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ORIGINAL PAPER

# Mediators of the effect of neighborhood poverty on physical functioning among breast cancer survivors: a longitudinal study

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**Abstract**
*Purpose* Female breast cancer survivors, a large and growing population, experience impaired physical functioning after treatment. Survivors living in impoverished neighborhoods may suffer even greater impairment, but the mechanisms linking neighborhood poverty and individual outcomes are poorly understood. This study sought to identify mediators of the effect of neighborhood poverty on physical functioning using longitudinal data from a Missouri cancer registry-based sample of 909 female breast cancer survivors.
*Methods* Survivors were recruited 1 year after diagnosis (Y1) and completed two telephone interviews, at Y1 and 1 year later (Y2). The association between census-tract-level poverty and physical functioning (RAND SF-36) was tested using a multilevel a priori path model with 19 hypothesized mediators, demographic and socioeconomic confounders, and covariates. Hypothesized mediators included clinical and treatment variables, psychosocial factors (depression, stress, social support), perceived neighborhood characteristics, behavioral risk factors (physical activity, smoking, body mass index, alcohol use), and comorbidity.
*Results* In unadjusted analysis, women living in neighborhoods with higher poverty were more likely to report lower physical functioning at Y2 ($\beta = -.19$, $p < .001$). The final mediated model fit the data well ($\chi^2(8) = 12.25$, $p = 0.14$; CFI = .996; RMSEA = .024). The effect of neighborhood poverty on physical functioning was fully mediated by physical activity and body mass index.
*Conclusions* Breast cancer survivors living in neighborhoods with greater poverty reported lower physical functioning, but this effect was fully explained by physical activity and body mass index. Community-based lifestyle interventions sensitive to the unique challenges faced by cancer survivors and the challenges of living in a high-poverty neighborhood are needed to ameliorate neighborhood socioeconomic disparities in physical functioning.

**Keywords** Quality of life · Survivors · Neighborhood · Poverty · Health behavior · Physical functioning

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## Introduction

In 2007, an estimated 2.7 million American women were alive with a breast cancer history [1]. Breast cancer survivors are a large and growing population, due in large part to advances in early detection and treatment. Consequently, the quality of life (QOL) of this population represents a public health issue of growing significance.

Breast cancer survivors may experience reduced health-related QOL, including poorer physical functioning, compared with non-cancer controls [2–7]. Physical functioning,

one of multiple QOL domains, measures the extent to which an individual can walk, climb stairs, run, and participate in activities of daily living. The consequences and costs of reduced physical functioning among survivors are high; both poorer physical function and declines in physical functioning over time are associated with worse prognosis [8, 9]. Declines in physical functioning may occur shortly after cancer diagnosis and treatment. Many, but not all breast cancer survivors return to normal physical functioning at some point following treatment [6, 7, 10, 11]. Many factors have been associated with differences in physical functioning and overall health-related QOL, including age, race, socioeconomic status, cancer stage, cancer-related symptoms, comorbidity, physical activity (PA), body mass index (BMI), and psychosocial factors [6, 12–18].

Survivors living in higher poverty neighborhoods may face an increased burden of poorer physical functioning and greater difficulty returning to normal physical function following treatment. Breast cancer survivors living in areas of higher poverty face worse health-related QOL outcomes including increased ambulatory care–sensitive hospitalizations (preventable hospitalizations for conditions such as asthma, diabetes, pneumonia, etc. that represent a breakdown in access to or the processes of primary care) and poorer survival [19–21]. However, the association between neighborhood poverty and physical functioning among breast cancer survivors remains unexplored.

Although mounting evidence has linked neighborhood poverty to a host of poorer health outcomes among cancer survivors [19–21], little is known about the mediating mechanisms underlying these associations. More generally, the mediating mechanisms linking neighborhood poverty to individual health outcomes are not yet known, and consequently, the identification of these mechanisms is considered a key priority for the advancement of the neighborhood effects literature [22–24]. Understanding these mechanisms in breast cancer survivors is an essential step toward targeting and developing effective environmental, health promotion, and/or public policy interventions for this growing population. However, the opportunity to improve the physical functioning of cancer survivors living in high-poverty neighborhoods will remain unrealized until mediating mechanisms are better understood. Therefore, the purpose of this longitudinal study was, first, to assess the effect of neighborhood-level poverty on physical functioning among female breast cancer survivors 2 years post-diagnosis and, second, to identify what potentially modifiable factors mediate the effect of poverty on physical functioning. To demonstrate the robustness of identified mediators and to provide greater confidence in our results, we also accounted for the effect of other independent variables by adding both confounders and covariates to our analysis.

