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Associations of perceived neighborhood safety and crime with cardiometabolic risk factors among a population with type 2 diabetes

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ABSTRACT

Little is known about how neighborhood crime may relate to health in diabetes patients. We examined associations between individuals' perceptions of neighborhood safety or violent crime and stress, physical activity, body mass index (BMI) or hemoglobin A1c (HbA1c) in a sample ($n=721$) of adults (mean age:63) with diabetes. Self-reported neighborhood safety, violent crime, physical activity, and stress were collected and linked to clinical measures of BMI and HbA1c. Approximately 54% and 15% of patients reported neighborhood safety concerns and violent crimes, respectively. Any neighborhood safety concerns ($\beta=1.14$, 95% C.I. 0.04–2.24) and violent crime ($\beta=2.04$, 95% C.I. 0.34–3.73) were associated with BMI in adjusted analysis. Any violent crime was associated with class II–III obesity ($BMI \geq 35$) ($OR=1.34$, 95% C.I.: 1.02, 1.75). There were no significant associations between neighborhood safety concerns or violent crime with stress, physical activity, or HbA1c. Neighborhood safety is associated with BMI and obesity. Further studies, including longitudinal designs, are needed to study how people with diabetes may be influenced by a sense of poor personal safety in their neighborhoods.

1. Introduction

Incidence and prevalence of chronic diseases, such as diabetes, and their sequelae are increasing in the U.S. (Centers for Disease Control and Prevention, 2014). Research to reduce diabetes morbidity and mortality have primarily targeted individual-level, lifestyle behaviors related to physical activity, diet, and medication adherence (Leal and Chaix, 2011). While the social environment may also influence these health outcomes, there are few published studies to date (Leal and Chaix, 2011). Neighborhood social environments include the relationships, interactions and other social processes of individuals and groups and have been examined using measures of social norms, social cohesion, and levels of safety or violence (Yen and Syme, 1999).

Neighborhood social environments, including features of neighborhood safety, may influence diabetes-related stress, physical activity, weight management, and glucose control (Boslaugh et al., 2004). Fear of walking in one's neighborhood, low level of trust in one's neighbors and social isolation may lead to increased stress and other poor psychosocial or health outcomes (Diez Roux, 2003; Lorenc et al., 2012). Crime strongly influences perceived neighborhood safety and includes reported and unreported crime that may occur or that may be perceived as occurring near someone's home (Diez Roux, 2003; Loukaitou-Sideris, 2006). Most neighborhood safety studies to date have used self-reported measures of neighborhood safety, as perceived safety, even when inaccurate, can constrain and contribute to a person's behavior and physiological responses such as stress (Loukaitou-Sideris, 2006).

Associations between perceived neighborhood safety with physical activity and obesity have been inconsistent in general populations. Several studies have documented that adolescent, women, and the elderly's physical activity and walking time is influenced by safety concerns (Boslaugh et al., 2004; Loukaitou-Sideris, 2006; Piro et al., 2006). Other studies also found that

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perceiving higher neighborhood safety was associated with having lower BMI (Christian et al., 2011; Fish et al., 2010; Pham do et al., 2014). Still other studies, however, have found no association of crime with BMI or physical activity (Powell-Wiley et al., 2013; Grafova et al., 2008). These mixed findings may be influenced by demographic factors such as age, urban residence and/or racial group differences among the populations.

While most studies have focused on the relationship between neighborhood safety and obesity/BMI, few studies have evaluated the relationship with stress or glucose control (Fish et al., 2010; Pham do et al., 2014; Brown et al., 2014). Moreover, only two studies have been conducted in populations with diabetes (Burdette and Hill, 2008; Gary et al., 2008; Moreno et al., 2014). While these studies included measures of self-reported crime, they did not examine the associations of crime and safety problems alone on clinical outcomes and focused mainly on an index of neighborhood problems such as neighborhood aesthetics, physical activity and food environments. For these and other studies examining neighborhood problems, however, crime is cited as the most commonly reported problem and considered a strong influence on neighborhood problem indices. The influence of crime and safety factors alone may therefore have an impact on cardiometabolic risk factors in these at-risk patients with diabetes.

