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A novel method for measuring the burden of breast cancer in neighborhoods

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ABSTRACT

Community-based breast cancer prevention efforts often focus on women who live in the same neighborhoods, as they tend to have similar demographic characteristics, health behaviors, and environmental exposures; yet little research describes methods of selecting neighborhoods of focus for community-based cancer prevention interventions. Studies frequently use demographics from census data, or single breast cancer outcomes (e.g., mortality, morbidity) in order to choose neighborhoods of focus for breast cancer interventions, which may not be optimal. This study presents a novel method for measuring the burden of breast cancer among neighborhoods that could be used for selecting neighborhoods of focus. In this study, we 1) calculate a metric composed of multiple breast cancer outcomes to describe the burden of breast cancer in census tracts Philadelphia, PA, USA; 2) map the neighborhoods with the greatest breast cancer burden; and 3) compare census tracts with the highest burden of breast cancer to those with demographics sometimes used for geo-based prioritization, i.e., race and income. The results of our study showed that race or income may not be appropriate proxies for neighborhood breast cancer burden; comparing the breast cancer burden with demographics at the census tract level, we found few overlaps with the highest percentage African American or the lowest median incomes. Agencies implementing community-based breast cancer interventions should consider this method to inform the selection of neighborhoods for breast cancer prevention interventions, including education, screening, and treatment.

1. Introduction

Among women in the United States (US), breast cancer (BC) is the second-most prevalent type of cancer, the most common cause of death from cancer among Hispanic women, and the second most common cause of death from cancer among Whites and most Non-Hispanic subgroups (Breast cancer statistics [Internet]. Centers for Disease Control and Prevention., 2020a). Approximately 1 in 8 women born today in the US will be diagnosed with BC at some point in their lives (American Cancer Society, 2017). Projections for 2022 estimate that there will be 290,560 new cases of invasive BC diagnosed and 43,780 BCE deaths among women in the U.S. (American Cancer Society, 2022). There are dramatic disparities in BC outcomes among African American and White women. Mortality rates are 40% higher among African American women relative to White women (28.4 vs 20.3 per 100,000), despite African American women having a lower incidence rate (126.7 vs 130.8 per 100,000). This disparity is amplified among African American women below 50 years of age, who have twice the mortality rate relative to White women (DeSantis et al., 2019).

At the population level, regular screening, early diagnosis, and timely treatment initiation reduces the mortality and morbidity associated with BC (Richards et al., 1999; Humphrey et al., 2002; Berry et al.,

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2005; Siu AL, U.S. Preventive Services Task Force (USPSTF), 2016). To promote early-stage BC diagnosis and treatment initiation, regular screening is recommended by national clinical guidelines (Nelson et al., 2009; Oeffinger et al., 2015; Siu AL, USPSTF, 2016). The US Preventive Services Task Force recommends biennial screening mammography for women aged 50 to 74 years, whereas any decisions about screening mammography in women younger than 50 years are recommended to be made on an individual basis by weighing the potential benefits and risks (including false-positive results, unnecessary biopsies, overdiagnosis, and overtreatment)(USPSTF, 2022). The American Cancer Society recommends that all women begin screening mammography by age 45, and also recommends giving women aged 40 years and older the choice to start screening mammography (Oeffinger et al., 2015). The Community Preventive Services Task Force recommends multi-component interventions targeting underserved communities in order to boost breast cancer screening rates among populations (Community Prevention Services Task Force, 2016). However, the research describing methods of selecting communities of focus for cancer interventions is scant.

Researchers, health systems, and other organizations conducting cancer prevention interventions choose communities in which to focus their efforts . In urban areas, BC research and cancer prevention interventions often focus on neighborhoods because people who live in the same neighborhoods often have similar demographic characteristics, as place of residence correlates with socioeconomic status and ethnicity (Diez Roux and Mair, 2010). Studies in the peer-reviewed literature use cancer outcome data at the neighborhood level to choose the geographical focus for cancer prevention interventions. Geo-based studies have used BC outcome data by different geographic units, including census block group (MacKinnon et al., 2007), census tract Crabbe et al., 2015; Markossian et al., 2014), city (Sighoko et al., 2018), zip code (Dai and Oyana, 2008), county (Mobley et al., 2017; Scott et al., 2017), and Health Service Area (Tatalovich et al., 2015) among others. Almost all of these studies examined individual cancer outcomes such as mortality, incidence, and/or stage (Huerta et al., 2018; Strömberg et al., 2019).

