Published in final edited form as:

Health Place. 2013 November ; 24: . doi:10.1016/j.healthplace.2013.09.005.

Do observed or perceived characteristics of the neighborhood environment mediate associations between neighborhood poverty and cumulative biological risk?

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Abstract

Objective—To examine contributions of observed and perceived neighborhood characteristics in explaining associations between neighborhood poverty and cumulative biological risk (CBR) in an urban community.

Methods—Multilevel regression analyses were conducted using cross-sectional data from a probability sample survey (n=919), and observational and census data. *Dependent variable*: CBR. *Independent variables*: Neighborhood disorder, deterioration and characteristics; perceived neighborhood social environment, physical environment, and neighborhood environment. *Covariates*: Neighborhood and individual demographics, health-related behaviors.

Results—Observed and perceived indicators of neighborhood conditions were significantly associated with CBR, after accounting for both neighborhood and individual level socioeconomic

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Contributors Statement:

A. Schulz conceptualized and oversaw all aspects of the study; G. Mentz conducted the analyses, contributed to the interpretation, and assisted with drafting the manuscript; L. Lachance and J. Johnson provided consultation regarding analyses and interpretation of findings, and edited the article; C. Stokes assisted with the acquisition of data, contributed to the interpretation and review of the article; S. Zenk provided conceptual guidance, assisted with the collection of data, and edited the article. R. Mandell contributed to the review of the literature, interpretation of findings, and contributed to drafting the manuscript. All authors approved the submitted version of the manuscript.

Human Participant Protection:

The University of Michigan Institutional Review Board for Protection of Human Subjects approved the study in January 2001 and survey participants provided informed consent. Data collection was conducted in accordance with ethical standards for the conduct of research with human subjects, and with the Helsinki Declaration of 1975, as revised in 2000.

indicators. Observed and perceived neighborhood environmental conditions mediated associations between neighborhood poverty and CBR.

Conclusions—Findings were consistent with the hypothesis that neighborhood conditions associated with economic divestment mediate associations between neighborhood poverty and CBR.

Keywords

allostatic load; neighborhood environment; urban health inequalities; neighborhood poverty

Introduction

The substantial literature demonstrating relationships between neighborhood socioeconomic status (SES) and a wide range of health outcomes (Borell, et al., 2004; Cox, et al., 2007; Diez-Roux & Mair, 2010; Diez-Roux, et al., 2001; Mair, et al., 2008; Pickett & Pearl, 2001; Winkleby, et al., 2007) has led to the suggestion that these effects occur through a broad range of behavioral and physiological mechanisms (House, 2002; Link, et al., 2008; Phelan, et al., 2010). Potential pathways linking neighborhood SES to health include effects of local environmental conditions (e.g., access to food, safe places for physical activity) on health-related behaviors (e.g., dietary practices, physical activity) (Izumi, et al., 2011; Laraia, et al., 2004; Larson & Story, 2009; Moreland, et al., 2002; Zenk, et al., 2009, 2013) as well as biological indicators of health (e.g., percent body fat, systolic blood pressure) (Dengel, et al., 2009; Li et al., 2009). Neighborhood SES may also be associated with environmental conditions that are conducive to stress, and thus are linked to health outcomes through physiologic responses to stress (Lazarus & Folkman, 1984; Selye, 1982). A small body of recent research has examined the hypothesis that neighborhood socioeconomic conditions may “get under the skin” (Bird, et al., 2010), affecting health through wear and tear on the body associated with cumulative exposure to stressful life conditions. Reported findings are generally consistent with this hypothesis (King, et al., 2011; Merkin, et al., 2009; Stimpson, et al., 2007), and one study reported evidence that associations between neighborhood poverty and allostatic load (as an indicator of cumulative biological risk) were mediated by self-reported stress (Schulz, et al., 2012). To date, no studies of which we are aware have examined the role of observed neighborhood environmental conditions as pathways linking neighborhood SES and cumulative biological indicators of risk. Our aim in this paper is to begin to fill this gap in the literature by explicitly examining the plausibility of observed as well as perceived neighborhood conditions as mediators of associations between neighborhood poverty and indicators of cumulative biological risk (CBR).

Literature Review

Conceptual model

This analysis builds on conceptual models and empirical research that suggest that associations between SES and health involve multiple dynamic processes and pathways (Figure 1) (House, 2002; Link, et al., 2008; Phelan, et al., 2010; Schulz, et al., 2005). Among these pathways are environmental conditions that may be considered conducive to stress if they are perceived as harmful, threatening or bothersome (Lazarus & Folkman, 1984) or that place a demand on individuals that results in physiological adaptational responses (Selye, 1982). Chronic exposure to such conditions has been linked to effects on the hypothalamic-pituitary-adrenal cortex, sympathetic nervous system and immune system (Heslop, et al., 2002; Kawachi & Berkman, 2003; Klinenberg, 2002; Maantay, 2001; McEwen, 2008; Sampson & Raudenbush, 2004), with subsequent implications for peripheral biology (Gunnar & Quevedo, 2007; Gunnar & Vazquez, 2006; Katz & Kahn,

1978; McEwen, 2003, 2008; Seeman, et al., 2010). These physiologic responses to stressful life conditions have been associated with enduring health outcomes, including cardiovascular disease, stroke, loss of physical and cognitive functioning, and all-cause mortality (McEwen & Gianaros, 2010; Seeman, et al., 1994, 2010).

