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Neighborhood obesogenic factors and breast cancer risk and mortality in the Southern community cohort study

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Obesity is an established risk factor for many cancers, including breast cancer. However, the complex nature of the underlying mechanisms, coupled with the interaction between individual characteristics and neighborhood obesogenic attributes, contributes to an energy imbalance and a sedentary lifestyle, promoting obesity. This has posed a challenge to our understanding of neighborhood obesogenic attributes associated with this increased risk of breast cancer. We aim to examine how neighborhood attributes affect breast cancer risk and prognosis in the Southern Community Cohort Study (SCCS). We examined a group of more than 41,000 women living in the southeastern United States. Our investigation focused on understanding the association between multiple neighborhood obesogenic indices, including neighborhood socioeconomic status (nSES), restaurant environment index (REI), retail-food environment index (RFEI), park and recreational facilities, and living in a business district. The association between obesogenic indices with breast cancer risk and mortality was analyzed using a multivariable Cox proportional hazards model controlling for individual-level SES and breast cancer risk factors. Additionally, we conducted a stratified analysis of obesogenic indices and breast cancer risk among Black or White participants. Breast cancer was diagnosed in 1,289 participants (3.1%), including 393 White (3.0%) and 896 Black participants (3.2%). Overall, no significant associations were found between neighborhood obesogenic factors and breast cancer risk. However, when analyzed by race and menopausal status, the REI showed an increased risk among White participants (aHR = 1.65, 95% CI 1.06–2.56, $p = 0.004$, tertile 3 vs. None), particularly postmenopausal women (aHR = 2.39, 95% CI 1.12–5.14, $p = 0.024$, tertile 3 vs. None). The REI was significantly associated with breast cancer mortality (aHR = 0.38, 95% CI 0.16–0.93, $p = 0.035$, tertile 1 vs. None). As a conclusion, the REI showed an increased risk among White participants largely attributed to postmenopausal women. The restaurant environment index was associated with reduced breast cancer mortality.

Keywords Breast cancer, Neighborhood obesogenic factors, Built environment, Neighborhood socioeconomic status, Southern community cohort study, Mortality

Our local living environment may play a crucial role in shaping health and health outcomes for a community[1–4] through factors such as access to nutritious food, support for physical activity, psychosocial health, and overall support for healthy life choices[1,5]. Neighborhood obesogenic factors are a partially modifiable construct consisting of socioeconomic indices and aspects of the built environment that contribute to a sedentary lifestyle[6], energy imbalance, and obesity[7–9]. For example, individuals living in a low socioeconomic environment are more likely to be obese[7]. Similarly, increased proximity to unhealthy restaurants, food deserts, limited neighborhood walkability, more commuting by car, and a higher perceived or real traffic density are linked with unhealthy weight gain and obesity[8,9]. However, areas with high walkability[10] and more access to recreational facilities, parks, and green spaces[11] are associated with higher levels of physical activity and a lower prevalence of obesity. Given

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the relationship between a person's neighborhood's built environment and obesity, neighborhood attributes may also play a significant role in the cancer experience, including cancer screening, risk, treatment, survivorship, and mortality[5,12].

Obesity has been identified as a risk or prognostic factor for as many as 14 types of cancer[13,14], including postmenopausal breast cancer[9]. Breast cancer is one of the most common cancers and the second leading cause of cancer death among women in the United States (U.S.)[15]. There are also race differences in tumor prognostic markers and mortality following diagnosis which may also be linked with obesity[16,17]. While an emerging body of literature has started to describe the association between neighborhood-related factors and breast cancer risk[9,18] or a poorer prognosis[19], the impact of the neighborhood social and built environment on race-specific breast cancer outcomes has received less attention[1,12]. Therefore, the purpose of this study was to investigate how neighborhood environment contributes to breast cancer risk and outcomes across racial and ethnic groups, potentially revealing components of the structural and built environment that are related to obesity also contribute to breast cancer disparities.

We hypothesize that residing in neighborhoods characterized by lower socioeconomic status, increased urbanization, greater availability of unhealthy foods, limited recreational facilities, and fewer parks is associated with a higher risk of breast cancer risk and mortality. We aim to examine the social determinants of obesity including social and built environment attributes and how these may affect breast cancer risks and outcomes among White and Black women. Our analyses include Black and White women living in the southeastern U.S. and participating in the Southern Community Cohort Study (SCCS). By design, SCCS recruitment included lower-income Black and White participants to reduce potential bias due to race differences in socioeconomic status (SES). We prospectively investigated the relationship between neighborhood obesogenic attributes independently associated with breast cancer mammography, breast cancer risk, and breast cancer-specific mortality after controlling for individual-level reproductive and other risk factors for breast cancer.

Methods

Source of data

Details of the SCCS design, recruitment strategy, and data collection protocols have been described in studies published elsewhere[20,21]. Briefly, the SCCS is a prospective cohort study that recruited a total of 84,508 male and female participants between 40 and 79 years of age from 12 southeastern states from 2002 to 2009. The latest participant follow-up interview was conducted in 2018. Approximately, 85% of the cohort participants were recruited from community health centers designed to provide necessary primary healthcare. The remaining 15% were recruited through direct mailings based on mailing lists for the general population in each state. The outcome variables in this study were breast cancer risk and breast cancer mortality. The SCCS participants were followed from the time of enrollment until the occurrence of cancer diagnosis, death, emigration, or the end of the follow-up period, whichever came first. Incident cancer diagnoses during follow-up were identified through linkage with state tumor registries or self-reports with medical chart confirmation. Vital status or mortality due to breast cancer was determined through linkage with the National Death Index. All participants provided written informed consent prior to data collection, and all protocols were approved by IRBs at Vanderbilt University Medical Center and Meharry Medical College. This analysis was conducted under a non-human subject's research waiver without access to study personal identifiers and approved by the IRB at the University of Tennessee Health Science Center. All methods were performed in accordance with the relevant guidelines and regulations.

Analytic sample

We focused on the 50,342 (59.57%) female SCCS participants, including 32,341 self-described Black and 15,438 self-described White women. We excluded 2,284 participants who self-reported as neither White nor Black, or of unknown race. We also excluded 312 participants with unknown marital status, 246 participants with missing smoking status or pack-years, and 1,696 participants with unknown BMI. Given our primary focus was on assessing the risk of breast cancer, we excluded 1087 participants reporting at baseline a prior breast cancer diagnosis. Additionally, we excluded 3670 participants with incomplete data related to at least one neighborhood SES (nSES) attribute or those who could not be linked to individual-level information. Our final analysis included 41,047 participants (Fig. 1; Table 1).

Source of neighborhood-level factors

ArcGIS Pro 2.5 software was used for spatial data collection. Neighborhood-level factors were collected from three main sources. Neighborhood sociodemographic data were gathered from the 2010 census data at the block group level. Data regarding the built environment, including restaurants, retail food establishments, business counts, and recreational facilities within a one-mile walking catchment of the central point of each block group, was extracted from OpenStreetMap (OSM). The walkability index at the block group level was accessed from the national walkability index database.

A composite measure of nSES was constructed through a principal component analysis utilizing census block data encompassing various indicators. These indicators included housing factors such as median rent and median house value, occupation metrics such as the proportion of individuals with blue-collar jobs and the proportion of individuals older than 16 without employment, educational variables such as the percentage of high school graduates and the years required to complete high school, as well as employment and income metrics like median income and the percentage of individuals living below the poverty level[22,23]. The nSES was classified into quintiles of the distribution, with quintile 1 representing the least economically wealthy neighborhoods and quintile 5 representing the most economically wealthy neighborhoods.

