

NEIGHBORHOOD SOCIOECONOMIC STATUS IN RELATION TO ALL-CAUSE, CANCER, AND CARDIOVASCULAR MORTALITY IN THE BLACK WOMEN'S HEALTH STUDY

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Background: Neighborhood socioeconomic status (SES) is associated with adverse health outcomes, but longitudinal data among Black Americans, who tend to live in more deprived neighborhoods, is lacking.

Objectives: We prospectively assessed the relation of neighborhood SES to mortality in the Black Women's Health Study.

Design: A prospective cohort of 59,000 Black women was followed from 1995-2011. Participant addresses were geocoded and US Census block group was identified. Neighborhood SES was measured by a score based on US Census block group data for six indicators of income, education and wealth.

Main outcome measures: Deaths were identified through the National Death Index. Cox proportional hazard models were used to estimate hazard ratios (HRs) and 95% CIs with control for covariates.

Results: Based on 2,598 deaths during 1995-2011, lower neighborhood SES was associated with increased all-cause and cancer mortality irrespective of individual education: among those with 16 or more years of education, HRs for lowest relative to highest neighborhood SES quartile were 1.42 (95% CI 1.18-1.71) for all-cause and 1.54 (95% CI 1.14-2.07) for cancer mortality. Neighborhood SES was associated with cardiovascular mortality among less-educated women.

Conclusions: Lower neighborhood SES is associated with greater risk of mortality among Black women. The presence of the association even among women with high levels of education suggests that individual SES may not overcome the unfavorable

INTRODUCTION

In the United States, numerous studies have found that low area-level socioeconomic status (SES) is associated with increased mortality.¹⁻³ Area-level SES is often characterized using data on poverty, household income, employment, and wealth for a geographic area, such as a county or a census block, or through the use of summary scores based on those factors.⁴ Areas of lower SES tend to suffer from limited access to healthy foods,⁵⁻⁷ educational and employment opportunities,⁸⁻¹⁰ recreational facilities,¹¹⁻¹³ and health care and other services,¹⁴⁻¹⁶ as well as increased exposure to environmental contamination,^{8,17} poor living and working conditions,^{8,10} and violence.¹⁰

Black Americans, including those in middle and upper classes, are more likely to live in poorer-quality and more economically disadvantaged neighborhoods than White Ameri-

cans of the same economic class.¹⁸⁻²²

As a result, large numbers of Blacks are exposed to the deleterious conditions associated with disadvantaged neighborhoods.^{23,24} However, longitudinal data on neighborhood SES and mortality among Black Americans are limited. Of three studies that reported data separately on Black Americans, two observed increased risks of mortality with residence in a low SES neighborhood,^{25,26} while another found no association.²⁷ One of the studies reported that the percentage population attributable risk for low neighborhood SES was highest among Black women.²⁶

Our objective was to investigate neighborhood SES in relation to all-cause, cancer, and cardiovascular mortality in Black women, with particular attention to whether associations remained after control for important risk factors for mortality and whether the associations were present within levels of individual SES.

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Keywords: Longitudinal Studies; Residence Characteristics; Socioeconomic Factors; Mortality; African Americans

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MATERIALS AND METHODS

Study Population

The BWHS is a prospective cohort study of 59,000 self-identified Black women who were aged 21-69 years at baseline and living mostly in urban areas across the United States.²⁸⁻³³ In 1995, health questionnaires were mailed to subscribers to a magazine commonly read by Black women who lived across the United States, as well as those who were members of the Black Nurses' Association and the National Education Association. The health questionnaire

Our objective was to investigate neighborhood SES in relation to all-cause, cancer, and cardiovascular mortality in Black women...

collected data on educational attainment, medical history, and other factors. Biennial questionnaires updated these data. Validation studies have demonstrated satisfactory reporting of height and weight,²⁹ dietary intake,³⁰ and physical activity.²⁹ Follow-up of the baseline cohort was successful for 87% of potential person years through 2011. The BWHS human subjects protocol, including informed consent for all participants, was approved by the Boston University Medical Center Institutional Review Board.