Individual outcomes such as incidence, tumor stage, and mortality have limitations that restrict their utility for targeting neighborhoods for breast cancer interventions. First, incidence measurement at the census tract level is susceptible to detection bias, whereby areas of high incidence may not be due to disease burden, but may be a function of early detection due to increased opportunity for screening or conversely hesitancy to screen due to medical mistrust . Second, tumor stage can be dependent on local screening resources since screening is noted to detect cancers in earlier stages, as well as the presence or absence of risk factors, and unequal genetic predisposition (as reflected in BC subtypes) by geography (Saini et al., 2019). Third, because mortality occurs at lower frequencies compared with morbidity, analyzing mortality at the neighborhood level can produce unstable results. While small area-estimation using Bayesian hierarchical spatio-temporal methods can be used to deal with unstable rates, generating them is methodologically challenging (Lawson, 2021), and might not be possible for all organizations conducting community-based cancer interventions.

Cancer outcomes do not always drive the selection of neighborhoods for cancer prevention initiatives, as this is sometimes based on neighborhood demographics. This may be due to many reasons including instability of cancer outcome rates due to low numbers of cases or deaths by neighborhood (Beyer et al., 2012), or difficulty accessing the underlying cancer outcome data and relative ease of obtaining neighborhood demographics via the U.S. Census. These demographics may be used to identify underserved communities composed of residents who are at increased risk for cancer and may benefit from cancer prevention interventions. Demographic-focused interventions are very important as the effectiveness of cancer prevention interventions varies dramatically based on age, education, and culture. However, consideration of cancer outcomes would allow area-based prevention interventions to focus on prevention efforts among neighborhood residents living in areas with the greatest BC burden. While BC outcomes at the neighborhood level including stage (Islami et al., 2013; Lin and Wimberly, 2017), incidence (Akinyemiju et al., 2015; Rushton et al., 2004), and mortality (Rushton et al., 2004; Smith and Madak-Erdogan, 2018) are often correlated with sociodemographic factors, this is not always the case (Brantley-Sieders et al., 2012).

We piloted a novel method to measure the burden of BC within neighborhoods in Philadelphia using an index composed of BC morbidity, American Joint Commission on Cancer (AJCC) stage, and mortality. In addition to other place-and-context-specific considerations, this BC composite score could be used by organizations to help prioritize the neighborhoods chosen for cancer prevention interventions. In this paper, we 1) describe the calculation of the BC composite score; 2) describe the geographic distribution of the neighborhoods in Philadelphia with the greatest burden of BC; and 3) identify if the same neighborhoods with the greatest burden of BC are those with characteristics (high percentage African American and low median household income) that are often used by agencies when deciding geographic areas of focus in U.S. cities.

2. Methods

2.1. Data Sources

We accessed information about cases of BC from the Pennsylvania Cancer Registry (PCR) that were diagnosed during 2005–2014 (N = 11,024). The PCR provides information on cases and deaths due to BC, including grade and stage, and demographics such as age, sex, race, and address. The cases included histologies for invasive breast cancer, with no in-situ cases included. For health outcomes requiring population denominators, we used U.S. census data from the Decennial Census (2010), by Philadelphia Census tracts (CTs). We used CTs to quantify BC-related health outcomes because accurate population data are accessible for CTs and could be used for standardized rate calculations. We used the indirect method in order to age-standardize morbidity and mortality rates by census tract in Philadelphia. We used age-stratified U.S. breast cancer mortality and morbidity rates 2010 Surveillance Epidemiology and End Results (SEER) data as reference data for age-adjustment (NCI, N.D.). We used U.S. Census American Communities Survey (2010–2014) data 5-year estimates to identify inflation adjusted median household income estimates, and the Percent- One Race- Black or African American variable from the 2010 decennial census, to identify income and percentage African American residents, respectively, by CT in Philadelphia. The study was approved by the Thomas Jefferson University Institutional Review Board.

