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Mammography facilities are accessible, so why is utilization so low?

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Abstract

Objective—This study examines new socio-ecological variables reflecting community context as predictors of mammography use.

Methods—The conceptual model is a hybrid of traditional health-behavioral and socio-ecological constructs with an emphasis on spatial interaction among women and their environments, differentiating between several levels of influence for community context. Multilevel probability models of mammography use are estimated. The study sample includes 70,129 women with traditional Medicare fee-for-service coverage for inpatient and outpatient services, drawn from the SEER–Medicare linked data. The study population lives in heterogeneous California, where mammography facilities are dense but utilization rates are low.

Results—Several contextual effects have large significant impacts on the probability of mammography use. Women living in areas with higher proportions of elderly in poverty are 33% less likely to use mammography. However, dually eligible women living in these poor areas are 2% more likely to use mammography than those without extra assistance living in these areas. Living in areas with higher commuter intensity, higher violent crime rates, greater land use mix (urbanicity), or more segregated Hispanic communities exhibit –14%, –1%, –6%, and –3% (lower) probability of use, respectively. Women living in segregated American Indian communities or in communities where more elderly women live alone exhibit 16% and 12% (higher) probability of use, respectively. Minority women living in more segregated communities by their minority are more likely to use mammography, suggesting social support, but this is significant for Native Americans only. Women with disability as their original reason for entitlement are found 40% more likely to use mammography when they reside in communities with high commuter intensity, suggesting greater ease of transportation for them in these environments.

Conclusions—Socio-ecological variables reflecting community context are important predictors of mammography use in insured elderly populations, often with larger magnitudes of effect than personal characteristics such as race or ethnicity (–3% to –7%), age (–2%), recent address change (–7%), disability (–5%) or dual eligibility status (–1%). Better understanding of community factors can enhance cancer control efforts.

Keywords

Spatial interaction model; Community context; Socio-ecological factors; Probability model; Multilevel model; Spatial epidemiology; Comprehensive cancer control; Mammography utilization

Introduction

A lot of attention has been paid to whether mammography facilities are conveniently placed [1]. Apart from service proximity, there are many other factors that might affect one's decision to use mammography. Patient factors related to reduced use of mammography include increased age, minority status, low income, low education, or literacy, poorer general health, poor understanding of the disease or mammography, lack of self-breast examination, no history of previous mammogram, rural residence, lack of transportation, costs, and a variety of cultural beliefs about risk and health or previous unpleasant experiences with the medical care system [2–22]. Lack of insurance and type of insurance are also important influences on screening among the general population. Women without insurance are less likely to get a mammogram [3–8], whereas those in Medicare or commercial health maintenance organizations (HMOs) are more likely to be screened or have cancers detected at an earlier stage [2,9,13,23,25,26]. Also, screening rates may be higher in regions with higher HMO penetration in Medicare and the private sector [24,26]. Studies have shown that longer distance to screening facilities and a lack of factors that compensate for that distance, such as car use or public transportation, are negatively correlated with mammography screening [27–29].

The model of social and environmental influences on human behaviors is known as the ecological perspective [30–38], which recognizes that many factors influence population health and at various levels of influence: intra-personal factors (individual characteristics such as knowledge and beliefs that influence behaviors), interpersonal neighborhood factors (social support, cultural cohesion, family, friends, peers that provide social identity), and both local (social context, physical environment, health care system) and more distal (institutional regulations, social and economic policies, media influences, ordinances, political climate) community factors. For example, residential racial or ethnic segregation is a contextual variable that has been associated with health outcomes [38–41]. Residential segregation is, but, one of a large collection of geospatial characteristics that might help in explaining cancer prevention behavior. For example, limited attention has been paid to aspects of social support such as recent immigrant status, English language proficiency, living alone, or other housing or care arrangements for the elderly.

The effect of socio-ecological characteristics of a woman's neighborhood of residence on her screening behavior has not been well studied. This paper fills this gap in the literature, examining a well-insured group of women with no restrictions on provider choice, living in a region with good density of mammography facilities but poor mammography use rates, to better understand the variety of community contextual factors that drive mammography use decisions. The methods are guided by a conceptual model which is a unique hybrid of traditional health-behavioral and socio-ecological constructs, with an emphasis on spatial interaction among women and their environments, differentiating between several levels of influence for community context. In addition to the direct effects of community context, we examine several interactions between personal and community contextual variables.

Methods

The study sample includes 70,129 California women from linked Surveillance Epidemiology and End Results (SEER)–Medicare data who were alive in 2002–2003, located in all regions

of the state. All women in the California SEER cancer registry with breast cancer and a 5% sample from the Medicare enrollment database, provided as a reference sample for women without cancer, were linked to Medicare enrollment and claims files. The linked files provide information about each person's type (and timing) of insurance coverage, disability status, demographic characteristics, use of hospital inpatient or outpatient services, and residential ZIP code information. Because the mammography use variable is determined from Medicare claims, only the traditional fee-for-service Medicare population with Part B (outpatient services) coverage was suitable for inclusion in the analysis. Persons with Medicare HMO coverage or lacking Part B insurance would not have claims on file with Medicare. The sample was trimmed to exclude women less than 65 or greater than 104 years of age, those with HMO coverage or lacking Part B insurance during 2002–2003, and a small number (less than 1%) who had invalid ZIP codes of residence. The final sample size ($n = 70,129$) reflects all available observations after trimming.