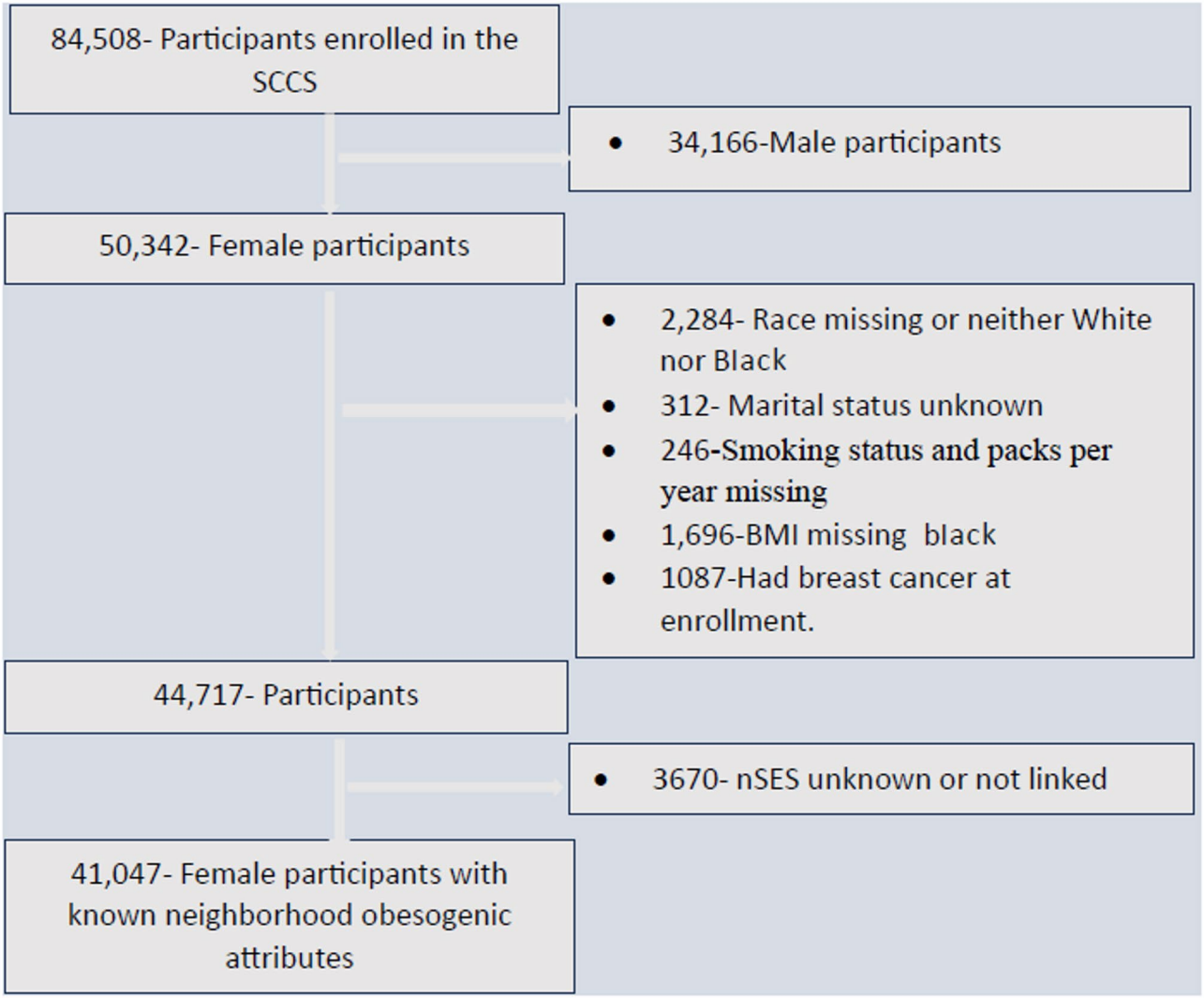


Fig. 1. Flowchart showing data screening and inclusion process, the Southern Community Cohort Study, 2002 to 2018.

The restaurant environment index (REI) was the ratio of a fast-food restaurant (e.g., Burger King and McDonald's) to other restaurants. The REI was classified as none (no fast-food and other restaurants), tertile 1, 2, 3, and no other restaurants). The retail-food environment index (RFEI) was the ratio of the number of convenience stores, liquor stores, and fast-food restaurants to supermarkets and farmers markets (e.g., Kroger, Sprouts, and Publix). The RFEI was also classified as none (no fast-food restaurant and retail food), tertile 1, 2, 3, or no retail food)[9,23]. Higher tertiles for the restaurant and retail-food environment indices suggest unhealthier neighborhoods regarding the food outlet conditions.

Businesses, parks, and recreational facilities were categorized as *none* (no businesses, no parks, or no recreational facilities) and *some* (any businesses, any parks, or any recreational facilities). The walkability index was categorized into four levels: least walkable, below average walkable, above average walkable, and most walkable environment[24].

Individual level factors

Individual-level factors included in the analyses were obtained via an in-person structured questionnaire interview at baseline. Questionnaire data included age at enrollment (continuous), age at menarche (≤ 10 years, 10–14 years, ≥ 15 years), ever pregnant (yes, no), number of pregnancies, number of live births, total months breastfeeding (0, 1–6, 7–15, not applicable or unknown), use of birth control pills (yes, no), health insurance coverage (yes, no), Medicaid coverage (yes, no, not applicable), menopause status at enrollment (yes, no or unknown), race (Black, White), employment status, marital status (married, single, separated/divorced/widowed), body mass index (< 18.5 kg/m^2, 18.5–24.9 kg/m^2, 25–29.9 kg/m^2, ≥ 30 kg/m^2), smoking status (never-smoker, former smoker with < 20 packs-years, former smokers with 20 + pack-years, former smoker with packs-years unknown, current smokers with < 20 packs-years, current smokers 20 + packs-years, and current smokers with packs-years unknown), household income (less than $15,000, $15,000 but < $25,000, $25,000 but < $50,000,

Variables	All, *n* = 41,047 *n* (%)	Black, *n* = 28,136 *n* (%)	White, *n* = 12,911 *n* (%)	*p*-value
	Mean (std)	Mean (std)	Mean (std)	
Age at enrollment	52.3(8.9)	51.7(8.8)	53.6(9.0)	< 0.0001
Total sitting hours per day	9.3 (5.0)	9.6 (5.2)	8.9(4.5)	< 0.0001
Total computer sitting minutes per day	32.3 (71.6)	28.1(68.8)	39.5(75.2)	< 0.0001
	n (%)	n (%)	n (%)	
Age at menarche (years)				< 0.001
≤ 10	3,904 (9.5)	2,615 (9.3)	1,289 (10.0)	
11–14	29,433 (71.7)	19,603 (69.7)	9,830 (76.1)	
≥ 15	7,710 (18.8)	5,918 (21.0)	1,792 (13.9)	
Ever pregnant				< 0.001
Yes	38,206 (93.3)	26,457 (94.2)	11,749 (91.3)	
No	2,748 (6.7)	1,625 (5.8)	1,123 (8.7)	
Number of pregnancies				< 0.001
0	2,751 (6.7)	1,627 (5.8)	1,124 (8.7)	
1	4,041 (9.9)	2,680 (9.6)	1,361 (10.6)	
2	7,958 (19.5)	4,928 (17.6)	3,030 (23.6)	
3	8,645 (21.1)	5,799 (20.7)	2,846 (22.1)	
4	6,541 (16.0)	4,603 (16.4)	1,938 (15.1)	
≥ 5	10,972 (26.8)	8,410 (30.0)	2,562 (19.9)	
Number of live births				< 0.001
0	4,216 (10.3)	2,649 (9.5)	1,567 (12.2)	
1	5,887 (14.4)	3,846 (13.7)	2,041 (15.9)	
2	10,369 (25.4)	6,348 (22.7)	4,021 (31.3)	
3	8,746 (21.4)	6,035 (21.6)	2,711 (21.1)	
4	5,285 (12.9)	3,879 (13.9)	1,406 (11.0)	
≥ 5	6,329 (15.5)	5,229 (18.7)	1,100 (8.6)	
Total months breastfeed				< 0.001
0 months	24,231 (59.5)	17,347 (62.2)	6,884 (53.8)	
1–6 months	6,073 (14.9)	3,865 (13.8)	2,208 (17.2)	
7-150 months	6,013 (14.8)	3,885 (13.9)	2,128 (16.6)	
Not applicable or Unknown	4,389 (10.8)	2,803 (10.1)	1,586 (12.4)	
Ever used birth control pills				< 0.001
Yes	28,477 (69.7)	19,223 (68.6)	9,254 (72.1)	
No	12,362 (30.3)	8,781 (31.4)	3,581 (27.9)	
Insurance coverage				0.163
Yes	25,377 (62.2)	17,329 (62.0)	8,048 (62.7)	
No	15,403 (37.8)	10,620 (38.0)	4,783 (37.3)	
Medicaid Coverage				< 0.001
Yes	9,696 (23.8)	7,273 (26.0)	2,423 (18.9)	
No	15,654 (38.4)	10,036 (35.9)	5,618 (43.8)	
Not applicable	15,421 (37.8)	10,635 (38.1)	4,786 (37.3)	
Menopause at enrollment				< 0.001
Yes	27,975 (68.2)	18,173 (64.6)	9,802 (75.9)	
No or unknown	13,072 (31.8)	9,963 (35.4)	3,109 (24.1)	
Family history of breast cancer				< 0.001
Yes	6,139 (15.0)	4,052 (14.4)	2,087 (16.2)	
No or unknown	34,908 (85.0)	24,084 (85.6)	10,824 (83.8)	
Marital status				< 0.001
Married	13,202 (32.2)	7,515 (26.7)	5,687 (44.0)	
Separated/divorced/Widowed	19,965 (48.6)	13,757 (48.9)	6,208 (48.1)	
Single	7,880 (19.2)	6,864 (24.4)	1,016 (7.9)	