Specifically, the conceptual model shown in Figure 1 suggests that associations between neighborhood SES and CBR (path A) may be explained, in part, through observed physical and social characteristics of neighborhood environments (path B), which may, in turn, be associated with physiological adaptational responses ultimately expressed as biological indicators of risk (path C). Associations between neighborhood SES and biological indicators of risk may also be mediated through residents' perceptions or self-reports of neighborhood characteristics (path D-E). It is also plausible that perceived neighborhood characteristics may mediate associations between observed characteristics and CBR (path F-E). Finally, the conceptual model recognizes behavioral pathways linking neighborhood SES with biological risk (paths G-H). Below, we review the literature associated with each of these potential pathways.

Socioeconomic Gradients and Cumulative Biological Risk

There has been growing interest in the construction of measures that capture the “cumulative physiologic toll on multiple major biological systems over the lifecourse” (Seeman, et al., 2010, p. 223) that result from exposure to stressful life circumstances. Several studies reported an inverse gradient between individual or household indicators of SES and one such measure, allostatic load (Seeman, et al., 2004, 2008, 2010; Singer & Ryff, 1999). A small number of recent studies reported similar patterns with neighborhood SES. Merkin and colleagues (2009), drawing on data from a nationally representative sample, reported a significant inverse relationship between neighborhood SES and allostatic load among non-Hispanic Blacks (NHB), with similar but not significant trends among non-Hispanic Whites (NHW) and Mexican Americans. Stimpson and colleagues (2007), using data from NHANES III, found a positive association between a composite measure of neighborhood deprivation and serum triglyceride levels, an indicator of biological risk and a component of allostatic load. Similarly, Schulz and colleagues (2012) reported a significant positive relationship between neighborhood poverty rate and allostatic load in an urban sample, with no differences in these associations among NHB, NHW, or Hispanics. King and colleagues (2011) examined associations between neighborhood affluence and disadvantage and cumulative biological risk (CBR) in a representative sample from Chicago, Illinois. They reported an inverse association between neighborhood affluence and CBR, but no significant association between neighborhood disadvantage and CBR. The authors postulated that their measure of affluence may tap important sources of variation among neighborhoods such as more features of the built environment that enable good nutrition and increased physical activity (e.g., food stores, well-maintained buildings, parks and streets). Together, this literature is generally consistent with the idea that there are associations between neighborhood socioeconomic characteristics and indicators of cumulative biological risk.

Neighborhood characteristics and cumulative biological risk

Neighborhood conditions associated with neighborhood SES may be conducive to stress, activating physiologic responses that, over time, influence peripheral biologic systems (King, et al., 2011). Associations between neighborhood poverty and indicators of CBR have been found to be attenuated with the inclusion of psychosocial measures such as individuals' perceptions of their local environment, after accounting for individual demographic characteristics and health-related behaviors (Schulz, et al., 2012). Reported associations between observed indicators of neighborhood environments and residents' perceptions or self-reports of those environments vary (Sampson & Raudenbush, 2004;

Caughy, et al., 2001; Lackey & Kaczynski, 2009; Lin & Moudon, 2010; McGinn, et al., 2007; Oh, et al., 2010), and there is some evidence to suggest that perceptions of neighborhood environments are shaped by both observed characteristics (e.g., neighborhood poverty, racial composition, observed neighborhood conditions) and subjective interpretations of those characteristics (Krysan, 2002a, 200b; Krysan & Farley, 2002; Sampson & Raudenbush, 2004, Schulz, et al., 2008). Wen and colleagues (2006) suggested that observed neighborhood characteristics and perceptions of the neighborhood “are linked yet distinct constructs, both of which are on the pathway from place to health with neighborhood perceptions seemingly more proximate to health.” Weden and colleagues (2008) proposed that subjective indicators of neighborhood environments may mediate associations between neighborhood demographic characteristics (e.g., percent below poverty, racial composition) and health outcomes. No studies of which we are aware have examined the independent and joint contributions of observed and perceived neighborhood environments to understanding associations between neighborhood poverty and CBR.

Research questions

Building on the conceptual model and empirical literature described above, we examined two main research questions. First, do observed and perceived indicators of neighborhood environmental characteristics mediate associations between neighborhood poverty and CBR? Second, we examined a second plausible mediation pathway, whether self-reported or perceived neighborhood characteristics mediated associations between observed neighborhood characteristics and CBR. To address the first research question, we tested the following hypotheses: 1) Observed and perceived indicators of neighborhood characteristics are independently associated with CBR (Figure 1, paths C, E); and 2) Associations between neighborhood poverty and CBR (path A) are mediated by observational (path B-C) and/or perceptual (path D-E) indicators of neighborhood environment characteristics. To assess the second research question, we tested a third hypothesis, that perceived neighborhood characteristics mediate associations between observed neighborhood characteristics and CBR (path F-E).

Methods

Sample

Data for this study were drawn from three sources: individual level data from the Healthy Environments Partnership (HEP) 2002 Community Survey; observational data from the HEP Neighborhood Observational Checklist (Zenk, et al., 2005, 2007) and 2000 Census data. The HEP Community Survey and Neighborhood Observational Checklist data were collected as part of a community-based participatory research study involving academic, health care, and community-based organizations in Detroit, Michigan (Schulz, et al., 2005). Procedures followed in collecting survey data were in accordance with ethical standards for treatment of human subjects and with the Helsinki Declaration of 1975, as revised in 2000, and all survey participants gave written informed consent prior to their inclusion in the study. The University of Michigan Institutional Review Board for Protection of Human Subjects approved the HEP study in January 2001.

