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Neighborhoods and systemic inflammation: High CRP among legal and unauthorized Brazilian migrants

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We estimate cross-sectional associations of neighborhood-level disorder, socioeconomic characteristics and social capital with individual-level systemic inflammation, measured as high C-reactive protein (CRP), using Boston Metropolitan Immigrant Health & Legal Status Survey (BM-IHLSS) data—a sample of relatively young, healthy foreign-born Brazilian adults. Logistic regression analyses suggest high CRP is positively associated with neighborhood disorder and negatively related to neighborhood social capital. Although we find no significant associations between other neighborhood socioeconomic variables and high CRP; males, those who were born in an urban area and those who had been graduated from high school were *less* likely to have had high CRP. Unauthorized Brazilian adults, those who smoked cigarettes daily and those who had a higher body mass index were *more* likely to have had high CRP. Our findings suggest that investigating sociogeographic stressors and social support may be important for understanding physiological dysregulation even among relatively healthy U.S. sub-populations.

1. Introduction

The observation that newcomers to a socioeconomically disadvantaged urban area may be at greater risk of various diseases and all-cause mortality was first recorded by John Graunt in the 17th century, and since then many physical and social risk factors have been implicated in this process (Macintyre and Ellaway, 2003). Indeed, the origins of American public health began by acknowledging the need to protect the working class, many of whom were immigrants residing in impoverished neighborhoods, from both environmental and social toxins associated with early and rapid industrialization and urbanization—that is at home and work (Duffy, 1992; Melosi, 2000). Residents of lower income areas have been shown to be more susceptible to conditions such as psychological distress and depression (Hill et al., 2005; Ross, 2000), obesity (Mujahid et al., 2008) and chronic disease (Cubbin et al., 2001; Murray et al., 2010). The mechanisms linking disadvantage to disease are varied and not always well-understood; however, lower income groups that are also disproportionately composed of ethno-racial minorities, including immigrants, are more likely to live in residentially segregated neighborhoods (Acevedo-Garcia and Lochner, 2003; Massey and Denton, 1998), areas of higher crime and with greater alcohol and fast food outlet density (Block et al., 2004; Cohen et al., 2008; Kwate et al., 2009), as well as areas with less access to municipal services like recreational facilities or walkable sidewalks that may promote health (Cubbin et al., 2001; Holmes and Marcelli, 2011; Lovasi et al., 2009a). Most studies demonstrating these links rely on measures of individual income, often aggregated to a "neighborhood" or local area boundary, to define associations between illness and disadvantage; however, those that have instead constructed measures of neighborhood-level SES have similarly found material deprivation to be associated with poor health outcomes (Bird et al., 2010; Merkin et al., 2009).

More recently and increasingly, neighborhood socioeconomic disadvantage has been linked to cardiometabolic disease (Augustin et al., 2008; Cubbin et al., 2001, 2006; Diez Roux et al., 2001; Murray et al., 2010) and cumulative biological risk for disease (Bird et al., 2010; Finch et al., 2010; Merkin et al., 2009). However, much less research exists on more specific links between neighborhood sociogeographic factors and physiological mechanisms that may be important for predicting disease onset (Buxton and Marcelli, 2010). Chronic systemic (as opposed to acute) inflammation has emerged as a potentially decisive risk factor for the development of cardiometabolic disease, and validation of high-sensitivity assays for inflammatory markers like C-reactive protein (CRP) have made it possible to measure inflammation in population-based studies (McDade et al., 2004). CRP—an acute phase protein produced in the liver in response to

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pro-inflammatory cytokines—has become a particularly important marker of inflammation as well as an accurate predictor of cardiovascular disease and mortality (McDade et al., 2006; Ridker, 2001; Rifai and Ridker, 2001). Furthermore, recent research has identified psychosocial factors that may be associated with inflammatory processes, such as chronic and acute stressors, social support and poor psychological health (McDade et al., 2006; Ranjit et al., 2007; Uchino, 2006). Yet only a handful of studies have investigated relationships between neighborhood sociogeographic environments, in which stressors may be generated and social support forged, and inflammation (Liang et al., 2008; Nazmi et al., 2010; Petersen et al., 2008; Schootman et al., 2010).

Furthermore, most population-based research investigating associations between cardiometabolic risk factors (including systemic inflammation) and neighborhood characteristics has included study populations with mean ages over 50. These populations exhibit a greater variety of risk factors and higher disease prevalence than populations with wider age distributions, and such data limit researchers' ability to study the etiology of chronic disease onset. In order to better understand how risk factors for cardiometabolic disease develop it is essential to study relatively young, healthy populations when researching sociogeographic environments and physiological health. By doing so it is possible to gain greater insight into: (1) how risk factors accumulate across the life course and lead to disease onset in older populations, and (2) opportunities for prevention earlier in life or later intervention. In this paper we employ data from the Boston Metropolitan Immigrant Health & Legal Status Survey (BM-IHLSS)—a random household sample of adult Brazilian migrants who resided in the Boston metropolitan area in 2007—to estimate linkages between systemic inflammation as measured by CRP, and its relationship to economic, physical and social aspects of the local environment.