For our present analyses, women

who reported a history of cancer, myocardial infarction, or stroke at baseline (n=2,252) or were missing data on education (n=110) or US Census block group (n=4,836) at baseline were excluded, leaving 51,803 participants. Because data on household income were collected later during follow-up (in 2003), subset analyses by household income were restricted to 2003-2011 and women with missing data on household income were excluded (n=2,194), leaving 33,625 women in those analyses.

Exposure and Outcome Data

Participants' addresses were geocoded and linked to data from the 2000 US Census and from the 2005-2011 iterations of the American Community Survey at the block group level; these data were assigned at the block group level to approximate residential neighborhood.^{31,34} A score for neighborhood SES was created using principal components analysis.^{4,34} Twenty-nine Census variables, which measured aspects of education, income and wealth, were included in the analysis. Six variables with the highest factor loadings – median household income, median housing value, % of households receiving interest/dividend/rental income, % of adults who are college graduates, % of employed persons aged >16 years in occupations classified as managerial, executive or professional, and % of households not headed by a single female – were selected for the SES score.³² The score was categorized into quartiles for analysis.

Mortality data were collected through linkage with the National Death Index Plus database.³⁵ Reports of deaths were also obtained from next of kin, the Social Security Administration Death Master File, and the US Post

Office. Deaths were coded using the ninth and tenth revision of the *International Classification of Diseases* (ICD-9, ICD-10). ICD-9 codes for deaths were converted to ICD-10 codes to provide consistent classification in the analysis. Participants were considered to have died from cancer if the underlying cause of death was recorded as C00-C98 in ICD-10. Underlying causes of death coded as I00-I99 were classified as deaths from cardiovascular disease.

Statistics

Participants' data on demographic, behavioral, and other factors were examined as potential confounders. Variables that changed the crude association between neighborhood SES and mortality by 10% or greater were retained in the analysis. These variables included: age (continuous), educational attainment (<12, 12, 13-15, ≥16 years), marital status (married/living as married, single/never married, divorced/separated, widowed), cigarette smoking (never smoker, former smoker with <20 pack-years, former smoker with ≥20 pack-years, current smoker with <20 pack-years, current smoker with ≥20 pack-years), adult height and weight, vigorous physical activity (none, <1, 1-2, 3-4, ≥5 hours/week), and time spent sitting watching television (<1, 1-2, 3-4, ≥5 hours/day). Body mass index (BMI) was calculated as the quotient of weight in kilograms (kg) by height in meters (m) squared and was categorized as <20, 20-24.9, 25-29.9, 30-34.9, ≥35 kg/m². In 1995 and in 2001, a National Cancer Institute-Block food frequency questionnaire was included in the biennial BWHS questionnaire.³⁶ A score for the "Western" dietary pattern, which describes greater consumption of red

meat and fried foods, was calculated from the food frequency questionnaire data using factor analysis.³³ Western dietary pattern and daily energy consumption were assessed as quintiles.

Cox proportional hazard models were used to estimate hazard ratios (HRs) and 95% CIs with control for age and years of follow-up. Participants contributed person-time from 1995 until death or loss to follow-up, or through the end of 2011, whichever occurred first. Multivariable models included control for age, education, marital status, cigarette smoking, BMI, vigorous physical activity, television

watching, Western dietary pattern, and daily energy intake. Indicator terms were used for missing data. Neighborhood SES and covariates were treated as time-varying in the models using the Andersen-Gill data structure.³⁷ In order to test for linear trend in the HRs, a categorical term was included in the regression model and was assessed as a continuous variable. In subset analyses, educational attainment was dichotomized as <16 and ≥16 years to obtain groups of similar size; household income was dichotomized as ≤\$50,000 and >\$50,000 for the same reason. To test for potential multiplicative interac-

tion, models with and without interaction terms were compared using the likelihood ratio test. Rate differences (RDs) and corresponding 95% CIs were calculated for adjusted models using Poisson regression; to test for linear trend, a continuous term was included in the model. SAS 9.3 (SAS Institute Inc., Cary, NC) was used for all analyses.

