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Temporal trends in area socioeconomic disparities in breast-cancer incidence and mortality, 1988–2005

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Abstract

Since an overarching goal of Healthy People 2010 was to eliminate health disparities, we determined temporal trends in socioeconomic disparities in five breast-cancer indicators (in situ, stage I, lymph-node positive, and locally advanced breast-cancer incidence, and breast-cancer mortality) by county socioeconomic deprivation using 1988–2005 population-based breast-cancer data. Using 1988–2005 data from women aged 40 and older from 200 counties in the Surveillance, Epidemiology, and End Results program, we examined trends in temporal disparities in the five breast-cancer indicators across quartiles of county socioeconomic deprivation. County-level trends were summarized using

the estimated annual percentage change. Observed county rates were smoothed using Bayesian hierarchical spatiotemporal methods to calculate measures of absolute and relative disparity (using absolute and relative concentration indices) and their changes over time. Large increases in in situ breast cancer rates since 1988 were observed for each of the deprivation quartiles. Absolute and relative disparity both increased over time, suggesting increasing disparities across levels of county deprivation. Absolute and relative concentration indices were near zero for the other four breast-cancer indicators, suggesting no disparities among the four quartiles of county deprivation during 1988–2005. Efforts to target counties aimed at increasing breast-cancer screening based on their level of deprivation will not likely be beneficial.

Keywords

Trends; Disparity; Deprivation; Breast cancer

Introduction

Breast-cancer screening, incidence, and mortality vary with both a woman's socioeconomic position and with that of her community. Several studies have shown that mammography use is lower among women of low socioeconomic position [1,2], and also among women living in areas with worse socioeconomic conditions regardless of their personal socioeconomic position [3]. Though studies show that the risk of breast cancer increases with increasing socioeconomic position and among women living in areas with better socioeconomic conditions [4,5], it is well established that low-income women and women who live in areas with worse socioeconomic conditions are at increased risk of breast-cancer death and have lower rates of survival [5,6].

Despite these findings, it is unclear if individual-level and area-level socioeconomic disparities in breast-cancer screening and associated changes in stage-specific breast cancer have declined over time. Some studies suggest that individual-level socioeconomic disparities in breast-cancer screening have become smaller over time [7], while other studies have observed no temporal changes [8]. Even less is known about the extent to which trends in breast-cancer incidence and mortality vary across area-level socioeconomic conditions. Reducing disparities, including those associated with area-level socioeconomic conditions, is an overarching goal of the Healthy People 2010 initiative and of the National Cancer Institute's (NCI) strategic plan [9,10]. The purpose of our analysis was to describe temporal trends in socioeconomic disparities in incidence of in situ, stage I, lymph-node positive, and locally advanced breast cancers (LABC) and in breast-cancer mortality by county socioeconomic deprivation across 200 counties using 1988–2005 population-based breast cancer data.

Methods

Data source

We used the 1988–2005 public-use county-level data from nine population-based surveillance, epidemiology, and end results (SEER) programs to calculate five breast-cancer indicators. We used 1988 as the first year of observation since this is the first year when detailed information about lymph node involvement, American Joint Commission on Cancer (AJCC) tumor-node-metastasis (TNM) staging, and tumor size were available in the SEER data. The SEER programs collect data about demographics, clinical characteristics of the tumor, treatment, and survival. During 1988–2005, the nine SEER programs included in our study covered 200 counties and about nine percent of the U.S. population. The analyses were based on women age 40 or older diagnosed with first primary breast cancer or who died from breast cancer from 1988 to 2005.

Breast-cancer indicators

Indicators of early-stage breast cancer included in situ breast cancer and invasive breast cancers that were <2 cm at the time of diagnosis (T1 tumors). We used two indicators of more advanced stage breast cancer: (1) the rate of lymph-node-positive breast cancers, and (2) the rate of LABC. We define LABC as tumors classified as T3 (tumors more than 5.0 cm of the greatest diameter) or T4 (any size tumor with direct extension to the chest wall or skin, and inflammatory carcinoma) [11]. The breast-cancer mortality rate was calculated for women who had breast cancer as the underlying cause of death on their death certificate. Women who were previously diagnosed with breast cancer but died from other causes were not included in the breast-cancer mortality rate [12].