## Materials and methods

### Study sample

Women aged ≥25 diagnosed with a first primary breast cancer between 1 June 2006 and 30 June 2008 were identified from the Missouri Cancer Registry. Women were initially recruited by mail and telephone calls were made to non-respondents. After obtaining informed consent, trained interviewers administered computer-assisted telephone interviews at one (Y1) and two years (Y2) after diagnosis. All data were collected between 2007 and 2010. By protocol guidelines, Y1 interviews occurred between 10 and 14 months after diagnosis. Women were excluded if, at Y1 or Y2, they scored more than 10 on the Orientation–Memory–Concentration test, a screen for cognitive impairment [25], had changed residence between years, or had residential street addresses that could not be geocoded. This study was approved by Institutional Review Boards at Washington University and the University of Missouri–Columbia.

### Measures

We sought to identify the relevant mechanisms linking neighborhood poverty to physical functioning by empirically testing potentially mediating pathways that were identified using both conceptual models and empirical studies as a guide. Specifically, we borrowed from conceptual models of health-related quality of life [26, 27] that explicitly demonstrate how characteristics of the individual and environment can contribute to physical functioning. We also drew from previous literature about neighborhood effects on various health outcomes [23, 24, 28–32], reviews of quality of life factors in breast cancer survivorship [6, 12–18], and disparities in breast cancer [19–21] when selecting variables and directional pathways in our model. Using this literature as a guide, our hypothesized path model specified a priori pathways that related all measures (mediators, confounders, or covariates) to the predictor (neighborhood poverty) and/or the outcome (physical functioning). Mediators are variables that are hypothesized to be caused or influenced by the predictor that in turn cause or influence the dependent (outcome) variable. Confounders, while also associated with both the predictor and outcome, do not lie in a hypothesized causal pathway, unlike mediators. Covariates are associated with either variable, but not both.

#### *Physical functioning*

We chose physical functioning as our QOL outcome because it is a frequently used outcome in other studies, and because it is closely linked to both comorbidity and

survival [8, 9]. Physical functioning was measured at Y2 using the RAND 36-Item Health Survey 1.0 [33, 34]. The 10-item scale measures physical aspects of health-related QOL, including walking, climbing stairs, daily maintenance activities such as carrying groceries and bathing oneself, and participation in vigorous (e.g., running) and moderate (e.g., vacuuming) activities. Scores are standardized and range from 0 to 100; higher scores indicate better functioning [33].

*Neighborhood poverty*

The predictor, neighborhood poverty rate, was measured using 2000 U.S. Census data, which was several years prior to the Y1 survey, and was defined as the continuous percentage of the population living below the federal poverty level in the participant's census tract of residence. Because it is unknown whether the mechanisms linking neighborhood SES and physical functioning differ based on the selected SES indicator, we opted to use a commonly used single-item measure. We specifically chose neighborhood-level poverty rate as the optimal single-item indicator of neighborhood SES for our study based on the literature indicating its robust association with a variety of health outcomes in diverse populations, because it is a standard measure that is easily interpreted across places and over time, it has been identified as an upstream determinant of downstream health and social factors in other longitudinal studies, and for its relevance for policy makers [21, 35, 36].

*Potential mediators*

Multiple hypothesized mediators measured at Y1 were considered, including clinical and treatment variables, comorbidity, perceived neighborhood conditions, psychosocial variables, and behavioral risk factors.

Clinical and treatment variables included a surgical side effects index as well as the following yes/no variables: axillary lymph node removal, chemotherapy, radiotherapy, ever using hormonal therapy (i.e., tamoxifen, raloxifene, or aromatase inhibitors), and type of surgery (lumpectomy vs. mastectomy [the 24 women with no surgery were omitted from this comparison]). Self-reported treatment has been shown to be accurate relative to medical record review [37]. For the surgical side effects index, women rated how often each of 5 breast surgery–associated side effects (e.g., arm weakness, arm lymphedema) affected them in the previous month using a 5-point scale ranging from "not at all" (1) to "all of the time" (5). This measure includes 5 of the 8 items from a previously developed and validated index ($\alpha = 0.74$[38]) [38–41].

Comorbidity was measured using Katz's validated self-report adaptation of the Charlson comorbidity index [42, 43], which captures the presence and/or history of multiple chronic conditions (e.g., myocardial infarction, diabetes, and other cancers). A weighted score accounts for both the presence and severity of comorbidities.

