and rural women for both screening and recent screening exists at each of the state, regional, and national levels. As breast cancer remains one of the major contributors to annual cancer deaths in the United States, the implementation of screening initiatives for vulnerable groups in areas where

screening estimates are significantly below the national average can ultimately reduce the number of deaths due to one of the most common cancer types in women.

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