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Journal

Journal of Biosocial Science, 51(6)

ISSN

0021-9320

Authors

LeBrón, Alana MW
Schulz, Amy J
Mentz, Graciela B
et al.

Publication Date

2019-11-01

DOI

10.1017/s002193201900004x

CAMBRIDGE
UNIVERSITY PRESS

ARTICLE

Social relationships, neighbourhood poverty and cumulative biological risk: findings from a multi-racial US urban community

Alana M. W. LeBrón[1,2*], Amy J. Schulz[3], Graciela B. Mentz[3], Barbara A. Israel[3] and Carmen A. Stokes[4]

[1]Department of Population Health and Disease Prevention, Program in Public Health, College of Health Sciences, University of California, Irvine, CA, USA, [2]Department of Chicano/Latino Studies, School of Social Sciences, University of California, Irvine, CA, USA, [3]Department of Health Behavior & Health Education, School of Public Health, University of Michigan, Ann Arbor, MI, USA and [4]School of Nursing, University of Michigan-Flint, Flint, MI, USA
*Corresponding author: Email: alebron@uci.edu

Abstract

Prior research has established associations between neighbourhood poverty and cumulative biological risk (CBR). CBR is conceptualized as indicative of the effects of stress on biological functioning, and is linked with increased morbidity and mortality. Studies suggest that supportive social relationships may be health protective, and may erode under conditions of poverty. This study examines whether social relationships are inversely associated with CBR and whether associations between neighbourhood poverty and CBR are mediated through social relationships. Data were from a stratified probability sample community survey ($n = 919$) of residents of Detroit, Michigan, USA (2002–2003) and from the 2000 US Census. The outcome variable, CBR, included anthropometric and clinical measures. Independent variables included four indicators of social relationships: social support, neighbourhood satisfaction, social cohesion and neighbourhood participation. Multilevel models were used to test both research questions, with neighbourhood poverty and social relationships included at the block group level, and social relationships also included at the individual level, to disentangle individual from neighbourhood effects. Findings suggest some associations between social relationships and CBR after accounting for neighbourhood poverty and individual characteristics. In models that accounted for all indicators of social relationships, individual-level social support was associated with greater CBR ($\beta = 0.12$, $p = 0.04$), while neighbourhood-level social support was marginally significantly protective of CBR (within-neighbourhood: $\beta = -0.36$, $p = 0.06$; between-neighbourhood: $\beta = -0.24$, $p = 0.06$). In contrast, individual-level neighbourhood satisfaction was protective of CBR ($\beta = -0.10$, $p = 0.02$), with no within-neighbourhood ($\beta = 0.06$, $p = 0.54$) or between-neighbourhood association ($\beta = -0.04$, $p = 0.38$). Results indicate no significant association between either social cohesion or neighbourhood participation and CBR. Associations between neighbourhood poverty and CBR were not mediated by social relationships. These findings suggest that neighbourhood-level social support and individual-level neighbourhood satisfaction may be health protective and that neighbourhood poverty, social support and neighbourhood satisfaction are associated with CBR through independent pathways.

Introduction

Prior research has demonstrated positive associations between neighbourhood poverty and cumulative biological risk (CBR) (Diez Roux & Mair, 2010; Schulz *et al.*, 2012). CBR has been conceptualized as indicative of the effects of stress on biological functioning (McEwen, 2008),

and has been linked with increased risk of morbidity and mortality (Seeman *et al.*, 2004a; Juster *et al.*, 2010). These adverse effects of stress on health occur through multiple pathways and may accumulate over time, contributing to racial, ethnic and socioeconomic inequities in health (House, 2002; Diez Roux & Mair, 2010; Phelan *et al.*, 2010). These effects appear to occur through contextual, behavioural and physiological mechanisms (House, 2002; Phelan *et al.*, 2010), including: effects of local environmental conditions (e.g. food access) on health-related behaviours (e.g. diet, physical activity) (Morland *et al.*, 2002; Larson & Story, 2009; Zenk *et al.*, 2009; Izumi *et al.*, 2011) and biological indicators of health (e.g. body fat, blood pressure) (Dengel *et al.*, 2009); environmental conditions that are conducive to stress, with links to health outcomes through physiologic responses to stress (Selye, 1982; Lazarus & Folkman, 1984); and physical exposures that may be inimical to health (e.g. air pollutants) (Brochu *et al.*, 2011).

One pathway through which neighbourhood poverty may contribute to adverse health outcomes is by reducing potential protective effects of positive social relationships, although evidence is mixed (Diez Roux & Mair, 2010). Prior studies have suggested that supportive social relationships may be health protective (Thoits, 2011; Uchino *et al.*, 2012), and that such positive social relationships may be eroded under conditions of poverty (Franzini *et al.*, 2005). Commonly conceptualized at the individual level, social relationships are theorized to promote health through behavioural (e.g. health-promoting behaviours) (Umberson *et al.*, 2010), psychosocial (e.g. symbolic meaning, norms, social support) (Umberson *et al.*, 2010; Thoits, 2011) and physiological pathways (e.g. reduced cardiovascular reactivity) (Glynn *et al.*, 1999). In addition to their individual-level effects, social relationships may also be conceptualized collectively as social characteristics within a locality (Macintyre *et al.*, 2002). To date, few studies have examined associations between neighbourhood poverty, social relationships and physical health, and the majority of these have used self-reported indicators of health (Diez Roux & Mair, 2010).

This paper examines whether social relationships are protective against the adverse effects of neighbourhood poverty on cumulative biological risk – a clinical and anthropometric indicator of biological risk – and the extent to which social relationships may mediate associations between neighbourhood poverty and CBR.

