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Perceived spatial stigma, body mass index and blood pressure: a global positioning system study among low-income housing residents in New York City

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Abstract

Previous research has highlighted the salience of spatial stigma on the lives of low-income residents, but has been theoretical in nature and/or has predominantly utilised qualitative methods with limited generalisability and ability to draw associations between spatial stigma and measured cardiovascular health outcomes. The primary objective of this study was to evaluate relationships between perceived spatial stigma, body mass index (BMI), and blood pressure among a sample of low-income housing residents in New York City (NYC). Data come from the community-based NYC Low-income Housing, Neighborhoods and Health Study. We completed a cross-sectional analysis with survey data, which included the four items on spatial stigma, as well objectively measured BMI and blood pressure data (analytic n=116; 96.7% of the total sample). Global positioning systems (GPS) tracking of the sample was conducted for a week. In multivariable models (controlling for individual-level age, gender, race/ethnicity, education level, employment status, total household income, neighborhood percent non-Hispanic Black and neighborhood median household income) we found that participants who reported living in an area with a *bad* neighborhood reputation had higher BMI (B=4.2, 95%CI: -0.01, 8.3, P=0.051), as well as higher systolic blood pressure (B=13.2, 95%CI: 3.2, 23.1, P=0.01) and diastolic blood pressure (B=8.5, 95%CI: 2.8, 14.3, P=0.004). In addition, participants who reported living in an area with a *bad* neighborhood reputation had increased risk of obesity/overweight [relative risk (RR)=1.32, 95%CI: 1.1, 1.4, P=0.02] and hypertension/pre-hypertension (RR=1.66, 95%CI: 1.2, 2.4, P=0.007). However, we found no differences in spatial mobility (based GPS data) among participants who reported living in neighborhoods with and without spatial stigma (P>0.05). Further research is needed to investigate how place-based stigma may be associated with impaired cardiovascular health among individuals in stigmatised neighborhoods to inform effective cardiovascular risk reduction interventions.

Introduction

Obesity and hypertension persist as major public health problems because of their high prevalence and associated co-morbidities. Obesity is a risk factor for type 2 diabetes (Nguyen *et al.*, 2008; Guh *et al.*, 2009), cardiovascular disease (Guh *et al.*, 2009), hypertension (Nguyen *et al.*, 2008), certain cancers (Guh *et al.*, 2009), and liver disease (Karlas *et al.*, 2013; Shulman, 2014). Hypertension is a risk factor for cardiovascular disease, kidney disease, and stroke (WHO, 2013). From the National Health and Nutrition Examination Survey (NHANES) 2011-2012, the prevalence of obesity among United States adults was estimated at 34.9% (Ogden *et al.*, 2014), while the prevalence of hypertension was 29.1% (Nwankwo *et al.*, 2013).

There are long-standing socio-economic disparities in obesity and hypertension rates in the United States, especially stark among low-income populations in the United States. Low-income populations have higher obesity and hypertension rates compared to the general population (Clarke *et al.*, 2009; Rossen and Schoendorf, 2012; Decker *et al.*, 2013; Krieger *et al.*, 2014). NHANES 2007-2010 data indicates that the prevalence of obesity among low-income adults (classified as below 138% of the federal poverty line) was nearly 40% (Decker *et al.*, 2013). In addition to low socioeconomic status being associated with higher mean blood pressure and hypertension prevalence, low-income individuals are less likely to receive treatment for their elevated blood pressure levels and have their hypertension optimally controlled (Colhoun *et al.*, 1998; Ostchega *et al.*, 2008; Brummett *et al.*, 2011; Egan *et al.*, 2014; Krieger *et al.*, 2014). Research also has documented high rates of obesity and hypertension among low-income housing residents (Digenis-Bury *et al.*, 2008; Duncan *et al.*, 2014c). For example, one Boston study found that the prevalence of self-reported hypertension among low-income housing residents was more than two times higher than the rate of hypertension among non-low-income housing residents (Digenis-Bury *et al.*, 2008). Additionally, low-income housing residents were nearly two times more likely to be obese than non-low-income housing residents (Digenis-Bury *et al.*, 2008).

Research shows that the spatial context, including the neighborhood environment, can influence obesity and hypertension rates (Kawachi and Berkman, 2003; Bennett *et al.*, 2008). For instance, neighborhoods with poor walkability, low neighborhood safety, high fast-food restaurant density, and low supermarket density have been shown to have higher obesity rates (Rundle *et al.*, 2007; Duncan *et al.*, 2009, 2014d; Saelens *et al.*, 2012; Lovasi *et al.*, 2013; Stark *et al.*, 2013; Pham do *et al.*, 2014; Troped *et al.*, 2014). These factors have also been associated with higher rates of hypertension (Chaix *et al.*, 2008; Mujahid *et al.*, 2008; Unger *et al.*, 2014). Other neighborhood characteristics associated with obesity and hypertension include social disorder (*e.g.* alcohol use, prostitution, drug addiction), physical disorder (*e.g.* broken windows, vandalism, litter, empty alcohol containers), and neighborhood violence, all of which may be sources of psychosocial stress and thus a potential mechanism connecting these neighborhood characteristics and deleterious cardio-metabolic health outcomes (Bennett *et al.*, 2007; Mujahid *et al.*, 2011; Lovasi *et al.*, 2013). These dimensions of neighborhoods have received substantial attention over the last several decades.