Statistical analysis

Because there is a lack of agreement about what constitutes area-level deprivation, we first constructed a county-level deprivation index for all U.S. counties using an iterative process of principal components analysis with varimax rotation. We selected 46 variables for analysis from the 2000 census that were identified from four key studies [13–16] and our own conceptualization of socioeconomic deprivation. Eight different domains were considered: education, employment, occupation, housing, poverty, racial/ethnic composition, residential stability, and other. We excluded 23 census variables that measured very similar construct or were the inverse of a census variable already included. Variables were standardized for the factor analysis, and one six-item common factor emerged: percentage without high school education, percentage unemployed, percentage living in crowded housing (>1 person/room), percentage without a car, percentage without a telephone, and percentage of population below federal poverty rate. Cronbach's alpha was 0.93, and 73.6% of the overall variance was explained by this factor. Because our study data also spanned the 1990 census, we calculated the correlation between the 2000 county index score and the 1990 county index score, computing each index score using the same six census variables. The correlation was 0.881, suggesting that counties with high levels of socioeconomic deprivation in 1990 also had high levels of socioeconomic deprivation in 2000. We also constructed the same six-item index using the data from only the 200 SEER counties; in these counties, the correlation was 0.997. This suggests that the index constructed using only the 200 SEER counties accurately reflected the county deprivation across all the counties across the United States. Therefore, for this study, we used the results from the 2000 census and the 200 SEER counties and grouped the 200 counties into four quartiles of 50 counties each.

Second, we smoothed the observed county rates for each of the five indicators using Bayesian hierarchical spatiotemporal methods to examine temporal trends in the five breast-cancer indicators by area deprivation. Bayesian hierarchical smoothing methods were used because reliability of the observed county rates is strongly affected by sparsely populated counties and county rates that are close in proximity are not independent of each other (spatial autocorrelation). Observed county rates were either age adjusted using the 2000 U.S. standard population when age–race–county–year-specific data included fewer than five breast-cancer cases or age-and-race adjusted using the 2000 U.S. population when age–race–county–year-specific data included at least five breast-cancer cases. We used three racial groups: White, Black, and Other race. Specifically, we used the Knorr-Held model to obtain the yearly, smoothed county rates for the study during the period 1988–2005 [17]. This model contained three fixed dummy terms, designating the four quartiles of the county deprivation and four random terms,

$$\log \theta_{ij} = \beta_0 + \beta_1 \times \text{ses}_1 + \beta_2 \times \text{ses}_2 + \beta_3 \times \text{ses}_3 + \mu_i + \nu_i + \delta_j + \phi_{ij}$$

where θ_{ij} is the county–year-specific standardized rate; β_0 is the intercept; $\beta_1, \beta_2, \beta_3$ are the county-level dummy variables for deprivation, μ_i and v_i , are the spatially structured and unstructured random terms, respectively; δ_j is the temporal random term; and ϕ_{ij} is the spatiotemporal random term.

Specification of the spatially structured random effect was derived from an intrinsic conditional autoregressive model (iCAR) in which adjacent counties were assumed to have similar disease risk [18]. The other three random effects were assumed to be independent of counties and with exchangeable normal priors. Markov Chain Monte Carlo methods were adopted to fit the models. The spatial adjacency matrix was created in ArcGIS (ESRI, Redlands, CA) using an add-in adjacency tool [19]. All the data were managed in SAS 9.1 (SAS Institute, Inc., Cary, NC). Construction of the Bayesian spatiotemporal models, including the county–year-specific breast-cancer indicator rates, was implemented in WinBUGS (Ver.1.4.3, Medical Research Council, UK). After running 20,000 iterations as burn-in, 20,000 more samples were used to obtain posterior parameter estimates, including county–year-specific breast-cancer indicator rates. For each of the 200 counties, we obtained 18 annual estimates with their associated 2.5 and 97.5% credible intervals (akin to 95% confidence intervals). After obtaining the estimated county rates for all the 200 SEER counties and 18 years, we calculated the median county rate for each year and quartile of county-level deprivation. Because the ranking of the estimated county rates fluctuate over time, the median rate was not necessarily for the same county each year during the study period. Model fit was evaluated using the Deviance Information Criteria, with lower values indicating better fit [20].