2.2. Sample

We cleaned the cancer registry data, correcting address misspellings. First, we ensured that each patient was included only once, as there were 363 cases with recurring breast cancer at a later date within the time period. Second, we removed cases without residential address information, including PO Boxes. We limited the dataset to Philadelphia residents only, and removed males from the dataset (N = 10,499). After geocoding female BC patients with ArcMap 10.8 offline, via Philadelphia street-centerline files, we matched 10,240 (97.5%) patients to an address in Philadelphia. We aggregated cases by Philadelphia's 384 CTs. For analysis, we removed census tracts that are primarily industrial in focus and non-residential. We focused only on CTs where 300 or more women ages 20 + resided, based on the 2010 Census, so that sufficient numbers of women could be available to benefit from potential neighborhood-based initiatives aimed to reduce the burden of BC. We did this to ensure that the areas selected were not only identified by BC burden alone, but also considered the volume of people that would benefit from BC prevention interventions.

2.3. Measures

We used information on AJCC stage version 6, the most recent and complete version provided by PCR at the time, to characterize the stage of the diagnosed BC among cases. We created an ordinal variable based on the AJCC stage group display value, representing lower to higher diagnosed stage for each patient. To identify the CTs with the highest percentage of African American residents, we used the Percent-One Race- Black or African American variable from the 2010 decennial census. To identify CTs with the lowest income, we used the inflation-adjusted Median Household Income in dollars 5-year estimates (2010–2014) from the American Communities Survey.

2.4. Statistical analysis

We focused on three BC outcomes to quantify at the CT level: standardized incidence ratio (SIR), standardized mortality ratio (SMR), and mean AJCC stage grouping. Using 2010 SEER data that described the age-stratified BC mortality rates as our reference data, we calculated SIRs and SMRs for each CT. We aggregated the ordinal BC stage grouping for cases by CT to create a mean stage grouping for each CT. For CTs containing 300 or more women ages 20+ (n = 373), we created a BC composite variable by summing the SMR, SIR, and mean stage grouping variables, each centered and scaled by their respective means and standard deviations. Creating the BC composite this way allowed us to assign equal weight to each of the three component variables. We calculated descriptive statistics for each of our outcomes. We mapped CTs with the highest 25 composite scores to identify the locations of neighborhoods with the greatest burden of BC. We then mapped CTs with the 25 highest percentage of individuals that identified as African American, lowest median household income, and then compared these CTs with those exhibiting the highest 25 BC composite scores. Although we generated the BC composite scores for most neighborhoods in Philadelphia, we chose to map CTs with the highest 25 composite scores to highlight a number of neighborhoods that might be useful for cancer prevention organizations, such as a mobile cancer screening program.

3. Results

Incidence: 373 of the 384 CTs in Philadelphia had at least 300 women over 20 years of age. Among the 373 CTs, 372 had at least one case of BC from 2005 to 2014. Among the 373 CTs, the mean number of incident BC cases was 27.39 (Standard Deviation (SD) = 14.1); min = 0, max = 72) and the mean SIR was 0.95 (SD = 0.24; min = 0, max = 1.71).

Mortality: Among the 373 CTs, 343 had at least one BC death. The mean number of deaths among the 373 CTs was 4.05 (SD = 2.85; min = 0, max = 15). The mean SMR was 0.81 (SD = 0.58; min = 0, max = 5.52).

AJCC Stage Grouping: For the 375 CTs with cases, we calculated the mean stage grouping of the cases within the CT. Among the CTs, the (mean) mean stage grouping was 3.45 (SE = 0.03; min = 0, max = 8).

BC Composite Score: After centering and scaling the SIR, SMR, and mean stage grouping variables by their respective means and standard deviations, we summed these measures to calculate the BC composite score for each CT. The mean BC composite score was 0.00 (SD = 2.12; min = -11.22, max = 13.04). We provide a histogram to further describe the distribution of the BC composite score among the 373 CTs (Fig. 1).

Neighborhood Prioritization and Comparisons: The graduated points in Fig. 2 show the 25 neighborhoods with the highest BC composite scores, representing those with the worst BC outcomes among Philadelphia CTs from 2005 to 2014. All of the CTs with the highest 25 BC composite scores were found in just 10 of the 18 total planning districts in Philadelphia; Upper Northwest, Upper North, Lower Northeast, North Delaware, River Wards, North, Lower North, Central, South, and University Southwest. In fact, 17 of the CTs with the highest BC composite scores were concentrated in four planning districts; Lower North contained 6 CTs, University/Southwest contained 5, and Upper Northwest and Central both contained 3 CTs with the highest BC composite scores.