Other neighborhood-related factors can result in psychosocial stress. For example, spatial stigma, or the *negative representations of place* that are attached to neighborhoods may have deleterious effects on the health of residents via psychosocial stress, among other potential pathways (Keene and Padilla, 2014). Spatial stigma has also been defined by the *co-occurrence of its components: labeling, stereotyping, separa-*

tion, status loss and discrimination (Chaix, 2009). Spatial stigma can include overall neighborhood reputation, media image of the respondents' neighborhood, negative perception of low-income housing residents, and feelings of judgment due to living in subsidised housing. Stigmatised neighborhoods and residents of those neighborhoods may be viewed poorly by the media, individuals living outside the neighborhood, and/or residents themselves. Consequently, these stigmatised neighborhoods or marginalised places can carry negative symbolic meanings that have implications for the health and well being of their residents. Despite evidence demonstrating the associations between neighborhood factors and cardiovascular health outcomes, the role of spatial stigma in obesity and hypertension disparities remains under-explored (Chaix, 2009), including among low-income populations. Previous research has highlighted the salience of spatial stigma on the lives of low-income residents, but has been theoretical in nature and/or has predominantly utilised qualitative methods with limited generalisability and ability to draw associations between spatial stigma and measured cardiovascular health outcomes (Sampson and Raudenbush, 2004; Thompson *et al.*, 2007; Keene and Padilla, 2010, 2014; Kelaher *et al.*, 2010; Tabuchi *et al.*, 2012).

Because very little empirical work has been conducted to examine the potential role of spatial stigma as it relates to cardiovascular health, including obesity and hypertension, in low-income populations, the aim of this study was to examine the relationship between spatial stigma, body mass index and blood pressure among a sample of low-income housing residents in New York City. Based on the previous theoretical and empirical research, we hypothesised that perceived spatial stigma would be associated with impaired cardiovascular health (*i.e.* elevated body mass index and/or blood pressure) among low-income housing residents in New York City. In a sub-analysis we incorporate global positioning systems (GPS) data to investigate whether participants with and without spatial stigma have different mobility patterns, which has not been evaluated previously and may help us understand why spatial stigma could matter for cardiovascular health profiles. In addition, we sought to investigate if individuals who spend more time in their residential neighborhoods are more sensitive to spatial stigma. We hypothesised that individuals who report living in neighborhoods with spatial stigma will be more spatially mobile and that individuals who spent more time in their residential neighborhood would be more sensitive to spatial stigma.

Materials and Methods

Study sample

Data used in this study come from the NYC Low-Income Housing, Neighborhoods and Health Study ($n=120$) (Duncan *et al.*, 2014c; Duncan and Regan, 2015). Recruitment was conducted through community-based outreach, which included handing out flyers outside of public housing developments in four different New York City neighborhoods, as well as through flyers posted and circulated by community-based organisations that work with low-income individuals (especially public housing residents), flyers posted in community locations (*e.g.* local stores) and through word of mouth (social networks). Adults were considered eligible for participation in the study if they self-reported living in low-income housing (*e.g.* public housing) in New York City; were 18 years of age or older; could speak and read English; self-reported not being pregnant; self-reported no difficulty in walking or climbing stairs; and were willing to wear a Global Positioning Systems (GPS) device (on their person; *e.g.* in their pocket) for one week. The vast

majority (80%) of the participants reported living in public housing (versus other low-income housing) and all participants reported being low-income (e.g. 5.8% of participants in the study reported living in Section 8 housing). We collected survey and objectively measured health (height, weight and blood pressure) data, which were collected in our research office. Data were collected between June and July 2014. Informed consent was obtained from all participants prior to data collection. We geocoded participant address data using methods used in our past work (Duncan *et al.*, 2011a, 2011b) in order to determine and map their neighborhood of residence. The participants came from 4 of the 5 New York City boroughs, 28 ZIP codes, 21 community districts, 17 United Hospital Fund (UHF)-defined neighborhoods, 41 census tracts and 50 census block groups, which are various ways to define neighborhoods in New York City (Duncan *et al.*, 2014a). See Figure 1 for the spatial distribution of the overall sample by borough, which shows that the majority of participants come from Manhattan (65.8%). The New York University School of Medicine Institutional Review Board reviewed and approved the research protocol.