Background

Neighbourhood socioeconomic position and health

A robust body of evidence links neighbourhood socioeconomic position (SEP) with health (Pickett & Pearl, 2001; Borrell *et al.*, 2004; Cox *et al.*, 2007; Winkleby *et al.*, 2007; Mair *et al.*, 2008; Diez Roux & Mair, 2010). This study is grounded in theoretical frameworks and empirical evidence linking neighbourhood socioeconomic characteristics to health through effects on neighbourhood physical and social characteristics (Schulz *et al.*, 2005a). Studies of neighbourhood social environments to date have been largely guided by social disorganization theory (Shaw & McKay, 1969). This theory suggests that neighbourhood conditions that are conducive to economic and social stress (e.g., neighbourhood poverty) may contribute to neighbourhood disorder as social relationships among residents weaken (Shaw & McKay, 1969). That is, under conditions of economic and social stress, neighbourhood residents encounter conflicting values and tensions (Shaw & McKay, 1969), and those tensions may have negative implications for collective social relationships within the neighbourhood. To the extent that these social relationships are health protective, their erosion may have adverse health implications (Shaw & McKay, 1969). Social disorganization theory has been critiqued for its limited attention to structural forces that shape neighbourhood social relationships and norms (Ralph, 2014). The purpose of this paper is to attempt to partially address this critique through explicit attention to structural socioeconomic inequities in health outcomes, and the potential role of social characteristics in mediating these associations.

The following section provides a review of the literature on associations between neighbourhood SEP, health and four indicators of social relationships: social support, neighbourhood satisfaction, social cohesion and neighbourhood participation. Because social relationships can be conceptualized at both the individual and neighbourhood level, this section closes with a brief review of methodological approaches to disentangling these effects.

Social support is conceptualized as access to relationships that provide emotional, instrumental, appraisal and informational support (Uchino, 2009; Umberson & Montez, 2010; Thoits, 2011). While substantial evidence links social support, assessed at the individual level, to multiple indicators of health (Seeman *et al*., 2004b; Uchino, 2006, 2009; Thoits, 2011), some studies suggest that individuals who are experiencing an adverse health outcome may leverage support to cope with their health concerns (Uchino, 2006; Sampson *et al*., 2013). Additionally, the evidence linking social support to neighbourhood SEP is mixed. Individual-level social support has been found to partially mediate an inverse association between neighbourhood poverty and depressive symptoms (Kim, 2010). As a between-neighbourhood phenomenon, neighbourhood-level social support mediated the association between neighbourhood poverty, neighbourhood disorder and self-rated health (Franzini *et al*., 2005). Kim (2010) posited that residents of high-poverty neighbourhoods may build relationships with neighbours to cope with neighbourhood stressors.

A second indicator of social relationships is *neighbourhood satisfaction*, conceptualized as residents' satisfaction with the neighbourhood. Hipp (2009) reported positive associations between individual reports of neighbourhood satisfaction and neighbourhood educational attainment, but not neighbourhood household income. Kruger and colleagues (2007) reported an inverse association between neighbourhood satisfaction and depressive symptoms. In a more specific test of mediation, Weden and colleagues (2008) reported that neighbourhood satisfaction mediated associations between a composite measure of neighbourhood disadvantage and self-rated health.

Social cohesion indicates the functional aspects of community such as shared sense of membership, influence, social integration and mutual emotional connections among neighbourhood residents (Chavis *et al*., 1986; Parker *et al*., 2001). Prior studies have reported that elements of social cohesion are positively correlated with neighbourhood SEP (Franzini *et al*., 2005), self-rated physical and mental health (Echeverria *et al*., 2008; Elliott *et al*., 2014), and inversely associated with incidence of myocardial infarction (Kim *et al*., 2014). In a multilevel analysis, Rios and colleagues (2012) found that trust and shared values among neighbours, and dependability of neighbours, assessed at the neighbourhood level, partially mediated associations between neighbourhood SEP and self-rated health and psychological distress.

Neighbourhood participation, measured by participation in informal or formal neighbourhood organizations and activities, may be indicative of social integration, with social ties developing through such participation (Thoits, 2011). Following a different interpretation of social disorganization theory (Shaw & McKay, 1969), others have conceptualized neighbourhood participation as an indicator of conflicting social values, as those who participate more actively may do so in order to address conditions in their neighbourhoods with which they are dissatisfied (Sampson *et al*., 1997; Swaroop & Morenoff, 2006). Perhaps reflecting these different mechanisms, Swaroop and Morenoff (2006) reported that with the exception of neighbourhoods with the highest levels of poverty, neighbourhood participation was higher in low-SEP neighbourhoods, where residents may organize to address community needs. Neighbourhood participation is positively associated with well-being (Dupere & Perkins, 2007) and inversely associated with rise in cortisol levels (an indicator of physiologic response to chronic stress) after waking (Karb *et al*., 2012). Daniel and colleagues (2008) suggested that problem-solving behaviours intending to exercise control over one's environment, such as neighbourhood participation, may mediate or moderate associations between neighbourhood poverty and cardiometabolic disease.

Multilevel models are useful for disentangling individual-level effects from neighbourhood-level effects on health. While multilevel mediation models have gained increasing attention in recent years, potential confounding is possible when within-group effects differ from between-

group effects (Raudenbush & Bryk, 2002). This challenge is generally addressed through the use of multilevel models that account for individual-level characteristics while examining the independent contributions of variance in aggregated characteristics across neighbourhoods (Ellaway & Macintyre, 2000; Subramanian *et al.*, 2003; Franzini *et al.*, 2005). Some studies of the association of neighbourhood SEP, social relations and health have engaged multilevel models to disentangle individual from neighbourhood-level effects. The analyses presented below employ a multilevel modeling approach.