The overall goal of this cross-sectional study was to examine how perceived neighborhood safety and violent crime is associated with cardiometabolic risk factors, independent of individual level sociodemographic characteristics. We conducted this analysis in a racially and ethnically diverse sample of insured adults with diabetes enrolled in a large, integrated healthcare delivery system. We hypothesized that perception of one's neighborhood as unsafe and individual's knowledge of recent incidents of neighborhood violent crime would be associated with higher stress, less physical activity, poorer cardiometabolic factors, including higher BMI and higher HbA1c.

2. Methods

2.1. Data and sample

2.1.1. Sample and study design

Data for this study were collected in 2010–2011 from a subset of participants of the Diabetes Study of Northern California (DISTANCE) cohort. DISTANCE is a large, ethnically-diverse cohort (n=20,188) of diabetic adults followed since 2005 by Kaiser Permanente Northern California (KPNC), a non-profit, integrated healthcare delivery system. A complete description of the DISTANCE study methods, cohort and survey has been published previously (Moffet et al., 2009).

The subsample excluded cohort members who had type I diabetes (n=990), those who completed a shortened DISTANCE survey at baseline (n=2229), non-English speakers (n=1238), residents living in tracts that were $\geq 80\%$ rural (n=262), members who had other, unknown, or missing race/ethnic information at the baseline DISTANCE survey (n=647), and those living in counties were 1 or more ethnic group had < 85 cohort members (n=4579). The remaining members (n=10,890) were eligible for the survey and 1500 were randomly selected to participate in a two day survey with oversampling of individuals who lived in a poorer food environment, defined as areas with a high kernel density score based on the presence of more fast food and conveniences stores than supermarkets and produce vendors (Jones-Smith et al., 2013). A total of 770 (out of 1500) respondents completed both days of the study survey, for a response rate of 57%. All study protocols were approved by UCSF and Kaiser Permanente Institutional Review Board Human Subjects Committee.

2.2. Study exposures

Perceived neighborhood safety measures were derived from seven survey questions about general neighborhood safety and awareness of the recent occurrence of specific violent crimes. Measures on neighborhood environment used in this study were validated in previous studies (Mujahid et al., 2007; Echeverria et al., 2004). To assess general neighborhood safety, participants were asked three questions, based on a five point Likert scale: if they felt their neighborhood was safe day or night, if violence was not a problem in their neighborhood, and if the neighborhood was safe from crime (Cronbach's alpha=0.78). Neighborhoods were considered to be safe if respondents “agreed” or “strongly agreed” that their neighborhoods were safe or free of violence and crime. Neighborhoods were considered unsafe if respondents “neither agreed nor disagreed”, “disagreed”, or “strongly disagreed” with any of these neighborhood safety questions.

Four questions based on a four point Likert scale asked whether specific violent crimes had occurred in the participant's neighborhood in the six months before the survey (Cronbach's alpha=0.83). Participants were asked how often there had been a fight which a weapon was used, gang fights, sexual assault or rape, and a robbery/ mugging in their neighborhood (responses: Often, Sometimes, Rarely, Never). Participants reporting that any of these crimes had occurred “often” or “sometimes” in their neighborhood were considered to live in a high crime neighborhood. Participants who reported that all these crimes occurred “rarely” or “never” occurred in their neighborhood were considered to live in a low crime neighborhood. Neighborhood's general safety and crime were treated as separate exposures for this analysis as they did not have a strong correlation and may capture separate facets of neighborhood safety (Pearson correlation=0.37 $p < 0.001$).