While the experience of systemic inflammation among Brazilian migrants in the Northeastern United States may not be fully generalizeable to the U.S. population as a whole, it is particularly compelling to study inflammation in this group for several reasons: first, as is the case with Latin American migrant populations more generally, Brazilian migrants are younger and healthier on average than the U.S. population (Marcelli et al., 2009a) therefore providing an opportunity to potentially discern processes by which risk factors for cardiometabolic disease develop into chronic illness. Second, whereas most research on migrant health focuses on migrants with relatively low socioeconomic status with low proportions of unauthorized residents, Brazilian migrants have notably high levels of educational attainment, earnings and unauthorized residents. Thus, although Brazilians are similar to many other U.S.-migrants in terms of being recent arrivals and can be expected to face many of the same barriers or hurdles, this is uncertain due to their unique SES and legal status profile (Marcelli et al., 2009a; Margolis, 1998). Brazilian migrants have also lived in their neighborhoods for shorter amounts of time than their neighbors in many cases, and may have a different experience of these neighborhoods depending on migration-related stressors. For example, some of the neighborhoods included in the BM-IHLSS contained a multitude of Brazilian-owned businesses, conceivably easing settlement for new residents, while others were situated near an Immigration and Customs Enforcement (ICE) office, a potentially threatening environment. This suggests another reason for studying Brazilian migrants—as the migrant population with the largest proportion of unauthorized residents in the United States (71% in the BM-IHLSS), Brazilians may have particular exposure to migration-related stressors, such as deportation fears or cultural differences with neighbors, and this stress may in turn have an effect on physiological regulation, such as inflammatory processes (Marcelli et al., 2009a). Finally, the BM-IHLSS is the only area-level probabilistic U.S. household survey to date that includes data on legal status, various sociogeographic life domains and bioindicators of health.

In this paper we thus hypothesize that migrants residing in neighborhoods with higher levels of disorder (i.e., violence, theft, property damage) and lower levels of social capital (i.e., neighbors getting along, helping one another, sharing the same values, knowing one another and not being afraid to go out at night) will be more likely to experience systemic chronic inflammation in the form of high C-reactive protein (CRP). We propose to test this hypothesis in sociogeographic context, i.e. treating neighborhood as one important domain in the larger social environment in which people are engaged, and with an eye to how neighborhood characteristics interact with individual behavior and characteristics, such as legal status, to influence systemic inflammation. As there is no commonly agreed upon definition of "neighborhood" in either the health literature or more generally, the BM-IHLSS relied on subject perceptions of what constituted their neighborhoods for measures of disorder and social capital (Coulton et al., 2001; Sawicki and Flynn, 1996; Weiss et al., 2007), and we have further linked these data to 2000 Census block-level data as we describe further in the next section.

2. Data and methods

The Boston Metropolitan Immigrant Health & Legal Status Survey (BM-IHLSS) was a community-based biodemographic research (CBBR) project designed and carried out in the Boston–Cambridge–Quincy, MA-NH Metropolitan Statistical Area (BCQ-MSA) in 2007 (Marcelli and Buxton, 2010; Marcelli and Heer, 1997; Marcelli et al., 2009a, 2009b; Minkler and Wallerstein, 2003). To our knowledge the BM-IHLSS is the first random household survey to collect both legal status and biological data from any foreign-born population in the United States. It builds on the 1994 Los Angeles County Mexican Immigrant Legal Status Survey (Marcelli and Heer, 1997) and subsequent studies that have either employed legal status information from the 1994 LAC-MILSS or adopted a variant of its legal status questions (Brown and Yu, 2002; Goldman et al., 2005; Ortega et al., 2007; Passel and Clark, 1998). Participants were randomly selected from 10 BCQ-MSA census tracts in which at least 7% of the population was born in Brazil. According to 2005–2009 American Community Survey data, the BCQ-MSA is home to the second largest population of foreign-born Brazilians in the United States (after the New York–Northern New Jersey–Long Island MSA) and this population has grown by 87% between 2000 and 2009 (U.S. Census Bureau, 2001, 2010). Data regarding migration and legal status, socioeconomic status, social capital, neighborhood characteristics and self-reported health behavior and conditions were collected from 307 foreign-born Brazilian adults and 120 of their U.S.- and foreign-born children. In addition, 249 of the Brazilian adult subjects (81%) provided biological data in the forms of height, weight and blood pressure measurements, and 176 subjects (57%) consented to providing blood droplets from which CRP, glycated hemoglobin (HbA1c) and Epstein-Barr Virus (EBV) measurements have been obtained.

Specifically, 12 teams of two interviewers who were born in Brazil were trained by an interdisciplinary team of researchers from Harvard University and the University of Massachusetts Boston in collaboration with the Brazilian Immigrant Center. Teams approached more than 4000 randomly selected households located in 100 randomly chosen census blocks up to three times, and after recording a subject's self-reported answers an interviewer asked whether the subject would agree to have his or her weight, height and blood pressure measured; to provide saliva by inserting a cotton swab into his or her mouth; and to permit the interviewer to collect five blood droplets using the conventional finger prick technique (Christensen, 2000; Jaszczak et al., 2009; McDade et al., 2007). Individual sample weights were computed using the conventional method of dividing one by the probability of random selection at each level (i.e., census tract, census block, housing unit, individual migrant). More detailed information about the BM-IHLSS study design and objectives is available from two peer-reviewed research reports (Marcelli et al., 2009a, 2009b).