The SEER–Medicare population within SEER regions is comparable to the general Medicare population in terms of age, sex, poverty, and education but is slightly more urban with a greater proportion of foreign-born residents [42]. California is one of 13 states with SEER registries and has the largest study population among them. California has widely variable mammography use over geographic regions and considerable heterogeneity in socio-economic and socio-cultural factors. California exhibits urbanization with dense traffic congestion and commuter intensity in some places, flanked by rural locales with isolated providers. There is also good geographic density of mammography service locations, so more than half the women in the sample lived in the same ZIP code as a mammography facility, and only 3% were located in a ZIP code more than 10 miles from a facility.

The conceptual model for the analysis is a spatial-interactions approach that recognizes the interplay between personal, social, and physical environments along the pathways to healthcare utilization. Following Mobley et al. [43], we blend the health behavioral and socio-ecological perspectives to create a hybrid spatial interactions model that explicitly considers the levels of influence that are central to the mainstream socio-ecological perspective and differentiates personal characteristics into the enabling, predisposing, and need constructs from the traditional behavioral health model [44]. The hybrid model (Fig. 1) positions the individual as making utilization choices (the final outcome) in a market context that has different levels of influence for different classes of contextual variables, and guides the selection of variables to be included in the analysis while suggesting the appropriate level of aggregation for them through its classification of the zones of influence.

The variables chosen for this work, where they fit in terms of the concept, and their sources are described in Table 1, which is divided into three sections corresponding to the conceptual model: individual characteristics (categorized into enabling, predisposing, and need categories), interpersonal/proximate factors, intermediate/community factors, and macro/fundamental (more distal) community factors. The interpersonal/proximate factors are measured at the Primary Care Service Area (PCSA), which is smaller than the county and based on elderly patient flows to their primary care physicians [45], whereas the intermediate/community factors are measured at the county level. This hierarchy has been compared to others using different neighborhood constructs, which all produce comparable findings [43]. The macro/fundamental factors category is not represented in the California analysis because these are viewed as state- or regional-level variables.

Individual characteristics

An important enabling characteristic is the type of health coverage. All women in the sample have both Parts A and B of traditional fee-for-service Medicare insurance, which allows free choice of provider and mammography facility. Some women have Part B coverage provided

by state Medicaid programs due to personal disability and/or limited income, which makes them dually eligible for Medicare and Medicaid. We expect that personal disability or dual eligibility status are the disabling characteristics, because physical limitations and low income may present additional burdens to care-seeking behavior. Shorter distance to the closest mammography facility is seen as an enabling characteristic. Another characteristic not seen in previous research is the recent address change—moving is expected to be a disruptive and a disabling characteristic.

Predisposing factors included in the model are: Medicare HMO coverage in the 2 years prior to the study period (because a recent mammogram might have been obtained under the HMO prior to joining fee-for-service, which could lower the probability of utilization in 2002–2003); age; race or ethnicity. Cancer diagnosis and utilization of flu shots are included as indicators of need. Persons with a previous cancer diagnosis are more likely to experience another cancer, and mammography is used in the course of treatment as a diagnostic. Those utilizing flu shots are considered to have stronger health-seeking behavior. Information on personal income, marital status, employment status, or education is not available in these data.

Interpersonal/proximate factors

Interpersonal/proximate factors include local neighborhood characteristics that impact a person's perception of risk or information about healthcare, through interactions with neighbors that shape opinions and beliefs. Neighbors and peers may also provide support—both physical and psychological—for health-seeking behaviors. While residential segregation is often viewed as a harmful macro/fundamental factor[38]—because it can influence the distribution of wealth, opportunity, and political influence toward the majority—in the local neighborhood, residential segregation may impact social integration and support. Massey and Denton's [46] isolation index is used as the residential segregation measure, defined separately for each race or ethnicity relative to whites. Higher values for these indices reflect greater segregation among the races and ethnicities from the white population. The index is expected to have positive impacts for some groups and negative impacts for others, because residential segregation has been associated in the literature with both better-and worse-health outcomes, depending on the race or ethnicity of the study population [38–41,47].

Two variables are included to reflect social or cultural cohesion: the proportion of local neighborhood population that has recently immigrated into the United States and the proportion of elderly residents with little or no English language ability. Both of these variables are expected to reduce cohesion and the probability of mammography use. Several stressor variables are included for each woman's local neighborhood: commuter intensity, elderly women in poverty, and elderly women living alone. Inter-driver courtesy, which in our real-life experience decreases in communities with high commuter intensity, is expected to affect the difficulty experienced by elderly who drive or for their caregivers who drive them. Areas with greater commuter intensity have been found to exhibit lower access to preventive care services among the elderly; [48] thus, commuter intensity is expected to reduce mammography use. Areas with higher proportions of elderly women living in poverty or living alone are expected to exhibit lower mammography use rates because of lower social and material support, and women living in such areas are expected to exhibit lower probability of utilization.

Intermediate/community factors

At the local community level are social context and physical environment factors that are impacted by fundamental/distal resources that shape the infrastructure supporting community life [38]. Important among these are characteristics of the healthcare system, such as physician shortage, facility density and proximity, and managed care climate. Managed care penetration in an area can change the way that medicine is practiced, with spillover effects on fee-for-

service Medicare patients [24], so women living in areas with greater managed care penetration—although not in managed care plans themselves—may exhibit different probabilities of mammography use. Use of mammography would be higher if area attitudes regarding prevention were enhanced but lower if crowding at facilities was subsequently greater, so we have no a priori expectation regarding the sign of the HMO spillover effect.