RESULTS

As shown in Table 1, women who lived in neighborhoods with the lowest quartile of SES had a higher prevalence

Table 1. Baseline individual and neighborhood characteristics^a within quartiles of neighborhood SES^b in the Black Women's Health Study, 1995-2011

| | Neighborhood SES ^{b,c} | | | |
|--|--|-------------------------|-------------------------|---|
| | Quartile 1: Lowest SES ^b , N=12,904 | Quartile 2, N=12,905 | Quartile 3, N=12,904 | Quartile 4: Highest SES ^b , N=12,904 |
| Individual characteristics | | | | |
| Age in 1995, mean (SD) | 38.7 (11.0) | 38.6 (10.7) | 38.3 (10.4) | 39.0 (10.4) |
| Education, ≥16 years, % | 28.9 | 40.5 | 49.0 | 63.3 |
| Married/living as married, % | 32.4 | 37.6 | 42.1 | 47.8 |
| Body mass index, ≥30 kg/m ² , % | 36.8 | 30.7 | 27.1 | 20.9 |
| TV watching, ≥5 hours/week, % | 20.7 | 15.7 | 12.8 | 10.4 |
| Vigorous exercise, <1 hour/week, % | 53.5 | 49.6 | 45.4 | 41.0 |
| Current smokers, % | 22.1 | 17.1 | 14.1 | 11.8 |
| Pack-years of smoking, 20+, % | 7.5 | 6.9 | 6.5 | 5.9 |
| Western dietary pattern, top quintile, % | 22.0 | 19.7 | 17.3 | 14.8 |
| Geographic region | | | | |
| Northeast, % | 26.6 | 29.4 | 29.2 | 25.6 |
| South, % | 30.1 | 31.0 | 30.6 | 27.2 |
| Midwest, % | 31.4 | 23.0 | 20.3 | 20.8 |
| West, % | 11.9 | 16.6 | 20.0 | 26.4 |
| Neighborhood characteristics | | | | |
| Median household income, mean (SD) | \$24,939 (\$8,096) | \$36,523 (\$9,244) | \$46,809 (\$11,602) | \$66,552 (\$21,947) |
| Median housing value, mean (SD) | \$90,647 (\$60,073) | \$116,900 (\$68,168) | \$139,956 (\$76,775) | \$225,128 (\$126,718) |
| % of households receiving interest, dividend, and/or rental income, mean (SD) | 10.8 (5.7) | 18.7 (6.9) | 28.5 (8.5) | 46.6 (12.5) |
| % of adult college graduates, mean (SD) | 12.0 (5.4) | 21.4 (6.7) | 32.7 (8.7) | 54.6 (13.6) |
| % of employed persons aged > 16 years in managerial, executive, or professional occupations, mean (SD) | 44.1 (10.1) | 54.9 (8.5) | 64.3 (7.7) | 78.1 (8.5) |
| % of households not headed by a single female, mean (SD) | 73.6 (8.6) | 82.9 (5.7) | 88.5 (4.8) | 94.1 (3.3) |

a. Values are standardized to the age distribution of the study population

b. SES, socioeconomic status

c. P for differences across levels of neighborhood SES are statistically significant (P<.05) for all variables except age in 1995

Neighborhood SES and Mortality Rates - Bethea et al

of obesity, sedentary behavior, cigarette smoking, and Western dietary pattern, relative to those in higher quartiles of neighborhood SES. Notably, well-educated women lived in every type of neighborhood: 28.9% of women who lived in the lowest quartile neighborhoods and 40.5% of those in the second lowest quartile were college graduates.

There were 2,598 deaths over 731,100 person-years of follow-up, including 947 deaths due to cancer and 659 deaths due to cardiovascular disease. As shown in Table 2, lower neighborhood SES was associated with increased all-cause mortality. The HR

for the lowest quartile of neighborhood SES, compared to the highest quartile, was 2.15 (95% CI: 1.91-2.41) with adjustment for age and years of follow-up only. Additional control for educational attainment, marital status, and behavioral and lifestyle factors attenuated the HR to 1.50 (1.32-1.69). Lower neighborhood SES was also associated with increased cancer mortality and cardiovascular mortality with HRs of 1.35 (1.09-1.67) and 1.40 (1.10-1.78), respectively, for the lowest quartile. An estimated 91 excess deaths (62-119) per 100,000 person-years occurred among women who lived in the lowest SES

neighborhoods, relative to the highest SES neighborhood. The rate difference between the lowest and highest quartiles of neighborhood SES was 17 for both cancer and cardiovascular mortality.