2.1. Measures

High-sensitivity C-Reactive Protein (*hsCRP*). Blood samples were collected by trained interviewers in the homes of randomly selected subjects using disposable lancets and standardized filter paper. These were stored as dried blood spots (DBS) at $-80\,^{\circ}$C in Brigham and Women's Hospital Biomarker and Actigraphy Data Coordinating Center. After completion of BM-IHLSS fieldwork, the DBS were sent to the Laboratory for Human Biology Research at Northwestern University where high-sensitivity enzyme immunoassays for CRP were conducted. This method has been validated; the hsCRP concentrations obtained from DBS were found to be very similar to those obtained from blood serum and DBS are an effective means of storing blood samples in population-based surveys for which laboratory examinations are not feasible (Finch et al., 2000; McDade et al., 2004). A regression equation is employed ($\text{plasma}=2.3372\times\text{DBS}+0.0778$) to convert the DBS values of hsCRP, which are lower than serum values as a result of lysed erythrocytes in the sample, to serum values (McDade, 2010). This is done in order to utilize recommended clinical risk thresholds for hsCRP, based on serum measures, in order to delineate high CRP (>3 mg/L) from moderate (1–3 mg/L) and low (<1 mg/L) values (Pearson et al., 2003). Some clinicians have suggested that values of hsCRP exceeding 10 mg/L may indicate nonspecific inflammation, thereby making higher levels less useful for predicting cardiovascular disease; however, Ridker and Cook (2004) have found that even very high levels of hsCRP (>10 mg/L) provide important diagnostic information. Therefore, the outcome variable we employ (*high CRP*) is a dichotomous variable indicating whether a subject had high CRP (hsCRP levels >3 mg/L and ≤ 20 mg/L). We use a cutoff of 20 mg/L in order to exclude active infection and retain as many subjects as possible who may be at cardiovascular risk (Ledue and Rifai, 2001). Because no studies or data of which we are aware include information on the distribution of CRP levels among foreign-born Brazilian migrant adults, the BM-IHLSS CRP data were compared, in separate analyses, to CRP levels reported in the 2005–2008 National Health and Nutrition Examination Survey (NHANES) data for the total U.S. adult population and foreign-born Latin American adults. NHANES utilizes a measure of CRP rather than hsCRP, and CRP levels >1 mg/dL are generally considered to be high (Visser et al., 1999). According to the NHANES data, the frequency of high CRP among U.S. adults ages 18–64 is approximately 18% (Centers for Disease Control and Prevention, 2010), which is similar to the 22% found in the BM-IHLSS Brazilian adult sample.

Neighborhood environment. Neighborhood factors that may be independently associated with high CRP are measured using self-reported responses to questions about various neighborhood characteristics, and relying on subjects' own definitions of "your neighborhood". The BM-IHLSS data are further linked to the 2000 Census Summary File 1 (SF1) data to obtain measures of socioeconomic status and population composition. The census data are estimated at the block level as this provides the most proximate local neighborhood geography and encompasses features that residents may encounter as part of their daily activities. The first three neighborhood measures, *population density per square mile* (POPULATION DENSITY), *percent minority residents (*% MINORITY) and *percent homeownership* (% OWNERSHIP), are continuous and measured at the block level using the SF1 data. Each of these variables is often used to assess neighborhood socioeconomic characteristics and stability: population density and the concentration of nonwhite populations have commonly been used as proxies for the neighborhood socioeconomic environment under the assumption that areas higher in density and with larger minority populations are more likely to be lower income, although the opposite relationship has been found in some studies of health behavior and the built environment (Gordon-Larsen et al., 2006; Lovasi et al., 2009b; Rohe and Stewart, 1996). Similarly for homeownership, the greater the rate of homeownership the wealthier and more stable the neighborhood is generally expected to be (Ross and Mirowsky, 2001). *Neighborhood disorder* (DISORDER) is measured using a dummy variable indicating whether respondents or their neighbors had experienced personal violence, had their homes broken into, had experienced property damage or had property stolen from them. *Neighborhood "social capital"* (SOCIAL CAPITAL) is an index (0–5) based on whether subjects agreed that their neighborhood is safe at night, and that their neighbors know each other, get along with one other, share similar values and are willing to help each other (Sampson and Raudenbush, 1999). Three of the five components constituting our social capital index are clearly suggestive of positive social relations (i.e., safety, getting along, willingness to help), and thus we assumed that higher scores indicated higher subject-assessed social capital. In other words, we acknowledge that the remaining two component variables—sharing values and knowing one another—may represent healthful or harmful social interactions depending on the characteristics of network members (Portes, 1998). Finally, we control for *length of residence*, in a subject's current neighborhood.

Individual socioeconomic characteristics include dichotomous variables indicating whether a subject was married (MARRIED), completed high school (HS GRADUATE), was currently employed (EMPLOYED), reported speaking English "very well" (ENGLISH) and was unauthorized to reside in the USA (UNAUTHORIZED). A continuous measure of total individual earnings for 2006 (the year prior to the survey) is also included (EARNINGS). Individual socioeconomic status, most often measured by years of education, income and occupation, has repeatedly been linked to health outcomes, as has marital status. For migrants, English-speaking ability is a measure of integration, and poor English skills may be a source of psychosocial stress (Padilla et al., 1998). Furthermore, unauthorized legal status may be an important stressor that is unique to foreign-born populations (Marcelli, 2004), and according to estimates from the BM-IHLSS, 71% of Brazilian migrant adults in New England were unauthorized in 2007 (Marcelli et al., 2009a), a figure nearly 20% higher than most estimates of the unauthorized Mexican migrant population in the United States (Passel, 2006).

Health status and behaviors. Markers of health status and behaviors that may be independently associated with inflammation are measured using self-reported responses to questions about psychological health and behavior as well as height, weight and blood pressure measurements and two additional biomarkers obtained from DBS assays (HbA1c and Epstein-Barr Virus). Serious psychological distress (DISTRESS) is defined as scoring a value of 13 or above using a well-known distress scale (the K6 scale) which ranges from 0 to 24; the scale is based on six questions with a 5-point Likert response, and gauges clinical and subclinical psychological illness in population-based studies (Kessler et al., 2002).

Psychological distress has been cited as a risk factor for cardiovascular disease and linked to increases in inflammation (Black, 2002; Hamer et al., 2008; Stansfeld et al., 2002). Body mass index (BMI) is a continuous variable calculated from height and weight measurements taken at the time of interview. HbA1c and Epstein-Barr Virus (EBV) are continuous measures of glycated hemoglobin and EBV antibodies obtained from DBS assays. Hypertension is a dichotomous variable indicating whether subjects had systolic blood pressure $\geq$ 140 mmHg, diastolic blood pressure $\geq$ 90 mmHg or had ever been told by a doctor that they had high blood pressure (Marcelli and Holmes, 2012). With respect to health behavior, nutrition was evaluated using a dichotomous variable indicating whether subjects consumed five or more servings of fruits and vegetables each day on average, physical activity was assessed according to whether subjects engaged in moderate (20 min) or vigorous (30 min) "physical activity" during the preceding week and smoking was measured according to whether subjects had smoked at least 100 cigarettes in their lifetime and currently smoked every day. Finally, sleep debt is a continuous measure indicating the difference between usual hours of sleep on non-work days and work days. Sleep deficiency, nutrition, smoking, obesity, high levels of glycated hemoglobin (Hba1c) and high blood pressure are all demonstrated risk factors for inflammation and cardiovascular disease (Buxton and Marcelli, 2010). Physical activity, alternatively, appears to have protective effects with respect to systemic inflammation (Ford, 2002).