Three perceived neighborhood conditions were measured. Using 4-point scales (strongly agree to strongly disagree), physical disorder/decay (6 items) and social disorder (9 items) captured the extent to which respondents' perceive physical or social cues in their neighborhoods that signify the breakdown of social control [44]. Collective efficacy, a 10-item 5-point scale ranging from either very likely to very unlikely and strongly agree to strongly disagree, measured resident's perceptions of the community's ability to control residents' behavior and to organize effectively [45].

Five psychosocial factors were measured. A score of 9 or greater on the 11-item version of the Center for Epidemiologic Studies Depression (CESD-11) scale [46] was used as an indicator of clinically significant depressive symptoms (yes vs. no). The 4-item Cohen's perceived stress scale assessed stress using a 5-point response scale (never to very often) [47]. The 19-item 5-point Medical Outcomes Study (MOS) scale measured perceived availability of social support (none of the time to all of the time) [48]. Finally, two yes/no questions captured community and social involvement: "Do you belong to a church or other religious organization where you meet with others on a regular basis?" and "Do you belong to any clubs or other social organizations where you meet with others on a regular basis?"

Behavioral risk factors were measured using standard questions from the Behavioral Risk Factor Surveillance System and included current smoking status (current, former, never), any participation in leisure time PA in the past month (yes vs. no), BMI (underweight [$<18.5$ kg/m$^2$], normal weight [18.5–24.9 kg/m$^2$], overweight [25.0–29.9 kg/m$^2$], obese [$\geq 30.0$ kg/m$^2$]), and alcohol use during the past month ($\leq 1$ drink per day vs. $>1$ drink per day).

*Potential confounders*

Potential confounding factors measured at Y1 included age (continuous), race (non-white vs. white), current marital status (married vs. unmarried), educational attainment ($\leq$high school, some college, or $\geq$college graduate), annual household income ($\leq$\$24,999, \$25–34,999, \$35–49,999, \$50–74,999, or $\geq$\$75,000), years lived at residence (continuous), having health insurance (yes vs. no), and ability to afford a doctor in the past 12 months (yes vs. no).

Additional potential confounders included each patient's stage at diagnosis (in situ, localized, or regional/distant) obtained from the Missouri Cancer Registry, and neighborhood (census tract) variables measured using 2000 U.S.

Census data, including residential stability (the continuous percentage of the population at same address 5 years ago) and urban/rural status (metropolitan Rural Urban Continuum Area codes 0–3 vs. non-metropolitan codes 4–10).

*Potential covariates*

Two potential covariates of the outcome were measured at Y2. Disease progression was defined as having any contralateral breast cancer, a recurrence of cancer in the same breast, or metastasis (yes vs. no). Current use of hormone therapy was coded yes versus no.

Data analysis

Descriptive (STATA 11.0) and multilevel path analyses (Mplus 5.2) were used to describe the sample and test the hypothesized model. Multilevel path analyses accounted for the clustering of individuals within census tracts. Path analyses can accommodate missing data in the predictors and outcomes and do not require listwise deletion.

*Direct effect model*

The direct effect of neighborhood poverty on physical functioning was examined first.

*Multiple confounders and covariates model*

To identify variables for inclusion in the subsequent mediation models, we first explored the associations between all hypothesized confounders with physical functioning and neighborhood poverty controlling for the direct effect of neighborhood poverty on physical functioning. If hypothesized confounders were not associated with both the predictor and outcome, they were included in subsequent analyses as covariates (associated with either variable) or were dropped if not associated with either variable. Hypothesized covariates that were not significantly associated with the outcome were dropped from subsequent analyses.

*Single- and multiple-mediator models*

All hypothesized mediators were tested in separate single-mediator models, and then all statistically significant mediators were first included in a multiple-mediator model without the inclusion of either covariate or confounder variables from the prior analyses. If two mediators were highly correlated with each other ($r \geq 0.70$), one was dropped. If mediators were not significantly associated with both the predictor and outcome, they were included in subsequent analyses as covariates (associated with either variable) or were dropped if not associated with either variable. Additionally, correlations between mediators were estimated. In each model, significant mediation was assessed using MacKinnon et al.'s recommended asymmetric confidence intervals [49] which provide more power than Sobel's Delta method [50] and may be a more accurate test when using categorical mediators [51]. Statistical significance is indicated when the confidence limits do not include zero.