Among women with high educational attainment, >16 years of education, low neighborhood SES was associated with increased all-cause mortality, with an HR of 1.42 (1.18-1.71), and with increased cancer mortality, with an HR of 1.54 (1.14-2.07). However, there was no significant association for cardiovascular mortality. Among women with fewer than 16 years of education, low neighborhood

Table 2. Neighborhood SES^a in relation to all-cause, cancer, and cardiovascular mortality in the Black Women's Health Study, 1995-2011

| | Deaths | Person-years | HR ^b | 95% CI | HR ^c | 95% CI | HR ^d | 95% CI | RD ^{a,d,e} | 95% CI |
|-------------------------------------|--------|--------------|-----------------|-------------|-----------------|-------------|-----------------|-------------|------------------------|-----------|
| All-cause mortality | | | | | | | | | | |
| Neighborhood SES ^a score | | | | | | | | | | |
| Quartile 1 (lowest) | 923 | 181,123 | 2.15 | (1.91-2.41) | 1.72 | (1.53-1.94) | 1.50 | (1.32-1.69) | 91 | (62, 119) |
| Quartile 2 | 621 | 181,439 | 1.52 | (1.34-1.72) | 1.34 | (1.18-1.51) | 1.24 | (1.09-1.41) | 41 | (18, 64) |
| Quartile 3 | 469 | 181,550 | 1.22 | (1.07-1.39) | 1.16 | (1.02-1.32) | 1.08 | (.95-1.24) | 19 | (3, 40) |
| Quartile 4 (highest) | 406 | 181,631 | Reference | | Reference | | Reference | | Reference ^f | |
| Missing | 179 | 6,509 | | | | | | | | |
| P ^g | | | <.01 | | <.01 | | <.01 | | <.01 | |
| Cancer mortality | | | | | | | | | | |
| Neighborhood SES ^a score | | | | | | | | | | |
| Quartile 1 (lowest) | 259 | 180,449 | 1.63 | (1.33-1.99) | 1.47 | (1.21-1.79) | 1.35 | (1.09-1.67) | 17 | (6, 28) |
| Quartile 2 | 216 | 181,023 | 1.43 | (1.16-1.77) | 1.36 | (1.12-1.66) | 1.29 | (1.04-1.60) | 14 | (4, 24) |
| Quartile 3 | 193 | 181,290 | 1.37 | (1.10-1.69) | 1.37 | (1.12-1.67) | 1.29 | (1.04-1.60) | 16 | (5, 27) |
| Quartile 4 (highest) | 149 | 181,369 | Reference | | Reference | | Reference | | Reference ^f | |
| Missing | 130 | 6,462 | | | | | | | | |
| P ^g | | | <.01 | | <.01 | | .01 | | .01 | |
| Cardiovascular mortality | | | | | | | | | | |
| Neighborhood SES ^a score | | | | | | | | | | |
| Quartile 1 (lowest) | 245 | 180,439 | 2.17 | (1.73-2.73) | 1.70 | (1.35-2.14) | 1.40 | (1.10-1.78) | 17 | (5, 29) |
| Quartile 2 | 167 | 180,961 | 1.56 | (1.23-2.00) | 1.32 | (1.04-1.69) | 1.22 | (.95-1.56) | 9 | (-1, 18) |
| Quartile 3 | 117 | 181,205 | 1.18 | (.91-1.54) | 1.07 | (.82-1.38) | 1.01 | (.78-1.32) | -2 | (-11, 7) |
| Quartile 4 (highest) | 106 | 181,329 | Reference | | Reference | | Reference | | Reference ^f | |
| Missing | 24 | 6,348 | | | | | | | | |
| P ^g | | | <.01 | | <.01 | | <.01 | | <.01 | |

a. SES, socioeconomic status; RD, risk difference

b. Adjusted for age and years of follow-up

c. Additionally adjusted for education and marital status

d. Additionally adjusted for cigarette smoking, body mass index, vigorous physical activity, television watching, Western diet, and energy consumption

e. Per 100,000 person-years

f. Rate per 100,000 person-years is 237 for all-cause mortality, 92 for cancer mortality, and 61 for cardiovascular mortality

g. P does not include missing neighborhood SES

SES was associated with increased all-cause (1.53; 1.30-1.80) and cardiovascular mortality (1.69; 1.23-2.34), but not with cancer mortality. No statistically significant interactions by educational attainment were observed.