Spatial stigma

We assessed spatial stigma using a four-item survey informed by prior work on spatial stigma and health disparities (Sampson and Raudenbush, 2004; Thompson *et al.*, 2007; Keene and Padilla, 2010, 2014; Kelaheer *et al.*, 2010; Tabuchi *et al.*, 2012). The first item was *Overall, what is the reputation of your neighborhood?* Response options included: *Good; Moderate; Bad* and *Don't know/Not sure*. The second item was *Overall, is the image of your neighborhood in the media positive?* Response options were: *Yes; No; and Don't know/Not sure*. The third item was *According to you, are people who live in your neighborhood seen negatively outside the neighborhood?* Response options included: *Yes; No; and Don't know/Not sure*. The fourth item was *Do you feel that people judge you because you live in low-income or subsidised housing?* Response options included: *Yes; No; and Don't know/Not sure*.

Body mass index

Following standard protocols, trained research assistants (medical students) measured the participant's height and weight. Participants were asked to remove their shoes, heavy outer clothing, hats, and any tall hair accessories prior to measurement of height and weight. Height was measured to the nearest tenth of a centimeter using a Seca 213 stadiometer, with each participant's back to the stadiometer and their head in the Frankfort position (Geeta *et al.*, 2009; Abidin and Adam, 2013; Bacardí-Gascón *et al.*, 2013; McGurk *et al.*, 2013; Prushansky *et al.*, 2013) Weight was measured to the nearest tenth of a kilogram with a Tantina 351 scale (Geeta *et al.*, 2009; Thomas *et al.*, 2010; Yahia *et al.*, 2011; Bacardí-Gascón *et al.*, 2013; Bammann *et al.*, 2013). Body mass index (BMI) was calculated using the standard formula of weight (kg)/[height (cm)/100]². Underweight is classified as a BMI less than 18.50; normal weight is classified as a BMI 18.50 to 24.99; overweight is classified as a BMI 25.00 to 29.99; and obesity is classified as a BMI above 30.00.

Blood pressure

The research assistants were also trained to measure each participant's blood pressure following standard protocols. Participants sat silently in a chair prior to and during measurement of their blood pressure with their arms outstretched, back supported, legs uncrossed and feet on the floor. After being seated for 15 to 30 seconds, we measured their blood pressure with a Welch Allyn Vital Signs 300 monitor (Hess *et al.*, 2007; Victor *et al.*, 2011; Ravenell *et al.*, 2013). Consistent with

the most recent Joint National Committee (JNC 8) guidelines, hypertension is classified as a systolic blood pressure greater than 140 mmHg, a diastolic blood pressure greater than 90 mmHg or self-reported use of blood pressure lowering medications. Pre-hypertension is classified as a systolic blood pressure between 120-139 mmHg, or a diastolic blood pressure between 80-89 mmHg. Normal blood pressure is classified as a systolic blood pressure less than 120 mmHg and a diastolic blood pressure less than 80 mmHg.

Global positioning system data processing

Consistent with other studies (Zenk *et al.*, 2011; Hurvitz and Moudon, 2012; McCluskey *et al.*, 2012; Wiehe *et al.*, 2013; Yan *et al.*, 2014; Clark *et al.*, 2014; Dessing *et al.*, 2014; Harrison *et al.*, 2014; Klinker *et al.*, 2014; Yen *et al.*, 2015), GPS tracking of the sample was conducted for one week. Prior to distribution, we programmed the GPS device to log in 30-second intervals (so if a participant wore the GPS device for an hour, and had no data loss it would have 120 GPS points recorded) (Duncan *et al.*, 2014c). During the study orientation and baseline assessment, participants were instructed to place the small QStarz's BT-Q1000XT GPS device on their belt (using the manufacturer-provided case) or in their pocket and to complete a travel diary. Participants were asked to wear the GPS units at all times, except when sleeping, swimming or showering. Consisting of a series of checkboxes, the travel diary asked the participant questions related to GPS protocol compliance, *Did you charge the GPS monitor today?* and *Did you carry the GPS monitor with you today?* This was meant to help the participant remember to charge the unit and carry it with him or her throughout the week. The GPS device was given to participants in a large plastic zipper storage bag, which also contained a mini USB charging cord for the GPS device, a USB wall adapter for charging, a manufacturer-provided GPS belt holder (if requested), a pamphlet containing background information on GPS and the travel diary. Upon completion of the week-long GPS protocol (*i.e.* carrying the unit for all journeys, charging the unit daily, and completing the travel diary), we went