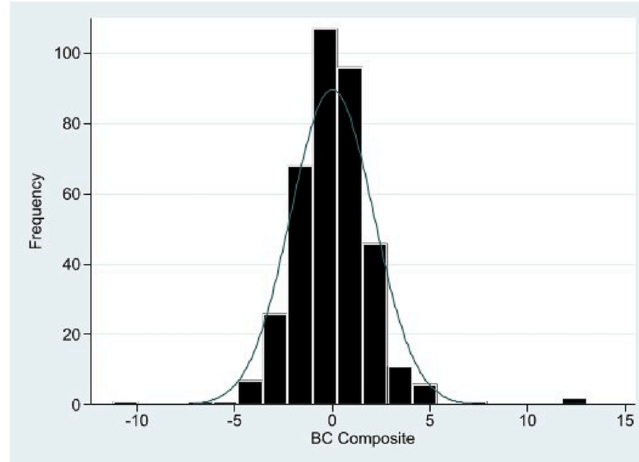

Fig. 1. Distribution of BC Composite Score among Census Tracts in Philadelphia: 2005–2014 (N = 373).

Fig. 2 also displays the census tracts with the highest percentage of African American residents (yellow) and the lowest median household income (blue), among all 373 CTs. None of the CTs had all three characteristics: among the top 25 BC composite, highest percentage of African Americans, and lowest median household income. Four of the CTs with one of the highest 25 BC composite scores were also CTs with one of the 25 highest percentage of African Americans. Two of the CTs with the highest 25 BC composite scores were also among the CTs with the lowest median household incomes.

Table 1 further characterizes the CTs with the 25 highest BC composite scores, highest percentage of African American residents, and lowest median household incomes in Philadelphia. The mean BC composite score among the 25 highest CTs was 4.41, whereas the mean BC composite scores among the CTs with the highest percentage of African American residents and lowest median incomes were 0.88 and −0.29, respectively. Notably, one of the CTs with the highest BC composite scores did not have a recorded median household income. In the CTs with the highest 25 BC composite scores, the majority of residents were African American (Mean = 69.37%), but the mean percentage was much lower than the mean among those CTs with the highest 25 percent African Americans (Mean = 96.1%). Additionally, the CTs with the highest 25 BC composite scores had a higher average median income ($31,129) compared to the average among CTs with the lowest 25 median household incomes in Philadelphia ($14,079).

4. Discussion

This study introduces a new method of measuring the burden of BC at the neighborhood-level using the BC composite score that is composed of BC morbidity, mortality, and AJCC stage grouping. We identified that the burden of BC in Philadelphia was not evenly geographically distributed during 2005–2014, with 17 of the neighborhoods with the greatest burden located in just four planning districts, Lower North, University/Southwest, Upper Northwest and Central. Our results are important for identifying neighborhoods and planning districts that should be the focus for BC prevention efforts. Philadelphia has three major hospital systems—Thomas Jefferson University, University of Pennsylvania, and Temple University (including Fox Chase Cancer Center)—all of which conduct community outreach, education events, and mammography screenings via mobile screening services. The efforts of these outreach and screening programs would benefit from the identification of neighborhoods with the greatest BC burden in