2.3. Study outcomes

Our study outcomes of interest included stress, physical activity, body mass index (BMI) and hemoglobin A1c (HbA1c). Stress, BMI, and HbA1c were considered as both continuous and dichotomous measures, while physical activity was analyzed as a dichotomous measure.

2.3.1. Perceived stress scale

Perceived stress was assessed using Cohen's 4-item Perceived Stress Scale (PSS-4 short version) asked over the past four weeks (Cohen et al., 1983). The PSS-4 is a self-reported five point scale (responses: never, almost never, sometimes, fairly often, very often) that asks how respondents view the stress of situations in one's life including how often respondents felt they were unable to control important things in their life or felt confident to handle personal problems. PSS-4 has been validated in ethnically diverse populations (Cohen et al., 1983; Warttig et al., 2013). For this study, we calculated the mean score for the PSS questions and dichotomized PSS into higher stress (mean PSS > 2) and lower stress (mean PSS ≤ 2).

2.3.2. Physical activity

Physical activity was measured using the International Physical Activity Questionnaire (IPAQ) short version that asks respondents about time spent walking and engaged in moderate, and vigorous physical activities (Craig et al., 2003) and assigns metabolic expenditures for physical activity. IPAQ cut points were used to create two categories: insufficient or sufficient physical activity.

2.3.3. BMI and hemoglobin A1c

Cardiometabolic clinical risk factors including body mass index (BMI, in kg/m^2) and glycosylated hemoglobin (HbA1c) were

Table 1
Sociodemographic characteristics and study outcomes.

Sociodemographic characteristics	Stress (n=704)			Physical activity (n=675)		BMI (n=644)		HbA1C (n=673)	
	Total study sample	High stress mean PSS > 2	p-Value*	Insufficient physical activity	p-Value*	Extreme obesity BMI > 35	p-Value*	HbA1C > 9%	p-Value*
All sample	721	42 (5.8%)		353 (49%)		199 (30.9%)		119 (17.7%)	
Mean age in years (SD)	63.2 (9.9)	60.5 (10)	0.08	64.1 (10.1)	**0.02**	59.7 (9.4)	< **0.000**	58.3 (8.8)	< **0.000**
Sex, n (%)									
Female	379 (52.6%)	30 (8.1%)	**0.01**	214 (60.8%)	< **0.000**	127 (37.6%)	< **0.000**	65 (18.6%)	0.53
Male	346 (47.4%)	12 (3.6%)		139 (43.0%)		72 (23.5%)		54 (16.7%)	
Race/ethnicity, n (%)									
White	165 (22.9%)	7 (4.3%)	0.55	79 (50%)	0.82	58 (38.7%)	< **0.000**	20 (12.7%)	**0.001**
African American	167 (23.2%)	10 (6.1%)		82 (52.6%)		63 (40.4%)		37 (23.6%)	
Latino	124 (17.2%)	8 (6.6%)		64 (56.6%)		33 (30.6%)		31 (27.2%)	
Asian	150 (20.8%)	7 (4.9%)		75 (53.2%)		10 (7.7%)		15 (10.8%)	
Other/missing	115 (16%)	10 (9%)		53 (49.5%)		35 (35%)		16 (15.1%)	
Education, n (%)									
≤ High School/GED/TS	377 (51.6%)	23 (6.3%)	0.71	201 (57.1%)	**0.009**	108 (31.8%)	0.62	70 (20.3%)	0.07
More than HS/GED/TS	344 (47.1%)	19 (5.6%)		152 (47.1%)		91 (29.9%)		49 (14.9%)	
% Poverty line, n (%)									
< 130%	62 (8.6%)	7 (12.7%)	**0.04**	39 (68.4%)	**0.002**	18 (33.3%)	0.44	15 (27.8%)	0.22
130– < 200%	70 (9.7%)	7 (10.1%)		29 (46.8%)		16 (26.7%)		12 (19.7%)	
200– < 400%	229 (31.8%)	15 (6.6%)		123 (56.7%)		63 (31.2%)		32 (14.8%)	
> 400%	265 (36.8%)	9 (3.4%)		113 (44.1%)		82 (33.7%)		47 (18.5%)	
Missing	95 (13.2%)	4 (4.6%)		49 (59%)		20 (23.5%)		13 (14.9%)	