Third, we used the joinpoint methodology to compare the median county rate for each of the deprivation quartiles and to identify significant changes in these rates over time for each of the five breast-cancer indicators [21,22]. Linear trends in rates from 1988 to 2005 were summarized using the estimated annual percentage change (EAPC). The EAPC was calculated by fitting a linear regression to the natural logarithm of the annual rates, using calendar year as a regression variable. Therefore, the model was

$$\ln(\text{rate}) = a * x + b$$

where x = calendar year and $\text{EAPC} = 100 * (e^a - 1)$. Joinpoint regression tests were used to identify an inflection point (hereafter, called joinpoint) with a significant change in the slope of the trend [21,22]. For our analysis, a minimum of four points between two joinpoints was required, and a maximum of three joinpoints was allowed. We also calculated the percentage change in the median county rates between 1988 and 2005 by county deprivation for each of the indicators. In addition, we statistically compared the predicted trend data for each of two deprivation quartiles. Specifically, we tested whether two joinpoint regression functions were identical (test of coincidence), or whether the two regression mean functions were parallel allowing different intercepts (test of parallelism) [23].

Fourth, we calculated trends in disparities across county deprivation for each of the breast-cancer indicators using the estimated rates or probabilities for all the counties. Disparity can be measured in two different ways, depending on whether one is concerned with measuring the relative or absolute distribution of these indicators across counties. The most frequent method of communicating information about disparities in epidemiology and public health is in relative terms (e.g., relative risk). Risk difference, a measure of absolute disparity, is used less frequently. We used measures of both relative disparity (relative concentration index [RCI]) and absolute disparity (absolute concentration index [ACI]) because of potential differences in findings between the two measures [24–26]. The RCI for grouped data can be written as

$$RCI = \left(\frac{2}{\mu} \right) \times \left(\sum p_j y_j X_j \right) - 1$$

where μ is the population average level of a breast-cancer indicator, p_j and y_j are the group's population proportion and average level of the breast-cancer indicator, respectively, and X_j is the relative rank of the j th deprivation group. X_j is defined as $p_j - 0.5 p_j$, where p_j is the cumulative share of the population up to and including group j , and p_j is the proportion of the population in group j . X_j represents the cumulative share of the population up to the midpoint of each group interval. The ACI was calculated by multiplying the RCI by the average level of the breast-cancer indicator. If there is no disparity, then the RCI and the ACI are 0. Disparity is present when the RCI or the ACI are greater than or less than zero. The RCI and ACI were implemented using the HD*calc software (version 1.0.5-Beta) from the National Cancer Institute [27].

Results

Early-stage breast cancers

From 1988 to 2005, 48,763 in situ breast cancers were diagnosed (Table 1). The average incidence rate showed a clear gradient across county deprivation with the rate being the highest for the least deprived counties and the lowest for the most deprived counties. Statistically, trends in the median rate for counties in deprivation quartiles—1 (least deprived) and 3 were coincident—as were trends in the median rates for counties in deprivation quartiles 2 and 4 (most deprived) (Fig. 1a). Both pairs of deprivation quartiles were statistically different from each other. There were no jointpoints in the median rates (Table 2), and differences in the annual average percentages of change were similar across county deprivation. Large increases in the percentage change since 1988 were observed for each of the deprivation quartiles. Absolute and relative concentration indices both increased over time (became more negative), suggesting increasing disparities across county deprivation (Fig. 1b). The slopes for the absolute and relative concentration indices were -0.590 (SE 0.184) and -1.210 (SE 0.376), respectively.