The HEP Community Survey was conducted with a stratified two-stage probability sample of occupied housing units, designed for 1,000 completed interviews with adults age >25 years across three areas of Detroit, allowing for comparisons of residents of similar demographics across geographic areas of the city (Schulz, et al., 2005). The survey sample was designed to achieve adequate variation in SES within each of the three predominant racial/ethnic groups in Detroit: African-American, Latino, and White. Households were sampled within each of 6 strata defined by racial composition and poverty level at the block

level, as follows: <40% poverty and <40% African American; <40% poverty and 40 and 80% African American; <40% poverty and 80% African American; >40% poverty and 40 African American; >40% poverty and 40 and 80% African American; and >40% and >80% African American. At each household unit, a listing was completed of eligible residents and one eligible adult was selected randomly for inclusion in the study. Of the 2,517 housing units in the initial sample, 1,297 were invalid (e.g., vacant), unable to be screened after repeated attempts (no one contacted after 12+ attempts, refused screener), or contained no eligible respondent (e.g., no one 25 or more years of age). Of the 1,220 households in which an eligible respondent was identified, interviewers were unable to contact the identified respondent after repeated attempts in 193 (16%). Of the 1,027 eligible respondents contacted, 105 (10%) refused to be interviewed, and paper and pencil interviews were completed with 922 respondents (90%), three of whom were subsequently determined to be ineligible. Assuming an 80% eligibility rate for noncontacted households, an estimated 1,663 housing units within the sample frame had an eligible respondent. The final sample consisted of 919 face-to-face interviews: interviews were completed with 75% of households in which an eligible respondent was identified (919 of 1,220), 55% of households with a known or potential respondent (919 of 1,663) and 90% of households in which an eligible respondent was contacted (919 of 1,027) (Schulz, et al., 2005). Sample weights were constructed to adjust for differential selection and response rates, allowing us to estimate population effects from the HEP sample. The 919 respondents were nested within 146 blocks and 69 census block groups.

The following clinical and anthropometric measures were included in the HEP survey: resting blood pressure, measured three times by a team of trained and certified phlebotomists using a portable cuff device (Omron model HEM 711AC) that passed Association for the Advancement of Medical Instrumentation standards (Yarows & Brook, 2000); waist circumference measured in centimeters; height measured in centimeters; and weight in pounds using a calibrated scale. In addition, glucose, albumin, total cholesterol, and high and low density lipid levels were derived from fasting blood samples from survey participants.

Observational data used in this analysis were derived from the HEP Neighborhood Observational Checklist (NOC) designed to measure observable neighborhood characteristics that affect (or reflect) neighborhood social relations, services, material resources, stress, and behaviors (Zenk et al., 2007). Consistent with methods employed in other studies (King, et al., 2011; Sampson & Raudenbush, 2004), in 2002, observers rated characteristics of each city block in the study area at one of three spatial scales (block face, street, or the entire block) using uniform operational definitions. Inter-rater reliability scores for observers as a group (Cronbach's alpha, percent agreement) and for each individual observer compared against a designated "gold standard" observer (percent agreement, Cohen's kappa) were calculated to assure adequate inter-rater reliability of the observational data. Measures used in the analyses presented here included items with acceptable inter-rater reliability scores (Kendall's Tau (τ) > 0.80; percent agreement > 80%; Cohen's kappa > 0.60). A more complete description of the NOC checklist can be found in Zenk and colleagues (2005), with detailed descriptions of data collection procedures, interviewer training, and inter-rater reliability scores found in Zenk and colleagues (2007) and Gravelle and colleagues (2006).

Measures

At the individual level, the dependent variable, cumulative biological stress (CBR), was adapted from similar measures of cumulative physiological toll on biological systems (Seeman, et al., 2010, King, et al., 2011). It included indicators of cardiovascular and metabolic dimensions of biological risk, as follows: systolic and diastolic blood pressure

derived by taking the mean of the second and third measured levels; waist circumference; glucose, HDL, LDL, total cholesterol and triglycerides from fasting blood draws; and self-reported use of medication for hypertension, diabetes, and hypercholesterolemia. An index of CBR was calculated as the sum of the following indicators: systolic blood pressure ≥ 140 ; diastolic blood pressure ≥ 90 ; waist circumference ≥ 102 cm [males] or ≥ 88 cm [females]; glucose ≥ 110 ; triglycerides ≥ 150 ; total cholesterol > 240 or total cholesterol ≤ 240 and LDL ≥ 130 ; and HDL (< 40 for men or < 50 for women). Building on previous studies (Geronimus, et al., 2006), the index included points for individuals whose systolic and diastolic blood pressure levels were below the high blood pressure cut points and who were taking hypertension medication; those with glucose levels below the high risk cut point who were taking medication, and those whose lipid levels were within the normal range and who were taking medication for dyslipidemia. Indicators of inflammatory processes (e.g., C-reactive protein), autonomic nervous system (e.g., epinephrine, norepinephrine), and hypothalamic-pituitary-adrenal axes (e.g., cortisol) commonly included in measures of allostatic load (Juster, et al., 2009; Seeman, et al., 2010) were not available in the dataset used for this study, and therefore not included. The mean for this index was 2.63 (S.E. = 0.07, min=0, max=7).