* p-Values were calculated using chi-square tests of association for categorical sociodemographic characteristic and analysis of variance for continuous sociodemographic characteristics.

summarized using the mean of measures collected during outpatient visits during 2012 from the KPNC electronic medical record (EMR). HbA1c, a lab measure that is indicative of blood glucose control over approximately the previous three months, was analyzed in a central KPNC laboratory. BMI and HbA1c were examined as continuous and dichotomous measures. Diabetic populations have higher than average rates of obesity and extreme obesity and reducing weight for patients at higher BMI is vital for diabetes management. We created dichotomous measures for obesity class II–III (BMI > 35; "extreme obesity" hereafter) and poorly controlled HbA1c (HbA1c > 9%) to examine poor clinical control. A cutoff of 9% for HbA1c is a well-accepted clinical threshold to demarcate poor glycemic control in patients with diabetes and this cutoff has been previously utilized with our study population.

2.4. Covariates

Covariates for the analysis include age, sex, race/ethnicity, education, and income. Age and sex were collected from KPNC administrative data, while other covariates were collected from the survey. Race/ethnicity was categorized as African American, Asian, Latino, White non-Latino, and one category comprising other races or those missing race. The racial/ethnic groups included in the 'other' race/ethnic group included individuals who were Pacific Islander, Native American/American Indian, Inuit/Eskimo/Aleut, of Mixed Races, and those who specified Other as a race/ethnic group. We grouped these race/ethnic groups together due to small numbers within each category. Socioeconomic indicators included self-reported education (defined as high school degree, GED, trade school or less or more than high school, GED, trade school), and household income. We defined household income as self-reported family income divided by the poverty line income for a given age and household size based on the US Department of Health and Human Services 2010 Poverty Guidelines. We categorized household income into four categories (< 130%, 130– < 200%, 200– < 400%, > 400% of the poverty line income). A missing indicator was included for the 13.2% respondents who chose not to report their income.

2.5. Statistical analysis

We assessed associations between perceived neighborhood safety and awareness of neighborhood violent crimes by patient sociodemographic factors and cardiometabolic outcomes using Chi-square tests and one-way analysis of variance tests for categorical and continuous measures of our exposures, respectively. We used Pearson correlations to examine associations between continuous sociodemographic characteristics and outcomes.

Linear and logistic regression using generalized linear models (GLM) using main effect terms, robust standard errors, and accounting for clustering (using Huber/White sandwich estimator) at the census block group level were used to examine unadjusted and adjusted associations between perceived crime and our outcomes measured continuously and categorically (McCullagh and Nelder, 1983). In addition, Modified Poisson and GLM was used to model the prevalence ratios for dichotomous outcomes that were common (i.e. extreme obesity and physical activity) in our population (> 20%) (Zou, 2004; Yelland et al., 2011). Age was centered in our models. In our sensitivity analysis we assessed how oversampling within poorer food environments may influence findings using a complete case analysis and testing for interactions. All analyses were performed using STATA/SE 13.1.

3. Results

Among our sample of 770 respondents, 39 (4.8%) people had missing values for both neighborhood safety and violent crime responses, 9 people had missing education, and 1 person was missing all outcomes, leaving a final analytic sample of 721 individuals. As not all respondents answered questions or had lab measurements for study outcomes, sample size varied by outcome (Table 1).