Individual exogenous characteristics were captured by measuring age in years since birth, skin color—self-reported according to a scale numbered 1–10 where 1 corresponds with the lightest pigmentation and 10 corresponds with the darkest (Massey and Martin, 2003)—and dichotomous variables for sex and whether the subject was born in an urban area in Brazil. Women, blacks and Latinos have been shown to be more likely to have high CRP than other groups (Albert et al., 2004; Araújo et al., 2004; Petersen et al., 2008; Winkleby et al., 1998; Woloshin and Schwartz, 2005). We also controlled for urbanicity in subject place of birth because more urbanized areas typically include residents who are of a higher socioeconomic status, are less likely to expose children to infection or other pro-inflammatory conditions, and offer access to established health care infrastructures (Crimmins and Finch, 2006; Vlahov et al., 2005).

Descriptive and multivariate regression results for cross-sectional analyses are reported below. STATA 10's "logit" command was used to perform all logistic regressions. Bias that may occur as a result of multiple respondents living in the same census blocks was controlled using STATA's "cluster" function (Huber, 1967). Three models were fitted: Model 1 controls for neighborhood characteristics and length of neighborhood residence along with individual exogenous characteristics, Model 2 adjusts for individual socioeconomic characteristics and Model 3 controls for all listed variables in addition to health conditions and behaviors. Logistic regression is employed in this analysis for two related reasons: (1) CRP distributions are not uniform across population groups and have been shown to differ between foreign- and U.S.-born populations in the United States (Centers for Disease Control and Prevention (CDC), 2010; Crimmins et al., 2007); and (2) it follows that employing standard cutoffs for high, normal and low CRP levels may provide the most useful comparison between Brazilian migrants and the rest of the U.S. population. In this paper we focus on high CRP using the clinical threshold of greater than 3 mg/L and less than or equal to 20 mg/L to exclude active infection.

3. Results

Of the 176 DBS samples collected from adult Brazilian BM-IHLSS subjects, CRP data are available for 157 (89%). The analyses are further restricted to the 151 subjects who had CRP readings less than or equal to 20 mg/L to exclude those who may be experiencing active infection. Subjects resided in 52 census blocks across the BCQ-MSA, with a mean of three per block. Seventy-three percent of these participants were estimated to have been unauthorized migrants, which is very similar to the estimated 71% of unauthorized migrants found in the entire Brazilian adult sample. Descriptive statistics are detailed in Table 1 below.

As the continuous measure of hsCRP (CRP2) in Table 1 illustrates, the mean level of hsCRP among Brazilian migrant adults residing in the BCQ-MSA at the time of the BM-IHLSS was 2.5 mg/L—within the moderate risk range. Altogether, approximately one in five (22%) Brazilian migrant adults residing in the BCQ-MSA at the time of the BM-IHLSS are estimated to have had high CRP. Consistent with past research, those with high CRP were slightly older than those with lower CRP levels (35 versus 33 years of age) and a higher proportion were women (approximately two-thirds versus 35%). Surprisingly, Brazilians with high CRP had lighter skin color on average (1.8 versus 2.3), but this may simply be an artifact of Brazilian migrants residing in the BCQ-MSA having relatively light skin pigmentation (2.2 on a scale of 1–10). In terms of individual socioeconomic characteristics, a higher proportion of migrants among those with high CRP were married (65 versus 51%); and lower proportions were employed (88 versus 91%), completed high school (64 versus 85%), reported speaking English "very well" (23 versus 32%)—and surprisingly—unauthorized to reside in the USA (66 versus 75%).

Higher proportions of Brazilian migrants with high CRP also smoked (27 versus 14%), appear to have been distressed (18 versus 5%), experienced sleep debt (1.4 versus 1.2 h/week) and had higher BMI (26.9 versus 25.5), HbA1c (4.9 versus 4.8) and EBV (97 versus 89) levels. Conversely, a lower proportion of those with high CRP engaged in regular physical activity (16 versus 30%) and a higher proportion reported consuming five servings of fruits and vegetables daily (27 versus 19%). Migrants with high CRP were also less likely to have had high blood pressure (3 versus 8%), which may seem antithetical as both CRP and hypertension are risk factors for cardiovascular disease. Research has demonstrated, however, that blood pressure and CRP are independent markers of disease (Blake et al., 2003) and do not necessarily have a causal relationship (Smith et al., 2005).

All of the variables in Table 1 discussed thus far are controls in our model—factors that may be independently associated with high CRP and confound any estimated relationship between neighborhood environment and high CRP if ignored. Among our main variables of interest, those individuals who had high CRP resided in their neighborhoods a slightly longer period of time on average (3.2 versus 2.3 years), and resided in less densely populated neighborhoods (approximately 20,000 versus 24,000 people/mile^2) with smaller proportions of ethno-racial minorities (36 versus 41%) but higher proportions of homeowners (43 versus 32%). Lastly, although migrants with high CRP also ranked their apparently higher socioeconomic status neighborhoods as having had more social capital on average (3.2 versus 3.0 on 0–5 index), they also were more likely to report neighborhood disorder (41 versus 26%).