Next, to examine the robustness of the mediators, we added the previously identified statistically significant confounders and covariates to the multiple-mediator model. We retained non-significant mediators as covariates and dropped non-significant covariates from further analyses.

Next, we included the hypothesized mediators found to be associated with only the outcome in the single-mediator models as additional covariates in the multiple-mediator model, and those that remained statistically significant were retained as covariates.

The final multiple-mediator model included all a priori and results-driven covariates and confounders, and correlations between all mediators, covariates, and confounders. All associations in the final model were statistically significant because previous steps in the analysis excluded variables that were not significantly associated with either the predictor or outcome. Overall model fit was assessed with multiple fit indices including Chi-square, the comparative fit index (CFI), and the Root Mean Square Error of Approximation (RMSEA) and its 90 % confidence intervals (CI). CFI values 0.95 or above suggest good fit [52, 53], and RMSEA values <.06 suggest good model fit [53].

## Results

Sample characteristics

Of the 4,020 female survivors eligible to participate, 675 could not be contacted after seven attempts. Of the remainder, 1,164 (34.8 %) completed the Y1 interview. The American Association for Public Opinion Research (AAPOR) response rate (RR1) at Y1 was 29.0 % [54]. Compared with participants, non-participants were more likely to be older and African American; neighborhood poverty rate did not differ significantly between participants and non-participants. Of the 1,164, 1,037 (88.9 %) completed the Y2 interview. Nearly all (98.4 %) completed the Y2 interview within 11–14 months following the Y1 interview (range, 9–18 months). After exclusion criteria were applied ($n = 87$ screened positive on the Orientation–Memory–Concentration test in either year; $n = 45$ moved

residence between interviews; $n = 2$ were not geocoded), 909 women were included in analyses.

Participants were primarily non-Hispanic White (92.0 %), had medical insurance (97.5 %), and the mean age was 57.9 (range, 27–91) (Table 1). The 909 participants were distributed across 577 census tracts (568 in Missouri; 9 in other states), with an average of 1.6 women per tract (range, 1–8). Most women had lived in the same residence over the study period (870 [95.7 %] during their diagnosis in the year prior to the Y1 survey and 622 [68.4 %] in the year 2000, when neighborhood poverty rate was measured).

### Direct effect model

The direct effect of neighborhood poverty on physical functioning was statistically significant, and it accounted for 3.5 % of the variance in physical functioning (Fig. 1a). Greater neighborhood poverty was associated with lower physical functioning.

### Multiple confounders and covariates model

Only income was a significant confounder (associated with both poverty and physical functioning). Covariates of neighborhood poverty rate included residential stability, urban/rural status, race, time lived at residence, and ability to afford a doctor in the past 12 months. Hypothesized confounder variables that were unrelated to the predictor and were instead retained as covariates of physical functioning included age, education, cancer stage at diagnosis, and currently receiving hormone therapy at Y2.

### Single-mediator models

Nine of the hypothesized mediators were statistically significant in single-mediator models: PA, BMI, physical disorder, social disorder, comorbidity, surgical side effects, smoking status, alcohol use, and collective efficacy. Several additional hypothesized mediators were significantly associated with physical functioning but not neighborhood poverty: perceived stress, depressive symptoms, social support, and type of breast cancer surgery and therefore were examined as potential covariates in the multiple-mediator model.

### Multiple-mediator models

An eight-mediator model was examined. Because physical and social disorders were highly correlated ($r = 0.76$, $p < .001$), only physical disorder was included (similar results were observed with social disorder [not shown]). Model fit was good ($\chi^2$[1] 1.83, $p = 0.18$; CFI = .999; RMSEA = .030; 90 % CI[<.001–.099]) but alcohol use and collective efficacy were no longer associated with the outcome and were dropped from further analyses. PA, BMI, physical disorder, comorbidity, surgical side effects, and smoking status were significant mediators.

Including all confounders and covariates in a six-mediator model maintained good fit ($\chi^2$[9] 14.63, $p = 0.10$; CFI = .996; RMSEA = .026, 90 % CI[<.001–.050]) but comorbidity, smoking status, and surgical side effects were no longer associated with neighborhood poverty and were therefore retained as covariates of physical functioning. Physical disorder was no longer associated with physical functioning and was retained as a covariate of neighborhood poverty in further analysis. Two covariates, education and cancer stage, were no longer associated with physical functioning and were dropped from further analysis. Two variables remained significant mediators: PA ($\alpha\beta = -.061$, CI: $-.075$ to $-.046$) and BMI ($\alpha\beta = -.050$, CI: $-.068$ to $-.033$).