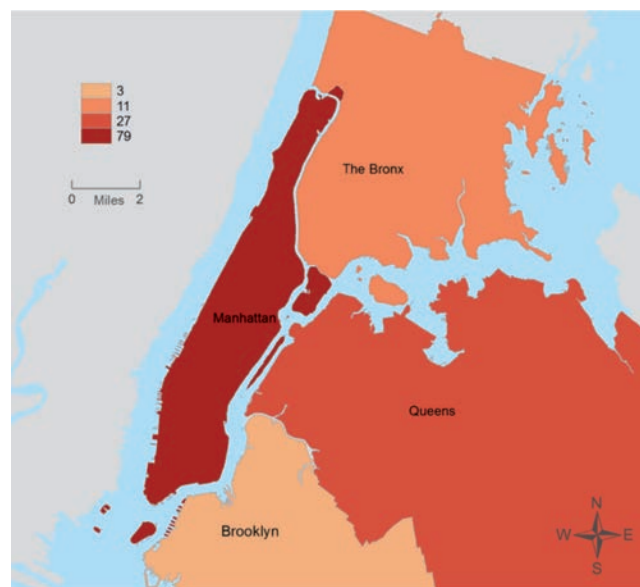


Figure 1. Number of participants by borough, New York City Low-income Housing, Neighborhoods, and Health Study.

to community locations (*i.e.* coffee shop, library) in the participant's neighborhood to obtain the GPS devices or participants returned to the project office to give back the GPS devices, depending on which option was most convenient for the individual. Participants compliance was high with a GPS return rate of 95.6%, and 114 of the overall study population had GPS data (Duncan *et al.*, 2014c). GPS participant data was downloaded using the Qstarz proprietary software and stored as .gpx files. The GPS data was then cleaned using several scripts written in the python programming language and ArcGIS Models to eliminate duplicate data, GPS points likely caused by multipath reflectance, GPS data likely caused by timing errors, and isolated GPS data (Python Software Foundation. Python Language Reference, version 2.7. Available at: <http://www.python.org>) and ArcGIS version 10.2 (ESRI, Redlands, CA, USA).

Global positioning system activity space size calculation and percent time in residential neighborhoods

Global positioning system activity space buffers were created using ArcGIS version 10 (ESRI). There are various ways to define an activity space (*e.g.* convex hull, one standard deviation ellipse and daily path area) as well as various distance thresholds for these measures (Zenk *et al.*, 2011; Christian, 2012). In this study, we used a daily path area (a buffering zone drawn around the GPS tracks), which is a common method in behavioral geography research to understand where participants spend the majority of their time and exposure to environments (Zenk *et al.*, 2011; Christian, 2012). Consistent with previous research (Zenk *et al.*, 2011; Christian, 2012), we buffered all the pre-processed GPS points at 0.5 mile and dissolved these separate features into a single feature, or space to create an activity space for each participant. A half-mile was selected to capture the immediate vicinity around activity locations, general area of exposure, and travel routes. While the literature is mixed on a common buffer size, one half-mile was selected because it has been shown to give a good estimate of exposure based on walkability studies, and is a commonly used distance in physical activity studies (Frank *et al.*, 2004; Cohen *et al.*, 2006; Troped *et al.*, 2010). The activity space size was expressed in square miles. In addition, we calculated the percent of GPS points within the residential neighborhood (*i.e.* percent of time spent in the neighborhood). Neighborhoods were defined as 400- and 800-meter street network buffers around one's residential address (Rundle *et al.*, 2009; Duncan *et al.*, 2011a, 2012, 2014b, 2014d; Jilcott *et al.*, 2011; Leung *et al.*, 2011; Schwartz *et al.*, 2011; Duncan and Hatzenbuehler, 2014; Reitzel *et al.*, 2014; James *et al.*, 2014; Troped *et al.*, 2014).

Other variables

Age categories included 18-24, 25-44, and 45+. Gender categories included male and female. Race/ethnicity categories included Black/African American, Asian/Asian American, Hispanic, White/Caucasian, and Other. Education levels included less than a 12th grade education, high school degree or GED, some college or vocational school, completion of bachelor's degree, and completion of graduate degree. Employment status groups were defined as *full-time*, *part-time*, *unemployed*, and *retired/school*. Household income included <\$25,000, \$25,000-\$49,999, \$50,000-\$74,999, and \$75,000+ categories. In addition, neighborhood percent non-Hispanic Black and neighborhood median household income at the census block group level were calculated using geographic information systems (GIS) software using data from the 2010 US Census and the 2009-2013 American Community Survey (United States Census Bureau, 2010).