Table 2 shows the parameter coefficients estimated from logistically regressing high CRP on all the variables listed in Table 1. Hypothesized directional associations between high CRP and each explanatory variable are indicated by a plus (+) or minus (−) sign following each variable name. A two-tailed hypothesis—employed when the relationship between an explanatory variable and high CRP is theoretically ambiguous (e.g., population density, being born in an urban area)—is demarcated by a both positive and a negative sign (+/−). We report parameter coefficients and convert these into changes in the

Table 1
Descriptive statistics (weighted).

		All adults μ (S.D.)	CRP ≤ 3 mg/L μ (S.D.)	CRP > 3 mg/L and ≤ 20 mg/L μ (S.D.)
Outcome variable				
High CRP	High CRP=1 if hsCRP > 3.0 mg/L and hsCRP < =20 mg/L (converted from DBS to serum values)	0.22 –	0.00 –	1.00 –
hsCRP (mg/L)	Levels of hsCRP (converted from DBS to serum values)	2.46 3.38	1.11 0.66	7.39 4.55
Neighborhood characteristics				
Length of residence (−)	Number of years and months subject has resided in neighborhood	2.46 2.49	2.26 2.07	3.18* 3.60
Population density (+/−)	Number of residents per square mile by census block (mean in 10,000 s)	23,288 14,844	24,235 14,182	19,834 16,835
Minority (+)	Percent of non-white residents by census block	0.40 0.20	0.41 0.20	0.36 0.20
Ownership (−)	Percent of residents who own their homes by census block	0.35 0.20	0.32 0.18	0.43* 0.24
Disorder (+)	Disorder=1 if subject or neighbors experienced personal violence, had their homes broken into, had anything stolen from their property or experienced damage to their personal property in the neighborhood	0.29 –	0.26 –	0.41 –
Social capital (−)	Index from 0 to 5 indicating to what extent the subject agrees or strongly agrees that the neighborhood is (1) safe at night, and neighbors (2) know each other, (3) get along, (4) share values and (5) help each other	3.00 1.49	2.96 1.49	3.15 1.50
Individual exogenous characteristics				
Age (+)	Subject age in years	33.55 9.56	33.03 9.21	35.48 10.70
Male (−)	Sex=1 if subject reported sex as male	0.59 –	0.65 –	0.35 –
Skin color (+)	Self-reported subject skin color, measured from lightest (1) to darkest (10)	2.18 1.36	2.29 1.44	1.81 0.92
Urban born (+/−)	Urban born=1 if subject was born in an urban area in Brazil	0.68 –	0.71 –	0.55* –
Individual socioeconomic characteristics				
Married (−)	Married=1 if subject was married at time of survey	0.54 –	0.51 –	0.65 –
HS graduate (−)	HS graduate=1 if subject graduated high school	0.80 –	0.85 –	0.64 –
Employed (−)	Employed=1 if subject worked last week	0.91 –	0.91 –	0.88 –
Earnings (−)	Subject earnings from all jobs in 2006 (thousands of dollars)	33.83 24.41	35.40 25.40	28.08 19.66
English (−)	English=1 if subject speaks English "very well"	0.30 –	0.32 –	0.23 –
Unauthorized (+)	Unauthorized=1 if subject is unauthorized to reside in the USA	0.73 –	0.75 –	0.66 –
Individual health status & behavior				
Distress (+)	Distress=1 if subject's K6 score > 12, indicating serious psychological distress	0.08 –	0.05 –	0.18 –
BMI (+)	Body mass index	25.82 3.72	25.53 3.41	26.86 4.61
HbA1c (+)	Glycated hemoglobin level (continuous)	4.80 0.63	4.76 0.53	4.94 0.90
Hypertension (+/−)	Hypertension=1 if subject has measured hypertension or has ever been told by a medical professional that s/he had hypertension	0.07 –	0.08 –	0.03 –
EBV (+)	Epstein-Barr Virus antibody level (continuous)	90.50 66.11	88.80 65.14	96.71 70.23
Nutrition (−)	Nutrition=1 if subject consumes an average of five or more fruits/vegetables per day	0.20 –	0.19 –	0.27 –
Physical activity (−)	Physical activity=1 if subject engaged in moderate (20 min) or vigorous (30 min) exercise at least one day during the previous week	0.27 –	0.30 –	0.16 –
Smoking (+)	Smoking=1 if subject smokes every day	0.17 –	0.14 –	0.27 –
Sleep debt (+)	Difference between self-reported non-workday and workday sleep hours	1.23 1.69	1.17 1.62	1.44 1.92
N (weighted)		**29,708**	**23,312**	**6,396**
N (unweighted)		**151**	**119**	**32**

* Difference in means is statistically significant, $p < 0.05$.

Table 2
Logistic regression of high CRP on neighborhood and other factors.