Research questions and hypotheses

The research questions that have guided this analysis build on, and extend, this body of research to cumulative biological risk (CBR) – a robust indicator of health (Seeman *et al.*, 2010; King *et al.*, 2011). This study focuses on three main questions: 1) are individual- and neighbourhood-level social relationships inversely associated with CBR; 2) are social relationships protective against CBR; and 3) are associations between neighbourhood poverty and CBR mediated through corrosive effects of neighbourhood poverty on social relationships? This study is guided by the following hypotheses, based on the literature reviewed above: social relationships, as individual- and neighbourhood-level characteristics, are associated with lower levels of CBR; and social relations, assessed at the individual and neighbourhood levels, mediate the inimical association of neighbourhood poverty and CBR.

Methods

Data

Data for this study were drawn from the Healthy Environments Partnership (HEP) 2002–2003 Community Survey (Schulz *et al.*, 2005a) and 2000 Census US data. The HEP Community Survey was collected as part of a community-based participatory research study in Detroit, Michigan, USA (Schulz *et al.*, 2005a).

The HEP Community Survey was conducted with a stratified two-stage probability sample of occupied housing units, designed for 1000 completed interviews with adults age ≥ 25 years across three areas of Detroit (Schulz *et al.*, 2005a). The survey sample was designed to achieve adequate variation in SEP within each of the three predominant racial/ethnic groups in Detroit: non-Latino Black (NLB), Latino and non-Latino White (NLW). Interviews were completed with 75% of households in which an eligible respondent was identified (919/1220) and 90% of households in which an eligible respondent was contacted (919/1027) (Schulz *et al.*, 2005a). The final sample consisted of 919 respondents nested within 146 blocks and 69 census block groups. Sample weights were created to account for differential selection and response rates and to match the sample to Census 2000 population distributions of the racial/ethnic groups across SEP in the study communities (Schulz *et al.*, 2005b).

Clinical and anthropometric measures taken at the time of the survey and used in this analysis included: resting blood pressure, measured three times by phlebotomists using a portable cuff device (Omron model HEM 711AC) that passed Association for the Advancement of Medical Instrumentation standards (Yarows & Brook, 2000), from which the mean of the second and third measurements was derived (LeBrón *et al.*, 2015, 2018); waist circumference (cm); height (cm); and weight (pounds) using a calibrated scale. Glucose, albumin, total cholesterol and high (HDL) and low (LDL) density lipid levels were derived from fasting blood samples.

Measures

Dependent variable

The dependent variable – cumulative biological risk (CBR) – is an individual-level measure adapted from similar measures to assess cumulative physiological tolls on biological systems

(Seeman *et al.*, 2010; King *et al.*, 2011). It included indicators of cardiovascular and metabolic dimensions of biological risk and self-reported use of medication for hypertension, diabetes and hypercholesterolaemia. A CBR index was calculated as the sum of the following indicators: SBP ≥ 140 mmHg; DBP ≥ 90 mmHg; 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 (males) or <50 (females). Building on previous studies (Geronimus *et al.*, 2006), the index includes points for individuals whose: SBP and DBP were below the high blood pressure criteria and who were taking hypertension medication; glucose levels were below the high-risk criteria and were taking medication; and lipid levels were within the normal range and were taking dyslipidaemia medication. The mean for this index was 2.63 (SE = 0.07, min = 0, max = 7).

Independent variables

Independent variables included self-report measures of social relationships derived from survey data examined at the individual level and aggregated to the block group level as a characteristic of the neighbourhood. *Social support* was a seven-item mean scale, including dimensions of emotional (e.g. someone to confide in, to trust to help solve problems, who makes you feel loved and cared for) and instrumental (e.g. help around the house, if sick, if couldn't use car, or if needed to borrow money) support. Response options ranged from never (1) to always (5) (Cronbach's alpha = 0.72). *Neighbourhood satisfaction* was a single item assessing the extent to which participants agreed with the statement: I would move out of this neighbourhood if I could. Response categories ranged from strongly agree (1) to strongly disagree (5). *Social cohesion* was a six-item mean scale measuring membership, influence, integration and emotional connection to the community (Chavis *et al.*, 1986; Parker *et al.*, 2001). Example items include: people in this neighbourhood share the same values, and I feel at home in this neighbourhood. Response options ranged from strongly agree (1) to strongly disagree (5), reverse coded so that a high score indicates high social cohesion (Cronbach's alpha = 0.78). *Neighbourhood participation* assessed participation in organized neighbourhood activities such as: (1) attending block clubs, neighbourhood association or police meetings; (2) participation in a neighbourhood cleanup or beautification project, crime watch or other neighbourhood activity; and (3) serving on a committee, organizing meetings or serving in a position of leadership for any local organization (e.g. block club, church, school or other organization). This variable was dichotomized into participation in at least one of these three domains (1) and no participation (0).

Neighbourhood poverty, assessed at the Census block group level, was the percentage 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% (referent) to allow for non-linear associations. Neighbourhood-level control variables included percentage NLB and percentage Latino.

Covariates

Control variables included individual demographic characteristics and health-related behaviours. Demographic variables included: age (years); sex (1 = female); self-reported race/ethnicity categorized as NLB, NLW and Latino; education (1 = ≥ 12 years); length of neighbourhood residence; and a dichotomous indicator of household poverty, calculated using the poverty-to-income ratio for 2000 US poverty thresholds (1 = ≤ poverty) (US Census Bureau, 2011). Length of neighbourhood residence was assessed by participant reports of the number of months or years they had lived in their neighbourhood.