From 1988 to 2005, 114,015 stage I breast cancers were diagnosed (Table 1). The average county rate for stage I breast cancer increased with increasing county deprivation. The median rates for the deprivation quartiles showed similar patterns of increase and then decreased over time (Fig. 2a). The year at which the highest rate was achieved was within the span of two years for each of the deprivation quartiles. Counties where deprivation was the highest had lower stage I breast cancer rates during the entire study period than counties with lower levels of deprivation. The stage I breast cancer rates in counties with the lowest three quartiles of deprivation were statistically the same, but these counties in each of these three lower-deprivation quartiles were each statistically higher than the counties with the highest deprivation ($P < 0.05$). As shown in Table 2, the annual increase was the highest for the most deprived counties (5.0% per year), while the percentages of decline were similar across county-deprivation quartiles. As a result, the overall percentage increase from 1988 to 2005 and the average annual percentage change were the largest for the most deprived counties (30.2 and 1.6% per year, respectively). Overall, there was no annual percentage of change in stage I breast cancer for the three least-deprived quartiles. Absolute and relative concentration indices showed no change over time and were near zero, suggesting no disparities across the four deprivation quartiles (Fig. 2b).

Late-stage breast cancer and mortality

From 1988 to 2005, 68,686 breast cancers were lymph-node positive (Table 1). The median rate of lymph-node-positive breast cancers was the lowest among counties with the highest deprivation. All the patterns in the median rates over time were the same across the four quartiles of deprivation (Fig. 3a; Table 2), except that the median rates for the most deprived counties (in quartile 4) were statistically lower than the median rates for the quartiles 2 and 3. Absolute and relative concentration indices showed no change over time and were near zero, suggesting no disparities across deprivation groups (Fig. 3b).

From 1988 to 2005, 25,696 LABC cases were diagnosed (Table 1). The median rates were very similar across the four deprivation quartiles. The patterns of the median rates over time were similar across deprivation quartiles (Fig. 4a; Table 2). Absolute and relative concentration indices showed no change over time and were near zero, suggesting no disparities among the four deprivation groups (Fig. 4b).

From 1988 to 2005, there were 55,774 breast-cancer deaths (Table 1). The median rate was the lowest for the most deprived counties. The pattern of decline in mortality was similar across county deprivation (Fig. 5a; Table 2), ranging from 1.8% per year for the most deprived counties to 2.5% per year for the least deprived counties. As a result, the decline in mortality rate was the greatest (34.7%) for the least deprived counties and the lowest (26.1%) for the most deprived counties. The joinpoint lines for quartiles 2 and 3 were the same, and both were higher than the median rates for the most deprived counties (quartile 4). Although the joinpoint lines for the median rates were statistically similar ($P = 0.147$), it appears that, in 1988, the median mortality rate for the least deprived counties was much higher than that for the most deprived counties, while in 2005, the median mortality rate for the least and most deprived counties was very similar. Absolute and relative concentration indices showed no change over time and were near zero, suggesting no disparities across deprivation quartiles (Fig. 5b).

Discussion

The purpose of this study was to examine temporal trends from 1988 to 2005 in socioeconomic disparities in incidence of early-stage and more advanced-stage breast cancers, and in breast-cancer mortality by county deprivation. Despite increases in breast-cancer screening, changes in early-stage breast-cancer incidence, and reductions in mortality over time [28,29], our results show that changes in absolute and relative disparities across county deprivation were generally absent during the study period except for in situ breast cancer, which increased over time; this suggests that, in general, population-wide improvements over time in breast-cancer incidence and mortality were similar between counties with high and low deprivation. Because in situ breast cancer is nearly always detected by mammography, it appears that disparities by county-level deprivation in mammography use have increased over time. While this observation may be of some concern, the widening disparity by county-level deprivation in mammography use did not result in widening disparities in advanced-stage breast cancer and mortality during the timeframe of this study. Thus, some of the increase in the incidence of in situ breast cancer may be related to the over-diagnosis of lesions of low and intermediate grade [30]. However, since it takes at least five years for in situ breast cancer to progress into invasive breast cancer [31], the widening disparity by county-level deprivation may not yet have manifested itself in the more advanced breast-cancer indicators. Despite the lack of county-level disparities, we observed, that socioeconomic disparities in breast-cancer incidence and mortality may still exist at different geographic levels (e.g., census tracts or metropolitan areas) or at the individual level [2].