The resulting two mediator model was then examined after adding the four variables identified in the single-mediator analyses as covariates of physical functioning (stress, depression symptoms, social support, and type of surgery). Two of these variables (social support and type of surgery) were no longer significant covariates in the full model and were dropped from further analyses.

The fit of the final two mediator model with one confounder (income) and multiple covariates was very good ($\chi^2$[12] 20.73, $p = 0.05$; CFI = .995; RMSEA = .028, 90 % CI [<.001–.048]). The effect of neighborhood poverty on physical functioning was fully mediated by PA and BMI (Fig. 1b; Table 2). The final model accounted for 48.0 % of the variance in physical functioning. Significant associations in the final model between all model variables (including covariates, confounders, and mediators) with the predictor and/or outcome are shown in Fig. 1b. Significant correlations between all model covariates, confounders, and mediators not shown in Fig. 1b are reported in Table 2 and are organized following the left-to-right layout of Fig. 1b.

In a sensitivity analysis, we repeated the final model analysis with only those women who lived in the same residence since 2000 ($n = 622$): the model fit was largely unchanged ($\chi^2$[12] 18.32, $p = 0.11$; CFI = .995; RMSEA = .029 90 % CI [<001–.054]) and PA and BMI remained significant mediators.

## Discussion

This study demonstrated that breast cancer survivors living in neighborhoods with higher poverty rates reported lower physical functioning, but this effect was fully mediated by PA and BMI. By identifying potential targets for intervention, these results significantly advance the study of

**Table 1** Sample characteristics among 909 breast cancer survivors at Year 1 (baseline)

| | *n* (%) or mean ± SD |
|---|---|
| Y2 physical functioning (range, 0–100) | 73.7 ± 25.1 |
| Neighborhood poverty (range, 0.4–44.0) | 9.7 ± 7.4 |
| Age (range, 27–91) | 57.9 ± 11.2 |
| Race/ethnicity | |
| Non-Hispanic White | 836 (92.0) |
| Other, multiple | 73 (8.0) |
| Education | |
| ≤High school | 315 (34.7) |
| 1–3 years college | 249 (27.4) |
| ≥College graduate | 343 (37.7) |
| Household income | |
| ≤24,999 | 140 (15.4) |
| $25–34,999 | 106 (11.7) |
| $35–49,999 | 137 (15.1) |
| $50–74,999 | 194 (21.3) |
| ≥$75,000 | 287 (31.6) |
| Marital status | |
| Married or living together | 641 (70.5) |
| Unmarried | 268 (29.5) |
| Time lived at residence in years (range, 0–60) | 15.6 ± 12.8 |
| Health insurance (yes vs. no) | 886 (97.5) |
| Can afford to see a doctor in the last year (yes vs. no) | 33 (3.6) |
| Residential stability (percent living in home 5 years ago) | 54.8 ± 9.9 |
| Urban (vs. rural) status | 608 (66.9) |
| Stage at diagnosis | |
| In situ | 174 (19.1) |
| Local | 205 (55.2) |
| Regional/distant | 227 (25.0) |
| Y2 Disease progression (yes vs. no) | 68 (7.5) |
| Type of definitive surgery | |
| Lumpectomy | 534 (58.8) |
| Masectomy | 351 (38.6) |
| No surgery | 24 (2.6) |
| Surgical side effects index (range, 5–23) | 8.1 ± 3.3 |
| Axillary lymph node removal (yes vs. no) | 709 (78.0) |
| Chemotherapy (yes vs. no) | 402 (44.2) |
| Radiotherapy (yes vs. no) | 653 (71.8) |
| Ever received hormone therapy (i.e., tamoxifen, raloxifene, or aromatase inhibitors) (yes vs. no) | 602 (66.2) |
| Y2 Currently receiving hormone therapy (i.e., tamoxifen, raloxifene, or aromatase inhibitors) (yes vs. no) | 486 (53.5) |
| Comorbidity index (range, 0–7) | 0.6 ± 1.2 |
| Physical disorder (range, 6–20) | 7.8 ± 2.4 |
| Social disorder (range, 9–27) | 12.6 ± 3.6 |
| Collective efficacy (range, 1.2–4) | 2.0 ± 0.4 |
| Clinically significant depressive symptoms (yes vs. no) | 183 (20.1) |
| Perceived stress scale (range, 4–18) | 7.4 ± 3.0 |
| Social support scale (range, 1.2–5) | 4.4 ± 0.7 |
| Regularly attends church or religious organization (yes vs. no) | 604 (66.5) |
| Regularly attends a club or social organization (yes vs. no) | 412 (45.3) |
| Smoking status | |
| Current smoker | 84 (9.2) |
| Former smoker | 312 (34.3) |
| Never smoked | 512 (56.3) |
| Body mass index | |
| Underweight (<18.5 kg/m$^2$) | 9 (1.0) |
| Normal (18.5–24.9 kg/m$^2$) | 266 (29.6) |
| Overweight (25.0 29.9 kg/m$^2$) | 314 (34.9) |
| Obese (≥30 kg/m$^2$) | 311 (34.6) |
| Leisure time physical activity (yes vs. no) | 693 (76.2) |
| >1 Alcoholic drinks/day (vs. ≤1/drinks day) | 470 (51.7) |