Individual level independent variables included three measures of self-reported neighborhood environment characteristics. *Perceived neighborhood social environment (NSE)* was a mean scale including six items assessing the frequency with which respondents indicated that aspects of the social environment such as gang activity, shootings, or theft were a problem in their neighborhood (response categories ranged from 1=never to 5=always), (Sampson, et al., 1997; Schulz, et al., 2008) (Cronbach's $\alpha = 0.84$). *Perceived neighborhood physical environment (NPE)* was a mean scale including seven items assessing agreement with statements about the physical environment such as, "houses in my neighborhood are generally well maintained" (reverse coded) and "there is air pollution like diesel from trucks or pollution from factories or incinerators in my neighborhood" (response categories ranged from 1=strongly disagree to 5=strongly agree) (Israel, et al., 2006; Schulz, et al., 2008) (Cronbach's $\alpha = 0.70$). *Perceived neighborhood environment* was a mean scale of 13 items that encompassed both the characteristics of the social and the physical environment included in the two previous scales, (Cronbach's $\alpha = 0.83$).

Individual level control variables included: age (years); sex (1=female); self-reported race and ethnicity categorized as non-Hispanic Black (NHB), non-Hispanic White (NHW), and Latino; education, (1= > 12 years); and a dichotomous indicator of household poverty, calculated using the poverty income ratio (PIR) (1= $<$ poverty). The PIR was independently calculated using 2000 census estimates for U.S. poverty thresholds and 2002 survey data available for total household income and the total number of people and children in the household. Individuals were classified as "in poverty" when total household income was below the poverty threshold (US Census Bureau, 2011).

Four indicators of health-related behaviors were included as controls. *Metabolic minutes* was a continuous measure of physical activity using methods described in the 2005 International Physical Activity Questionnaire (IPAQ Research Committee, 2005). *Dietary practices* were assessed using the Healthy Eating Index (HEI), a composite measure of five food groups and four nutrients based on daily servings that is widely used as an overall indicator of dietary quality (Kennedy, et al., 1995). The HEI was used in the analysis as a continuous measure. *Smoking* was assessed through a series of items asking about current and former tobacco use, such as, "have you ever smoked cigarettes regularly?", "do you currently smoke cigarettes?" (Frazier, et al., 1992; Gentry, et al., 1985) with parallel questions about smoking cigars and tobacco pipes. Smoking was coded as a categorical

variable (Current smoker =0; Former =1, Never smoked = 2). *Alcohol* use was assessed as self-reported frequency and amount of alcohol use (Block, et al., 1994). Initially constructed as a continuous variable (number of drinks per month), due to its skewed distribution (e.g., 50% of the sample reported no alcohol consumption per month), alcohol use was dichotomized in these analyses with 1=any, 0=none.

At the neighborhood level, we used three measures of observed neighborhood characteristics. Each was calculated at the block level, reflecting the mean of the proportion of block faces (or streets) within each “rook” neighborhood that had the attribute. “Rook” neighborhoods are the focal block in which the survey participant lived and adjacent blocks sharing a common border with the focal block (so-called “rook” neighbors). *Neighborhood disorder* (henceforth *disorder*) reflects visible physical cues of lack of order and social control (Ross & Mirowsky, 1999; Sampson & Raudenbush, 2004; Skogan, 1990). *Disorder* was measured based on the presence of each of the following indicators: graffiti; empty beer bottles; vacant lots in poor condition; abandoned/undriveable cars; piles of garbage or dumped material; moderate to heavy strewn garbage; most residential grounds in poor condition; and most commercial/industrial/institutional grounds in poor condition (Cronbach’s alpha = 0.65).

Neighborhood physical deterioration (henceforth, *deterioration*) builds on the work of Ross and Mirowsky (1999) and Sampson and Raudenbush (2004) and represents physical indicators of neighborhood disinvestment that are beyond the control of individual residents. It includes presence of each of the following indicators: vacant lots; vacant non-residential buildings; vacant residential buildings; abandoned/burned-out residential building; and the condition of most residential and commercial or industrial properties (Cronbach’s alpha= 0.65).

Finally *neighborhood characteristics* was a composite scale incorporating observed indicators of the neighborhood physical (deterioration) and social (disorder) environments described above (Cronbach’s alpha = 0.81).

At the census block group level (level 3), *neighborhood poverty* was the percent of households below the poverty line, derived from 2000 Census data. This measure was constructed in quintiles, with 1 <21.9% ; 2= 21.9<28.3%;3= 28.3<32.5% 4= 32.5<42.0%; and 5 42.0%. (ref). Neighborhood level control variables included percent non-Hispanic Black and percent Latino at the block group level.

Data Analysis

Over 94% of data was completed, with the largest proportion of missing data regarding household income. Although the proportion of missing data was low, in preparation for analysis, we used multiple imputation procedures derived from Bayesian models (Barnard et al., 2001) to impute missing values using the %IMPUTE routine (Imputation and Variance Estimation software, Ann Arbor MI) in SAS 9.1 (SAS Institute Inc, Cary NC, 2002–2003). Multiple imputation allowed us to use the complete case approach and thus obtain robust standard error estimates (Rubin, 1996; Schafer, 1997). Weights were created to ensure appropriate representation of racial and ethnic groups across SES in the sample, and were applied to adjust for probabilities of selection within strata, non-response bias, and to match the sample to Census 2000 population distributions of the study communities as well (Schulz, et al., 2005).