Continued

Variables	All, $n = 41,047$ n (%) Mean (std)	Black, $n = 28,136$ n (%) Mean (std)	White, $n = 12,911$ n (%) Mean (std)	p-value
Smoking status and pack-year				
Never-smoker	18,130 (44.2)	13,304 (47.3)	4,826 (37.4)	
Former, less than 20 pack-years	5,468 (13.2)	3,740 (13.3)	1,728 (13.4)	
Former, 20 or more pack-years	2,987 (7.3)	1,452 (11.3)	1,636(11.1)	
Former, pack-years unknown	368 (0.9)	98 (0.8)	125(0.8)	< 0.001
Current, less than 20 pack-years	7,921 (19.3)	6,358 (22.6)	1,563 (12.1)	
Current, 20 or more pack-years	6,019 (14.7)	2,807 (10.0)	3,212 (24.9)	
Current, pack-years unknown	154 (0.4)	122 (0.4)	32 (0.3)	
BMI				
Underweight	540 (1.3)	307 (1.1)	233 (1.8)	
Normal	7,630 (18.6)	4,413 (15.7)	3,217 (24.9)	< 0.001
Overweight	10,538 (25.7)	7,152 (25.4)	3,386 (26.2)	
Obese	22,339 (54.4)	16,264 (57.8)	6,075 (47.1)	
Mammogram				
Yes	34,071 (83.0)	22,974 (81.6)	11,097 (85.9)	< 0.001
No or unknown	6,976 (17.0)	5,162 (18.4)	1,814 (14.1)	
Employment status at enrollment				
Employed	24,183 (58.9)	16,359 (58.1)	7,824 (60.6)	< 0.001
Not employed or Unknown	16,864 (41.1)	11,777 (41.9)	5,087 (39.4)	
Diabetes mellites at enrollment				
Yes	9,602 (23.4)	6,965 (24.7)	2,637 (20.4)	< 0.001
No or unknown	31,445 (76.6)	21,171 (75.3)	10,274 (79.6)	
Household income at enrollment				
Less than $15,000	22,996 (56.0)	16,538 (58.8)	6,458 (50.0)	
At least $15,000 but less than $25,000	8,980 (21.9)	6,457 (22.9)	2,523 (19.5)	
At least $25,000 but less than $50,000	5,523 (13.5)	3,500 (12.4)	2,023 (15.7)	< 0.001
At least $50,000 but less than $100,000	2,395 (5.8)	1,113 (4.0)	1,282 (9.9)	
$100,000 or more	604 (1.5)	173 (0.6)	431 (3.3)	
Unknown	549 (1.3)	355 (1.3)	194 (1.5)	
Educational status				
Less than 9 years	3,046 (7.4)	2,051 (7.3)	995 (7.7)	
9-11 years	8,664 (21.1)	6,423 (22.8)	2,241 (17.4)	
12 years, completed high school, or GED	13,527 (32.9)	9,268 (32.9)	4,259 (33.0)	
Vocational, technical, or business training	2,450 (6.0)	1,668 (5.9)	782 (6.1)	
Some college or junior college	8,391 (20.4)	5,736 (20.4)	2,655 (20.6)	< 0.001
Graduated from college	3,203 (7.8)	2,021 (7.2)	1,182 (9.2)	
Graduate school (up to and including a master's degree)	1,292 (3.2)	715 (2.5)	577 (4.5)	
Graduate school beyond a master's degree	452 (1.1)	236 (0.8)	216 (1.7)	
Unknown (refused/don't know/missing)	22 (0.05)	18 (0.06)	4 (0.03)	

Table 1. Study population characteristics by race, the Southern community cohort Study, 2002 to 2018. BMI-body mass index; std- standard deviation.

$50,000 but less than $100,000, $100,000 or more, or unknown (refused/do not know/missing)), total sitting hours, total computer sitting minutes, history of diabetes (yes, no or unknown), family history of breast cancer (yes, no or unknown), and any past mammography (yes, no or unknown).

Statistical analysis

We described the data using frequency, percentage, and measure of central locations and dispersions. The median follow-up time with interquartile range (IQR) was calculated. We assessed the association between neighborhood obesogenic factors and breast cancer risk using a multivariable Cox proportional hazard model to calculate hazard ratios and corresponding 95% confidence intervals. Race-specific models were also developed. We further stratified the analysis based on the women's menopause status and BMI at the time of enrollment. Each model included covariates to control for individual-level breast cancer risk factors and other neighborhood obesogenic attributes. During the multivariable model adjustments, we conducted a sensitivity analysis to examine the association between neighborhood obesogenic attributes and breast cancer risk, both with and without accounting for individual household income level and mammography testing status. We found that

these variables had no significant influence on the association. We have also treated participants age and BMI as time varying variables in the model. We have checked the interaction between the nSES and the walkability index.

We also used a multivariable Cox proportional hazard model to calculate hazard ratios and corresponding 95% confidence intervals to investigate the association between neighborhood obesogenic attributes and breast cancer mortality. We included covariates in the multivariable model to control for individual level breast cancer risk factors and other neighborhood obesogenic attributes. We checked the model with and without the cancer stage at the time of diagnosis.

All statistical analyses were conducted using Stata version 17.0 (Stata Corp LP, College Station, TX, USA) based on two-sided probability, and $P < 0.05$ was considered statistically significant.

Results

The analysis included 41,047 participants, including 28,136 Black (68.0%) and 12,911 White (32.0%) participants. The mean participant age at the time of enrollment was 52.3 years, with an approximately 2-year higher mean age for White (53.6 years) compared to Black (51.7 years) participants. The follow-up time ranges from 1 to 196 months with a median follow-up time of 135 months (IQR: 110, 153). Approximately 10% of the participants experienced menarche at age 10 years or earlier. Overall, 5.8% of Black women and 8.7% of White women reported no prior pregnancy. Among participants with a prior pregnancy, 18.7% of Black women and 8.6% of White women reported five or more live births. Most participants, including 68.6% of Black women and 72.1% of White women, had previously used birth control pills. Approximately, 40.0% of participants never participated in breastfeeding, and a history of breast-feeding was somewhat more prevalent among White participants. Additionally, at the time of enrollment, 64.6% of Black participants and 75.9% of White participants reported being postmenopausal.

Approximately, 62% of both Black and White women had health insurance coverage, and nearly 60% of both Black and White participants were employed. Most participants smoked at some time (56.0%) and approximately 24% were former smokers. More White participants were current smokers compared to Black participants (20 or more pack-years: 24.9% vs. 10.0%, respectively), while Black participants (22.6%) smoked less than 20 pack years compared to White participants (11.1%). The study revealed that 58.8% of Black and 50.0% of White participants had household incomes below $15,000 annually. In terms of education, 22.8% of Black and 17.4% of White participants had completed 9–12 years, while 2.5% of Black and 4.5% of White participants pursued graduate studies, including obtaining a master's degree (Table 1).

Table 2 summarizes neighborhood obesogenic factors stratified by race. Approximately one in four Black individuals (24.3%) resided in the lowest nSES quintile while 13.3% of Black women resided in the highest nSES quintile. In contrast, 10.2% of White participants lived in the lowest nSES quintile, while 28.09% lived in the highest nSES quintile. The majority of white (67.2%) and Black (65.1%) participants lived in a block group without a public park or in a block group without a recreational facility (White: 71.2%, Black: 70.2%). Similarly, 36.4% of White participants and 23.6% of Black participants lived in areas identified as least walkable.

The prevalence of a past mammogram among all participants was 83.0% (White: 85.9%, Black: 81.6%) (Table 1). Mammography significantly varied with nSES among both Black and White women. Among Black participants, the proportion of mammography testing decreased from 23.8% among those residing in the poorest (quintile 1) neighborhoods to 13.6% among those residing in the wealthiest (quintile 5) neighborhoods. In contrast, among White participants, these percentages increased from 9.5% among those residing in the poorest (quintile 1) neighborhood to 25.5% among those residing in wealthier (quintile 4) neighborhoods, while it decreased to 9.0% among those residing in the wealthiest (quintile 5) neighborhoods. This shows that White participants in the wealthiest quintile of nSES were less likely to have a prior mammogram compared to comparable Black participants (9.0% vs. 13.6%, respectively) (Table 3). In contrast, mammography significantly varied with the restaurant environment index, retail food environment, and walkability index among Black women only.

Moreover, 5.77% of White participants compared to 8.7% of their Black counterparts in the lowest quintile of the restaurant environment index had undergone mammography testing. Among Black women who underwent mammography, 23.8% lived in the least walkable neighborhoods, while 35.5% of White women who underwent mammography testing lived in the least walkable neighborhoods. Mammography testing was higher among Blacks who completed 9–12 years (22.2% vs. 16.7%), while it was higher among White participants for those who completed some college or junior college (16.8% vs. 20.9%) and graduated from college (4.2% vs. 9.5%). Similarly, mammography testing was significantly higher among Black participants with an annual household income of less than $25,000, while it was higher among White participants with an annual household income of at least $25,000. Further, mammography testing was significantly higher among Black compared to White (44.5% vs. 36.5%) participants who enrolled in the cohort in their 40s, while there was no significant difference among Black and White participants who enrolled in the cohort in their 50s (35.7% vs. 36.6%), 60s (14.9% vs. 20.9%), and 70s (4.9% vs. 6.0%) (Table 3).