All variables measured at Year 1 (data collected 2007–2009) unless specified Y2 (Year 2 data collected 2008–2010)

neighborhood conditions and QOL among breast cancer survivors.

Both greater PA and lower BMI are associated with better QOL outcomes and increased survival among cancer survivors [18, 55–63]. For example, a recent home-based diet and exercise intervention significantly reduced the rate of declines in physical functioning among older, overweight long-term cancer survivors [64]. Accordingly, weight management and exercise programs are increasingly accepted as critical components of cancer rehabilitation and supportive care [65]. However, while a burgeoning literature has explored optimal individually based interventions[58, 66–68] and recommendations for PA among cancer survivors have been issued [60, 69, 70], both PA and BMI are suboptimal among cancer survivors [71, 72]. In this study, nearly one quarter (24.4 %) of survivors reported *no* leisure time PA whatsoever in the previous month and 69.5 % were overweight or obese.

While numerous lifestyle interventions have been developed specifically for cancer survivors, we demonstrate the importance of addressing neighborhood context in the development and delivery of these interventions. However, the feasibility of implementing interventions targeted to both cancer survivor status and neighborhood poverty is uncertain. Interventions targeting community-dwelling cancer

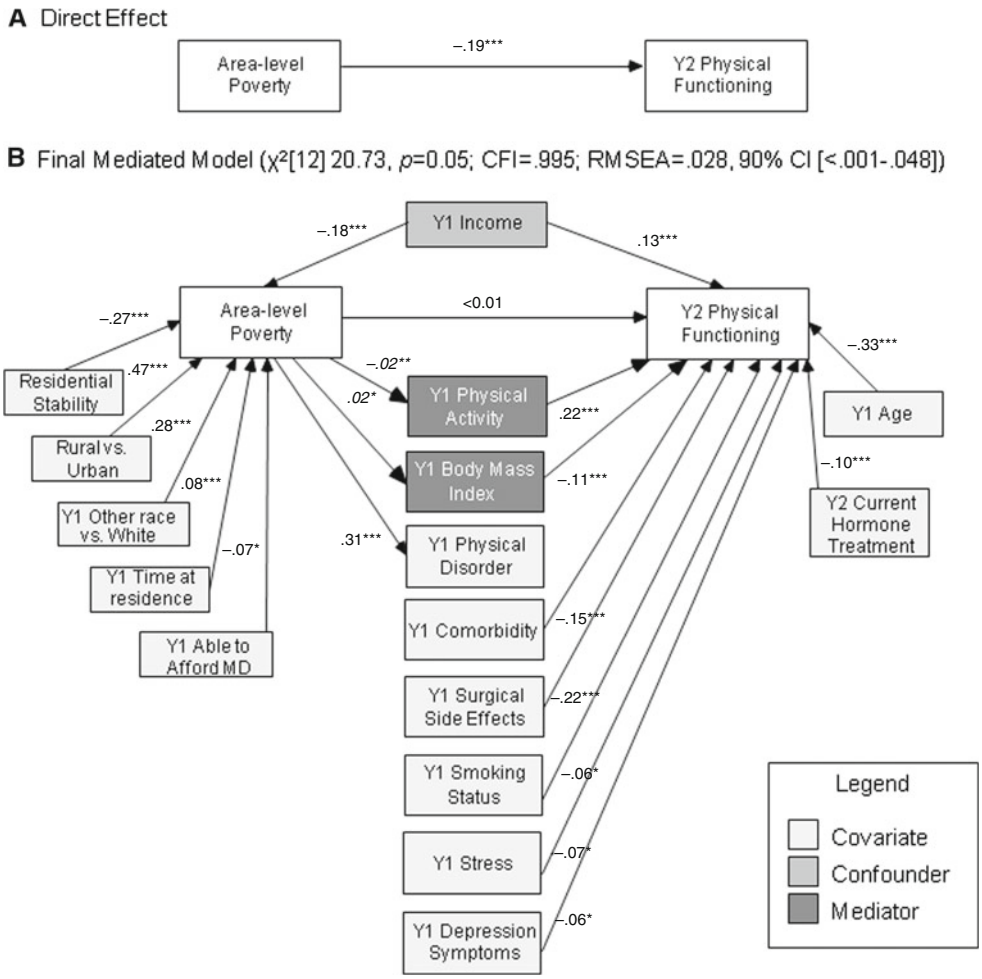


**Fig. 1** Direct (**a**) and mediated (**b**) effects of neighborhood-level poverty on physical functioning among breast cancer survivors mediated by BMI and physical activity and controlling for covariates and correlations between variables ($n = 909$). *Note*: Standardized estimates shown. $*p < .05$; $**p < .01$; $***p < .001$; Y1 and Y2 indicate measurement with the Year 1 (data collected 2007–2009) or Year 2 (data collected 2008–2010) survey, respectively. Area-level poverty, residential stability, and urban/rural status were measured using the 2000 U.S. Census. Italicized estimates of association between poverty and categorical mediators are unstandardized probit regression coefficients. Significant correlations between model covariates, confounders, and mediators not shown in Fig. 1 are reported in Table 2

survivors living in high-poverty neighborhoods may face serious impediments to recruitment and retention such as competing