	Model 1			Model 2			Model 3			
	ß	S.E.	Prob. (%)	ß	S.E.	Prob. (%)	ß	S.E.	Prob. (%)	O.R.
Neighborhood characteristics										
Length of residence (−)	0.023	(0.089)	0.97	0.066	(0.097)	2.77	0.076	(0.103)	3.20	1.079
Pop. density (+/−)	−0.00002	(0.000)	−4.21	−0.000004	(0.000)	−1.08	−0.00003	(0.000)	−7.80	1.000
Minority (+)	−0.504	(1.459)	−1.69	−0.672	(1.719)	−2.25	−0.645	(1.606)	−2.16	0.525
Ownership (−)	2.268	(1.381)	7.52	3.097	(1.564)	10.27**	1.775	(1.614)	5.89	5.901
Disorder (+)	0.666	(0.544)	11.26	0.735	(0.559)	12.41*	1.122	(0.532)	18.96	3.072**
Social capital (−)	−0.037	(0.185)	−0.93	−0.133	(0.205)	−3.34	−0.292	(0.221)	−7.35	0.746*
Individual characteristics										
Age (+)	0.013	(0.024)	2.05	0.026	(0.025)	4.12	−0.013	(0.032)	−2.10	0.987
Male (−)	−1.284	(0.563)	−21.69**	−1.173	(0.710)	−19.82**	−1.839	(0.801)	−31.07	0.159**
Skin color (+)	−0.294	(0.220)	−6.74	−0.409	(0.231)	−9.38	−0.549	(0.239)	−12.60	0.577
Urban born (+/−)	−1.015	(0.454)	−17.15**	−1.248	(0.570)	−21.08**	−1.691	(0.572)	−28.56	0.184***
Individual socioeconomic characteristics										
Married (−)				0.103	(0.543)	1.74	0.351	(0.562)	5.93	1.421
HS graduate (−)				−1.709	(0.555)	−28.88***	−2.313	(0.678)	−39.07	0.099***
Employed (−)				−0.448	(0.819)	−7.57	−1.392	(1.078)	−23.52	0.249*
Earnings (−)				−0.033	(0.018)	−13.51**	−0.017	(0.019)	−7.07	0.983
English (−)				−0.917	(0.557)	−15.49**	−1.316	(0.531)	−22.23	0.268***
Unauthorized (+)				1.044	(0.543)	17.64**	1.265	(0.595)	21.38	3.544***
Health status and behavior										
Distress (+)							2.145	(1.016)	36.24	8.544**
BMI (+)							0.161	(0.077)	10.16	1.175**
HbA1c (+)							0.225	(0.416)	2.39	1.253
Hypertension (+/−)							−0.757	(1.449)	−12.79	0.469
Epstein-Barr Virus (+)							−0.003	(0.006)	−2.90	0.997
Nutrition (−)							−0.022	(0.723)	−0.38	0.978
Physical activity (−)							0.357	(0.758)	6.04	1.429
Smoking (+)							1.570	(0.626)	26.53	4.809***
Sleep debt (+)							0.030	(0.175)	0.85	1.030
Constant term (+/−)	−0.330	(1.719)		1.294	(2.047)		−0.172	(2.556)		
Concordant Pairs	0.804			0.794			0.813			
Prob > chi2	0.012			0.000			0.000			
Pseudo R2	0.170			0.255			0.362			

* $p \leq .10$.
** $p \leq .05$.
*** $p \leq .01$.

probability that a migrant had high CRP as a result of a one-unit (for dichotomous explanatory variables) or one standard deviation (for continuous explanatory variables) change for two straightforward reasons. First, as is customary in economics, we prefer to show estimated associations explicitly rather asking readers to infer them from odds ratios. And second, regardless of how estimated relationships are reported, most researchers eventually employ the language of probability when discussing regression results (Buxton and Marcelli, 2010; Studenmund, 2001).

In our final model, which controls for both individual socioeconomic status and health, we estimate that two neighborhood-level factors were significantly associated with high CRP among adult Brazilian migrants in metropolitan Boston during the summer of 2007. First, those residing in a neighborhood characterized as disordered were 19% more likely to have had high CRP than those who did not. Second, those who reported higher neighborhood social capital were 7% less likely to have had high CRP. Three more conventional explanatory variables for area-level socioeconomic status—minority composition, population density and the rate of homeownership—do not appear to have been significantly related to high CRP. Statistically significant changes in the probability of having had high CRP are illustrated in Fig. 1 by the filled bars, and the empty bars represent variables that were included in our final model but are not significant.

Consistent with the literature, Brazilian migrant men are significantly and substantially (31%) less likely to have high CRP than Brazilian migrant women. Age and skin color, on the other hand, do not appear to be independently associated with high CRP. This is not surprising, however, given that this population is relatively young and white. Additionally, in separate analyses employing categorical measures of race akin to those used by the U.S. Census Bureau, no significant associations were found. Alternatively, subjects who were born in an urban area of Brazil, what we consider a crude proxy for having grown up in an environment with relatively more resources, were almost 30% less likely to have high CRP.

We also find that those who were graduated from high school were 39% less likely to have had high CRP, those who spoke English very well were 22% less likely and those who were residing in the United States illegally were 21% more likely. These relationships remain statistically significant in our third model, which controls for health behaviors and status, having been employed also becomes significant, and only one of our remaining four individual-level socioeconomic status variables (being married) had a different association with CRP than hypothesized, i.e. it was positively associated. However, little is yet known about the effects of spousal relationships on inflammation specifically, and the quality of marital relationships is likely as important for predicting outcomes such as high CRP as the state of being married itself (Kiecolt-Glaser et al., 2010).

Finally, three of our nine health behavior and health status variables are estimated to be positively and independently associated with high CRP (psychological distress, a higher height-adjusted body weight and smoking), and only two are

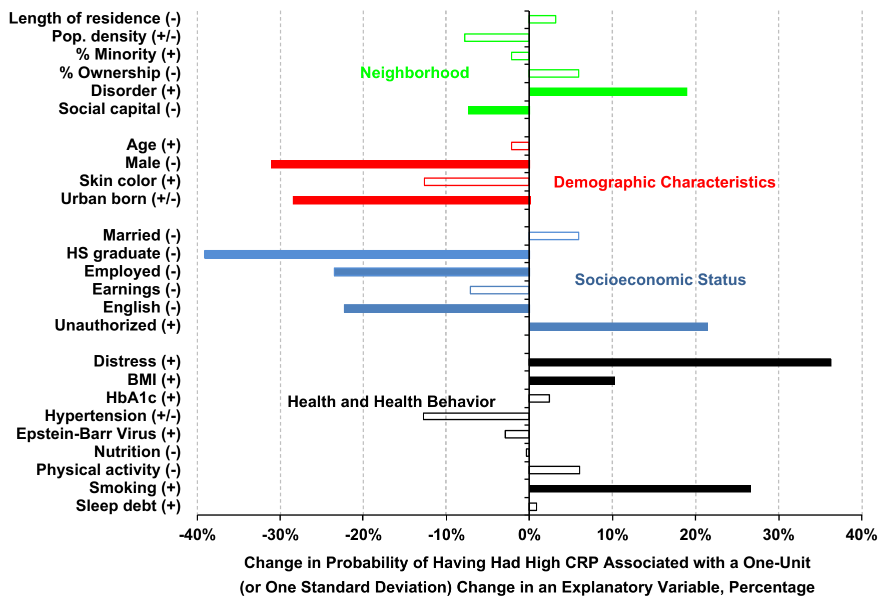

Fig. 1. Change in the probability of having high CRP.