Availability of medical oncologists and nurses is expected to increase the probability of mammography use. Women living in areas with primary care physician shortages are expected to have lower probability of use. Primary care physician shortage is indicated using Health Resources and Services Administration (HRSA)'s measure at the county level. An alternative measure of physician availability is the ratio of International Medical Graduates (IMGs)—physicians of foreign origin, who train in the United States—to native U.S.-born physicians. One study has found that IMGs have disproportionately located in U.S. counties of greatest need, compared with native medical graduates [49], which reflects successful efforts through the J-1 visa waiver program that encourage this [50]. Another study found that poor rural places with higher ratios of IMGs to native physicians had improved access to preventive care services for the elderly [48]. However, IMGs tend to settle in both urban and rural enclaves [50], so the expected impact of IMG presence on a woman's mammography use is uncertain a priori.

Women living in counties with higher violent crime rates are expected to be less likely to use mammography. There is considerable research examining the link between crime/disorder and fear [51] and evidence that fear may be limiting women's movement around their environments [52], especially for older women [53].

A land use mix index is used in the model to differentiate between sprawling suburbia, rural places, and mixed inner-city environments. More mixed environments are associated with a greater variety of walkable destinations, and women living in them may exhibit lower cardiac risk [41]. Less mixed environments are associated with greater dependence on transportation resources because transport is required to do most anything outside the home. More mixed environments might increase the probability of mammography use, especially if mammography facility locations are mixed in among other destinations sought by elderly women. However, the opposite might be expected for elderly women who do not walk and need other forms of transportation (and parking) in busy urban areas, so we cannot predict the direction of this effect a priori.

Empirical analysis

A multilevel probit model of individual women's mammography use was estimated using the Generalized Estimating Equations (GEE) approach in SAS that corrects model standard errors for redundancies imposed by having common community factors across women residing in the same neighborhoods. Failure to adjust in this way would result in downward-biased standard errors and misleading *p*-values for the regression coefficients. A base model was estimated first with no interactions between the person and community-level variables, followed by four models with different specifications of interaction effects. Because there are very few predicted values in the tails of the probability distribution in these data, a linear probability model would be a good approximation to the highly nonlinear probit model. This simplifies the interpretation of the interaction effects among the covariates to effects at the means [54]. The statistical significance of four interaction effects of particular interest was assessed:

1. person's age and commuter intensity (expect a negative effect if one cares less about traffic congestion as one ages and no longer drives),

2. person's disability status and commuter intensity (expect a positive effect if services for the disabled are more abundant in areas with denser traffic),
3. person's dual eligibility status and neighborhood poverty (expect a positive effect if financial resources from dual eligibility programs ameliorate the disadvantages of poverty in the neighborhood), and
4. person's ethnicity and degree of residential segregation of that ethnicity in their neighborhood of residence (expect a positive effect if segregation increases social support and a negative effect if segregation decreases social support).

Results

The sample statistics are presented in Table 2, and the empirical results are presented in Table 3. The estimated coefficients have been transformed into their marginal probability equivalents. The base model's prediction success rate is 71%, with sensitivity (percentage correctly predicted "yes") of 80% and specificity (percentage correctly predicted "no") of 60%; thus, the fit is good.

Person-level findings

The impacts of person-level variables are essentially the same across the five models.

Enabling characteristics—Women with disability as the original reason for Medicare entitlement are about 5% less likely to use mammography, and women with dual eligibility for Medicare and Medicaid are about 1% less likely to use mammography. Women who moved to another ZIP code during 2002–2003 are about 7% less likely to use mammography.

Living further than average distance from a mammography provider is associated with a lower probability of use, but the effect is very small (–0.001 per mile above the mean). Women at the 75th percentile of the distance distribution have a provider within 2.5 miles (and are 2.5 miles above the mean distance), so are expected to have about a quarter of a percent lower probability of use than women with mean distance to providers. To assess whether it was crowding, rather than proximity of facilities, that mattered, we included a variable reflecting the number of facilities in the woman's community per thousand elderly women (a county-level contextual variable). This variable never achieved statistical significance, even when distance to closest facility was excluded from the models.

Predisposing characteristics—Every additional year of age is associated with about a 2% decline in the probability of mammography use, reflecting on average the attitude that there is less benefit from screening with advancing age. A woman's race or ethnicity also predicts probability of use, but the estimated effect falls to about one-third of its former size (not shown) with the inclusion of community contextual factors. Holding constant statistically the community contextual variables, the estimated effects of a woman's race or ethnicity (except Hispanic) is negative compared whites; that is, these races and ethnicities are less likely to use mammography. Compared with whites, African Americans are about 3% less likely, whereas Asians, Native Americans, or other races/ethnicities are about 7% less likely to use mammography.

Need characteristics—Women who have been diagnosed with breast cancer are about 30% more likely to use mammography than women without breast cancer. This is as expected because mammography use is often part of the course of treatment. Women who have been diagnosed with other types of cancer are about 7% more likely to use mammography than women who have never been diagnosed with cancer, suggesting that having a cancer diagnosis

may increase awareness of the importance of breast cancer screening. Women who received a flu shot from their doctor were about 17% more likely to use mammography, also suggesting better preventive-care behavior.

Interpersonal neighborhood-level contextual effects

The Hispanic isolation effect is negative in all models, suggesting a small (1–3%) lower probability of use among women living in segregated Hispanic neighborhoods. By contrast, the Native American isolation effect is large and positive in all models, suggesting that women living in areas with greater segregation of Native Americans are about 16% more likely to use mammography. The effect is more than twice the magnitude of the individual Native American race effect (which is negative), so seems to more than offset the individual effect.