Breast cancer during follow-up was diagnosed among 1,289 participants (3.1%), including 393 White participants (3.0%) and 896 Black participants (3.2%). Of all breast cancer cases, 17.45% were diagnosed among participants residing in the wealthiest neighborhoods (quintile 5), while the proportion exceeded 20% for those residing in quintiles 2, 3, and 4. Additionally, the highest proportion of breast cancer cases was observed among participants residing in areas with no fast-food restaurants, no restaurants of other types (73.00%), or no retail food outlets (56.71%). Furthermore, only 6.9% of breast cancer cases were diagnosed among participants living in the most walkable neighborhoods (Fig. 2).

Following adjustment for individual-level breast cancer risk factors, none of the neighborhood's obesogenic factors showed a significant association with breast cancer (Table 4). However, upon stratification by race, the

Variables	All, $n=41,047$ n (%)	Black, $n=28,136$ n (%)	White, $n=12,911$ n (%)	p-value
nSES[a]				
Quintile 1(lowest nSES)	8,260 (20.1)	6,949 (24.7)	1,311 (10.2)	
Quintile 2	8,547 (20.8)	6,649 (23.6)	1,898 (14.7)	
Quintile 3	8,583 (20.9)	5,800 (20.6)	2,783 (21.6)	<0.001
Quintile 4	8,280 (20.2)	4,988 (17.7)	3,292 (25.5)	
Quintile 5(highest nSES)	7,377 (18.0)	3,750 (13.4)	3,627 (28.1)	
Restaurant Environment Index				
None	30,717 (74.8)	20,952 (74.5)	9,765 (75.6)	
Tertile 1	3,258 (7.9)	2,508 (8.9)	750 (5.8)	
Tertile 2	977 (2.4)	653 (2.3)	324 (2.5)	<0.001
Tertile 3	1,541 (3.8)	983 (3.5)	558 (4.3)	
no restaurant	4,554 (11.1)	3,040 (10.8)	1,514 (11.7)	
Retail Food Environment Index				
None	24,138 (58.8)	15,424 (54.8)	8,714 (67.5)	
Tertile 1	1,101(2.7)	837 (3.0)	264 (2.0)	
Tertile 2	879 (2.1)	658 (2.3)	221 (1.7)	<0.001
Tertile 3	861 (2.1)	571 (2.0)	290 (2.3)	
no retail food	14,068 (34.3)	10,646 (37.8)	3,422(26.5)	
Number of parks				
None	26,997 (65.8)	18,317 (65.1)	8,680 (67.2)	<0.001
Some	14,050 (34.2)	9,819 (34.9)	4,231 (32.8)	
Number of recreation facilities				
None	28,943 (70.5)	19,747 (70.2)	9,196(71.2)	0.032
Some	12,104 (29.5)	8,389 (29.8)	3,715 (28.8)	
Number of businesses				
None	35,032 (85.4)	24,185 (86.0)	10,847(84.0)	<0.001
Some	6,015 (14.6)	3,951(14.0)	2,064 (16.0)	
Walkability index[d]				
Least walkable	11,340 (27.6)	6,645(23.6)	4,695 (36.4)	
Below average	16,248 (39.6)	11,070 (39.3)	5,178 (40.1)	<0.001
Above average	10,332 (25.2)	8,034 (28.6)	2,298 (17.8)	
Most walkable	3,127 (7.6)	2,387 (8.5)	740 (5.7)	

Table 2. Neighborhood obesogenic factors by race; the Southern community cohort Study, 2002 to 2018. nSES-neighborhood socioeconomic status; [a]cut of values for nSES quintiles: quintile 1 (-1.704 to -0.812), quintile 2 (-0.811 to -0.494), quintile 3 (-0.493 to -0.090), quintile 4 (-0.089 to 0.641), and quintile 5 (0.642 to 7.819; [b] Restaurant Environment Index: None (no fast-food restaurant and other restaurants), tertile 1 (0.020 to 1.000), tertile 2 (1.001 to 2.000), tertile 3 (2.001 to 17.000), and no other restaurants except fast foods; [c]Retail Food Environment Index: none (no fast-food restaurant and retail food), tertile 1 (0. 0.417 to 1.000), tertile 2 (1.001 to 3.000), tertile 3 (3.001 to 23.000), and no retail food except fast foods); [d]Walkability index: least walkable (1.000 to 5.750), below average walkable (5.760 to 10.500), above average walkable (10.510 to 15.250), and most walkable environment (15.260 to 20.000).

Restaurant Environment Index was associated with an elevated risk of breast cancer among White participants (aHR = 1.65, 95% CI 1.06–2.56, $p=0.004$, tertile 3 vs. None). In contrast, neighborhood obesogenic factors were not statistically significantly associated with breast cancer risk among Black participants. The nSES and walkability index exhibited a statistically non-significant increase in breast cancer risk among both Black and White participants. Similarly, the Retail Food Environment Index indicated a statistically non-significant increase in breast cancer risk among Black participants, whereas it demonstrated a decrease among White participants (Table 4).

Upon further stratification of the analysis based on menopause status and race, the retail food environment index was found to be associated with an increased risk of breast cancer among post-menopausal White participants (aHR = 2.39, 95% CI 1.12–5.14, $p=0.024$, tertile 3 vs. None). No neighborhood obesogenic indices were associated with breast cancer risk among all pre-menopausal women and post-menopausal Black women (Table 5).

Analyses exploring obesogenic indices and breast cancer by race and BMI found restaurant environment index significantly associated with an increased risk of breast cancer among obese White participants (aHR = 2.93, 95% CI: 1.15–7.46, $p=0.024$, for Tertile 3 vs. None), normal-weight White (aHR = 5.27, 95% CI: 1.11–24.99, $p=0.036$,

	All		Black			White		
		Mammography						
	Yes, %	No or unknown, %	Yes, %	No or unknown, %	P- value*	Yes, %	No or unknown, %	p-value*
nSES								
Quintile 1	19.2	24.7	23.8	28.5		9.5	14.1	
Quintile 2	20.4	23.1	23.2	25.4		14.4	16.7	
Quintile 3	21.2	19.5	21.1	18.7	< 0.001	21.6	21.6	< 0.001
Quintile 4	20.6	17.9	18.3	15.3		25.5	25.3	
Quintile 5	18.6	14.8	13.6	12.2		9.0	22.4	
Restaurant Environment Index								
None	74.8	75.0	74.5	74.54		75.5	76.3	
Tertile 1	7.7	8.8	8.7	9.82		5.8	6.1	
Tertile 2	2.4	2.5	2.3	2.62	0.004	2.5	2.1	0.460
Tertile 3	3.8	3.5	3.6	3.14		4.3	4.7	
no restaurant	11.3	10.1	11.0	9.88		11.9	10.8	
Retail Food Environment Index								
None	59.3	56.3	55.4	52.42		67.5	67.3	
Tertile 1	2.6	3.0	2.9	3.22		2.0	2.5	
Tertile 2	2.1	2.3	2.3	2.54	0.004	1.7	1.8	0.561
Tertile 3	2.1	2.3	2.0	2.21		2.2	2.4	
no retail food	33.9	36.1	37.4	39.62		26.6	26.0	
Number of parks								
None	65.9	65.2	65.3	64.3	0.201	67.1	67.8	0.573
Some	34.1	34.8	34.7	35.7		32.9	32.2	
Number of recreation facilities								
None	70.6	70.1	70.4	69.4	0.158	71.1	72.3	0.289
Some	29.4	29.9	29.6	30.6		28.9	27.7	
Number of businesses								
None	85.3	85.5	85.9	86.0	0.864	84.0	84.1	0.945
Some	14.7	14.5	14.1	14.0		16.0	15.9	
Walkability index								
Least walkable	27.9	26.1	23.8	22.8		36.5	35.5	
Below average	39.8	38.4	39.6	38.2	< 0.001	40.3	39.0	0.151
Above average	25.1	25.9	28.7	28.1		17.5	19.6	
Most walkable	7.2	9.6	7.9	10.9		5.7	5.9	
Age at enrollment								
40–49	41.9	70.2	44.5	73.0		36.5	62.9	
50–59	36.0	20.6	35.7	19.5	< 0.001	36.6	23.2	< 0.001
60–69	16.8	6.2	14.9	5.1		20.9	9.3	
70–79	5.3	3.0	4.9	2.4		6.0	4.6	
Insurance coverage								
Yes	64.0	44.0	63.8	44.8	< 0.001	64.5	42.1	< 0.001
No	36.0	56.0	36.2	55.2		35.5	57.9	
Household income at enrollment								
Less than $15,000	54.8	68.3	57.7	69.2		48.6	66.2	
At least $15,000 but less than $25,000	22.0	20.4	23.2	20.9		19.6	19.2	
At least $25,000 but less than $50,000	14.0	8.0	13.0	7.3	< 0.001	16.2	9.5	< 0.001
At least $50,000 but less than $100,000	6.2	1.7	4.2	1.1		10.5	3.2	
$100,000 or more	1.6	0.4	0.7	0.2		3.5	0.9	
Unknown	1.4	1.2	1.3	1.3		1.6	1.0	