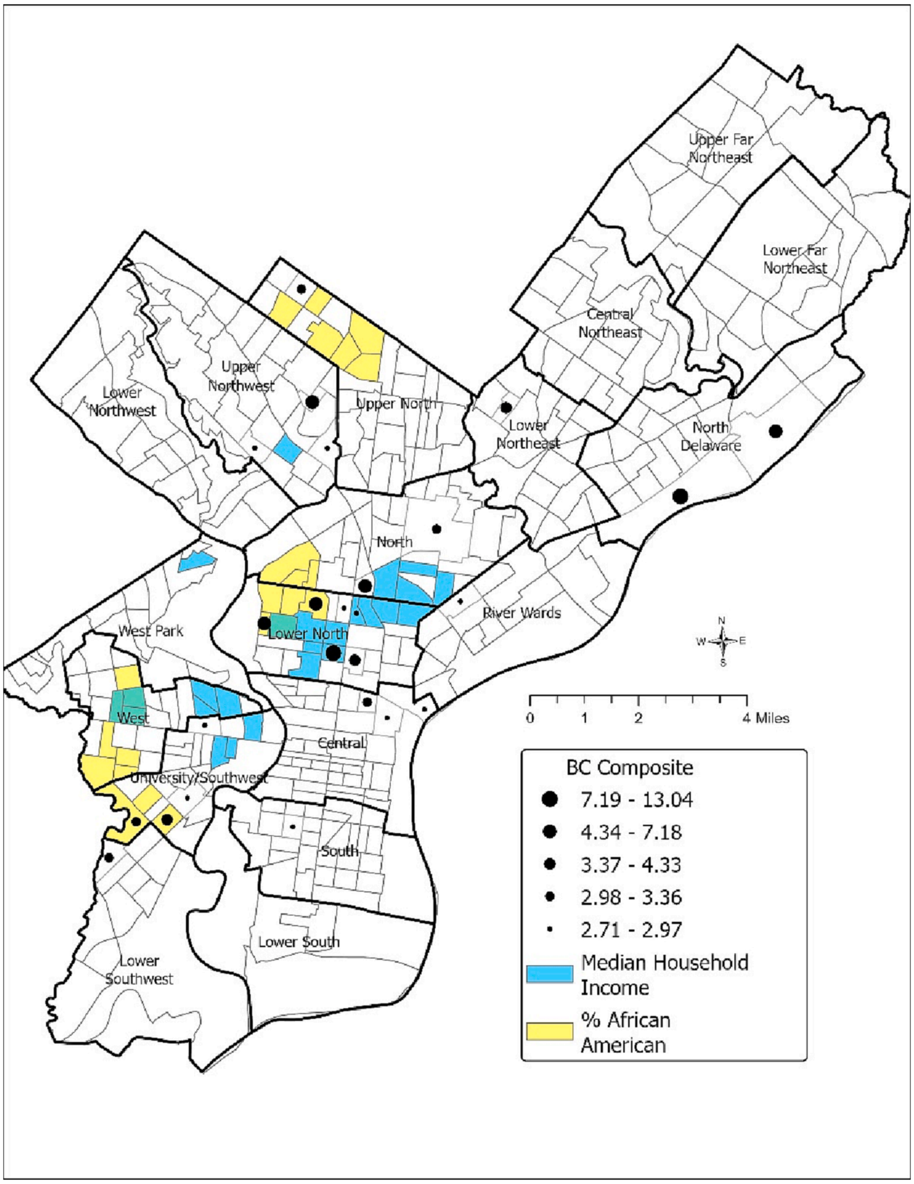

Fig. 2. (Color): Census Tracts in Philadelphia with the 25 highest Breast Cancer Composite, 2005–2014; the 25 highest percentage of African American Residents; and the 25 lowest Median Household Incomes.

Philadelphia so that screening efforts can be targeted.

Our findings show that using the BC composite is an important tool to choose neighborhoods with the greatest burden, compared to decision-making based solely on race or income. On one hand, the planning districts that contained the CTs with the highest BC composite scores were also areas that had high percentages of African Americans and low median household incomes, compared to other planning districts in Philadelphia. However, when comparing the BC composite with demographics at the CT level, we see few overlaps with the highest percentage of African Americans or the lowest median incomes. There was more overlap among CTs with the highest BC composite and highest percentage African American CTs (4) compared with CTs with the highest BC composite and lowest household income (2).

Researchers have clearly identified associations between race, income, and BC outcomes. However, due to multifactorial causal mechanisms for BC, these relationships differ depending upon the BC outcome analyzed. For example, studies show that higher income is associated with higher BC incidence among populations (Lehrer et al., 2016). Primarily this relationship is due to early detection among people with higher income and ease of ability to access to healthcare resources to find cancers earlier when they are more easily treatable. However, the opposite relationship has been identified for income and BC mortality-as income increases, mortality rates decrease and survival time increases (Gordon et al., 1992), although mortality studies have not shown as consistent a relationship as morbidity studies (Akinyemiju et al., 2015). Studies that explore relationships between race and incidence have shown varying results, with associations varying by demographic, environmental exposure, or healthcare access. However, after controlling for confounding factors, researchers have found that BC mortality is higher among Black women compared to White women. Further, studies have identified that race modified the effect of income and 5-year BC survival; as income increased, 5-year survival significantly increased, but only among White women, not Black women (Lehrer et al., 2016). These inconsistent relationships between race, income and individual BC outcomes support the use of our BC composite which combines morbidity, mortality and stage grouping, to characterize neighborhood burden of BC, and as an additional tool to use for neighborhood-based cancer control prioritization.

Table 1
Census Tracts in Philadelphia with the Highest Breast Cancer Composite Scores, Highest Percentage (%) of African American Residents and Lowest Median Household Incomes: 2005–2014.