The findings of this study are in contrast to a recent study that found reductions in absolute and relative disparities in breast-cancer incidence and mortality from 1987 to 2004 [32]. One

possible reason for our conflicting results is the use of smoothed county data by taking into account the spatial relationships (adjacency) among counties. Smoothing methods have been ignored in many ecological analyses that have focused on examining disparities in incidence and mortality as a function of area-level characteristics [13,32,33]. By not taking into account the spatial relationships among counties, data for counties with the same area-level characteristics are combined regardless of their proximity. Such counties may be from vastly different geographic areas but have the same deprivation level. By ignoring the spatial proximity, it is assumed that residents from any particular county are unaffected by the county deprivation at a neighboring county. Furthermore, by using observed data rather than smoothed county data, study results could be affected by extreme rates that are based on few breast cancers or small population size. By using smoothed county rates, our disparity measures were less affected by such extremes, resulting in more appropriate disparity estimates. A second possible reason for the contrasting results is that Harper et al. [32] only used the percent of the population below federal poverty rate while we constructed a multi-variable deprivation index. Although our index included the percentage of the population below the poverty rate, it also included five other county characteristics (percentage without high school education, unemployed, living in crowded housing, without a car, and without a telephone). Our index captures a concept of deprivation that is broader than county poverty rate alone. For example, of the 103 counties in the least deprived poverty category (0–9.9% poverty rate), only 47 (45.6%) are in our least-deprived quartile, suggesting that other county characteristics may be high even though the poverty rate was low.

Our study has some limitations. First, we restricted our data to women aged 40 and older to focus on the age group for which routine breast-cancer-screening had been recommended [34], although recently the U.S. Preventive Services Task Force revised its screening recommendations for women aged 40–49 years [35]. Second, we used county as the smallest geographic entity within a state since it is the smallest geographic unit with the social, political, and legal responsibility for providing a broad range of services, including health-related services. We recognize that comparisons across counties present a number of challenges in that one county in one state may not be comparable to counties in another state in terms of size and population density. Also, we recognize that the breast-cancer indicators are not independent of each other. For example, 53.7% of women diagnosed with LABC had positive lymph nodes, and some women (3.3%) who were diagnosed with early-stage breast cancer earlier during the study period may have subsequently died. Regardless of the overlap, we observed important differences in rates across the indicators.

In conclusion, absolute and relative disparities across county deprivation were generally absent from 1988 to 2005, except for in situ breast cancer, where disparity by county deprivation increased over time. Since disparities in late-stage breast-cancer indicators and breast-cancer mortality rate were absent across county deprivation, targeting counties to increase breast-cancer screening based on the extent of their deprivation will not be beneficial.

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Fig. 1.
a Median-predicted stage 0 breast-cancer incidence rates by county deprivation, 1988–2005.
b Absolute and relative concentration index for stage 0 breast cancer by year, 1988–2005

Fig. 2.
a Median-predicted county rates of stage I breast cancer by county deprivation, 1988–2005.
b Absolute and relative concentration index for stage I breast cancer by year, 1988–2005

Fig. 3.
a Median-predicted lymph-node positive breast-cancer rates by county deprivation, 1988–2005. **b** Absolute and relative concentration index for lymph-node positive breast-cancer incidence by year, 1988–2005

Fig. 4.
a Median-predicted locally advanced breast-cancer rates by county deprivation, 1988–2005.
b Absolute and relative concentration index for locally advanced breast-cancer incidence by year, 1988–2005

Fig. 5.
a Median-predicted county breast-cancer mortality rates by county deprivation, 1988–2005.
b Absolute and relative concentration index for breast-cancer mortality by year, 1988–2005

Table 1
Average frequency and rate for five breast-cancer indicators by quartile of county-level deprivation, 1988–2005