Statistical analyses

The analytic sample for the primary analyses included only participants who answered all four spatial stigma items ($n=116$; 96.7%). Using this restricted sample, we first generated descriptive statistics for the sample by participant demographics. Then, we computed descriptive statistics for all spatial stigma items and set all stigma responses of *Don't know/Not sure* to missing. In analysing the GPS data to determine whether participants with and without spatial stigma have different mobility patterns, we first used a measure of activity space size. Additionally, we investigated whether individuals with larger proportions of time exposed to their residential neighborhoods were more sensitive to spatial stigma, using GPS percent of time in residential buffers (400 and 800 meter network buffers). Analyses for activity space size used simple linear regression, and those for network buffers used generalised linear modeling with a logit link and a binomial distribution with robust standard errors.

After this, we fit a series of multivariable models including each of the four spatial stigma items. In particular, each model included only one spatial stigma item in light of potential multicollinearity. Outcomes for multivariable analyses included BMI, systolic blood pressure, diastolic blood pressure, overweight/obesity status, and hypertension/pre-hypertension status. A series of five regression models were constructed. Three linear regression models included BMI and blood pressure (for systolic and diastolic) as continuous dependent variables. Overweight-obesity and pre-hypertension-hypertension status were dichotomised into overweight-obese versus not and pre-hypertensive-hypertensive versus not groups and used in two regression models.

The degree of potential clustering due to neighborhood effects was estimated using intercept-only random-effects linear and logistic regression models, clustered by census block group. Large intraclass correlation coefficients were found for diastolic blood pressure (18.9%) and hypertension/pre-hypertension status (24.0%). For diastolic and hypertensive/pre-hypertensive models, regression analyses utilised clustered robust standard errors due to large ICC levels.

As overweight/obese and pre-hypertensive/hypertensive status are common in our study sample, odds ratios were likely to overestimate the effect (Thompson *et al.*, 1998; McNutt *et al.*, 2003; Behrens *et al.*, 2004; Schmidt and Kohlmann, 2008). Therefore, relative risks (RRs; *i.e.*, prevalence ratios) were calculated rather than odds ratios. Odds ratios were obtained using logistic regression and converted to relative risks. Modified Poisson regression with clustered robust variances were used to estimate relative risks for the hypertension/prehypertension model. Covariates for all models included individual-level age, gender, race/ethnicity, education level, employment status, total household income neighborhood percent non-Hispanic Black (continuous variable) and neighborhood median household income (continuous variable). Statistical analysis was performed using Stata version 13 (Stata Corp; College Station, TX, USA). All P values reported are two-sided. Statistical significance was evaluated by 95% confidence intervals (CIs) and P values less than 0.05.

Results

Table 1 presents socio-demographic characteristics of the sample of low-income housing residents. Over half (56%) of the sample was female, 68% were Black/African American, and 39% were 45 years or older. A large proportion of the sample was obese and/or hypertensive: 40% were obese and 38% of the sample was hypertensive. Slightly over half (52%) reported a *moderate* neighborhood reputation, while 21%



reported their neighborhood reputation as *bad* (Table 2). Almost 36% reported that the media did not positively view their neighborhood. 41% reported negative external perception and 58% reported that they feel judged from living in low-income housing.

We found no differences in spatial mobility (based on GPS data) among participants who reported living in neighborhoods with and without spatial stigma ($P>0.05$) (Table 2). For example, participants reporting living in a neighborhood with a *good* reputation had a mean activity space of 13.8 square miles, living in a neighborhood with a *moderate* reputation had a mean activity space of 12.7 square miles, and living in a neighborhood with a *bad* reputation had a mean activity space of 12.3 square miles ($P=0.89$). Moreover, we found that individuals exposed to a larger fraction of their time to their residential neighborhood were not more sensitive to spatial stigma ($P>0.05$). For example, participants reporting living in a neighborhood with a *good* reputation spent 52.6% of time in their residential neighborhood (400-meter network buffer), living in a neighborhood with a *moderate* reputation spent 59.9% of time in their residential neighborhood (400-meter network buffer), and living in a neighborhood with a *bad* reputation spent 43.7% of time in their residential neighborhood (400-meter network

buffer) ($P=0.35$). Multivariable models of spatial stigma, BMI and blood pressure are shown in Table 3. Participants who reported living in an area that had a *bad* neighborhood reputation had higher BMI ($B=4.2$, 95%CI: -0.01, 8.3, $P=0.051$), as well as higher systolic blood pressure ($B=13.2$, 95%CI: 3.2, 23.1, $P=0.01$) and diastolic blood pressure ($B=8.5$, 95%CI: 2.8, 14.3, $P=0.004$). In addition, participants who reported living in an area with a *bad* neighborhood reputation had increased prevalence of obesity/overweight ($RR=1.32$, 95%CI: 1.1, 1.4, $P=0.02$) and hypertension/pre-hypertension ($RR=1.66$, 95%CI: 1.2, 2.4, $P=0.007$). Finally, we found that reporting feeling judged from living in public housing have lower diastolic blood pressure ($B=-5.5$, 95%CI: -10.2, -0.66, $P=0.027$).