	Highest BC Composite Scores				Highest % African American				Lowest Median Household Income			
Rank	Tract	BC Composite Score	% African American	Median Household Income ($)	Tract	BC Composite Score	% African American	Median Household Income ($)	Tract	BC Composite Score	% African American	Median Household Income ($)
1	38100	13.04	26.9	25,139	26600	0.95	97.0	39,500	08802	−2.98	11.5	8,993
2	14700	12.13	43	11,578	16902	1.92	96.8	21,035	09000	2.4	8.0	10,807
3	89100	7.18	71.7	–	15102	2.02	96.6	12,241	14700[a]	12.13	43.0	11,578
4	17400	5.32	91	18,319	16901	−0.4	96.5	25,292	08801	−11.22	9.2	11,944
5	24800	5.3	95.3	38,048	10200	−0.54	96.5	13,183	14800	−2.97	90.1	11,989
6	16800	5.23	95.8	27,574	07102	1.34	96.4	28,286	15102	2.02	96.6	12,241
7	15101	5.09	96.1	21,000	08102	−2.38	96.4	32,478	16300	−0.77	18.4	12,343
8	14600	4.33	52.2	24,833	17100	0.44	96.3	28,811	16400	−2.18	41.7	12,436
9	07000	4.33	95.4	26,685	09400	−1.75	96.3	16,753	19501	−1.8	16.8	12,791
10	30501	3.9	54.2	33,814	15101[a]	5.09	96.1	21,000	13900	1.94	82.5	12,865
11	13100	3.36	72.9	39,868	17202	0.47	96.1	21,875	10200	−0.54	96.5	13,183
12	26000	3.27	95.1	58,947	26500	0.46	96.1	36,818	10600	−1.74	90.2	13,342
13	06500	3.25	95.7	24,350	26400	−1.75	96.1	39,145	16500	1.25	91.4	14,894
14	38300	3.13	36.2	21,250	09500	0.75	96.0	16,383	17702	−2.58	21.2	14,907
15	06400	3.06	76.3	34,153	17201	0.73	96.0	21,096	10800	1.16	87.3	15,392
16	14200	2.97	8.3	80,154	16800[a]	5.23	95.8	27,574	15300	0.15	45.4	15,609
17	16702	2.94	89.1	20,565	08200	−0.4	95.8	38,617	17500	1.22	31.6	15,743
18	36700	2.89	16.1	83,086	26700	−1.31	95.8	32,593	16600[a]	2.78	75.6	15,855
19	07400	2.89	88.1	20,317	06500[a]	3.25	95.7	24,350	10700	−1.68	95.1	16,105
20	17800	2.86	28.9	20,484	26301	1.02	95.6	40,808	12201	−0.96	37.9	16,107
21	03100	2.8	87	25,588	11200	−0.25	95.6	23,936	15200	0.04	94.2	16,195
22	16600	2.78	75.6	15,855	08101	1.51	95.5	24,759	09500	0.75	96.0	16,383
23	23900	2.78	73.1	27,583	26100	−0.22	95.5	49,156	17601	0.89	11.7	16,531
24	09200	2.75	77.1	20,357	07000[a]	4.33	95.4	26,685	09400	−1.75	96.3	16,753
25	24500	2.71	93.1	27,556	08302	1.45	95.4	30,075	24100	−2.40	80.5	16,985
Mean		4.41	69.37	31,129		0.88	96.1	27,698		−0.28	58.7	14,079

[a] Also one of the census tracts with the highest 25 BC composite scores.

Our study is not without limitations. First, although we assume that all cases of BC were captured by the PA Cancer Registry, we have no way of confirming the extent to which it is complete. Second, similar to the McIntire et al. (2018) study on prostate cancer, some census tracts in Philadelphia had small numbers of cases and deaths. Using each of these outcomes by themselves to characterize burden of disease, without using statistical procedures to stabilize rates, would not be adequate. However, because we calculated the BC composite as a sum of SIR, SMR, and stage grouping, we bolster the distortion caused by unstable rates at the CT level.

Our findings show that using race and income as a proxy for BC burden is not ideal, considering the lack of overlap between the CTs with the top 25 BC composite and those with the highest percentage of African American residents and lowest household income. In order to measure breast cancer burden, healthcare and public health agencies implementing community-based BC interventions should consider using the novel method of a BC composite as a tool to identify areas of priority for BC prevention interventions, including education, screening, and treatment.

Declaration of Competing Interest

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

Data availability

The authors do not have permission to share data.

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