Three level hierarchical regression models for a continuous outcome were estimated using HLM 7.0 (Scientific Software International, Lincolnwood, IL, 2006), consistent with the structure of the data. Level 1 was the 919 survey respondents (individual level data); level 2

was the 146 blocks (observed neighborhood characteristic data); and level 3 was the 69 census block groups in which respondents resided (Census data). To test associations of neighborhood poverty and CBR, we regressed CBR on percent poverty. Next, to test associations between the observed neighborhood characteristics (*disorder, deterioration, neighborhood characteristics*) and CBR, we regressed CBR on each indicator in separate models, controlling for neighborhood poverty and individual level covariates. We did the same for the perceptual measures of neighborhood environments, entering each in separate models. Finally, we examined models that included both the observed and perceived neighborhood characteristics to assess their joint effects. Specifically, models were run with observed and perceived indicators of the social environment (*disorder, NSE*), physical environment (*deterioration, NPE*), and combined social and physical environment characteristics (*neighborhood characteristics, perceived neighborhood environment*) (see Figure 2). All models controlled for neighborhood and individual level covariates. Finally, we tested for mediation effects. Following recommendations by Zhang and colleagues (2009) for tests of mediation effects when using multilevel data, perceived neighborhood social environment was group mean centered in order to decompose between-group from within-group variation in these models. We used test statistics proposed by Freedman and Schatzkin (1992), using the difference in the point estimates in models with and without the mediator, standardized by the joint variance. It can be written as:

$$t_{N-2} = \frac{a - a'}{\sqrt{\sigma_c^2 + \sigma_{c'}^2 - 2\sigma_c\sigma_{c'}\sqrt{1 - \rho_{XM}}}}$$

where ρ_{XM} refers to the correlation between the independent variable X and the mediator M. In addition, models were run testing for effect modification by age, gender and household income

Results

Table 1 shows descriptive statistics for the individual, block and block group neighborhood-level variables. About half of participants were female; about one-fifth were Latino and NHW, respectively, with the majority NHB. At the block group level, on average about one-third of households had incomes below the federal poverty level, and about two-thirds of households were NHB.

Table 2 shows results from multilevel regression analyses testing relationships between neighborhood poverty, observed *neighborhood characteristics* and *perceived neighborhood environment*, and CBR. Model 1 shows an inverse association between neighborhood poverty and CBR, with those residing in neighborhoods with the highest levels of poverty most likely to have higher CBR. Model 2 adds the *neighborhood characteristics* scale, which was significantly associated with CBR ($\beta = -2.136$, $p = 0.006$). Each of the two component scales, *disorder* ($\beta = -1.541$, $p = 0.017$), and *deterioration* ($\beta = -1.972$, $p = 0.021$) were also significantly associated with CBR (results not shown).

Model 3 shows perceived *neighborhood environment* was significantly associated with CBR ($\beta = -0.257$, $p = 0.002$), as were each of the two component scales, *NSE* ($\beta = -0.182$, $p = 0.006$) and *NPE* ($\beta = -0.202$, $p = 0.003$) (results not shown). Model 4 includes both observed and perceived indicators of the neighborhood environment. Observed *neighborhood characteristics* ($\beta = -1.906$, $p = 0.018$), and perceived *neighborhood environment* ($\beta = -0.253$, $p = 0.003$) were each significantly associated with CBR. Results were comparable for models including the observed and perceived social environment subscales, with both *disorder* and *NSE* retaining statistical significance (results not shown). Patterns were similar for models including the

disorder and *NSE* subscales, and for those including *deterioration* and *NPE*, although *deterioration* was no longer statistically significant in models that included *NPE* (results not shown).

Finally, results from the Freedman and Shatzkin (1992) tests for mediation shown in Table 3 suggest that associations between neighborhood poverty and CBR were mediated by observed and perceived indicators of neighborhood environmental characteristics included in these models. *Disorder*, *deterioration*, and *neighborhood characteristics* each show significant mediation effects ($p < 0.001$). Similarly, each of the three indicators of perceived neighborhood characteristics, *NSE*, *NPE*, and perceived *neighborhood environment* significantly mediate the association between neighborhood poverty and CBR ($p < 0.001$). Not surprisingly, mediation effects were also significant for models including paired observed and perceived measures of the neighborhood environment. Finally, results from tests of the hypothesis that perceived measures of the neighborhood environment mediate the association between the observed measures of the neighborhood environment and CBR do not allow us to reject the null hypothesis of no mediation effect.

Discussion

There were three main findings from the analyses reported here. First, observed and perceived indicators of the neighborhood environment were associated with CBR, after accounting for neighborhood poverty, racial and ethnic composition of neighborhoods, and individual level demographic characteristics and behavior indicators. We found no evidence that these associations were modified by age, gender or household income. Second, formal tests for mediation support the hypothesis that observed and perceived measures of the neighborhood environment significantly mediate associations between neighborhood poverty and CBR. We were unable to reject the null hypothesis that perceptions of the neighborhood environment do not mediate associations between observed indicators of the neighborhood environment and CBR. We discuss each of these results in greater detail in the following paragraphs.

Are observed and perceived neighborhood characteristics associated with CBR?

Results reported here are consistent with the hypothesis that neighborhood conditions associated with neighborhood poverty are associated with CBR. Observed and perceived measures that combine social and physical characteristics of neighborhood environments (*neighborhood characteristics*, *perceived neighborhood environment*), included together in models, showed independent associations with CBR. Patterns were similar for models that tested subscales capturing social characteristics of the neighborhood (*disorder*, *NSE*). Associations between observed neighborhood physical *deterioration* and CBR were attenuated with the inclusion of perceived *NPE*. These patterns were apparent after accounting for neighborhood poverty, racial and ethnic composition, individual level demographic characteristics, and health-related behaviors.

Do observed or perceived neighborhood characteristics mediate associations between neighborhood poverty and CBR?