Continued

	All		Black			White		
		Mammography						
Educational status								
Less than 9 years	7.3	8.5	7.2	8.0		7.8	10.3	
9-11 years	20.4	28.2	22.2	29.4		16.7	25.1	
12 years, completed high school, or GED	32.6	36.3	32.6	36.6		32.8	35.6	
Vocational, technical, or business training	6.1	4.5	6.1	4.2		6.1	5.1	
Some college or junior college	20.8	16.8	16.8	20.8	< 0.001	20.9	16.7	< 0.001
Graduated from college	8.1	4.5	4.2	7.5		9.5	5.1	
Graduate school (up to and including a master's degree)	3.4	0.8	0.6	2.8		4.7	1.3	
Graduate school beyond a master's degree	1.2	0.4	0.3	0.9		1.7	0.7	
Unknown (refused/don't know/missing)	0.05	0.08	0.08	0.06		0.03	0.1	

Table 3. Mammography testing by race, neighborhood and individual level factors, the Southern community cohort Study, 2002 to 2018. * chi-square (χ^2) p-values for column percentage among black and white participants.

for Tertile 3 vs. None) and Black (aHR = 4.52, 95% CI: 1.50–13.60, $p = 0.007$, for Tertile 2 vs. None) participants. Additionally, the Retail Food Environment Index was associated with an increased risk of breast cancer among obese Black participants (aHR = 1.34, 95% CI: 1.06–1.69, $p = 0.013$, for No retail food vs. None) (Table 6).

Breast cancer was the cause of death for 168 of the 1,289 women diagnosed with breast cancer. In the multivariable model, in the absence of the cancer stage variable at diagnosis, neighborhood obesogenic attributes were not statistically significantly associated with mortality due to breast cancer. However, never receiving a mammogram was significantly associated with a higher risk of breast cancer mortality compared to participants who underwent mammography (aHR = 1.65 95% CI 1.01–2.64, $p < 0.045$). After adjusting for the stage of cancer at the diagnosis along with other covariates, mammogram testing status was turned to statistically non-significant (aHR = 1.23 95% CI 0.75–2.01, $p = 0.410$). However, the restaurant environment index showed a statistically significant decrease in breast cancer mortality (aHR = 0.38, 95% CI 0.16–0.93, $p = 0.035$, tertile 1 vs. None). (Table 7). Race-specific analyses were unstable due to the small sample size.

Discussion

We analyzed a diverse cohort of over 41,000 women residing in the southeastern United States to determine the impact of neighborhood-level attributes in breast cancer. In our analysis, race designations should be interpreted as social rather than biological constructs, as we had no reason to believe at the time of study initiation that neighborhood-level attributes would impact breast cancer pathophysiology in a race-specific manner. We found that approximately one in every four Black women in our analysis resided in the lowest nSES quintile, and about one in every ten White participants lived in the lowest nSES quintile. Furthermore, one-tenth of Black participants lived in the highest-nSES quintile and approximately one-fourth of White participants lived in the highest-nSES quintile. Furthermore, after controlling for individual BMI and established breast cancer risk factors, the distribution of obesogenic attributes within neighborhoods demonstrated significant and race-specific associations with breast cancer risk.

The utilization of mammography testing displayed variations associated with both race and obesogenic attributes of the neighborhood. The proportion of mammography testing decreased as nSES increased among Black participants. However, for White participants, the rate of mammography testing generally increased as nSES levels rose, with the exception being the weightiest neighborhood among white participants. Mammography utilization is a critical step toward breast cancer diagnosis requiring healthcare access to this specific service. Among those who underwent mammography, 64.0% of the participants (63.8 for Black and 64.5% for White participants) had insurance coverage. The testing was significantly higher among Black participants with an annual household income of less than $25,000, while higher among White participants with an annual household income of at least $25,000. Similarly, mammography testing was significantly higher among Black participants who enrolled in the cohort in their 40s, while there was no significant difference among Black and White participants who enrolled in the cohort in their 50s, 60s, and 70s. Mammography was significantly associated with nSES, with White participants in the wealthiest quintile of nSES less likely to report a prior mammogram compared to Black participants. Previous studies reported that participants residing in the highest socioeconomic disadvantage neighborhood are less likely to receive mammography testing[25–27], while some other studies revealed that there was no statistically significant relationship between the neighborhood socioeconomic status and mammography testing[28]. Similarly, our study revealed that the indices of an obesogenic environment were associated with mammography. White individuals in the lowest quintile of the restaurant environment score had a lower record of mammography compared to similar Black participants. In contrast, less than 25% of Black participants living in the least walkable neighborhoods had mammography testing, compared to 35.5% of their White counterparts. Overall, about two-thirds of study participants lived in neighborhoods without any recreational facilities or parks, providing an additional potential indicator of neighborhoods that may be targeted for enhanced mammography services.

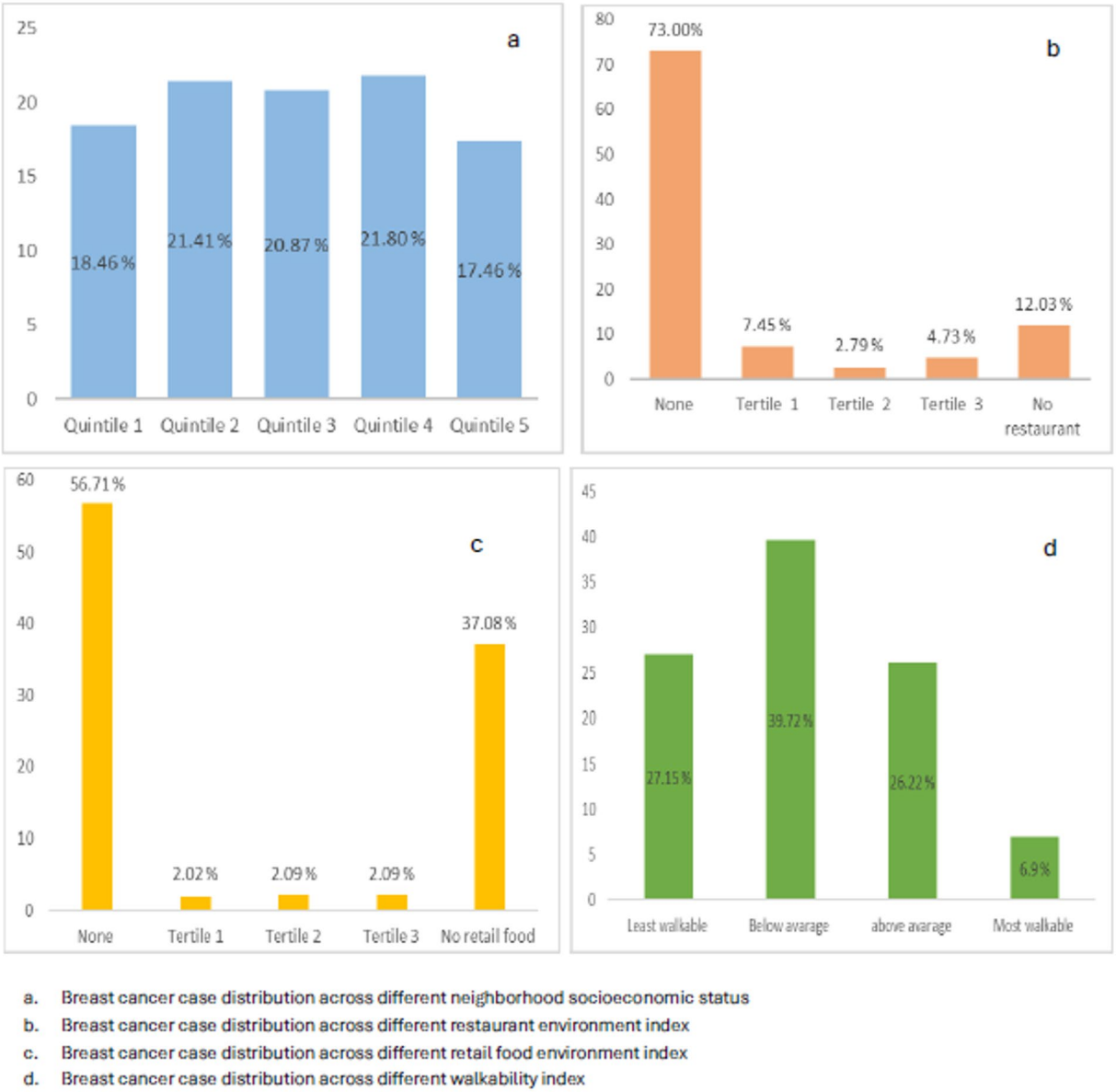


Fig. 2. Breast cancer case distribution across different neighborhood level factors, the Southern Community Cohort Study, 2002 to 2018.