With adjustment for household income among women followed during 2003-2011, the HRs for the lowest quartile of neighborhood SES compared to the highest quartile were 1.61 (1.29-2.01), 1.53 (1.05-2.23), and 1.45 (0.94-2.23), for all-cause, cancer, and cardiovascular mortality, respectively. Among women with more than \$50,000 in household income, low neighborhood SES was associated with increased risk of all-cause (1.49; 1.03-2.17) and cancer mortality (2.09; 1.11-3.93). Among women with \$50,000 or less in household income, low neighborhood SES was associated with greater all-cause (1.39; 1.03-1.86) and cardiovascular mortality (1.75; 0.95-3.23), but not with cancer mortality. No statistically significant interactions by income were observed.

DISCUSSION

In our present study, lower neighborhood SES was associated with increased risk of all-cause, cancer, and cardiovascular mortality among Black women. The associations were attenuated by control for educational attainment, household income, and health-related characteristics. The association of neighborhood SES with all-cause and cancer mortality, but not cardiovascular mortality, was present even among college graduates and those earning more than \$50,000. This finding is of particular relevance to Black Americans,

who are more likely to live in disadvantaged neighborhoods regardless of their educational attainment or income.^{24,38}

In the Southern Community Cohort Study and the National Institutes of Health-AARP Diet and Health Study, census tract deprivation was positively associated with overall mortality,^{39,40} although the association in the latter study was only present for those who had rated their health as good to excellent.⁴⁰ Low census tract SES was also associated with higher mortality in a cohort of veterans in the Ambulatory Care Quality Improvement Project, but the finding was only present at the extremes of the SES measure.⁴¹ A recent systematic review of 21 prospective studies calculated a relative risk of 1.06 for all-cause mortality comparing the lowest tertile of area-level deprivation to the highest.⁴² Eleven of the studies used neighborhood- or census-block-level scores to approximate area-level deprivation; the relative risk in those studies was 1.05.

With regard to race-specific results, no association between neighborhood SES and mortality among Black Americans was observed in the Atherosclerosis Risk in Communities Study (ARIC),²⁷ while a higher risk of mortality was associated with low area SES in the Cardiovascular Health Study (CHS) and in an analysis of National Health Interview Survey (NHIS) data.^{25,26} The analyses in the CHS and the ARIC had small sample sizes of Black Americans (929 and 4,205, respectively). Only the NHIS study presented data among Black women, with low neighborhood SES being associated with a 37% increase in mortality risk after adjustment for individual education.²⁶ These studies were limited in geographic represen-

tation and, while each study controlled for age, sex, income, occupation, and education, important factors, such as cigarette smoking, were not controlled.

Low area-level SES has been associated with increased risk of cancer mortality in a few prospective studies,^{39,43-45} although a systematic review found no association.⁴² Among Black Americans in the ARIC, cancer mortality rates were 30% higher in the lowest tertile of census block SES compared to the highest (.9-1.8).²⁷ This result is consistent with our findings.

In our present study, lower neighborhood SES was associated with increased risk of all-cause, cancer, and cardiovascular mortality among Black women.