Living in a community where a larger proportion of workers commute long distances to work is associated with about 14% lower probability of use. This confirms our hypothesis that these areas are more difficult for elderly drivers or their caregivers and that this impedes utilization. Women who live in neighborhoods where a greater proportion of elderly women live alone *higher* probability of mammography use (about 12%). Women living in neighborhoods with a higher proportion of elderly living in poverty is the largest contextual effect, suggesting that women who live there are much less likely to use mammography (33% lower probability).

Two acculturation variables included in the models—proportion of elderly with little or no English language ability and proportion of the local population that recently immigrated to the United States—are generally not statistically significant, but the estimated signs are consistently negative across models.

Intermediate community-level contextual effects

Women living in areas with greater numbers of oncologists or mammography facilities per capita, or areas coded as having primary care physician shortages do not have statistically significant differences in their probability of use. The IMG ratio of foreign-born to U.S.-born physicians is the strongest predictor among provider variables, and the effect is positive, suggesting a 6% higher probability of use. Women living in counties with greater numbers of nurses per capita are more likely to use mammography, but the effect is quite small. Women living in counties with higher violent crime rates are about 1% less likely to use mammography, which is not surprising and is consistent with recent literature [51–53]. Women living in counties with a more varied land use are about 6% less likely to use mammography, which is informative because we had no a priori expectations for this variable.

Interaction effects

Three of the four hypothesized interaction effects between women and their community characteristics achieved statistical significance. Dually eligible women living in communities with a higher proportion of elderly in poverty were about 2% more likely than non-dually eligible women in these areas to use mammography. Persons with disability as the reason for Medicare entitlement who lived in communities with greater commuter intensity were about 40% more likely to use mammography than non-disabled women in these communities. American Indian women living in segregated American Indian communities were about 42% more likely to use mammography than other women living in those communities.

Discussion

Person-specific effect estimates were very consistent across the five models estimated (main model and four interaction effects models). Women with disability as the original reason for entitlement, those dually eligible for Medicare and Medicaid, and those who recently changed

address were less likely (−5%, −1%, −7%, respectively) to use mammography, suggesting that these characteristics are associated with impeded access to mammography. Minority women have lower probability of use than whites (−3% to −7%), but the estimated effect fell to about one-third of its former size with the inclusion of community contextual factors. This concurs with other literature and suggests that characteristics of places can be confounded with race or ethnicity, heightening the importance of conducting multilevel modeling.

We find that a variety of other contextual factors generally have greater impacts on use than these personal factors or facility accessibility. Women living in communities, where a greater proportion of elderly women live alone were found to be about 12% more likely to use mammography. One might speculate that the more health conscious, independent women in California tend to congregate in certain communities. If this phenomenon holds widely in other SEER states, it bears closer scrutiny because it might be useful to inform targeted comprehensive cancer control efforts. Women living in communities with greater proportions of elderly in poverty have much lower probability of use (33% lower on average), which is the largest contextual effect. This is modified by a woman's Medicare dual eligibility status. The interaction effect between area poverty and personal dual eligibility suggests that dually eligible women in poor communities are about 2% more likely to use services than their nondually eligible neighbors. This suggests that support from state Medicaid programs has improved mammography use. Commuter intensity, which reflects road congestion and driver courtesy, is another large negative effect (14% lower probability of use on average). This effect is greatly moderated by disability status: the interaction effect between commuter intensity in the neighborhood and a woman's disability status is positive. Disabled women living in commuter-intense communities are more likely to use mammography than non-disabled women in these communities, suggesting that disabled women in California may have better transportation resources in commuter-intense neighborhoods.

Findings are mixed for women living in communities more segregated by race or ethnicity: living in more segregated Hispanic communities is associated with about 3% lower use, whereas living in more segregated Native American communities is associated with about 16% higher use. Furthermore, there is a significant interaction effect between a woman's Native American ethnicity and greater Native American segregation in her neighborhood—Native American women living in more segregated Native American communities have even higher probability of mammography use—suggesting that these communities have been very proactive in encouraging Native Americans to use mammography. There were no significant interaction effects of this type for other races or ethnicities.

Geographic accessibility was not found to be as important as other contextual factors. Distance to the closest facility or facility density had very small effects. These findings reflect the fact that facility density is good across most of California and the women studied are fully insured by traditional Medicare, with the ability to use any provider desired. Findings suggest at most small or statistically weak effects of provider availability (primary care physicians, oncologists, mammography facilities) on the probability of mammography use. However, women living in communities with a higher ratio of foreign-born to U.S.-born physicians have significantly higher probability of use (+6%). This may reflect a better match between the diversity of races and ethnicities among the women and the physicians who serve them in areas with higher IMG ratios. This finding is also consistent with other research showing improved access to primary care services for elderly in areas with higher IMG ratios [48]. These findings are not surprising, because the literature shows that foreign-born physicians trained in the United States have disproportionately located in counties of greatest need, compared with U.S. medical graduates [49].

This study is limited to a well-insured sample of elderly women living in California, and may not be a representative of all women in California or in other places. Our ability to infer socioeconomic status was limited to a dual eligibility flag in the data. The SEER–Medicare linked data may not be spatially representative of all areas because the random sampling was based on social security numbers and not stratified by geography. Thus we must treat the sample as a convenient one and refrain from generalizing the results. Also, because the study is cross-sectional in nature, we cannot infer causality and can only identify associations between variables. These limitations open the door for future work using other areas or population for validation of these findings for broader populations.