Results reported here are consistent with the hypothesis that observed and perceived indicators of the social and physical characteristics of neighborhoods mediate associations between neighborhood poverty and CBR. They are consistent with findings reported elsewhere suggesting associations between neighborhood SES and neighborhood environmental conditions (i.e., graffiti, litter, poorly maintained resident grounds, resident buildings and public spaces, vacant/burned residences and commercial establishments) (Caughy, et al., 2001; Sampson & Raudenbush, 2009; Odgers, et al., 2012). They extend

those previous findings to suggest that both the observed conditions themselves and residents' self-reports or perceptions of the neighborhood environment contribute to associations between neighborhood poverty and the health of residents.

These findings are consistent with stress process frameworks that hypothesize that stressful life conditions (e.g., *disorder*, *deterioration*) associated with neighborhood poverty can set in motion a set of physiological responses as the body attempts to maintain equilibrium. Under conditions of chronic stress, these responses accumulate to contribute to increased health risk. These findings are consistent with findings reported elsewhere indicating that residents of neighborhoods with lower SES experience greater health risk (Diez-Roux & Mair, 2010; Merkin, et al., 2009; Schulz, et al., 2012; Stimpson, et al., 2007). They extend the literature linking neighborhood characteristics associated with neighborhood poverty with physiologic responses to stress, and suggest that these associations are apparent after accounting for their potential effects on health-related behaviors as well as the demographic characteristics of residents. Thus, while a number of studies have suggested that neighborhood characteristics associated with poverty may be associated with health through their associations with health-related behaviors, the findings presented here suggest that those effects extend beyond health-related behaviors. Specifically, these findings are consistent with the hypothesis that neighborhood poverty may be associated with increased health risk through associations with observed and perceived neighborhood characteristics which are, in turn, associated with indicators of physiological response to stress. These pathways are robust after accounting for several behavioral indicators, including physical activity, dietary intakes, and smoking. By demonstrating independent associations between neighborhood characteristics and CBR above and beyond the effects of health-related behaviors, we contribute to a body of evidence that suggests that neighborhood characteristics may "get under the skin" through pathways that operate above and beyond the influence of neighborhoods on health-related behaviors.

Do perceptions of neighborhood environments mediate associations between observed characteristics and CBR?

Results reported here do not allow us to reject the null hypothesis of no mediation effect of perceived neighborhood characteristics on the association between observed characteristics and CBR. These results are consistent with evidence that associations between observed *neighborhood characteristics* and CBR, and *disorder* and CBR are not attenuated with the inclusion of *neighborhood environment* and *NSE*, respectively. Despite the attenuation of associations between *deterioration* and CBR by *NPE*, the mediation test does not meet criteria for statistical significance. Together, these results lend support to observations made by a number of other scholars in this area, noting that associations between observed indicators of neighborhood environments and residents' perceptions or self-reports of those environments are complex (Sampson & Raudenbush, 2004; Caughy, et al., 2001; Lin & Moudon, 2010; Lackey & Kaczynski, 2009; McGinn, et al., 2007; Oh, et al., 2010). They are consistent with the idea that observed indicators of neighborhood environments may be associated with health outcomes independent from participants' perceptions of neighborhood characteristics. They offer additional support for observations made by scholars in this area that subjective reports or perceptions of neighborhood contexts, while likely linked to observed characteristics are also shaped by subjective interpretations shaped by life experiences and social locations (Krysan, 2002a, 2002b; Krysan & Farley, 2002; Sampson & Raudenbush, 2004; Schulz, et al., 2008; Weden, et al., 2008; Wen, et al., 2006). Our findings suggest that both may have important implications for health.

Limitations and implications for future research

There are a number of limitations to the findings reported here. The use of cross-sectional data limits our ability to test the order of associations between variables, or to examine exposures over the lifecourse. This is a particular challenge for analyses examining CBR and similar health outcomes that may emerge over time as a result of cumulative or chronic exposures to stressful life conditions. In analyses reported elsewhere (Schulz, et al., 2012), there was no relationship between length of residence in a neighborhood and allostatic load, and no evidence that relationships between neighborhood poverty and allostatic load were modified by length of residence in the neighborhood. While there is no a priori reason to suggest that individuals with heightened indicators of CBR would congregate in poor neighborhoods, or in neighborhoods with high levels of disorder and deterioration, the possibility remains that associations between neighborhood characteristics and CBR result from compositional, rather than contextual effects (Oates, 2004). Despite these limitations, this manuscript is among the first to test associations between observed indicators of the neighborhood environment and CBR, and to assess the extent to which these associations may be mediated through or explained by perceptions of neighborhood environments. Future research using longitudinal data will be helpful in allowing researchers to make more rigorous inferences about the causal order implied in the conceptual model presented here, establishing the order of associations, and examining implications of duration of exposure to neighborhood poverty, neighborhood conditions (e.g., neighborhood deterioration), and associated psychosocial stress.

Second, given our relatively modest sample size, analyses with larger samples that enable specific parameter estimates across various contexts (e.g., varying degrees of physical disorder) would further our understanding of relationships between observed neighborhood characteristics, and CBR. Analyses that examine mediating pathways across contexts (e.g., rural, regional) would also contribute to an understanding of the extent to which mediating pathways described here may vary across contexts.