In the analytic sample, the mean age was 63.2 (SD=9.9), 52.6% were female and 22.9% were white, 23.3% African American, 17.2% Latino, 20.8% Asian, and 16% were those with another race/ethnicity or unknown race/ethnicity. Forty two participants (5.8%) had high stress, 353 (49%) had insufficient physical activity, 119 (17.7%)

had poorly controlled HbA1c, and 199 (30.9%) people were extremely obese (BMI > 35). In our study, 385 (54.3%) respondents reported at least one general neighborhood safety concern and 110 (16.1%) were aware of at least one incidence of violent crime in their neighborhood.

High stress was associated with female sex (8.1% vs. 3.6% for males) and low-income (12.7% with lowest income vs 3.4% with highest income). Insufficient physical activity was associated with female sex, (60.8% vs. 43% of males), less education (57.1% with ≤ high school, 47.1% > high school), and low-income (68.4% lowest income vs. 44.1% highest income). Extreme obesity (BMI > 35) was associated with younger age (mean:59.7) compared to those below extreme obesity (mean age:65.3), and more common in females (37.6% vs. 24% in males). Differences were also seen in extreme obesity associations by race/ethnicity; Whites (39%), African-Americans (40%), Latinos (31%), Asians (8%), and all other or unknown race/ethnicities (35%). Poorly controlled HbA1c was associated with only age ($p < 0.000$) and race/ethnicity (12.7% of Whites, 23.6% of African-Americans, 27.2% of Latinos, 10.8% of Asians, and 15.1% of all other or unknown race). Sociodemographic characteristics and continuous measures of stress, BMI, and HbA1c revealed the same trends as categorized measures of the outcomes (not shown).

Reporting low general neighborhood safety was more common for women (61.5%) than men (46.5%) and among certain race/ethnic groups such as African-Americans (64.6%) and other race/ethnicity (61.4%) compared to Asians (37%) (Table 2). Those who had lower education indicated higher neighborhood crime (19.3%) compared to those with higher education (12.5%).

3.1. Multivariate results

We specified multivariate logistic regression models of dichotomous measures of stress, physical activity, BMI, and HbA1c in relation to any neighborhood safety concern and report of any violent crime (Table 3). Neighborhood general safety was not significantly associated with extreme obesity in our model (OR: 1.24, 95% CI.97–1.59, p = .09). High neighborhood crime was associated with an increased odds of having extreme obesity (OR: 1.34, 95% CI 1.02–1.75) after adjusting for age, gender, race/ethnicity, income, and education. There was no association between having higher neighborhood safety reports or crime with dichotomous measures of stress, physical activity, and Hba1c.

Unlike our categorical analysis of BMI, the analysis using continuous BMI found significant associations with both neighborhood safety and crime in our models (Table 3). Participants' perception of having an unsafe neighborhood and reports of high crime was associated with a 1.14 unit higher (95% CI: 0.04–2.24) and 2.04 unit higher BMI (95%CI: 0.34–3.73) respectively, compared to participants not reporting living in an unsafe neighborhood, independent of age, gender, race/ethnicity, income, and education. There was no association between safety and continuous stress or HbA1c. In sensitivity analysis, respondents living in poor food environments had higher increases in mean BMI and higher increases in extreme obesity when they perceived poor neighborhood safety and violent crime than respondents living in better food environments.

There was no association between neighborhood general safety or crime and measures of stress, HbA1c, and dichotomous physical activity. We did not have sufficient power to test interactions between race and perceived crime.

4. Discussion

In our study of patients with diabetes we examined whether two measures of perceived neighborhood safety, general neighborhood safety and neighborhood crime, were related to cardiometabolic risk factors including stress, physical activity, BMI, and HbA1c. We found that high neighborhood violent crime was associated with extreme obesity (BMI > 35) independent of age, sex, race/ethnicity, income, and education. We also found associations between both neighborhood safety and violent crime and BMI measured continuously. For example, an average male of height of 5′11″ living in a high crime neighborhood would be 14 pounds heavier than a male living in low crime neighborhood. There were no associations with the other study outcomes of stress, physical activity, and HbA1c.