Both Black and White participants residing in neighborhoods lacking parks demonstrated a higher breast cancer risk compared to those in neighborhoods with parks, although this difference did not reach statistical significance. A previous study reported that residing in neighborhoods with urban green areas, including parks, was associated with a reduced risk of breast cancer[29]. Similarly, although residing in neighborhoods with parks and breast cancer mortality was not statistically associated in our study, another study reported that living in neighborhoods without parks was associated with better breast cancer-specific survival, particularly among women living in high-SES neighborhoods[30]. Breast cancer risk showed a significant association with areas characterized by a high density of a retail food environment index, particularly among white post-menopause and obese women. Residing in unhealthy food environments are major barrier to a healthy food lifestyle because it often leads to reduced access to supermarkets[31], while increasing access to convenience stores and fast-food restaurants typically offer unhealthy food choices[32], which increases the risk of breast cancer.

Although there is no statistically significant associations between neighborhood obesogenic factors and breast cancer risk among black women, a higher proportion of Black women were found to reside in poorer neighborhoods compared to their White counterparts and thus a greater proportion of Black participants may live in neighborhoods with limited access to healthy food choices and sufficient public spaces consistent with supporting a healthy lifestyle. Additionally, race-specific associations may be related to a distinction in neighborhood characteristics between Black and White participants beyond that which may be characterized by differences in SES. The social distribution of residential environments may not be uniform across defined

Variables	All		Black women		White women	
	Cases	HR (95%CI)	Cases	HR (95%CI)	Cases	HR (95%CI)
nSES						
Quintile 5(high)	225	Reference	116	Reference	109	Reference
Quintile 4	281	1.11 (0.92–1.33)	181	1.60 (0.91–1.48)	100	1.04 (0.78–1.38)
Quintile 3	269	1.05 (0.87–1.27)	179	1.02 (0.80–1.31)	90	1.15 (0.86–1.55)
Quintile 2	276	1.09 (0.91–1.32)	219	1.12 (0.88–1.42)	57	1.05 (0.75–1.48)
Quintile 1(low)	238	0.95 (0.78–1.15)	201	0.94 (0.74–1.20)	37	1.06 (0.72–1.57)
Restaurant Environment Index						
None	941	Reference	656	Reference	285	Reference
Tertile 1	96	0.99 (0.73–1.34)	74	0.87 (0.62–1.23)	22	1.58 (0.79–3.15)
Tertile 2	36	1.23 (0.82–1.83)	29	1.31 (0.83–2.05)	NR	1.08 (0.43–2.71)
Tertile 3	61	1.32 (0.92–1.89)	33	0.97 (0.61–1.53)	28	**2.69 (1.37–5.32)**
no restaurant	155	1.08 (0.82–1.42)	104	0.97 (0.71–1.33)	51	1.61 (0.88–2.95)
Retail Food Environment Index						
None	731	Reference	474	Reference	257	Reference
Tertile 1	26	0.94 (0.61–1.45)	21	1.03 (0.63–1.67)	NR	0.63 (0.23–1.70)
Tertile 2	27	1.07 (0.69–1.66)	20	1.12 (0.67–1.65)	NR	0.89 (0.37–1.96)
Tertile 3	27	0.98 (0.63–1.54)	20	1.20 (0.71–2.64)	NR	0.52 (0.21–1.96)
No retail food	478	1.08 (0.92–1.28)	361	1.12 (0.93–1.27)	117	0.89 (0.59–1.35)
Number parks						
Some	450	Reference	318	Reference	132	Reference
None	839	1.13 (0.90–1.41)	578	1.09 (0.84–1.41)	261	1.25 (0.79–1.99)
Number of recreation facility						
Some	395	Reference	278	Reference	117	Reference
None	894	0.93 (0.79–1.11)	618	0.91 (0.74–1.01)	276	1.03 (0.73–1.44)
Number business						
None	1,085	Reference	766	Reference	319	Reference
Some	204	1.14 (0.96–1.35)	130	1.11 (0.90–1.37)	74	1.20 (0.88–1.64
Walkability Index						
Least walkable	350	1.12 (0.85–1.49)	210	1.06 (0.77–1.47)	140	1.36 (0.77–2.42)
Below average	512	1.11 (0.86–1.44)	350	1.03 (0.77–1.39)	162	1.39 (0.81–2.38)
Above average	338	1.13 (0.88–1.45)	264	1.07 (0.80–1.42)	74	1.31 (0.77–2.25)
Most Walkable	89	Reference	72	Reference	17	Reference

Table 4. Neighborhood obesogenic factors and risk of breast cancer, the Southern community cohort Study, 2002 to 2018. Controlled for age at enrollment, age at menarche, smoking status and pack year, marital status, employment status, household income, diabetes milieus, family history of breast cancer, body mass index at enrollment, ever pregnant, number of pregnancies, number of live births, ever use birth control, total months breastfed, insurance coverage. NR-Not reportable.

race groups. This would be represented by a higher percentage of White women living in neighborhoods characterized as 'least walkable' compared to their Black counterparts. Perhaps affluent neighborhoods have a built environment such that street connectivity and land use render them less conducive to walking compared to poorer neighborhoods or inner-city areas. While higher SES participants living in wealthier neighborhoods may possess the resources to adopt a more physically active lifestyle, some neighborhoods with lower socioeconomic status may have walkable areas that are unappealing or even unsafe for walking. The complex nature of these patterns should drive improvement in neighborhood characterization and may present unique opportunities for future interventions in these areas[1]. Furthermore, given the interconnected nature of race, social determinants of health (SDoH), and the risks associated with many cancers, including breast cancer, it is crucial to emphasize the significance of integrating SES, obesity, and SDoH measures at the individual-level with those at the neighborhood-level factors in research addressing racial disparities in breast cancer[33].

Breast cancer mortality did not show a statistically significant association with neighborhood obesogenic attributes, except for the restaurant environment index. In contrast, and as expected, breast cancer mortality was significantly associated with lower mammography testing in the absence of the stage of cancer at the diagnosis in the model. A prior study found an association between obesogenic factors, such as nSES, and breast cancer mortality that varied across different racial and ethnic groups[34]. Unfortunately, the relatively low number of breast cancer-related deaths in our study led to statistical underpowering, limiting our capacity to analyze potential variations among distinct racial groups. Nevertheless, we did not see evidence that neighborhood-level criteria affect breast cancer prognosis after controlling for individual-level SES and other parameters, suggesting