demands for the participants' time, residential instability, lack of transportation, inconsistent telephone service, and medical mistrust [73–78]. Other potential barriers include the limited geographic proximity of targeted high-poverty neighborhoods to each other and the relative scarcity of cancer survivors in any given neighborhood. However, because the identified mediators in this study likely underlie physical functioning outcomes in other chronically ill groups (e.g., diabetics), one option would be community-based interventions designed for high-poverty neighborhoods that target all chronically ill residents. Intervention subcomponents could be added as needed to address disease-specific issues, such as the unique motives, barriers, and preferences for activity held by cancer survivors [62]. Another practical approach involves adapting existing patient-based cancer survivorship interventions in order to address different neighborhood contexts, particularly the unique challenges faced by residents of high-poverty neighborhoods. For example, exercise recommendations for walking outdoors may not be as relevant to survivors living in high-poverty, high-crime neighborhoods and could be adapted accordingly. The relevance of the local environment to the success of lifestyle interventions is of paramount importance. In a comprehensive review, the World Health Organization concluded that the most effective strategies to improve diet and PA are multi-component population-level interventions that are adapted to the local context [79]. To date, however, limited data are available to guide interventions for cancer survivors or other chronically ill individuals at a community or systems level [80–82].

Consistent with the previous research among healthy adults [83, 84], this study demonstrated less PA and higher BMI among survivors living in higher poverty neighborhoods. Multiple factors may contribute to these observed differences, including differences in the built environment, such as sidewalks in varying states of disrepair and the prevalence of abandoned buildings, recreational facilities, fast food restaurants, and grocery stores, as well as differences in social norms and perceptions about neighborhood safety or the availability of recreational resources [85–90].

**Table 2** Significant correlations between model covariates, confounders, and mediators in the final mediated model (not shown in Fig. 1b)