Four indicators of health-related behaviours were included as controls to assess the extent to which social relationships are associated with CBR through pathways that are distinct from behaviours. *Metabolic minutes* was a continuous measure of physical activity using the 2005 International Physical Activity Questionnaire (IPAQ Research Committee, 2005). *Dietary*

practices was a continuous measure assessed using the Healthy Eating Index (HEI) – a composite measure of daily servings of food groups and nutrients (Kennedy *et al.*, 1995). *Smoking* was assessed through items asking about current and former tobacco, cigar and tobacco pipe use (Gentry *et al.*, 1985; Frazier *et al.*, 1992), coded as a categorical variable (current = 0, former = 1, never = 2). An analysis of descriptive statistics indicated a modest though statistically significant correlation between physical activity and dietary practices ($r = 0.08$; $p = 0.01$). Because these are control variables, rather than independent variables, both were retained in the models as covariates. *Alcohol use* was assessed as self-reported frequency and amount of alcohol use (Block *et al.*, 1994). Due to its skewed distribution (with more than half of participants reporting no alcohol consumption), alcohol use was dichotomized (1 = any drinks/month, 0 = none).

Statistical analysis

Hierarchical linear models were used to test these research questions regarding the effects of social indicators on CBR and their potential mediation of the association of CBR and neighbourhood poverty. Potential confounding in multilevel mediation effects estimates can arise when within-group effects differ from between-group effects when conducting these tests. The appropriate methodological approach to test unbiased mediation effects is to disentangle the individual effects from the characteristics of the neighbourhood (Ellaway & Macintyre, 2000; Subramanian *et al.*, 2003). To use this approach, consistent with the structure of the data, two-level hierarchical regression models were used for a continuous outcome, using HLM 7.0 (Scientific Software International, Lincolnwood, IL, 2006). At the upper level of multilevel models, standard error estimates are more robust for a larger number of groups (e.g. block groups) regardless of the group size (e.g. number of individuals in a block group) (Maas & Hox, 2005). There were 919 survey participants nested within 69 block groups, with an average of thirteen individuals per block group.

To test the cross-sectional mediation (MacKinnon & Fairchild, 2009) of social relationships on the association of poverty and CBR, this study followed recommendations by Zhang and Preacher (2009) for an unbiased approach for testing mediation when using multilevel data. Specifically, the following model was used, using social support (SS) as an example:

$$\text{Level 1 (individual)}: \ \text{CBR} = \beta_0 + \beta_1(\text{SS} - \text{Mean(SS)}) + \ \ldots$$

$$\text{Level 2 (neighbourhood)}: \ \gamma_0 = \delta_0 + \delta_1^{'} \times \text{poverty} + \delta_2^{'} \times \text{Mean(SS)} \ \ldots \qquad (1)$$

In this model, the individual-level measure was grand mean centred and its aggregate at the block group level was included at the neighbourhood level. The mediation test statistics proposed by Freedman and Schatzkin (1992) suggested using the difference in the point estimates in models with and without the mediator, standardized by the joint variance. Using model (1) as an example, it can be written as:

$$t_{N-2} = \frac{\delta_1 - \delta_1{}'}{\sqrt{\sigma^2_{\delta_1} + \sigma^2_{\delta_1^{'}} - 2\sigma_{\delta_1}\sigma_{\delta_1{}'}\sqrt{1-\rho}}}$$

where δ_1 and $\delta_1^{'}$ are the parameters testing for the poverty effect when social support is excluded and included from the model respectively, and ρ refers to the correlation between the independent variable (poverty) and the mediator (SS).

The individual-level parameter represents the expected effect of a difference in CBR between two participants in the same neighbourhood who differ by one unit in the social relationship indicator. The neighbourhood-level parameter indicates the expected effect of a one-unit difference in neighbourhood-level social relations for two residents with the same individual-level social relationship indicator who live in neighbourhoods with different neighbourhood mean

levels of the social relationship indicator on CBR (within-neighbourhood effect). The difference between these two parameters (i.e. individual and neighbourhood) is the between-neighbourhood effect, which indicates the effect of different neighbourhood mean levels of social relations on CBR. Models assessing this research question also included neighbourhood poverty and neighbourhood level and individual demographic controls.

Although the proportion of missing data (6%) was low, multiple imputation procedures derived from Bayesian models (Barnard *et al.*, 2001) were used to impute missing values using the %IMPUTE routine (IVEware, Ann Arbor MI) in SAS 9.1 (SAS Institute Inc., Cary NC). Multiple imputations allowed the complete case approach to be used and thus obtain robust standard error estimates (Rubin, 1996). In sensitivity analyses, participants who were taking medication for hypertension, diabetes or cholesterol at the time of the assessment were excluded from the high-risk CBR sub-categories.

Results

Table 1 shows descriptive statistics for the individual and block group variables. Slightly more than half of the participants were female; about one-fifth identified as Latino or NLW, with the majority of participants identifying as NLB. Approximately one-third of participants had less than a high school education and nearly 40% reported household incomes at or below the federal poverty level. This reflects the sampling design, intending to sample housing units across SEP for the three largest racial/ethnic groups in Detroit. Sampling design weights, described in the Methods section, adjust this distribution to reflect the distribution of Detroit residents by household and Census tract poverty level in Detroit at the time the survey was conducted. At the block group level, on average about one-third of households had incomes at or below the poverty level, reflecting the distribution of households below the poverty line, and about two-thirds of households were NLB.

Table 2 shows results from multilevel regression analyses testing associations between neighbourhood poverty, social relationships and CBR. Model 1 indicates positive associations between neighbourhood poverty and CBR, accounting for individual-level controls (Schulz *et al.*, 2013). Models 2–5 each add one measure of social relationships (social support, neighbourhood satisfaction, social cohesion and neighbourhood participation) and Model 6 includes all four social relationship measures.