not signed as anticipated; physical activity had a positive association with high CRP while Epstein-Barr Virus had a negative association. Brazilian migrant adults whose BMI was measured to be about four points higher had about a 10% higher probability of having had high CRP, those who smoked cigarettes daily were 27% more likely, and those experiencing serious psychological distress were 36% more likely.

4. Discussion

Only a few existing studies have examined relationships between inflammation and neighborhood factors (Petersen et al., 2008; Schootman et al., 2010), and only one of which we are aware has gone beyond conventional neighborhood socioeconomic (SES) characteristics to investigate other sociogeographic aspects of local environments that may be linked to high CRP (Nazmi et al., 2010). We report new evidence from 2007 Boston Metropolitan Immigrant Health & Legal Status (BM-IHLSS) data that neighborhood-level disorder and social capital are associated with high CRP among Brazilian migrant adults residing in the Boston–Cambridge–Quincy metropolitan statistical area. These two factors, furthermore, are estimated to be particularly salient predictors of high CRP even though more conventional area-level SES indicators such as home ownership and ethnoracial diversity are included in our models. And they are estimated to be increasingly important once individual-level SES and health variables were included in our model.

That neighborhood-level environmental factors remain significantly associated with high CRP in our model even after controlling for individual health and SES variables may provide further evidence that psychosocial and environmental stressors have a particular impact on inflammation. As noted above, neighborhood disorder has repeatedly been found in public health literature to be associated with increased psychological distress, and distress in turn—which is highly significant in our analyses—has been linked to high CRP and inflammation more generally (Hill et al., 2005; McDade et al., 2006; Ross and Mirowsky, 2009). Lack of social support has additionally been linked to compromised physiological function, and our finding regarding the relationship between low neighborhood social capital and high CRP may offer more evidence of this phenomenon (Kiecolt-Glaser et al., 2010; Uchino, 2006). As these are cross-sectional data; however, the true relationships between these measures and chronic inflammation may be obscured.

We should like to note from Table 2 that higher neighborhood disorder and social capital become significant only after controlling for individual-level socioeconomic status and health-related factors. One might expect, for instance, that individual SES and health behaviors would mediate any observed associations between neighborhood factors and inflammation, but they instead appear to clarify these relationships. In other words, Model 1 likely suffers from omitted variable (specification) bias as systemic inflammation is not an isolated biological process. Incorporating individual socioeconomic and health-related variables into our model not only provides an estimate of how these are directly associated with high CRP, but also elucidates how neighborhood environment and inflammation are related by placing the latter in context of individual risk factors. For example, obese individuals have been found to exhibit chronic systemic inflammation; thus, controlling for BMI should allow for a clearer picture of whether neighborhood environment influences CRP directly or through pathways not proxied in our model (Visser et al., 1999). Likewise, inflammation is a process tied to infection; thus, accounting for EBV levels as an indicator of generalized infection likely crystallizes any relationships between CRP and other explanatory variables.

The negative association between being born in an urban area in Brazil (and although insignificant, block-level population density) and high CRP is contrary to past findings indicating negative effects of high residential density and urban living on health; however, more recent evidence has suggested that higher levels of urbanization may be an advantage for health as more densely-populated urban areas are home to greater social and material resources, such as health care services and opportunities for civic participation (Kim et al., 2006; Vlahov et al., 2005). Furthermore, those residing in more urban areas may be less likely to face a variety of infectious or other inflammatory exposures in childhood, thereby potentially lowering their risk of systemic inflammation over the life course (Finch and Crimmins, 2004; Gurven et al., 2008). It would be ideal to examine the effects of early living conditions and ongoing exposure to urban environments using panel data to better understand the effects of these environments on inflammation, immune function and overall health. Little is known about the pathways from neighborhoods or other urban areas to physiological health in general, and the current study, though employing cross-sectional data, is only the second of which we are aware that specifically evaluates both socioeconomic and other neighborhood characteristics in relation to inflammation.

With respect to our findings on the relationships between high CRP and health status and behavior, existing evidence intimates that health behaviors including sleep and physical activity influence inflammation, and CRP specifically (Ford, 2002; Frey et al., 2007; Meier-Ewert et al., 2004). That these variables were not found to be significant as reported in Table 2 and Fig. 1, nor in separate analyses controlling simply for exogenous characteristics and these variables, only makes our findings regarding BMI and smoking and distress among Brazilian migrants more compelling. More generally, as the BM-IHLSS data represent a young and generally healthy population, it is possible that smoking and BMI are indicative of pathology earlier in life whereas the effects of the other behaviors have more cumulative or palliative effects as disease sets in later in life. It is possible that high blood pressure was not estimated to be statistically associated with high CRP because the BM-IHLSS instrument did not include questions about anti-inflammatory medication.

It is also worth commenting on the estimated positive relationship between being female or unauthorized to reside in the USA and high CRP among adult Brazilian migrants. The 2005–2008 NHANES data indicate that women aged 18–64 in the United States are approximately 1.5 times as likely as men to have high CRP, and among foreign-born Mexicans—the only foreign-born group that may be identified—this gap is greater (Centers for Disease Control and Prevention, 2010). We also found that Brazilian men are 31% less likely to exhibit high CRP than women, and at least two studies conducted among Brazilians in Brazil similarly identified this gender gap in young and otherwise healthy populations (Araújo et al., 2004; Ribeiro, 1997). It will be worthwhile in future studies to clearly articulate hypotheses regarding the environmental and psychosocial factors that may help explain this disparity, in addition to potential hormonal differences that may influence CRP levels.