Third, there are a number of personal, interpersonal or household characteristics that may influence CBR directly (Theall, et al., 2012), modify associations between neighborhood disorder, deterioration and CBR, or modify associations between perceptions of the neighborhood environment and CBR. We tested, and did not find evidence to support, modification of results reported here by age, sex, or household income. The absence of variations in associations between neighborhood poverty and CBR by race and ethnicity using this sample has been reported previously (Schulz, et al. 2012). These results are consistent with others who have reported no evidence of variation by sex (Bird, et al. 2010). Reports of variations by race and ethnicity differ, with some finding no evidence (Bird, et al. 2010; Schulz, et al. 2012), while others report stronger associations among African Americans compared to whites and Mexican Americans in national samples (Merkin, et al. 2009). As previously discussed in the literature, these differences may be attributable to differences in the distribution of poverty by race and ethnicity across different samples (Merkin, et al., 2009; Schulz, et al. 2012). A number of other individual characteristics may be relevant, such as availability of social support, relationships with other residents of the neighborhood, or length of residence in the neighborhood. The extent to which such characteristics may exacerbate or protect against the adverse associations between neighborhood disorder and deterioration and physiological wear and tear reported here is an important area for further examination.

A fourth limitation has to do with the measure of CBR used in the analyses reported here. CBR is a more general indicator of biological health than allostatic load, though they tap many of the same body systems and include many of the same indicators. There is no universally accepted means of measuring CBR (or allostatic load); it has been suggested that

studies capture indicators across as many regulatory systems as possible (Seeman, 2010). The present study included biomarkers for cardiovascular and metabolic function (Juster, 2009). Biomarkers for immune and neuroendocrine function were not available in this dataset, and therefore were not included. While the measure of CBR used here did not capture information on the most comprehensive set of physiological parameters across multiple regulatory systems, findings are consistent with those previously reported using more comprehensive measures. Specifically, Bird and colleagues (2010) reported a positive association between neighborhood socioeconomic status and a measure of allostatic load that encompassed cardiovascular, metabolic and inflammatory dimensions. King and colleagues (2011), using a similar measure, reported inverse associations with neighborhood affluence, and a positive but non-significant association with neighborhood disadvantage. Merkin and colleagues (2009) reported associations between neighborhood socioeconomic status and a measure of allostatic load encompassing similar dimensions. The more circumscribed measure of CBR used in the analyses reported here may contribute to an underestimate of associations between indicators of neighborhood characteristics associated with disadvantage and risk (Alley, et al. 2006; Bird, et al. 2010).

Finally, while observed and perceived measures of the neighborhood environment assessed here were constructed to tap comparable domains (e.g., social environment, physical environment), and included comparable items, the measures were not mirror images. The finding that the observed and perceived indicators of the social environment and the combined physical and social environments were independently associated with CBR, and that the perceptual indicators did not mediate the observed measures, may reflect these differences in specific indicators. Future studies may benefit from using observational and perceptual measures whose items more closely match.

Concluding comments

Despite these limitations, the findings presented contribute to the broad literature suggesting that neighborhood conditions associated with concentrations of poverty are significantly associated with increased biological risk. They extend previous findings by incorporating both observed and perceived indicators of neighborhood characteristics. The findings reported here establish associations between observed indicators of neighborhood environmental conditions conducive to stress and CBR. Further, they suggest that these associations are evident above and beyond the effects of health-related behaviors. Perceptions of the neighborhood environment are significantly associated with CBR, after accounting for observed physical and social characteristics of the environment and controls. Furthermore, we present evidence that both observed and perceived indicators of the neighborhood environment significantly mediate associations between neighborhood poverty and CBR.

These results join a growing, although still relatively young, body of literature linking neighborhood, as well as individual, indicators of disadvantage to biological indicators of risk of future morbidity and mortality (Bird, et al., 2010; Merkin, et al., 2009; Seeman, et al., 2010). They are consistent with a larger body of literature linking neighborhood poverty with long-term health effects through pathways that are not wholly captured by household or individual socioeconomic indicators (Diez-Roux & Mair, 2010), or through effects on health-related behaviors. They suggest that interventions that focus solely on health-related behaviors pathways may be insufficient to eliminate socioeconomic differences in health outcomes (Daniel, et al., 2008). Efforts to eliminate pervasive health inequities must attend to underlying economic, political and social processes that perpetuate the concentration of poverty within urban neighborhoods. Policies that increase economic opportunities within urban neighborhoods with high concentrations of poverty, and alleviate stressful environmental conditions, are critical aspects of efforts to promote health equity.

Acknowledgments

The Healthy Environments Partnership (HEP) (www.hepdetroit.org) is a community-based participatory research partnership affiliated with the Detroit Community-Academic Urban Research Center (www.detroiturc.org). We thank the members of the HEP Steering Committee for their contributions to the work presented here, including representatives from Brightmoor Community Center, Detroit Department of Health and Wellness Promotion, Detroit Hispanic Development Corporation, Friends of Parkside, Henry Ford Health System, Warren Conner Development Coalition, and University of Michigan School of Public Health. The study and analysis were supported by the National Institute of Environmental Health Sciences (NIEHS) (R01ES10936, R01ES014234) and National Institute of Minority Health and Health Disparities (NIMHD) (P60 MD002249). The results presented here are solely the responsibility of the authors and do not necessarily represent the views of NIEHS. We thank Sue Andersen for her assistance in the preparation of this manuscript.

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Figure 1.

Conceptual framework for associations between neighborhood poverty, neighborhood disorder and physical deterioration, neighborhood environmental stress and cumulative biological risk*

*Pathways and boxes indicated in grey are not tested in the models presented here. They are included as controls to assess the sensitivity of the models.

Figure 2.
Observed and perceived measures of neighborhood environment.