As indicated in Models 2–5, when included individually in models, patterns suggest a trend towards a positive association between social support and CBR at the individual level ($\beta = 0.10$, SE = 0.06, $p = 0.095$) and a negative association at the neighbourhood level ($\beta = -0.34$, SE = 0.19, $p = 0.07$; Model 2). Individual-level neighbourhood satisfaction was inversely associated with CBR ($\beta = -0.08$, SE = 0.04, $p = 0.03$), with no significant association at the neighbourhood level ($\beta = 0.09$, SE = 0.09, $p = 0.31$; Model 3). Social cohesion (Model 4) and neighbourhood participation (Model 5) were not significantly associated with CBR at either the individual or neighbourhood levels. When all four social relationship indicators were included together (Model 6) similar patterns were identified. Individual-level social support was positively associated with CBR ($\beta = 0.12$, SE = 0.06, $p = 0.04$), while neighbourhood-level social support showed an inverse association ($\beta = -0.36$, SE = 0.19, $p = 0.06$), though this latter association was only marginally significant. In this same model, individual-level neighbourhood satisfaction was inversely associated with CBR ($\beta = -0.10$, SE = 0.04, $p = 0.02$), while there was no difference in CBR by neighbourhood-level neighbourhood satisfaction ($\beta = 0.06$, SE = 0.10, $p = 0.54$). Results suggest no association of social cohesion (individual: $\beta = 0.04$, SE = 0.08, $p = 0.59$; neighbourhood: $\beta = 0.10$, SE = 0.18, $p = 0.58$) or neighbourhood participation (individual: $\beta = 0.01$, SE = 0.06, $p = 0.93$; neighbourhood: $\beta = 0.12$, SE = 0.18, $p = 0.52$) with CBR.

As shown in Table 3, between-neighbourhood effect estimates based on Model 6 of Table 2 suggest that residents of neighbourhoods with higher mean social support had marginally

Table 1. Descriptive statistics of study sample for individual- and neighbourhood-level variables ($N = 919$), Detroit, US, 2002–2003

Variable	%	Mean	SE
Individual level			
Age (years)		46.3	0.6
Female	52.3		
Race/ethnicity			
Non-Latino Black (NLB)	56.8		
Latino	22.2		
Non-Latino White (NLW)	18.7		
Education			
< High school	37.0		
High school	29.0		
> High school	32.8		—
Other	2.3		—
Household income at or below poverty level	36.4		—
Perceived neighbourhood environment characteristics (combined)		2.9	0.0
Cumulative biological risk (CBR)		2.6	0.1
Smoking			
Current	37.1		—
Former	22.4		—
Never	40.4		—
Healthy Eating Index		64.3	0.4
Physical activity (MET minutes)		3659.5	144.3
Alcohol use	47.3		
Social support		3.7	0.0
Neighbourhood satisfaction		2.4	0.1
Social cohesion		3.6	0.0
Neighbourhood participation	43.5		
Length of residence in the neighbourhood (years)		18.5	0.6
Neighbourhood level (block group)			
Percentage below poverty		32.5	0.4
Poverty (quintile)			
$< 20^{th}$	18.8		
$20–40^{th}$	20.3		
$40–60^{th}$	10.1		

Table 1. *Continued*

Variable	%	Mean	SE
60–80th	29.0		
≥80th (reference)	21.7		
Percentage NLB		67.5	1.2
Percentage Latino		15.2	0.9
Social support		3.7	0.0
Neighbourhood satisfaction		2.4	0.0
Social cohesion		3.5	0.0
Neighbourhood participation		0.8	0.0

Weighted means and standard error are reported for individual-level variables; unweighted means and standard deviations are reported for neighbourhood-level variables.

significantly lower CBR than residents of neighbourhoods with lower mean social support ($\beta = -0.24$, SE = 0.15, $p = 0.06$), accounting for individual and neighbourhood controls and other social relationship indicators. Thus, as advanced by Raudenbusch (Raudenbush & Bryk, 2002), while individual-level social support was positively associated with CBR, neighbourhood-level social support trended towards an inverse or protective effect. Across neighbourhoods, there was no difference in the association of neighbourhood satisfaction ($\beta = -0.04$, SE = 0.13, $p = 0.38$), social cohesion ($\beta = 0.14$, SE = 0.08, $p = 0.95$) or neighbourhood participation ($\beta = 0.12$, SE = 0.15, $p = 0.78$) with CBR.

Table 4 shows results from tests of the hypothesis that associations between neighbourhood poverty and CBR are mediated by social relationships. Results provide no support for the hypothesis that any of the four indicators of social relationships examined significantly mediate associations between neighbourhood poverty and CBR.

Finally, in sensitivity analyses, participants who were taking medication for conditions encompassed in this measure were removed from the high-risk CBR sub-categories. Results did not indicate substantial differences in the associations between neighbourhood poverty, social relations and CBR when removing participants who were taking medication at the time of the assessment (data not shown).