Discussion

No study, to our best knowledge, has quantitatively assessed relationships between spatial stigma and cardiovascular health, especially among low-income housing residents who traditionally have high rates

Table 1. Socio-demographic characteristics of the sample of New York City low-income housing residents (n=116).

			Overall	95% CI
		%		
Individual-level	Gender	Male	43.9	34.9, 53.2
		Female	56.1	46.8, 65.1
	Race/ethnicity	Black	67.5	58.3, 75.6
		Asian	0.9	0.0, 6.1
		White	4.4	1.8, 10.2
		Hispanic	23.7	16.7, 32.5
		Other	3.5	1.3, 9.1
	Age	18-24	25.9	18.6, 34.7
		25-44	35.3	27.1, 44.6
		45+	38.8	30.3, 48.1
	Education	Less than high-school education	28.9	21.3, 38.1
		High school/GED	40.4	31.6, 49.7
		Some college	23.7	16.7, 32.5
		College graduate	5.3	2.4, 11.3
		Graduate degree	1.8	0.0, 6.9
	Income	Less than \$25,000	72.3	63.2, 79.9
		\$25,000-\$49,999	20.5	14.0, 29.2
		\$50,000-\$74,999	5.5	2.4, 11.5
		\$75,000+	1.8	0.0, 7.0
	Employment	Full-time	14.9	9.4, 22.8
		Part-time	18.4	12.3, 26.8
		Unemployed	54.4	45.1, 63.4
		Retired	5.3	2.4, 11.4
School		7.0	3.5, 13.5	
BMI	BMI (SD)	29.4 (7.9)	28.0, 30.8	
	Underweight	1.7	0.4, 6.8	
	Normal weight	31.9	24.0, 41.0	
	Overweight	26.7	19.4, 35.6	
	Obese	39.7	31.1, 48.9	
Blood pressure	Systolic (SD) ^o	129.1 (18.8)	125.6, 132.6	
	Diastolic (SD) ^o	76.6 (13.1)	74.2, 79.0	
	Normal	31.0	23.2, 40.1	
	Pre-hypertensive	31.0	23.2, 40.1	
	Hypertensive	37.9	29.5, 42.2	
Neighborhood-level				
	Neighborhood percent non-Hispanic Black (SD)	28.4 (20.6)	24.7, 32.2	
	Neighborhood median household income (SD)	44,341.8 (27,767.6)	39,235.0, 49,448.6	

CI, confidence interval; GED, general educational development; BMI, body mass index; SD, standard deviation. ^oValues are expressed as mmHg.



of obesity and hypertension (Digenis-Bury *et al.*, 2008; Duncan *et al.*, 2014c). In this study, we primarily sought to evaluate relationships between spatial stigma, BMI, and blood pressure among a sample of low-income housing residents in New York City. We found that a *bad* neighborhood reputation was associated with increased BMI, as well as related to increases in both systolic and diastolic blood pressure. We also found that participants who reported living in an area with a *bad* neighborhood reputation had increased prevalence of obesity/overweight and hypertension/pre-hypertension. This highlights that neighborhood reputation as compared with the other dimensions of spatial stigma may be the most salient aspect related to cardiovascular health, as other dimensions of spatial stigma were not associated with body mass index or blood pressure.

While the connection between spatial stigma and health is fairly understudied, our overall results complement past theoretical and qualitative literature on spatial stigma and health disparities. This past research has suggested that spatial stigma acts as a psychosocial stressor and can contribute to a range of physical and mental health out-

comes (Sampson and Raudenbush, 2004; Keene and Padilla, 2010, 2014; Kelaher *et al.*, 2010; Tabuchi *et al.*, 2012). Negative place-based identity from neighborhoods can be transferred to the residents of these neighborhoods who incorporate this identity, which negatively affects their behavior. High levels of spatial stigma may induce *stress*, which is in turn associated with increased BMI and blood pressure. The stress from spatial stigma may be due in part to individuals who reside in stigmatised neighborhoods (*e.g.* high-poverty neighborhoods) facing daily discrimination when others view them negatively because of where they live, such as discrimination based on negative stereotypes that people hold about certain neighborhoods. In addition, another possible mechanism is through more *depressive feelings* related to altered individual identity as affected by the negative collective identify (Tabuchi *et al.*, 2012): that is, spatial stigma can produce a negative view of self, which in turn can affect absence of efforts to manage one's body weight, to monitor one's blood pressure (Chaix, 2009). This discrimination may also limit people's economic and health-promoting opportunities. Specifically, it has been postulated that spatial stigma

Table 2. Prevalence of spatial stigma in New York City Low-income Housing, Neighborhoods and Health Study.