This study's main contribution was the focus on contextual factors not well explored in the health utilization literature. Results suggest that residential segregation, commuter intensity, violent crime rates, the tendency for elderly women to live alone, land use mix, and prevalence of foreign-born physicians are environmental contextual factors that significantly affect the probability of mammography use for well-insured elderly women in California. A fruitful area of future research is to examine whether these patterns vary across states and regions or other populations. A multistate study might be useful in assessing whether some Macro/Fundamental factors vary from state to state (such as Medicaid policies, comprehensive cancer control efforts and media campaigns, or other state regulations or ordinances). Further study might also inform further comprehensive cancer control efforts and facilitate targeted interventions to improve utilization rates and population health in specific communities.

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References

1. U.S. General Accounting Office (GAO) (2002) Mammography: capacity generally exists to deliver services. Report to the Chairman, special committee on aging, U.S. Senate. Publication # GAO-02-532, April 2002
2. Haas JS, Phillips KA, Sonneborn D, McCulloch CE, Liang SY. Effect of managed care insurance on the use of preventive care for specific ethnic groups in the United States. *Med Care* 2002;40(9):743–751.10.1097/00005650-200209000-00004 [PubMed: 12218765]
3. Mainous AG III, Hueston WJ, Love MM, Griffith CH III. Access to care for the uninsured: is access to a physician enough? *Am J Public Health* 1999;89(6):910–912.10.2105/AJPH.89.6.910 [PubMed: 10358685]
4. Qureshi M, Thacker HL, Litaker DG, Kippes C. Differences in breast cancer screening rates: an issue of ethnicity or socioeconomic? *J Womens Health Gend Based Med* 2009;9(9):1025–1031.10.1089/15246090050200060 [PubMed: 11103103]
5. Sambamoorthi U, McAlpine DD. Racial, ethnic, socioeconomic, and access disparities in the use of preventive services among women. *Prev Med* 2003;37(5):475–484.10.1016/S0091-7435(03)00172-5 [PubMed: 14572431]
6. Valdin A, Cargill LC. Access and barriers to mammography in New England community health centers. *J Fam Pract* 1997;45(3):243–249. [PubMed: 9300004]
7. Adams EK, Florence CS, Thorpe KE, Becker ER, Joski PJ. Preventive care: female cancer screening, 1996–2000. *Am J Prev Med* 2003;25(4):301–307.10.1016/S0749-3797(03)00216-2 [PubMed: 14580631]

8. O'Malley MS, Earp JA, Hawley ST, Schell MJ, Mathews HF, Mitchell J. The association of race/ethnicity, socioeconomic status, and physician recommendation for mammography: who gets the message about breast cancer screening? *Am J Public Health* 2001;91(1):49–54. [PubMed: 11189825]
9. McWilliams JM, Zaslavsky AM, Meara E, Ayanian JZ. Impact of Medicare coverage on basic clinical services for previously uninsured adults. *JAMA* 2003;290(6):757–764.10.1001/jama. 290.6.757 [PubMed: 12915428]
10. Coughlin SS, Uhler RJ. Breast and cervical cancer screening practices among Hispanic women in the United States and Puerto Rico, 1998–1999. *Prev Med* 2002;34(2):242–251.10.1006/pmed.2001.0984 [PubMed: 11817921]
11. Garbers S, Jessop DJ, Foti H, Uribealarea M, Chiasson MA. Barriers to breast cancer screening for low-income Mexican and Dominican women in New York City. *J Urban Health* 2003;80(1):81–91. [PubMed: 12612098]
12. Klassen AC, Smith AL, Meissner HI, Zabora J, Curbow B, Mandelblatt J. If we gave away mammograms, who would get them? A neighborhood evaluation of a no-cost breast cancer screening program. *Prev Med* 2002;34(1):13–21.10.1006/pmed.2001.0956 [PubMed: 11749092]
13. Mandelblatt JS, Gold K, O'Malley AS, Taylor K, Cagney K, Hopkins JS, Kerner J. Breast and cervix cancer screening among multiethnic women: role of age, health, and source of care. *Prev Med* 1999;28(4):418–425.10.1006/pmed.1998.0446 [PubMed: 10090871]
14. Wu ZH, Black SA, Markides KS. Prevalence and associated factors of cancer screening: why are so many older Mexican American women never screened? *Prev Med* 2001;33(4):268–273. 10.1006/pmed.2001.0880 [PubMed: 11570830]
15. Kelahe M, Stellman JM. The impact of Medicare funding on the use of mammography among older women: implications for improving access to screening. *Prev Med* 2000;31(6):658–664. 10.1006/pmed.2000.0759 [PubMed: 11133332]
16. Lauver DR, Settersten L, Kane JH, Henriques JB. Tailored messages, external barriers, and women's utilization of professional breast cancer screening over time. *Cancer* 2003;97(11):2724–2735.10.1002/cncr.11397 [PubMed: 12767084]
17. Young RF, Waller JB Jr, Smitherman H. A breast cancer education and on-site screening intervention for unscreened African American women. *J Cancer Educ* 2002;17(4):231–236. [PubMed: 12556062]
18. Risendal B, Roe D, DeZapen J, Papenfuss M, Giuliano A. Influence of health care, cost, and culture on breast cancer screening: issues facing urban American Indian women. *Prev Med* 1999;29(6 Pt 1): 501–509.10.1006/pmed.1999.0564 [PubMed: 10600431]
19. Bobo JK, Dean D, Stovall C, Mendez M, Caplan L. Factors that may discourage annual mammography among low-income women with access to free mammograms: a study using multiethnic, multiracial focus groups. *Psychol Rep* 1999;85(2):405–416. 10.2466/PRO.85.6.405-416 [PubMed: 10611770]
20. Borrayo EA, Jenkins SR. Feeling frugal: socioeconomic status, acculturation, and cultural health beliefs among women of Mexican descent. *Cult Divers Ethnic Minor Psychol* 2003;9(2):197–206.10.1037/1099-9809.9.2.197
21. Pearlman DN, Rakowski W, Ehrich B, Clark MA. Breast cancer screening practices among black, Hispanic, and white women: reassessing differences. *Am J Prev Med* 1996;12(5):327–337. [PubMed: 8909641]
22. Roetzheim RG, Chirikos TN. Breast cancer detection and outcomes in a disability beneficiary population. *J Health Care Poor Underserved* 2002;13(4):461–476.10.1177/104920802762475111 Nov [PubMed: 12407963]
23. Riley GF, Potosky AL, Klabunde CN, Warren JL, Ballard-Barbash R. Stage at diagnosis and treatment patterns among older women with breast cancer: an HMO and fee-for-service comparison. *JAMA* 1999;281(8):720–726.10.1001/jama.281.8.720 [PubMed: 10052442]
24. Baker LC. Managed care spillover effects. *Annu Rev Public Health* 2003;24:435–456. [PubMed: 12471276]Epub 06 Nov 2001
25. Riley GF, Potosky AL, Lubitz JD, Brown ML. Stage of cancer at diagnosis for Medicare HMO and fee-for-service enrollees. *Am J Public Health* 1994;84(10):1598–1604.10.2105/AJPH.84.10.1598 Oct [PubMed: 7943477]