	All		Black women		White women	
Variables	Cases	HR (95%CI)	Cases	HR (95%CI)	Cases	HR (95%CI)
Pre-menopause women						
nSES						
Quintile 5(high)	60	Reference	39	Reference	21	Reference
Quintile 4	78	1.14 [0.80–1.62]	60	1.25 [0.82–1.90]	18	0.87 [0.43–1.74]
Quintile 3	65	0.88 [0.61–1.28]	49	0.85 [0.55–1.34]	16	0.98 [0.48-2.00]
Quintile 2	64	0.83 [0.57–1.21]	56	0.86 [0.56–1.34]	NR	0.67 [0.27–1.69]
Quintile 1(low)	66	0.84 [0.58–1.24]	62	0.88 [0.57–1.36]	NR	0.59 [0.19–1.82]
Restaurant Environment Index						
None	230	Reference	186	Reference	44	Reference
Tertile 1	30	1.04 [0.59–1.83]	26	0.92 [0.50–1.70]	NR	2.07 [0.34–12.43]
Tertile 2	13	1.47 [0.72-3.00]	11	1.41 [0.65–1.34]	NR	2.21 [0.28–17.11]
Tertile 3	16	1.10 [0.54–2.26]	NR	0.67 [0.27–1.34]	NR	5.07 [0.95–27.15]
no restaurant	44	1.14 [0.68–1.92]	34	1.06 [0.60–1.90]	10	2.12 [0.43–10.38]
Retail Food Environment Index						
None	167	Reference	129	Reference	38	Reference
Tertile 1	NR	1.07 [0.48–2.35]	NR	1.23 [0.54–2.76]	NR	
Tertile 2	NR	0.88 [0.36–2.18]	NR	0.97 [0.36–2.64]	NR	0.65 [0.07–6.50]
Tertile 3	NR	1.30 [0.58–2.91]	NR	1.65 [0.68–3.98]	NR	0.33 [0.03–3.35]
No retail food	142	1.26 [0.92–1.72]	115	1.20 [0.85–1.70]	27	1.18 [0.44–3.12]
Number parks						
Some	131	Reference	104	Reference	27	Reference
None	202	1.09 [0.70–1.68]	162	1.03 [0.64–1.65]	40	1.67 [0.47–6.04]
Number of recreation facility						
Some	114	Reference	88	Reference	26	Reference
None	219	0.90 [0.65–1.25]	178	0.96 [0.67–1.36]	41	0.59 [0.26–1.33]
Number business						
None	279	1.06 [0.65–1.26]	224	1.09 [0.75–1.58]	55	0.84 [0.40–1.80]
Some	54	Reference	42	Reference	12	Reference
Walkability Index						
Least walkable	77	1.47 [0.86–2.51]	57	1.23 [0.69–2.02]	20	7.21 [0.45–7.01]
Below average	128	1.51 [0.93–2.44]	96	1.17 [0.70–1.96]	32	8.05 [0.57–7.26]
Above average	101	1.42 [0.89–2.25]	87	1.18 [0.72–1.91]	60	6.58 [0.41–5.50]
Most Walkable	27	Reference	26	Reference	NR	Reference
Post-menopause women						
nSES						
Quintile 5(high)	165	Reference	77	Reference	88	Reference
Quintile 4	203	1.09 [0.88–1.35]	121	1.11 [0.83–1.49]	82	1.06 [0.77–1.46]
Quintile 3	204	1.10 [0.86–1.37]	130	1.08 [0.81–1.45]	74	1.17 [0.85–1.63]
Quintile 2	212	1.19 [0.96–1.84]	163	1.23 [0.93–1.64]	49	1.12 [0.78–1.63]
Quintile 1(low)	172	0.98 [0.77–1.39]	139	0.95 [0.71–1.28]	33	1.16 [0.76–1.77]
Restaurant Environment Index						
None	711	Reference	470	Reference	241	Reference
Tertile 1	66	0.97 [0.67–1.39]	48	0.85 [0.56–1.29]	18	1.52 [0.71–1.54]
Tertile 2	23	1.12 [0.68–1.84]	18	1.26 [0.72–2.21]	NR	0.93 [0.32–2.06]
Tertile 3	45	1.39 [0.91–1.12]	24	1.10 [0.64–1.87]	21	**2.39 [1.12–5.14]**
no restaurant	111	1.07 [0.77–1.48]	70	0.94 [0.64–1.38]	41	1.57 [0.81–3.06]
Retail Food Environment Index						
None	564	Reference	345	Reference	219	Reference
Tertile 1	18	0.90 [0.54–1.51]	13	0.95 [0.51–1.74]	NR	0.74 [0.29–2.59]
Tertile 2	20	1.13 [0.68–1.89]	14	1.19 [0.65–2.20]	NR	0.94 [0.21–2.52]
Tertile 3	18	0.89 [0.52–1.55]	12	1.07 [0.55–2.08]	NR	0.56 [0.40–2.79]
No retail food	336	1.02 [0.83–1.24]	246	1.08 [0.87–1.36]	90	0.80 [0.62–1.52]
Number parks						
Some	319	Reference	214	Reference	105	Reference
Continued						
None	637	1.13 [0.87–1.47]	416	1.11 [0.82–1.52]	221	1.18 [0.71–1.94]

Variables	All		Black women		White women	
	Cases	HR (95%CI)	Cases	HR (95%CI)	Cases	HR (95%CI)
Number of recreation facility						
Some	281	Reference	190	Reference	91	Reference
None	675	0.94 [0.77–1.15]	440	0.88 [0.70–1.12]	235	1.12 [0.76–1.34]
Number business						
None	806	1.17 [0.96–1.44]	542	1.13 [0.87–1.45]	264	1.28 [0.91–1.80]
Some	150	Reference	88	Reference	62	Reference
Walkability Index						
Least walkable	273	1.03 [0.74–1.44]	153	1.01 [0.67–1.50]	120	1.09 [0.59–1.99]
Below average	384	1.01 [0.75–1.37]	254	0.99 [0.69–1.43]	130	1.06 [0.60–1.88]
Above average	237	1.04 [0.77–1.41]	177	1.03 [0.72–1.46]	60	1.06 [0.60–1.87]
Most Walkable	62	Reference	46	Reference	16	Reference

Table 5. Neighborhood obesogenic factors and risk of breast cancer among pre- and post-menopause women, the Southern community cohort Study, 2002 to 2018. Controlled for age at enrollment, age at menarche, smoking status and pack year, marital status, employment status, household income, diabetes milieus, family history of breast cancer, body mass index at enrollment, ever pregnant, number of pregnancies, number of live births, ever use birth control, total months breastfed, insurance coverage. NR-Not reportable.

any contribution of neighborhood obesogenic factors to breast cancer risk among Black or White women does not necessarily extend to breast cancer survival after diagnosis.

This research has some noteworthy strengths. The SCCS is a prospective cohort study with substantial enrollment of low-income participation across both Black and White women. Individual-level data on BMI, SES, and other breast cancer risk factors were available for analysis. Multiple neighborhood-level indices associated with the built environment and potentially influencing obesity were computed. Limitations of this analysis included the relatively smaller number of mortality outcomes and the lack of tumor pathology data. In addition, risk factors such as participants' nutritional habits, exercise, alcohol consumption, and history of hormonal diseases were not included in this analysis. Furthermore, we were unable to compute neighborhood characteristics such as street connectivity and traffic density, participants access to transport to travel to fast-food vendors, and changes in the neighborhood's obesogenic environment over time, which might have added further insights to our observed race-specific associations.

Conclusion

In general, our study identified race-specific statistically significant associations between neighborhood obesogenic factors and mammography and the risk of breast cancer. The REI showed an increased risk among white participants largely attributed to postmenopausal and obese women. Additionally, Black women in a more walkable neighborhood were less likely to obtain a mammogram compared to their white counterparts. Regarding breast cancer mortality, no notable associations were observed with neighborhood factors, except for the restaurant environment index. These findings underscore the influence of neighborhood-level factors on racial disparities in breast cancer risk, emphasizing the potential impact of public health policies on the well-being of low-income individuals in the Southeastern U.S. Overall, our results underscore the necessity for further exploration of the complex relationships between SDoH including neighborhood level factors and health outcomes, aiming to alleviate suffering within the most vulnerable communities.

Variables	All aHR (95%CI)	Black persons aHR (95%CI)	White persons aHR (95%CI)
Normal weight (BMI: 18.5–24.9 kg/m^2)			
nSES			
Quintile 5(high)	Reference	Reference	Reference
Quintile 4	1.50 [0.98–2.29]	1.47 [0.78–2.76]	1.41 [0.78–2.57]
Quintile 3	1.27 [0.80–2.02]	0.82 [0.40–1.68]	1.86 [0.99–3.46]
Quintile 2	1.37 [0.85–2.21]	1.10 [0.56–2.15]	1.69 [0.82–3.51]
Quintile 1(low)	0.78 [0.45–1.35]	0.58 [0.27–1.22]	1.25 [0.51–3.08]
Restaurant Environment Index			
None	Reference	Reference	Reference
Tertile 1	0.51 [0.66–3.47]	1.22 [0.46–3.27]	2.15 [0.43–10.69]
Tertile 2	3.82 [1.54–9.47]	**4.52 [1.50-13.62]**	4.06 [0.77–21.41]
Tertile 3	2.46 [0.97–6.25]	1.17 [0.32–4.23]	**5.27 [1.11–24.99]**
no restaurant	1.88 [0.88-4,03]	1.21 [0.46–3.21]	3.42 [0.83–14.08]
Retail food environment Index			
None	Reference	Reference	Reference
Tertile 1[a]	0.51 [0.16–1.57]	0.73 [0.22–2.41]	
Tertile 2	0.43 [0.14–1.37]	0.38 [0.08–1.86]	0.55 [0.09–3.35]
Tertile 3	0.62 [0.23–1.71]	0.80 [0.23–2.73]	0.32 [0.05–2.08]
No retail food	0.63 [3.7–1.06]	0.57 [0.30–1.06]	0.59 [0.21–1.65]
Number of parks			
Some	Reference	Reference	Reference
None	1.03 [0.57–1.84]	0.89 [0.42–1.87]	1.33 [0.49–3.66]
Number of recreation facility			
Some	Reference	Reference	Reference
None	0.94 [0.61–1.46]	1.05 [0.59–1.88]	0.78 [0.39–1.53]
Number of businesses			
None	Reference	Reference	Reference
Some	1.11 [0.73–1.69]	1.02 [0.56–1.85]	1.36 [0.73–2.52]
Walkability index			
Least walkable	1.30 [0.67–2.55]	0.83 [0.34–1.99]	3.36 [0.89–12.59]
Below average	1.27 [0.70–2.30]	0.87 [0.41–1.84]	2.96 [0.86–10.23]
Above average	1.08 [0.61–1.93]	0.86 [0.43–1.72]	2.01 [0.57–7.13]
Most walkable	Reference	Reference	Reference
Overweight (BMI: 25–29.9 kg/m^2)			
nSES			
Quintile 5(high)	Reference	Reference	Reference
Quintile 4	0.93 [0.65–1.33]	0.99 [0.62–1.60]	0.83 [0.47–1.48]
Quintile 3	0.89 [0.61–1.29]	0.82 [0.50–1.34]	1.05 [0.59–1.89]
Quintile 2	0.90 [0.62–1.31]	0.84 [0.52–1.35]	1.05 [0.55–2.01]
Quintile 1(low)	1.07 [0.74–1.56]	1.01 [0.63–1.61]	1.34 [0.66–2.75]
Restaurant environment Index			
None[a]	Reference	Reference	Reference
Tertile 1	1.37 [0.75–2.48]	1.26 [0.64–2.46]	1.51 [0.40–5.68]
Tertile 2	0.78 [0.29–2.11]	0.59 [0.17–2.06]	1.52 [0.26–8.79]
Tertile 3	0.89 [0.61–1.29]	1.46 [0.61–3.51]	1.31 [0.28–6.04]
no restaurant	0.93 [0.65–1.33]	1.16 [0.61–2.21]	1.36 [0.42–4.39]
Retail food environment Index			
None[b]	Reference	Reference	Reference
Tertile 1	0.68 [0.28–1.78]	0.69 [0.23–2.05]	0.66 [0.08–5.72]
Tertile 2	1.27 [0.55–2.89]	1.25 [0.48–3.26]	1.71 [0.32–9.24]
Tertile 3	0.52 [0.17–1.57]	0.37 [0.08–1.68]	1.08 [0.18–6.27]
No retail food	0.94 [0.67–1.32]	0.95 [0.65–1.39]	1.05 [0.49–2.26]
Number of parks			
Some	Reference	Reference	Reference
None	1.13 [0.73–1.77]	1.04 [0.62–1.74]	1.48 [0.60–3.64]