This study is one of few studies examining neighborhood safety and cardiometabolic risk factors among a racially and ethnically

Table 2
Sociodemographic characteristics and study exposures, perceived general neighborhood safety and violent crime.

Sociodemographic characteristics	**Neighborhood general safety n = 709**			**Neighborhood violent crime n = 683**		
	Safe neighborhood (45.7%)	**Unsafe neighborhood** (54.3%)	**p-Value***	**Low violent crime** (83.9%)	**High violent crime** (16.1%)	**p-Value***
Mean age in years (SD)	63.2 (10.2)	63 (9.7)	0.769	63.5 (9.9)	62.6 (10)	0.369
Sex, n (%)						
Female	143 (38.5%)	228 (61.5%)	< **0.000**	294 (82.6%)	62 (17.4%)	0.331
Male	181 (53.6%)	157 (46.5%)		279 (85.3%)	48 (14.7%)	
Race/ethnicity, n (%)						
White	80 (49.4%)	82 (50.6%)	< **0.000**	136 (86.1%)	22 (13.9%)	0. 257
African American	58 (35.3%)	106 (64.6%)		133 (84.7%)	24 (15.3%)	
Latino	50 (41.0%)	72 (59.0%)		93 (78.2%)	26 (21.9%)	
Asian	92 (62.6%)	55 (37.4%)		124 (87.3%)	18 (12.7%)	
Other/missing race	44 (38.6%)	70 (61.4%)		87 (81.3%)	20 (18.7%)	
Education, n (%)						
≤ High School/GED/TS	159 (43.1%)	210 (56.9%)	0.146	293 (80.7%)	70 (19.3%)	**0.016**
More than HS/GED/TS	165 (48.5%)	175 (51.5%)		280 (87.5%)	40 (12.5%)	
% Poverty line, n (%)						
< 130%	21 (35%)	39 (65%)	0.282	48 (78.7%)	13 (21.3%)	0.374
130– < 200%	34 (50%)	34 (50%)		56 (83.6%)	11 (16.4%)	
200– < 400%	97 (43.7%)	125 (56.3%)		175 (82.6%)	37 (17.5%)	
> 400%	130 (49.2%)	134 (55.8%)		211 (84.1%)	40 (15.9%)	
Missing	42 (44.2%)	53 (55.8%)		83 (90.2%)	9 (9.8%)	

* p-Values were calculated using chi-square tests of association for categorical sociodemographic characteristic and analysis of variance for continuous sociodemographic characteristics.

Table 3
Associations from adjusted clustered multivariate regression of stress, physical activity, BMI, and HbA1c by perceived general neighborhood safety or neighborhood violent crime.

Dichotomized outcomes	**High stress (n=704)**		**Insufficient physical activity (n=675)**		**Extremely overweight (BMI > 35) (n=644)**		**Uncontrolled HbA1c (HbA1c > 9%) (n=673)**	
	OR 95%CI	p-Value	PR 95%CI	p-Value	PR 95%CI	p-Value	OR 95%CI	p-Value
Unsafe neighborhood [a]	1.10 [0.50–2.43]	0.82	0.94 [0.79–1.10]	0.42	1.24 [0.97–1.59]	0.09	0.80 [0.49–1.30]	0.37
High neighborhood violent crime[b]	2.04 [0.83–4.98]	0.12	0.91 [0.73–1.15]	0.43	1.34 [1.02–1.75]	**0.03**	0.83 [0.43–1.59]	0.57
Continuous outcomes	**Stress**		**Physical activity**		**BMI**		**HbA1c**	
	β 95%CI	p-value	N/A[c]	N/A	p-Value	β 95%CI	p-Value	β 95%CI
Unsafe neighborhood[a]	0.05 [−0.07, 0.17]	0.45	n/a	n/a	1.14 [0.04, 2.24]	**0.04**	−0.08 [−0.32, 0.17]	0.53
High neighborhood Violent crime[b]	0.13 [−0.03, 0.29]	0.12	n/a	n/a	2.04 [0.34, 3.73]	**0.02**	−0.02 [−0.35, 0.32]	0.93

Models adjusted for age, sex, race/ethnicity, household income, and education.