26. Baker LC, Brown ML. Managed care, consolidation among health care providers, and health care: evidence from mammography. *Rand J Econ* 1999;30(2):351–374.10.2307/2556084 [PubMed: 10558503]
27. Maxwell AJ. Relocation of a static breast screening unit: a study of factors affecting attendance. *J Med Screen* 2000;7(2):114–115.10.1136/jms.7.2.114 [PubMed: 11002454]
28. Hyndman JC, Holman CD, Dawes VP. Effect of distance and social disadvantage on the response to invitations to attend mammography screening. *J Med Screen* 2000;7(3):141–145. 10.1136/jms.7.3.141 [PubMed: 11126163]
29. Engelman KK, Hawley DB, Gazaway R, Mosier MC, Ahluwalia JS, Ellerbeck EF. Impact of geographic barriers on the utilization of mammograms by older rural women. *J Am Geriatr Soc* 2002;0(1):62–68.10.1046/j.1532-5415.2002.50009.x [PubMed: 12028248]
30. Bronfenbrenner, U. The ecology of human development experiments by nature and design. Harvard University Press; Cambridge: 1979.
31. Sallis JF, Bauman A, Pratt M. Environmental and policy interventions to promote physical activity. *Am J Prev Med* 1998;15:379–397.10.1016/S0749-3797(98)00076-2 [PubMed: 9838979]
32. Sallis, JF.; Owen, N. Physical activity and behavioral medicine. Sage; Thousand Oaks, CA: 1999.
33. Sallis JF, Owen N, Frank LD. Behavioral epidemiology: a systematic framework to classify phases of research on health promotion and disease prevention. *Ann Behav Med* 2000;22(4):294–298.10.1007/BF02895665 [PubMed: 11253440]
34. Baranowski T, Anderson C, Carmack C. Mediating variable framework in physical activity interventions: how are we doing? How might we do better? *Am J Prev Med* 1998;15:266–297.10.1016/S0749-3797(98)00080-4 [PubMed: 9838973]
35. Smedley, BD.; Syme, SL., editors. Promoting health: strategies from social and behavioral research. National Academies Press/Institute of Medicine; Washington, DC: 2000.
36. Wakefield J, Salway R. A statistical framework for ecological and aggregate studies. *J R Stat Soc Ser A* 2001;164:119–137.
37. Schmid T, Pratt M, Witmer L. A framework for physical activity policy research. *J Phys Act Health* 2006;3(Suppl 1):S20–S29.
38. Schulz AJ, Kannan S, Dvorchak JT, Israel BA, Allen A III, James SA, House JS, Lepkowski J. Social and physical environments and disparities in risk for cardiovascular disease: the healthy environments partnership conceptual model. *Environ Health Perspect* 2005;113(12):1817–1825. [PubMed: 16330371]
39. Williams DR, Collins C. Racial residential segregation: a fundamental cause of racial disparities in health. *Public Health Rep* 2001;116(5):404–416. [PubMed: 12042604]
40. Palloni A, Arias E. Paradox lost: explaining the Hispanic adult mortality advantage. *Demography* 2004;41(3):385–415. 10.1353/dem.2004.0024 [PubMed: 15461007]
41. Mobley LR, Root E, Finkelstein E, Khavjou O, Will J. Relationships between the built environment and other contextual factors, obesity, and cardiac risk. *Am J Prev Med* 2006;30(4):327–332.10.1016/j.amepre.2005.12.001 [PubMed: 16530620]
42. Warren JL, Klabunde CN, Schrag D, Bach PB, Riley GF. Overview of the SEER Medicare data: content, research applications, and generalizability to the United States elderly population. *Med Care* 2002;40:IV-3–IV-18.
43. Mobley LR, Kuo TM, Andrews L. How sensitive are multilevel regression findings to defined area of context?: a case study of mammography use in California. *Med Care Res Rev* 2008;65(3):315–337. [PubMed: 18259047]
44. Aday LA, Andersen R. A framework for the study of access to medical care. *Health Serv Res* 1974;9(3):208–220. [PubMed: 4436074]
45. Goodman DC, Mick SS, Bott D, Stukel T, Chang C, Marth N, Poage J, Carretta HJ. Primary care service areas: a new tool for the evaluation of primary care services. *Health Serv Res* 2003;38(1):287–310.10.1111/1475-6773.00116 [PubMed: 12650392]
46. Massey DS, Denton NA. The dimensions of residential segregation. *Soc Forces* 1988;67(2):281–315.10.2307/2579183