		Percent of overall (analytic sample) (n=116)	Mean of activity space size (n=102)	P*	Percent in residential buffer (400-meters)	P*	Percent in residential buffer (800-meters)	P*
Neighborhood reputation	Good	19.8	13.8	.89	52.6	.35	59.1	.57
	Moderate	51.7	12.7		59.9		65.8	
	Bad	20.7	12.3		43.7		54.0	
	Don't know/not sure	7.8	15.9		48.8		58.1	
Positive media image	Yes	27.6	14.7	.69	56.8	.87	62.3	.73
	No	35.3	13.6		48.5		57.4	
	Don't know/not sure	37.1	12.6		57.0		64.5	
Negative external perception	Yes	40.5	13.8	.77	52.2	.37	62.2	.64
	No	27.6	14.5		54.4		59.5	
	Don't know/not sure	31.9	11.8		59.7		66.5	
Feel judged from housing	Yes	57.8	14.6	.32	53.4	.69	61.4	.81
	No	24.1	12.2		52.8		58.9	
	Don't know/not sure	18.1	11.0		57.7		64.7	

*P trend for neighborhood reputation (all hypothesis tests set *Don't know/not sure* to missing).

Table 3. Multivariable models of spatial stigma, body mass index and blood pressure (n=116).

		Model 1: BMI			Model 2: Obese/overweight vs Not			Model 3: Blood pressure (systolic)			Model 4: Blood pressure (diastolic)			Model 5: HTN/Pre-HTN vs Not		
		β	95% CI	P	RR	95% CI	P	β	95% CI	P	β	95% CI	P	RR	95% CI	P
Neighborhood reputation	Good (ref)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Moderate	-.07	-3.5, 3.4	.97	.92	.55, 1.2	.61	7.3	-.92, 15.4	.081	.68	-4.3, 5.6	.784	1.31	.97, 1.8	.075
	Bad	4.2	-.01, 8.3	.051	1.32	1.1, 1.4	0.02	13.2	3.2, 23.1	0.01	8.5	2.8, 14.3	.004	1.66	1.2, 2.4	.007
Positive media image	Yes (ref)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	No	1.1	-3.3, 5.4	.627	1.19	.70, 1.5	.43	-6.4	-16.7, 3.9	.218	-6.4	-8.4, 7.1	.867	.82	.65, 1.0	.104
Negative external perception	No (ref)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Yes	1.3	-2.7, 5.2	.518	.97	.57, 1.2	.85	-4.96	-14.5, 4.6	.302	-1.98	-8.8, 4.9	.561	.85	.63, 1.1	.252
Feel judged from housing	No (ref)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Yes	-.77	-4.3, 2.8	.668	1.03	.65, 1.3	.87	-6.04	-13.9, 1.9	.132	-5.5	-10.2, -66	.027	.86	.67, 1.1	.241

BMI, body mass index; HTN, hypertension; CI, confidence interval; RR, relative risk. All models adjusted for individual-level age, gender, race/ethnicity, income, education, employment status, neighborhood percent non-Hispanic Black and neighborhood median household income. For overall spatial stigma, the reference group is *Good perceptions of the neighborhood*. For positive media image, reference group is *Yes, overall media image is positive*. For negative external perception, reference group is *No, people in my neighborhood are not seen negatively outside the neighborhood*. For housing judgment, reference group is *No, people do not judge me because I live in low-income/subsidised housing*.



restricts residents' access to health-promoting resources and limits economic opportunities, and thus contributes to persistent health disparities (Thompson *et al.*, 2007; Keene and Padilla, 2014). For example, employers may discriminate in the hiring process against addresses from disadvantaged neighborhoods (Kirschenman and Neckerman, 1991; Wilson, 1996). In addition, spatial stigma, including neighborhood reputation, can affect the type of resources and opportunities in that neighborhood. It is plausible that certain *respected* brands might not want their stores to be located in neighborhoods marked by spatial stigma. The finding about being judged from living in public housing being associated with reduced diastolic blood pressure was unexpected. This may suggest that participants in affluent neighborhoods are more judged because in poor neighborhoods as everyone find it normal. So one would only be judged when being in an affluent neighborhood and at the same time living in public housing. In addition, in a sub-analysis we incorporated GPS data to investigate whether participants with and without spatial stigma have different spatial mobility patterns and we found no differences. Perhaps spatial mobility is influenced by other macro-social factors such as neighborhood poverty. Moreover, we found that individuals exposed to a larger fraction of their time to their residential neighborhood were not more sensitive to spatial stigma. It is unclear why spatial stigma was not more salient to individuals who spend more time in their residential neighborhoods.