| Variables | Standardized estimates |
|---|---|
| Income | |
| Rural versus urban | −.17*** |
| Other race versus white | −.11*** |
| Time at residence | −.07* |
| Able to afford MD | .24*** |
| Physical activity | .25*** |
| Body Mass Index (BMI) | −.15*** |
| Physical disorder | −.22*** |
| Comorbidity | −.26*** |
| Surgical side effects | −.13*** |
| Smoking status | −.17*** |
| Stress | −.16*** |
| Depression symptoms | −.17*** |
| Age | −.30*** |
| Residential stability | |
| Time at residence | .18*** |
| Surgical side effects | −.08* |
| Rural versus urban | |
| Other race versus white | −.15** |
| Physical disorder | −.11* |
| Other race versus white | |
| Time at residence | −.07* |
| Able to afford MD | −.09** |
| Y2 Hormone treatment | .06* |
| Physical activity | −.12** |
| Body mass index (BMI) | .08* |
| Physical disorder | .12*** |
| Comorbidity | .13*** |
| Surgical side effects | .09*** |
| Time at residence | |
| Able to afford MD | .08* |
| Surgical side effects | −.10** |
| Smoking status | −.07* |
| Depression symptoms | −.08* |
| Age | .39*** |
| Y2 Hormone treatment | −.08* |
| Able to afford MD | |
| Physical disorder | −.07** |
| Comorbidity | −.10*** |
| Surgical side effects | −.11*** |
| Smoking status | −.13*** |
| Stress | −.18*** |
| Depression symptoms | −.19*** |
| Age | .11** |
| Physical activity | |
| Body mass index (BMI) | −.24*** |
| Physical disorder | −.17*** |
| Comorbidity | −.27*** |
| Surgical side effects | −.16*** |
| Smoking status | −.12** |
| Stress | −.19*** |
| Depression symptoms | −.21*** |
| BMI | |
| Physical disorder | .08* |
| Comorbidity | .16*** |
| Smoking status | −.07* |
| Depression symptoms | .10* |
| Physical disorder | |
| Comorbidity | .09** |
| Surgical side effects | .15*** |
| Smoking status | .10*** |
| Stress | .22*** |
| Depression symptoms | .21*** |
| Comorbidity | |
| Surgical side effects | .15*** |
| Smoking status | .08* |
| Stress | .16*** |
| Depression symptoms | .18*** |
| Age | .24*** |
| Surgical side effects | |
| Smoking status | .13*** |
| Stress | .39*** |
| Depression symptoms | .39*** |
| Y2 Hormone treatment | .13*** |
| Age | −.17*** |
| Smoking status | |
| Stress | .18*** |
| Depression symptoms | .15*** |
| Y2 Hormone treatment | .07* |
| Stress | |
| Depression symptoms | .56*** |
| Age | −.18*** |
| Y2 Hormone treatment | .07* |
| Age | |
| Depression symptoms | −.09** |
| Y2 Hormone treatment | |
| Depression symptoms | .09** |

* $p < .05$, ** $p < .01$, *** $p < .001$. All variables measured at Year 1 (data collected 2007–2009) unless specified Y2 (Year 2 data collected 2008–2010)

Several limitations should be noted. First, although we recruited a population-based sample and had a good follow-up response rate (88.9 %), we had a low Y1 response rate and higher non-response at Y1 by African Americans,

potentially limiting generalizability. Second, we used self-reported and several single-item measures and did not measure diet. While the use of a single-item measure of PA is a limitation of our study, it was a significant mediator in our model, providing strong evidence of PA as an important mediator. The use of more objective (e.g., number of steps measured by an accelerometer) and reliable PA measures (e.g., multi-item measures of moderate or vigorous PA per week) could help to monitor compliance with PA recommendations and further elucidate the tested pathways. Third, because Y1 physical functioning was not included, it was not possible to study the effect of neighborhood poverty on change in physical functioning. Notably, however, our longitudinal study allowed for the exploration of the associations of poverty and multiple other factors measured at or before Y1 on Y2 physical functioning. Fourth, women were surveyed only twice. Additional data collection points would allow for more nuanced tests of mediation. However, our use of sensitivity analyses and a time-lagged mediation model (measurement of the predictor, neighborhood poverty, using 2000 Census data preceded the measurement of the Y1 mediators which preceded the Y2 outcome) increase our confidence in the observed meditational pathways.

Despite these limitations, our study confirms the hypothesized effects of neighborhood poverty on physical functioning among breast cancer survivors and that lifestyle factors (PA and BMI) fully mediated this effect. As such, lifestyle interventions that can address both the unique challenges faced by cancer survivors and the challenges of living in a high-poverty neighborhood are needed. Such interventions, if developed with an eye for feasibility and testability, have the potential to reduce observed neighborhood socioeconomic disparities in physical functioning, thereby improving QOL across diverse neighborhoods. Given the documented relationship between health-related QOL and survival [8, 9], our findings also provide some insight into the mechanisms driving cancer survival disparities between socioeconomically disadvantaged and more advantaged populations that deserves future study. Accordingly, next steps could include the development and testing of a conceptual framework and a longer causal model that posit testable hypotheses linking neighborhood factors to health-related QOL and ultimately, to survival outcomes. Notably, our use of path analysis with longitudinal data presents several advantages over the more commonly used "black box" regression methods and cross-sectional studies. Particular advantages here included the ability to distinguish between confounders and covariates and the simultaneous estimation of both direct and mediated effects. These methods hold promise for researchers interested in disentangling the mediating mechanisms underlying observed associations between neighborhood factors and individual health outcomes.

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