47. Schulz AJ, Williams DR, Israel BA, Lempert LB. Racial and spatial relations as fundamental determinants of health in Detroit. *Milbank Q* 2002;80(4):677–707.10.1111/1468-0009.00028 [PubMed: 12532644]
48. Mobley, LR.; Root, ED.; Anselin, L.; Lozano-Gracia, N.; Koschinsky, J. Spatial analysis of elderly access to primary care services. *Int J Health Geogr*. 2006. Epub 15 May 2006. <http://www.ijhealthgeographics.com/content/5/1/19>
49. Mick S, Lee S, Wodchis W. Variations in geographical distribution of foreign and domestically trained physicians in the United States: 'safety nets' or 'surplus exacerbation'? *Soc Sci Med* 2000;50:185–202.10.1016/S0277-9536(99)00183-5 [PubMed: 10619689]
50. CAH/FLEX National Tracking Project, Findings from the field. The role of international medical graduates in America's small rural "critical access" hospitals. 2003 June 20;3(1)
51. Loukaitou-Sideris A, Eck J. Crime prevention and active living. *Am J Health Promot* 2007 March/April;21(Suppl 4):380–389. [PubMed: 17465184]
52. Keane C. Evaluating the influence of fear of crime as an environmental mobility restrictor on women's routine activities. *Environ Behav* 1998;30(1):60–74.10.1177/0013916598301003
53. Meyer E, Post L. Alone at night: a feminist ecological model of community violence. *Fem Criminol* 2006;1:207–227.10.1177/1557085106289919
54. Ai C, Norton E. Interaction terms in logit and probit models. *Econ Lett* 2003;80:123–129.10.1016/S0165-1765(03)00032-6

Fig. 1.
 Spatial interaction model of mammography utilization

Table 1
Variables chosen for analysis, their contextual relevance, and sources

<i>Characteristic of sample women</i>	
Enabling/Disabling	Developed from linked California SEER cancer registry and Medicare data, provided by the National Cancer Institute, 2000–2003
Personal disability as original reason for Medicare entitlement	
Moved to a new residence in 2002–2003	
Months with dual eligibility—where entitled to both Medicare and Medicaid, 2002–2003	
Distance to closest mammography facility	
Predisposing	
Age in 2002	
Months enrolled in a Medicare HMO anytime in 2000–2001: prior period	
Race or ethnicity (white, African American, Asian, Hispanic, Native American, other)	
Need	
Had previous cancer diagnosis, breast or other cancers	
Obtained flu shot from doctor in 2002–2003	
<i>Interpersonal/proximate factors (PCSA)</i>	
<i>Social integration and support</i> : isolation index describing segregation by race or ethnicity (white, African American, Asian, Hispanic, Native American, other)	Developed from U.S. Census 2000 micro data at tract and ZCTA levels
<i>Stressor, driver courtesy</i> : commuter intensity reflecting the proportion of the workforce in each woman's residential area commuting 60 min or more each way to work	
<i>Social or cultural cohesion</i> : proportion of the population in each woman's residential area immigrating into the United States between 1995–2000	
<i>Social or cultural cohesion</i> : proportion of the elderly in each woman's residential area with little or no English language ability	
<i>Stressor, living conditions</i> : proportion of female elderly in each woman's residential area living alone	
<i>Stressor, living conditions</i> : proportion of elderly in each woman's residential area living below the federal poverty level	
<i>Intermediate/community factors (county)</i>	
<i>Health care system</i> : number of mammography facilities per thousand elderly women in each woman's residential area, 2002–2003	SEER–Medicare linked data and U.S. Census
<i>Health care system</i> : number of oncologists (or nurses) per thousand elderly, 2001 (2000)	Area resource file
<i>Health care system</i> : ratio of counts of international medical graduates (IMGs) to U.S.-born physicians (generalists and specialists), 2000–2001	HRSA geospatial data warehouse: http://datawarehouse.hrsa.gov/
<i>Health care system</i> : county designated as a primary care provider shortage area in whole or part of county, 2002: http://bhpr.hrsa.gov/shortage/hpsacritpcm.htm	Area resource file from HRSA
<i>Health care system</i> : managed care penetration, defined as proportion of the county population insured by HMOs, 2002–2003	InterStudy
<i>Social context</i> : number of violent crimes known to police per thousand population	U.S. Department of Justice and FBI
<i>Physical environment</i> : index of land use mix	National Land Use/Land Cover data, U.S. Geological Survey

HMO Health Maintenance Organization; SEER Surveillance Epidemiology and End Results; ZCTA ZIP Code Tabulation Area; HRSA Health Resources and Services Administration; PCSA Primary Care Service Area

Table 2

Sample statistics for person-level variables: means (standard deviations) or proportions, expressed as a percentage