Discussion

There are three key findings from the research reported here. First, the results indicate that social support is associated with cumulative biological risk: on average, individuals reporting higher levels of social support had higher CBR, whereas when comparing two individuals differing in individual-level social support living in the same neighbourhood, neighbourhood-level social support was inversely, though marginally, significantly associated with CBR. This pattern held after accounting for neighbourhood poverty, other indicators of social relationships, health-related behaviours and demographic characteristics. Second, on average, individuals reporting higher levels of self-reported neighbourhood satisfaction had lower CBR after accounting for neighbourhood poverty and neighbourhood and individual characteristics. There was no association between neighbourhood-level neighbourhood satisfaction and CBR. The results presented here do not provide evidence that social cohesion or neighbourhood participation – assessed as individual and within-neighbourhood characteristics – were associated with CBR. Third, when comparing two individuals with similar individual-level social support, residents of neighbourhoods with higher average social support had lower CBR than residents of neighbourhoods with

Table 2. Cumulative biological risk regressed on neighbourhood poverty and social relationships

	Model 1			Model 2 Social support			Model 3 Neighbourhood satisfaction			Model 4 Social cohesion			Model 5 Neighbourhood participation			Model 6 Social relationships (combined)		
	β^a	SE	*p*-value	β^a	SE	*p*-value	β^a	SE	*p*-value	β^a	SE	*p*-value	β^a	SE	*p*-value	β^a	SE	*p*-value
Intercept	2.70	0.05	<0.01	2.69	0.05	<0.01	2.70	0.05	<0.01	2.69	0.05	<0.01	2.70	0.05	<0.01	2.70	0.05	<0.01
Neighbourhood level (block group)																		
%Poverty (reference: > 80th)																		
<20th	−0.28	0.15	0.08	−0.26	0.15	0.09	−0.29	0.16	0.07	−0.30	0.16	0.06	−0.30	0.15	0.05	−0.30	0.15	0.05
20–40th	−0.06	0.12	0.64	−0.09	0.13	0.49	−0.07	0.13	0.58	−0.07	0.13	0.59	−0.05	0.12	0.66	−0.09	0.13	0.51
40–60th	−0.34	0.16	0.04	−0.36	0.17	0.04	−0.37	0.17	0.03	−0.36	0.16	0.03	−0.37	0.16	0.02	−0.41	0.17	0.02
60–80th	−0.11	0.15	0.46	−0.13	0.15	0.36	−0.13	0.15	0.39	−0.12	0.15	0.43	−0.12	0.15	0.42	−0.15	0.15	0.34
Social support				−0.34	0.19	0.07										−0.36	0.19	0.06
Neighbourhood satisfaction							0.09	0.09	0.31							0.06	0.10	0.54
Social cohesion										0.13	0.14	0.36				0.10	0.18	0.58
Neighbourhood participation													0.16	0.18	0.36	0.12	0.18	0.52
Individual level																		
Social support				0.10	0.06	0.10										0.12	0.06	0.04
Neighbourhood satisfaction							−0.08	0.04	0.03							−0.10	0.04	0.02
Social cohesion										−0.03	0.06	0.64				0.04	0.08	0.59
Neighbourhood participation													0.01	0.06	0.86	0.01	0.06	0.93
σ^2		1.94			1.93			1.92			1.93			1.93			1.91	
tau beta[b]	<0.01			<0.01			<0.01			<0.01			<0.01			<0.01		

[a]Neighbourhood-level controls include percentage NLB and Latino residents. Individual-level controls include: age, sex, educational attainment, race/ethnicity, household poverty level, physical activity, Healthy Eating Index, alcohol use, smoking and length of neighbourhood residence.
[b]tau beta indicates the Kendall correlation rank coefficient.

Table 3. Tests of individual- and neighbourhood-level associations of social relationships and cumulative biological risk

	Social support			Neighbourhood satisfaction			Social cohesion			Neighbourhood participation		
Association level	β[a]	SE	*p*-value	β	SE	*p*-value	β	SE	*p*-value	β	SE	*p*-value
Individual	0.12	0.06	0.04	−0.10	0.04	0.02	0.04	0.08	0.59	0.01	0.06	0.93
Within-neighbourhood	−0.36	0.19	0.06	0.06	0.10	0.54	0.10	0.18	0.58	0.12	0.18	0.52
Between-neighbourhood	−0.24	0.15	0.06	−0.04	0.13	0.38	0.14	0.08	0.95	0.12	0.15	0.78

[a]Coefficients based upon tests generated from Table 2, Model 6 (Raudenbush & Bryk, 2002).

Table 4. Tests of mediation of associations between neighbourhood poverty and cumulative biological risk by indicator of social relationships[a]

Antecedent	Outcome	Mediator	A − A'/σ(A − A')	*p*-value
%Poverty	CBR	Social relationships		
		Social support	0.58	0.72
		Neighbourhood satisfaction	0.69	0.75
		Social cohesion	0.53	0.70
		Neighbourhood participation	0.46	0.68

[a]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*'): $A - A'/\sigma(A - A')$.

lower average social support. Results do not indicate support for a between-neighbourhood association of neighbourhood satisfaction, social cohesion and neighbourhood participation and CBR. Results indicate no evidence that any of the four indicators of social relationships mediated associations between neighbourhood poverty and CBR. Rather, associations between neighbourhood poverty and CBR remained robust after accounting for all four measures of social relationships. The results reported above lend little support to social disorganization theory – specifically that associations between neighbourhood poverty and health may be mediated by effects of neighbourhood poverty on social relationships. Results are consistent with conceptual frameworks suggesting that health is influenced by a complex interplay of individual and neighbourhood characteristics. Each of these findings is discussed in greater detail below.

Are individual- and neighbourhood-level social relationships protective of health?