County deprivation	Stage 0		Stage I		Lymph node positive		LABC		Mortality	
	Frequency	Rate*	Frequency	Rate	Frequency	Rate	Frequency	Rate	Frequency	Rate
Q1 (least)	11,510	37.8	26,081	108.3	15,465	62.9	5,362	19.1	11,680	48.3
Q2	4,298	27.9	12,953	103.1	8,005	67.3	2,625	18.8	6,121	51.3
Q3	17,527	31.5	41,380	104.1	23,583	63.8	8,666	20.2	19,284	49.9
Q4 (most)	15,428	26.7	33,601	84.1	21,633	56.1	9,043	20.7	18,689	44.8
Total	48,763	31.0	114,015	100.6	68,686	62.4	25,696	29.7	55,774	48.8

* Median of county-year-specific standardized rates

Table 2

Trends in the median rate of five breast-cancer indicators by quartiles of the county-level deprivation index, 1988–2005

Breast-cancer indicator County deprivation	Trend 1		Trend 2		Trend 3		Percentage (%) change, 1988–2005	Average annual Percentage change
	Years	EAPC (95% CI)	Years	EAPC (95% CI)	Years	EAPC (95% CI)		
Stage 0 incidence								
Q1 (least)	1988–2005	6.5 (5.7, 7.3)					191.9	6.5 (5.8, 7.2)
Q2	1988–2005	5.4 (3.6, 7.2)					144.3	5.4 (3.8, 7.0)
Q3	1988–2005	6.6 (4.7, 8.6)					198.5	6.6 (4.8, 8.5)
Q4 (most)	1988–2005	5.6 (3.7, 7.6)					153.1	5.6 (3.8, 7.4)
Stage I incidence								
Q1 (least)	1988–2001	1.8 (0.9, 2.7)	2001–2005	−4.9 (−10.5, 1.1)			3.0	0.2 (−1.2, 1.6)
Q2	1988–1998	2.9 (1.9, 3.8)	1998–2005	−3.4 (−5.1, −1.7)			4.1	0.2 (−0.6, 1.1)
Q3	1988–1999	2.6 (1.5, 3.7)	1999–2005	−2.6 (−5.4, 0.2)			12.8	0.7 (−0.4, 1.8)
Q4 (most)	1988–1999	5.0 (3.7, 6.3)	1999–2005	−4.4 (−7.5, −1.3)			30.2	1.6 (0.3, 2.8)
Lymph node positive								
Q1 (least)	1988–1997	−1.2 (−2.8, 0.6)	1997–2000	9.0 (−12.7, 36.2)	2000–2005	−6.0 (−10.7, −1.1)	−14.4	−0.9 (−4.6, 2.9)
Q2	1988–1993	−4.8 (−8.4, −0.9)	1993–2005	0.4 (−0.7, 1.6)			−17.7	−1.1 (−2.4, 0.1)
Q3	1988–2005	−0.1 (−0.7, 0.5)					−1.4	−0.1 (−0.7, 0.5)
Q4 (most)	1988–1997	−1.6 (−2.3, −0.9)	1997–2000	5.6 (−3.9, 16.1)	2000–2005	−4.1 (−6.3, −2.0)	−17.5	−1.1 (−2.7, 0.5)
LABC incidence								
Q1 (least)	1988–2005	0.3 (−1.4, 2.1)					5.7	0.3 (−1.3, 2.0)
Q2	1988–2005	−1.4 (−3.3, 0.5)					−21.3	−1.4 (−3.1, 0.4)
Q3	1988–2005	−0.7 (−2.4, 1.0)					−11.5	−0.7 (−2.3, 0.9)
Q4 (most)	1988–1999	1.0 (−0.7, 2.8)	1999–2005	−5.2 (−10.2, 0.1)			−18.8	−1.2 (−3.2, 0.8)
Mortality rate								
Q1 (least)	1988–2005	−2.5 (−2.8, −2.1)					−34.7	−2.5 (−2.8, −2.1)
Q2	1988–2005	−2.0 (−2.6, −1.4)					−29.3	−2.0 (−2.6, −1.4)
Q3	1988–2005	−2.0 (−2.5, −1.5)					−28.6	−2.0 (−2.5, −1.5)
Q4 (most)	1988–2005	−1.8 (−2.9, −0.7)					−26.1	−1.8 (−2.9, −0.7)

* $P < 0.05$, LABC locally advanced breast cancer, EAPC estimated annual percent change, CI confidence interval