Variable	Total (n = 70,129)	Women with mammography (n = 41,376)	Women without mammography (n = 28,753)
Age as of 2002	76.5 (7.2)	75.3 (6.4)	78.3 (7.9)
% With breast cancer	32.58	45.02	14.65
% Flu shot in 2002–2003	54.43	63.08	41.98
Months with dual eligibility (24 max)	5.8 (10.1)	4.1 (9.0)	8.2 (11.2)
Months with HMO coverage 2000–2001	1.5 (5.3)	1.5 (5.3)	1.5 (5.2)
% Personal disability: yes	6.18	5.52	7.13
Distance to closest mammography facility, in miles	1.9 (3.9)	1.9 (3.9)	2.0 (4.1)
% Changed ZIP code of address between 2002 and 2003	3.63	2.46	5.33
% With other types of cancer	2.73	2.54	2.99
Race/ethnicity			
Asian	6.88	5.03	9.56
African American	4.88	3.85	6.35
Hispanic	4.09	3.22	5.35
Native American/Alaska Native	0.32	0.27	0.40
Other	3.10	2.71	3.67
White	80.73	84.92	74.67
Variable	Area	Mean	SD
<i>Sample statistics for area-level contextual variables: by PCSA (n = 333) or county (n = 57)</i>			
Isolation index for African Americans	PCSA	0.049	0.078
Isolation index for Hispanics	PCSA	0.312	0.237
Isolation index for Asians	PCSA	0.067	0.085
Isolation index for Native Americans	PCSA	0.022	0.057
Isolation index for Pacific Islanders	PCSA	0.003	0.004
Proportion of workers commuting >60 min to work	PCSA	0.102	0.059
Proportion of elderly with little or no English	PCSA	0.287	0.168
Proportion of elderly in poverty	PCSA	0.079	0.038
Proportion of female elderly living alone	PCSA	0.318	0.067
Proportion of population immigrating into the United States between 1995–2000	PCSA	0.179	0.069
Number of mammography facilities per thousand elderly women	COUNTY	1.559	1.890
Number of oncologists per thousand elderly	COUNTY	0.084	0.074
Number of nurses per thousand elderly	COUNTY	30.773	69.926
Ratio of international to U.S. medical graduates (general and specialists)	COUNTY	0.191	0.121
Primary care physician shortage area	COUNTY	0.842	0.368
HMO penetration	COUNTY	0.244	0.237
Violent crime rate	COUNTY	4.076	1.308
Index of land use mix	COUNTY	0.159	0.180

Variable	Total (n = 70,129)	Women with mammography (n = 41,376)	Women without mammography (n = 28,753)

Table 3
Binary probit model (GEE cluster estimator): marginal probabilities ($n = 70,129$)

Variable	Marginal Probability			
Personal Characteristics				
Enabling				
Personal disability	−0.05*	−0.04*	−0.09*	−0.05*
Changed ZIP code of address between 2002 and 2003	−0.07*	−0.07*	−0.07*	−0.07*
Months with HMO coverage 2000–2001	0.00**	0.00**	0.00**	0.00**
Months with dual eligibility	−0.01*	−0.01*	−0.01*	−0.01*
Distance to closest mammography facility	0.00**	0.00**	0.00**	0.00**
Predisposing				
Age as of 2002	−0.02*	−0.02*	−0.02*	−0.02*
Asian	−0.07*	−0.05*	−0.04*	−0.05*
African American	−0.03*	−0.03*	−0.03*	−0.03*
Hispanic	−0.01	0.01	0.00	0.01
Native American	−0.07**	−0.07*	−0.07*	−0.10
Other	−0.07*	−0.02*	−0.05*	−0.01*
Need				
Other cancer diagnosis	0.07*	0.07*	0.07*	0.07*
Breast cancer diagnosis	0.30*	0.30*	0.30*	0.30*
Flu shot in 2002–2003	0.18*	0.18*	0.18*	0.18*
Interpersonal community-level contextual variables (PCSA)				
Isolation index for African Americans	−0.04	−0.07	−0.07	−0.07
Isolation index for Hispanics	−0.03**	−0.01**	−0.01**	−0.04**
Isolation index for Asians	0.00	−0.03	−0.03	−0.04
Isolation index for Native Americans	0.16*	0.17**	0.16**	0.10*
Isolation index for Pacific Islanders	−0.04	−0.07	−0.07	−0.07
Proportion of workers commuting >60 min to work	−0.14**	−0.14**	−0.17*	−0.14**
Proportion of elderly with little or no English	−0.03	−0.03	−0.03	−0.03
Proportion of population immigrating into the US between 1995–2000	0.04	0.03	0.04	0.05
Proportion of female elderly living alone	0.12**	0.13**	0.12**	0.13**

Variable	Marginal Probability			
Proportion of elderly in poverty	-0.33**	-0.50*	-0.33**	-0.35**
Intermediate/community factors (county)				
Number of mammography facilities per thousand elderly women	0.00	0.00	0.00	0.00
Number of oncologists per thousand elderly	0.01	0.00	0.00	0.00
Number of nurses per thousand elderly	0.00**	0.00**	0.00**	0.00
Ratio of international to U.S. medical graduates (general and specialists)	0.06**	0.06**	0.06**	0.06**
Primary care physician shortage area	0.01	0.01	0.01	0.01
HMO penetration	0.02	0.02	0.02	0.02
Violent crime rate	-0.01*	-0.01*	-0.01*	-0.01*
Index of land use mix	-0.06*	-0.07*	-0.06*	-0.07*
Interaction Effects				
Age in 2002 interacted with proportion of workers commuting >60 min to work	0.01			
Dual eligibility interacted with proportion of elderly in poverty				
Disabled interacted with Proportion of workers commuting >60 min to work		0.02**	0.40*	
Woman is African American interacted with isolation index for African Americans				0.06
Woman is Hispanic interacted with isolation index for Hispanics				0.07
Woman is Native American interacted with isolation index for Native American				0.42*

* Statistically significant at $p < 0.01$ ** Statistically significant at $p < 0.05$