Table 1

Weighted descriptive statistics for individual- and neighborhood-level variables (n=919)

	%	Mean	S.E.
Individual variables			
Age, years (mean)		46.3	0.84
Female (%)	52.3		--
Race/Ethnicity (%)			
African-American	56.8		--
Latino	22.2		--
White	18.8		--
Other	2.3		--
Education (%)			
Less than high school	36.9		--
High school	29.0		
More than high school	32.8.1		--
Other	2.3		
Household income above poverty (%)	37.8		
Perceived neighborhood social environment (NSE)		2.7	0.01
Perceived neighborhood physical environment (NPE)		3.1	0.05
Perceived neighborhood environment (combo)		2.9	0.06
Cumulative biological risk (CBR)		2.6	0.07
Smoking (%)			
Current	37.1		
Former	22.4		
Never	40.4		
Healthy Eating Index		64.1	0.43
Physical activity (MET minutes)		3698.7	152.10
Alcohol use (%)	47.3		
Neighborhood variables (census block)			
Neighborhood disorder (disorder)		36.7	0.87
Neighborhood deterioration (deterioration)		18.9	0.67
Neighborhood environment		29.0	0.07
Neighborhood variables (census block group)			
Percent below poverty		32.5	1.43
Poverty in quintiles			
Q1 (<20%)		18.8	
Q2 (20-<40 th)		20.3	
Q3 (40-<60 th)		10.1	
Q4 (60-<80 th)		29.0	
Q5 (80 th , ref)		21.7	
Percent African American		67.5	4.27
Percent Latino		15.2	3.22

Table 2

Cumulative biological risk (CBR), regressed on neighborhood percent poverty, observed and perceived neighborhood characteristics, controlling for individual and neighborhood level covariates^a

	Model 1			Model 2			Model 3			Model 4		
	Estimate	S.E.	p-value	Estimate	S.E.	p-value	Estimate	S.E.	p-value	Estimate	S.E.	p-value
Intercept	2.568	0.203	0.000	2.555	0.203	0.000	2.585	0.199	0.000	2.574	0.200	0.000
Level 3 (Block Group)												
Non-Hispanic Black (%)	0.006	0.003	0.079	-0.001	0.004	0.827	0.004	0.003	0.240	-0.002	0.004	0.648
Latino (%)	0.006	0.004	0.161	0.000	0.004	0.980	0.004	0.004	0.335	-0.001	0.005	0.867
Poverty												
Q1(<20th)	-0.330	0.170	0.057	-0.137	0.190	0.472	-0.202	0.187	0.283	-0.051	0.210	0.809
Q2(20<40th)	-0.085	0.144	0.557	-0.039	0.147	0.791	-0.014	0.136	0.919	0.014	0.140	0.920
Q3(40<60th)	-0.379	0.188	0.048	-0.424	0.176	0.019	-0.325	0.195	0.100	-0.376	0.181	0.042
Q4(60<80th)	-0.168	0.158	0.292	-0.133	0.159	0.406	-0.147	0.148	0.323	-0.120	0.147	0.417
Q5(80th+, ref)	1.000											
Level 2 (Rook)												
Neighborhood												
Environment ^b				2.136	0.764	0.006				1.906	0.793	0.018
Level 1 (Individual)												
Perceived neighborhood environment ^c							0.257	0.079	0.002	0.253	0.084	0.003
Sigma_squared	1.916			1.91631			1.87713			1.879		
	0.081			0.06001			0.08088			0.063		
	0.000			0.00036			0.00044			0.000		

^aControl variables include individual age, gender, household income below poverty, education, race and ethnicity, metabolic minutes, healthy eating index, smoking and alcohol use; and neighborhood percent African American and percent Latino.

^bCombined observed neighborhood disorder and observed neighborhood physical deterioration.

^cCombined perceived neighborhood social environment and perceived neighborhood physical environment.

Table 3

Results from tests of mediation of associations between neighborhood poverty (antecedent) and CBR (outcome) by observed and perceived neighborhood characteristics, and tests of mediation of associations between observed neighborhood characteristics and CBR by perceived neighborhood characteristics*

Antecedent	Outcome	Mediator	A	A'	A-A'/sigma(A-A')	pvalue
<u>Observed Neighborhood Characteristics</u>						
		Physical deterioration	-0.962	-0.721	-4.698	<0.001
		Disorder	-0.962	-0.814	-3.997	<0.001
		Neighborhood characteristics	-0.962	-0.733	-4.593	<0.001
<u>Perceived neighborhood characteristics</u>						
% poverty	CBR	Physical environment	-0.962	-0.800	-4.188	<0.001
		Social environment	-0.962	-0.716	-4.856	<0.001
		Neighborhood Environment (Combo)	-0.962	-0.689	-5.039	<0.001
<u>Observed+Perceived Neighborhood Characteristics</u>						
		Physical deterioration+ Physical environment	-0.962	-0.540	-5.955	<0.001
		Physical disorder + Social environment	-0.962	-0.577	-5.762	<0.001
		Neighborhood characteristics+Neighborhood environment	-0.962	-0.533	-4.962	<0.001
<u>Perceived neighborhood Characteristics</u>						
Physical deterioration	CBR	Neighborhood physical environment	-0.721	-0.540	0.732	0.768
Disorder	CBR	Neighborhood social environment	-0.814	-0.577	-0.027	0.489
Neighborhood characteristics	CBR	Neighborhood environment (Combo)	-0.733	-0.533	0.290	0.614

* Tests were conducted using Freeman and Schatzkin tests for mediation, difference in association between the antecedent and outcome without the mediator in the model (A) and with the mediator included in the model (A'); A-A'/sigma(A-A').