An analysis of eight prospective studies found a relative risk of 1.09 for area-level deprivation in relation to cardiovascular mortality.⁴² Two studies presented data for the relation of neighborhood SES to cardiovascular mortality in Black Americans; in the ARIC, there was no association,²⁷ while in the CHS, there was a 20% increase in risk.²⁵

To our knowledge, only one prospective study, using the NHIS, has published data from Black Americans on the relation of neighborhood SES to mortality within strata of individual SES.²⁶ In Black Americans, all-cause mortality rates were high-

est in low SES neighborhoods compared to higher SES neighborhoods at each level of individual SES, as measured by an income-to-needs ratio.²⁶

The potential mechanisms for associations of low neighborhood SES with higher mortality are both social and biological. Residents of low SES neighborhoods have reduced access to health-promoting resources,²³ such as adequate preventive care,¹⁴⁻¹⁶ healthy foods,⁵⁻⁷ and built environments that promote physical activity,¹¹⁻¹³ all of which influence risk of mortality. Residents of low SES neighborhoods may also experience greater psychosocial stress due to exposure to crime,⁴⁶⁻⁴⁸ social disorder,^{49,50} racial or economic segregation,^{38,51,52} lack of municipal services,^{8,53} and limited access to mental health services.^{54,55} Allostatic load, a measure of the biological response to stress, has been positively associated with mortality.^{56,57} Black Americans tend to have a higher allostatic load than do White Americans⁵⁸⁻⁶⁰ and high allostatic load has been associated with low neighborhood SES,^{61,62} particularly among Blacks.⁶³

Our present study adds prospective data to the sparse information on the relation of neighborhood SES to mortality risk among Black women; only one previous study prospectively investigated this association among Black women.²⁶ An additional strength was the variability of individual SES within categories of neighborhood SES, such that many participants with high individual SES resided in poor neighborhoods.³¹ These circumstances are due in part to the legacy of discrimination in housing and lending practices in the US, which has resulted in Black Americans being much more likely to live in disadvantaged neigh-

borhoods than White Americans of the same individual SES.³⁸ This variability enabled us to stratify by education and by income, which showed that the influence of low neighborhood SES was present even for BWHS participants with high individual SES.

The BWHS is a prospective study, which reduces the risk of recall bias for important covariates. Because the covariates were updated over time in the present study, we were able to address changes in individual behaviors. Some women changed residences over follow-up, but tended to stay within the same quartile of neighborhood SES. Analyses restricted to non-movers showed similar results to those presented. Our analyses stratified according to income were limited by the collection of those data in 2003 and we were unable to account for occupation or employment status as a measure of individual SES. However, the observation that the association between education and mortality is stronger among minority populations than among non-Hispanic, White populations^{64,65} suggests that educational attainment provides a robust measure of individual SES.⁶⁶ BWHS participants tend to have more years of education than Black women in the general population and underrepresent the 15% of Black women nationally of the same ages who did not graduate high school.⁶⁷ In addition, most BWHS participants live in urban areas. However, the relation of neighborhood SES to all-cause mortality and to cardiovascular mortality was present among participants with <16 years of education and among participants with <\$50,000 in household income and BWHS participants represent all regions of the United States. Thus, the findings should

be generalizable to a high proportion of Black women in the United States.

CONCLUSION

High individual SES is often associated with positive health-related behaviors, such as a balanced diet and physically active lifestyle, and with access to health care. However, our findings and those from previous studies that stratified on individual SES suggest that these factors do not compensate for the adverse impacts associated with residence in low SES neighborhoods. Thus, additional attention is needed to identify the aspects of residential environments responsible for the adverse effect on mortality.

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CONFLICT OF INTEREST

We have no conflicts of interest to disclose. The Black Women's Health Study was approved by the Boston University Medical Center Institutional Review Board and all procedures were conducted in accord with the ethical standards of the Institutional Review Board and the Helsinki Declaration of 1975, as revised in the year 2000. Each BWHS participant provided informed consent.

AUTHOR CONTRIBUTIONS

Research concept and design: Bethea, Palmer, Rosenberg, Cozier; Acquisition of data: Bethea, Rosenberg, Cozier; Data

analysis and interpretation: Bethea, Palmer, Rosenberg, Cozier; Manuscript draft: Bethea, Palmer, Rosenberg, Cozier; Statistical expertise: Bethea, Cozier; Acquisition of funding: Palmer, Rosenberg, Cozier; Administrative: Bethea, Rosenberg, Cozier; Supervision: Bethea, Palmer, Cozier

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Neighborhood SES and Mortality Rates - Bethea et al

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