Continued

Variables	All	Black persons	White persons
	aHR (95%CI)	aHR (95%CI)	aHR (95%CI)
Number of recreation facility			
Some	Reference	Reference	Reference
None	0.93 [0.66–1.30]	0.85 [0.58–1.25]	1.19 [0.59–2.40]
Number of businesses			
None	Reference	Reference	Reference
Some	0.93 [0.64–1.34]	0.93 [0.60–1.45]	0.84 [0.43–1.64]
Walkability index			
Least walkable	1.29 [0.71–2.34]	1.70 [0.83–3.47]	0.68 [0.23–2.05]
Below average	1.24 [0.72–2.15]	1.48 [0.77–2.85]	0.77 [0.27–2.18]
Above average	1.51 [0.88–2.56]	1.80 [0.96–3.37]	0.93 [0.33–2.58]
Most walkable	Reference	Reference	Reference
Obese (BMI ≥ 30 kg/m^2)			
nSES			
Quintile 5(high)	Reference	Reference	Reference
Quintile 4	1.08 [0.84–1.38]	1.17 [0.86–1.61]	0.99 [0.66–1.49]
Quintile 3	1.05 [0.82–1.34]	1.13 [0.82–1.54]	0.99 [0.65–1.52]
Quintile 2	1.11 [0.87–1.42]	1.26 [0.93–1.71]	0.84 [0.52–1.38]
Quintile 1(low)	0.89 [0.69–1.16]	0.95 [0.69–1.31]	0.86 [0.48–1.52]
Restaurant environment Index			
None	Reference	Reference	Reference
Tertile 1	0.81 [0.54–1.21]	0.69 [0.44–1.08]	1.63 [0.60–4.38]
Tertile 2	0.99 [0.58–1.70]	1.19 [0.67–2.11]	0.31 [0.04–2.57]
Tertile 3	1.11 [0.69–1.77]	0.74 [0.40–1.36]	**2.93 [1.15–7.46]**
no restaurant	0.91 [0.64–1.30]	0.86 [0.58–1.27]	1.42 [0.59–3.40]
Retail food environment Index			
None	Reference	Reference	Reference
Tertile 1	1.25 [0.73–2.13]	1.25 [0.68–2.31]	0.94 [0.28–3.12]
Tertile 2	1.23 [0.68–2.23]	1.35 [0.69–2.65]	0.80 [0.21–3.01]
Tertile 3	1.33 [0.74–2.41]	1.79 [0.92–3.49]	0.46 [0.12–1.83]
No retail food	1.27 [1.03–1.57]	**1.34 [1.06–1.69]**	0.87 [0.48–1.58]
Number of parks			
Some	Reference	Reference	Reference
None	1.14 [0.85–1.52]	1.15 [0.83–1.59]	1.15 [0.60–2.20]
Number of recreation facility			
Some	Reference	Reference	Reference
None	0.93 [0.75–1.17]	0.90 [0.70–1.15]	1.05 [0.64–1.72]
Number of businesses			
None	Reference	Reference	Reference
Some	1.23 [0.98–1.53]	1.19 [0.91–1.55]	1.39 [0.90–2.17]
Walkability index			
Least walkable	1.04 [0.72–1.50]	0.97 [0.64–1.48]	1.27 [0.57–2.84]
Below average	1.05 [0.75–1.47]	0.96 [0.66–1.41]	1.37 [0.65–2.91]
Above average	1.01 [0.72–1.40]	0.94 [0.64–1.36]	1.13 [0.53–2.42]
Most walkable	Reference	Reference	Reference

Table 6. Neighborhood obesogenic factors and risk of breast cancer stratified by BMI categories and race, the Southern community cohort Study, 2002 to 2018. Controlled for age at enrollment, age at menarche, smoking status and pack year, marital status, employment status, household income, diabetes milieus, family history of breast cancer, body mass index at enrollment, ever pregnant, number of pregnancies, number of live births, ever use birth control, total months breastfed, insurance coverage. [a] No deaths were recorded among White participants with normal weight residing in the first tertile of RFEI.

Variables	All	
	Deaths (168)	aHR (95%CI)
nSES		
Quintile 5(high)	29	Reference
Quintile 4	29	0.75 [0.42–1.32]
Quintile 3	35	0.98[0.55–1.73]
Quintile 2	49	1.48 [0.86–2.56]
Quintile 1(low)	26	0.88 [0.48–1.63]
Restaurant Environment Index		
None	127	Reference
Tertile 1	10	**0.38 [0.16–0.93]**
Tertile 2	NR	0.45 [0.15–1.38]
Tertile 3	NR	0.32 [0.09–1.13]
no restaurant	19	0.70 [0.34–1.44]
Retail Food Environment Index		
None	88	Reference
Tertile 1	NR	2.55 [0.94–6.92]
Tertile 2	NR	0.61 [0.11–3.54]
Tertile 3	NR	2.16 [0.54–8.70]
No retail food	66	1.37 [0.87–2.16]
Number parks		
Some	60	Reference
None	108	0.81 [0.45–1.46]
Number of recreation facility		
Some	52	Reference
None	118	1.14 [0.69–1.86]
Number business		
None	141	Reference
Some	27	1.24 [0.74–2.07]
Walkability index		
Least walkable	38	0.67 [0.29–1.52]
Below average	63	0.84 [0.41–1.74]
Above average	54	0.86 [0.42–1.75]
Most Walkable	13	Reference
Mammography testing		
Yes	154	Reference
No	14	1.56 [0.84–2.91]

Table 7. Neighborhood obesogenic factors and incidence of breast cancer mortality, the Southern community cohort Study, 2002 to 2018. Controlled for age at enrollment, smoking status and pack year, marital status, employment status, household income, diabetes milieus, family history of breast cancer, body mass index at enrollment, age at menarche, ever pregnant, number of pregnancies, number of live births, ever use birth control, total months breastfed, insurance coverage, stage at cancer diagnoses. NR-not reportable.

Data availability

The data underlying this manuscript were received from the Southern Community Cohort Study through a data access agreement (https://ors.southerncommunitystudy.org) and linked with neighborhood obesogenic attrib utes. These data can be available following the data access guidelines established by the Southern Community Cohort Study.

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Authors' contributions

F.A. Kumsa conceived the study, developed the study protocol, conducted data analysis, and drafted the manuscript. J.H. Fowke also played a pivotal role in conceiving the study and analytic strategy and provided critical review and editing. S. Hashtarkhani curated neighborhood-level data and critically reviewed the manuscript. B. White participated in the overall coordination of the project and critically reviewed and edited the manuscript. M. J. Shrubsole facilitated access to SCCS data and critically reviewed the manuscript. A. Shaban-Nejad also conceived the study, oversaw the administrative process, provided critical review and editing, supervised the analysis, and secured funding. All authors have thoroughly reviewed this paper and granted their final approval for its submission.

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Declarations

Competing interests
The authors do not have any conflicts of interest to declare.

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