Results reported here indicate modest and mixed support for the hypothesis that social relationships are protective of health. Individual-level social support was positively associated with CBR, contrary to the hypothesized direction of effect. This finding joins a small literature with similar findings. For example, Cousson-Gélie and colleagues (2007) reported a positive association of social support and breast cancer mortality. A larger literature suggests that greater social support may be associated with favourable self-reported health and clinically assessed indicators of reduced cardiovascular risk (Seeman *et al.*, 2004b; Uchino, 2006, 2009; Umberson & Montez, 2010), and that neighbourhood SEP and social support are linked to health (Franzini *et al.*, 2005; Kim, 2010). The latter studies used self-reported health indicators and are thus vulnerable to same-source bias, whereas the present study was strengthened by the use of clinical and anthropometric health indicators (Duncan & Raudenbush, 1999). For example, Kim (2010) and Franzini and colleagues (2005) found that greater social support was associated with fewer depressive symptoms and more favourable self-rated health, respectively, accounting for neighbourhood SEP. Residents with less-favourable health may seek and mobilize greater social support and build relationships with neighbours in order to cope with health concerns (Uchino, 2006; Sampson *et al.*, 2013), which could help to explain the positive association of social support and CBR reported here. Additionally, under conditions of chronic stress, the physiologic effects of social support on CBR may manifest over time, whereas associations of social support with depressive symptoms may be more immediate (Umberson & Montez, 2010). The review of the literature described above – regarding associations of social support, neighbourhood SEP and health – identified one study by Kim (2010) that incorporated cross-sectional and three-year follow-up measures of health, and no studies that explicitly examined these associations over time. A cross-sectional association of social support and health may reflect those with poorer health mobilizing greater social support (Uchino, 2006), which would then suggest a positive association of social support and health in cross-sectional analyses. This cross-sectional analysis is not able to disentangle the extent to which associations reflect

garnering of socially supportive relations as health concerns have emerged or the health implications of social resources over the life course.

Neighbourhood-level social support was inversely associated with CBR. Holding individual-level social support constant, an individual living in a neighbourhood with higher neighbourhood social support would experience reduced CBR compared with an individual in a neighbourhood with lower mean neighbourhood social support. Findings presented here extend and strengthen those previously reported through the use of an objective measure of CBR derived from clinical and anthropometric data, reducing the risk of single-source bias (Podsakoff & Organ, 1986). In addition, the use of multilevel models allows us to disentangle individual- from neighbourhood-level effects, in this case suggesting differing patterns and potential pathways at individual and neighbourhood levels.

The association of neighbourhood satisfaction with CBR was contingent upon whether it was assessed as an individual or neighbourhood characteristic. While there was no association of neighbourhood-level neighbourhood satisfaction with CBR, residents reporting higher individual-level neighbourhood satisfaction had lower CBR than residents reporting lower neighbourhood satisfaction – an association that operated independent of neighbourhood poverty and health-related behaviours. This inverse association of individual-level neighbourhood satisfaction and CBR resonates with the literature indicating an association of greater neighbourhood satisfaction with better self-rated mental and overall health (Kruger *et al.*, 2007; Weden *et al.*, 2008). The results reported here extend previously reported associations of neighbourhood satisfaction to indicators of cardiovascular risk. Different individual- and neighbourhood-level associations of neighbourhood satisfaction with CBR suggest a need to examine the aspects of neighbourhood satisfaction (e.g. quality of life, social ties to neighbours) that may shape health differently across contexts. This is, based on the review of literature described above, the first attempt to test such an association as a neighbourhood-level characteristic. Previous reports of associations between neighbourhood satisfaction and depressive symptoms were modelled at the individual level (Kruger *et al.*, 2007).

The divergent individual-level associations of social support and neighbourhood satisfaction with CBR reported here may reflect different aspects of relationships assessed by these measures. The indicator of social support assessed supportive relationships on which participants perceived they could draw – relationships that were not bound by a particular geographic area. In contrast, neighbourhood satisfaction assessed residents' satisfaction with their specific residential neighbourhood. Additionally, assessments of neighbourhood satisfaction could be informed by social, physical and economic aspects of participants' neighbourhood, including, but not limited to, social relationships with neighbours. These contrasting associations of individual-level social support and neighbourhood satisfaction with CBR suggest a need to disentangle dimensions of social relationships that shape health, and for studies that evaluate these associations with clinical and anthropometric measures of health.

Results do not provide support for the hypothesis of an inverse association between social cohesion and CBR, contrary to cross-sectional studies involving self-reported indicators of health (Rios *et al.*, 2012; Elliott *et al.*, 2014) and one longitudinal study of the incidence of cardiovascular events (Kim *et al.*, 2014). The implications of social cohesion for CBR may unfold over a longer period than that for self-reported health indicators. Additionally, the results presented here differ from associations previously reported with neighbourhood participation and mental health, suggesting that the associations are sensitive to health indicators, and as reported by Dupere and Perkins (2007), to neighbourhood social and physical conditions. Differences in independent (e.g. typologies with multiple components) and dependent measures used across these studies (e.g. mental health, self-reported health) may contribute to these differences.

Are social relationships as between-neighbourhood characteristics protective of health?

Results indicate limited support that social relationships, as between-neighbourhood characteristics, are protective against CBR. Patterns across neighbourhoods indicate a marginally

significant inverse association between neighbourhood-level social support and CBR. This finding is consistent with the hypothesis that neighbourhood-level social support may be health protective, and is consistent with results reported by Franzini and colleagues (2005) indicating a positive association between neighbourhood-level social support and self-rated health. Results did not support the hypothesis of a between-neighbourhood association of neighbourhood satisfaction, social cohesion and neighbourhood participation with CBR, accounting for neighbourhood poverty, and other individual and neighbourhood factors.

Do neighbourhood social relationships mediate associations between neighbourhood poverty and CBR?

Based on tests of mediation, the null hypothesis that social relationships do not mediate associations between neighbourhood poverty and CBR cannot be ruled out. Results suggest that associations between neighbourhood poverty and CBR operate through pathways that are independent from the effects of social relationships. Previously reported findings suggest that perceived and observed neighbourhood conditions mediate associations between neighbourhood poverty and CBR (Schulz *et al.*, 2013), suggesting that these pathways are distinct from the effects of social relationships.