No previous study has analyzed the relationship between legal status and physiological function among any foreign-born population residing in the United States. We estimated that unauthorized adult Brazilian migrants—the majority in the BM-IHLSS data—were 21% more likely to have had high CRP than were their legal compatriots. This is a striking finding given the relatively young mean age (35 years among those with high CRP) and the near absence of diagnosed cardiometabolic disease among adult Brazilian migrants residing in metropolitan Boston. Some research in economics and sociology suggests that a legal status penalty may exist for earnings (Marcelli, 2004) and social capital formation (Granberry and Marcelli, 2007) among Mexican migrants residing in the USA, and findings reported in this article imply this penalty may extend to physiological regulation for Latin American migrants. This will of course require further study.

What lessons regarding interventions or policies derive from applying our sociogeographic model of biological health to the 2007 BM-IHLSS data? The few studies reporting that sociogeographic environment and physiological dysregulation are related have focused largely on social support exchanged between individuals with close personal ties (Uchino, 2006). Our results complement these findings by suggesting that broader social processes—such as less intimate interactions occurring within neighborhoods or other relatively small local areas—are also important for influencing biological and thus long-term health. In particular, collective efficacy and other social capital theorists argue that civic group participation among neighborhood residents (e.g. sports clubs, neighborhood associations) may increase residents' attachment to their neighborhoods and thus their stake in maintaining neighborhood well-being (Browning and Cagney, 2002; Putnam, 2000). Furthermore, a neighborhood's capacity to organize around common goals plays a role in determining how effective residents are in negotiating with public institutions (e.g. police, city council) to obtain services (Sampson, 2003). This capacity in turn may influence neighborhood disorder; for example, previous research indicates that neighborhoods higher in collective efficacy tend to have lower crime rates (Sampson et al., 1997). The social and material resources thus afforded to neighborhoods exhibiting greater collective efficacy may influence health, though it remains to be seen what kinds of interventions may be most effective in supporting such civic organization (Cohen et al., 2006), especially among socioeconomically vulnerable populations.

Perhaps a first step toward fostering health among U.S. migrants would be to promote awareness of local community-based organizations (CBOs) dedicated to assisting them. Fewer than 50% of all foreign-born Brazilian adults residing in metropolitan Boston, for instance, were familiar with community organizations committed to providing employment, legal and other services according to the 2007 BM-IHLSS data. Furthermore, given that a plurality of Brazilians, regardless of gender or legal status, appear to have been actively engaged in their church or a social media group—two of several "civic" organizations about which BM-IHLSS respondents were asked to detail their participation—social capital accumulation among Brazilian migrants may be fostered by CBOs by reaching out in these domains. Neither churches nor the internet necessarily include one's neighbors, of course, but they might, and even if they do not they may help connect individuals who might benefit from knowing one another. Such efforts may be especially important for Brazilian migrants residing in metropolitan Boston because more than two-thirds are estimated to be residing in the USA illegally and unauthorized Brazilians were found to be 21% more likely to have had high CRP compared to their legal compatriots. Fear of exposure or unwanted attention has the potential to prevent unauthorized as well as legal migrants from fully engaging in existing civic organizations or even reporting incidents of crime to the authorities. Although reducing such disincentives to civic engagement will require national-level immigrant policy reforms that help migrants integrate more quickly and thoroughly, local entities such as the cities of Cambridge and Somerville in the BCQ-MSA have adopted sanctuary policies preventing city employees from inquiring about legal status when providing services. It remains to be seen, of course, whether such progressive policies (Sullivan, 2009) or increased CBO outreach efforts will result in more active civic engagement among migrants, and whether this would improve migrant health.

The foregoing analyses have several limitations. First, the BM-IHLSS data are cross-sectional and representative of a group of foreign-born migrants from Brazil who were residing in New England in 2007. It is difficult to conclude whether our findings can be generalized to geographically and ethnoracially diverse populations, and it is not possible to infer causality regardless of how robust the estimated parameters. Second, the CRP concentrations are derived from DBS samples rather than blood serum and converted to serum-equivalent values using a regression equation, which although a validated technique, may slightly skew the CRP results (McDade, 2010; McDade et al., 2004). Third, the BM-IHLSS survey did not include questions regarding medication currently being taken for management of cardiovascular risk factors; however, no one in the sample reported having been diagnosed with cardiovascular disease. Lastly, of necessity due to the concentration of foreign-born

Brazilians, the local area analyzed in this study consisted of a relatively small number of census blocks (52) in a circumscribed area (Eastern Massachusetts). This gives rise to the modifiable areal unit problem (Openshaw, 1984), or the propensity for substantial variation to occur in evaluating an outcome depending on the geography in which it is studied. However, recent neighborhood-health studies have suggested that this variation may be minimal and small areal units may be best for capturing relationships between neighborhood characteristics and health outcomes (Tarkiainen et al., 2010; Weiss et al., 2007).

Despite these limitations, the BM-IHLSS data are the only data available with representative information concerning individual- and neighborhood-level characteristics among foreign-born Brazilians in the United States. They are also the only data of which we are aware that have information on both legal status and biological markers of health. Thus, our findings emanate from analysis of the first community-based biodemographic research (CBBR) data available and suggest that additional research is required to fully understand the specific pathways between neighborhood characteristics and inflammation. More generally, it may prove useful to investigate the influence of stressors in other sociogeographic domains, such as the household and workplace, to gain a more comprehensive picture of the mechanisms that cut across these domains to influence physiological regulation and disparities in systemic inflammation.

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