Spatial stigma is an illuminating but understudied phenomenon that may contribute to persistent health disparities among low-income and marginalised populations. However, further research is needed. For instance, the role of spatial stigma may vary across different geographic contexts and across different population groups, including non-low-income populations. Our study only evaluated spatial stigma in low-income urban environments, and thus future research should continue to evaluate the role of spatial stigma on cardiovascular health as well as other health outcomes in larger samples and samples across different geographies, including in rural locations. Future research could also assess how resilient these findings are across age, gender or racial/ethnic subgroups. In addition, future research can identify mediating mechanisms of behavioral nature (*e.g.* perhaps increased food intake) or psychological nature (*e.g.* depression) linking spatial stigma to cardiovascular health. Understanding the mediating role of health behaviors and health states can guide intervention development. While spatial stigma can be measured using individual-level survey research methods, as was done in this study, other research methods can be used, including objective methods such as newspaper reports as well as using an econometric approach to produce objective indicators of stigma in each neighborhood by aggregating survey responses from different participants residing in this neighborhood (Gauvin *et al.*, 2005; Fone *et al.*, 2006; Mujahid *et al.*, 2007; De Jong *et al.*, 2011; Corsi *et al.*, 2012). For example, researchers could conduct street-intercept surveys with individuals in neighborhoods as previous research has shown that this particular survey method can yield more representative samples when compared to traditional sampling methods (*e.g.* random digit dialing) (Miller *et al.*, 1997; Ompad *et al.*, 2008) and then aggregate responses to a neighborhood unit for analyses. Furthermore, there is an additional research opportunity to psychometrically develop an instrument of spatial stigma that would assist in these types of research investigations. This future research may help us further understand and eventually reduce health disparities experienced among low-income housing residents. For instance, in addition to structural policy environmental interventions, psychosocial interventions that address spatial stigma may be needed to improve cardiovascular health among residents in low-income housing. Media outlets could be provided with and provide more constructive and de-stigmatising images of low-income

neighborhoods and their residents, which could be a public health intervention.

This study is subject to several limitations that we noted here. First, our results may not be generalisable to low-income populations in other non-urban regions of the United States: we had a convenient relatively small sample of low-income housing residents in New York City. Having a small sample size likely reduced power to detect significant effects. However, our sample includes a multi-ethnic sample of low-income housing residents across different New York City neighborhoods and our study is the first quantitative study of spatial stigma on cardio-metabolic health among the studied population. In addition, while 116 participants is a relatively small sample size for general population, many GPS studies have fewer than 100 participants so the sample sized used here is on par with and even exceeds the sample size of many GPS-based research. Selection bias might also be a concern: we could assume that high BMI negatively influences participation in the study, and that stigma also negatively influences participation. It would cause bias in the spatial stigma BMI association. The selection bias we describe would likely pull the positive association that we document towards the null. In addition, the study was limited to English speaking low-income housing residents, and consequently our findings may not be generalisable to non-English speaking low-income housing populations. While self-report bias can be an issue with self-reported blood pressure as well as self-reported height and weight data, we were able to objectively measure both blood pressure and BMI, which is an important strength of our study. However, blood pressure was calculated by a single measurement. A clinical diagnosis of hypertension usually requires multiple blood pressure measurements and several previous studies have used the average of two or more measurements. The use of a single measurement may overestimate the prevalence of hypertension. Social desirability bias, with regards to perceived spatial stigma, may also be an issue. Furthermore, residual confounding is a potential limitation. For instance, the survey did not evaluate residential history and thus we were not able to control for that. This study was a cross-sectional analysis. As such, our study does not provide evidence that spatial stigma is casually associated with cardiovascular health outcomes. In addition, reverse causation may be a concern. From an environmental psychology point of view, it might be that obese people, if they have a lower self-esteem from this condition, tend to perceive less favorably their neighborhood. If that were true, this reverse causation would contribute to the positive association that we found between spatial stigma and BMI. Finally, there are caveats about the GPS analysis. It should be noted that while GPS data allows for potentially highly accurate point locations of participants, these data may be limited when the GPS receiver cannot find enough satellites to triangulate its location. In addition after a long period without satellite communication, GPS receivers may take additional time to acquire a fix location and these issues are exacerbated in cities with many thick and tall concrete buildings. Additionally, while the GPS analysis by spatial stigma indicators is very novel, we must note that the modifier areal unit problem is a limitation. In particular, the selected buffer size around the GPS points could have influenced the findings.

Conclusions

In conclusion, overall perceived spatial stigma was significantly associated with increased BMI, as well as significantly related to increases in both systolic and diastolic blood pressure. We also found that participants who reported living in an area with a *bad* neighbor-

hood reputation had increased risk of obesity/overweight and hypertension/pre-hypertension. Further research is needed to investigate how place-based stigma may be associated with impaired cardiovascular health among individuals in stigmatised neighborhoods to inform effective cardiovascular risk reduction and quality-of-life interventions.

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