The finding of no mediating role of these four indicators of social relations on the association of neighbourhood poverty and CBR contributes to a modest literature, some of which suggests a mediation effect. These differences may reflect differences across studies in terms of indicators of neighbourhood SEP (i.e. individual vs composite indicator) and health (i.e. self-rated vs clinically and anthropometrically assessed). Additionally, several previous studies involved older, more economically advantaged residents and neighbourhoods, and larger geographic regions (e.g. national samples, states metropolitan areas). In this Detroit-based sample, the lowest quintile of neighbourhood poverty was <21.9%, reflecting a high percentage of households below the poverty line.

These findings of no mediation effect of social relations on the association of neighbourhood poverty and CBR, alongside a persistent association of neighbourhood poverty and CBR, are not consistent with social disorganization theory (Shaw & McKay, 1969). In *post hoc* analyses, neighbourhood poverty was not significantly associated with any of the social relationship indicators, suggesting that adverse health implications of neighbourhood poverty were independent of effects on social relationships. Accordingly, interventions to promote and protect social relations may not alter associations of neighbourhood poverty and CBR, particularly in areas where poverty is fairly highly concentrated such as the neighbourhoods included in this study. Based on the findings reported here, interventions to improve neighbourhood economic conditions may promote health, including, for example, policies to lift communities out of poverty, programmes to mitigate the adverse health implications of poverty and interventions and policies that improve neighbourhood physical contexts, particularly in neighbourhoods characterized by high levels of poverty (Stock *et al.*, 2014).

Study limitations and strengths

This study has several limitations. The use of cross-sectional data precludes the establishment of causal associations (MacKinnon & Fairchild, 2009). Additionally, the study sample was drawn from low-to-moderate income, predominantly Latino and NLB communities in Detroit, and is not representative of the US as a whole. Future research, with samples with larger income gradients and other geographic areas, may yield stronger associations between neighbourhood SEP, social relationships and health. Furthermore, tests of neighbourhood social relationships were limited to four indicators, and do not reflect the entire set of social relationships that might be examined. The indicator of neighbourhood participation used in this study best assesses any neighbourhood participation on the part of the study participant. It does not capture other characteristics of neighbourhood participation such as frequency, type of participation, motivations for participation or household-level neighbourhood participation. Moreover, the neighbourhood-level measure of social relationships consisted of the mean of each indicator of social relationships reported by individual

participants in the same neighbourhood. Thus, it does not reflect an independent indicator of social relationships in the neighbourhood as a whole. Further, a small subset of block groups had low within-group sample sizes. However, the strength of upper-level estimates in multilevel models is contingent upon the larger sample size of neighbourhoods rather than the number of individuals within each neighbourhood (Maas & Hox, 2005). In this dataset, the 69 block groups had an average of thirteen individual indicators. The large number of block groups lends strength to these findings. Finally, while the study controlled for length of residence, it did not disentangle life course implications of length of neighbourhood residence for the associations reported here. Future studies that are adequately powered with a large enough sample size are warranted that examine variations in these associations by age and other social statuses, such as gender.

Despite these limitations, this study extends the literature in several important ways. It contributes to the literature that conceptualizes social relationships as characteristics of individual residents and neighbourhood contexts, and tests their role in associations between neighbourhood poverty and health. The use of multiple indicators of social relationships facilitates an examination of the aspects of social relationships that may shape health differently. The health indicator, cumulative biological risk (Seeman *et al*., 2010; King *et al*., 2011) is a robust and objective measure of health, and extends previous studies that have relied upon self-reported health outcomes.

Conclusions

Results reported here indicate limited evidence for associations between social relationships and CBR. Contrary to hypotheses, individual-level social support was positively associated with CBR, while neighbourhood-level social support operated in the hypothesized direction. This may reflect a pattern in which individuals with higher CBR experience greater social support due to health challenges and that as a neighbourhood characteristic, social support is health protective. Associations between individual-level neighbourhood satisfaction and CBR were in the hypothesized direction, with individuals reporting higher levels of satisfaction with their neighbourhoods having lower CBR. The findings reported here are consistent with the idea that social support as a neighbourhood characteristic, and neighbourhood satisfaction among residents within neighbourhoods, are health protective. Findings suggest that associations of social support and neighbourhood satisfaction with CBR operate independently of, and do not mediate, associations of neighbourhood poverty and health-related behaviours – factors previously demonstrated to be associated with CBR (Schulz *et al*., 2012, 2013). These findings are consistent with the idea that neighbourhood poverty is associated with CBR through pathways other than the indicators of social relationships tested here. As such, interventions to strengthen socially supportive relationships may complement policies to promote health, but should not be considered an alternative to interventions designed to directly address neighbourhood poverty and its effects on cardiovascular risk.

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 Chandler Park Conservancy, Detroit Health Department, Detroit Hispanic Development Corporation, Detroit Institute for Population Health, Eastside Community Network, Friends of Parkside, Henry Ford Health System, the University of Michigan School of Public Health and community members at large. We thank the HEP Community Survey participants for their participation in the study.

Ethical Approval. Data collection procedures accorded with ethical standards for the treatment of human subjects and with the Helsinki Declaration. The University of Michigan Institutional Review Board approved this study in January 2001.

Conflicts of Interest. The authors have no conflicts of interest to declare.

Funding. The study and analysis were supported by the National Institute of Environmental Health Sciences (NIEHS) (R01ES10936, R01ES014234); National Institute of Minority Health and Health Disparities (NIMHD) (P60 MD002249, R24MD001619); the University of Michigan Center for Research on Ethnicity, Culture, and Health; and the University of

Michigan National Center for Institutional Diversity. The results presented here are solely the responsibility of the authors and do not necessarily represent the views of these supporting institutions.

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