[a] Neighborhood Safety – general neighborhood safety: unsafe, if participants disagreed or strongly disagreed with any question regarding whether their neighborhood was safe day or night, if violence was not a problem in their neighborhood, and if the neighborhood was safe from crime. Safe if participants agreed, strongly agreed or neither agreed or disagreed to all questions.

[b] Neighborhood Violent Crime – neighborhood violent crime: high crime if participants reported often/sometimes to any question asking whether there had often or sometimes been a fight which a weapon was used, gang fights, sexual assault or rape, and a robbery/mugging in their neighborhood. Low violent crime if participants reported rarely or never to all questions.

[c] Physical Activity scale (IPAQ) is not used as a continuous measure.

diverse urban group of diabetes patients. We found that neighborhood safety was associated with BMI and specifically with obesity (BMI over 35) which, among patients with diabetes is associated with increase morbidity (Eeg-Olofsson et al., 2009). While crime has been examined in a set of neighborhood problems, we were able to demonstrate an independent effect of neighborhood safety on BMI (Gary et al., 2008; Moreno et al., 2014). Our findings are consistent with other studies that found associations between composite measures of neighborhood problems and BMI but not with HbA1c in patients with diabetes. Moreno et al. found that reporting higher number of neighborhood problems was associated with higher BMI in a population of low-income rural Latinos with diabetes (Moreno et al., 2014). This study cited crime as the most common neighborhood problem of the composite. Gary et al. (2008) did not find an association between higher neighborhood problems and HbA1c but in contrast with our study, the authors found a clinically small but significant association with decreased physical activity. No other studies have found associations between two distinct measure of neighborhood safety and violence with BMI.

Our study also examined different measurements of perceived neighborhood safety. Our measure of general neighborhood safety asked how safe neighborhoods were day and night, and how much neighborhood violence and crime was a problem while a second measure asked about the occurrence of certain violent crimes in the last six months. These measures may examine distinct exposures of poor neighborhood safety as correlations between these measures was low (Pearson correlation$=0.37$ $p<0.001$). Living in neighborhoods with high violent crime, for example, may reflect acute stressor(s) within neighborhoods while concerns about general neighborhood safety may be a chronic stressor over time. Studies of stress have identified that both acute and chronic stressors may affect development differently and our neighborhood safety measures may capture nuances of residential safety that could affect health behaviors and health risk factors distinctly. Our study did not find any association between neighborhood safety and physical activity, stress, and HbA1c. The fact that we found no association is important because patients with diabetes in this study's managed care plan may have increased access to medications, care, or resources that may minimize poor neighborhood safety effects on stress, physical activity, and HbA1c levels. In addition, the physical activity measure used in our study could not be used to differentiate leisure versus transport related physical activity. One study found that murders in a neighborhood were associated to transport related, but not leisure related walking in a general population (Kerr et al., 2015).

Several limitations should be noted. First, this was a cross-sectional survey study and findings should be interpreted appropriately. Only 15% of individuals reported high violent crime in the neighborhood which limits statistical power to detect differences in uncommon exposures, especially in multivariate models. In addition, due to small numbers, we were unable to generate an aggregate measure of perceived neighborhood crime, which can result in a more reliable measure of a neighborhood feature and reduce same-source bias. While the measure we used was validated based on aggregating participants' responses within neighborhoods, self-reported measures may or may not reflect actual or objective crime or safety concerns (Mujahid et al., 2007). Even if self-reports of safety are inaccurate, however, perceptions may nonetheless serve to influence behavior and physiology (Loukaitou-Sideris, 2006; Browning and Cagney, 2002). One study found that while perceived measures were not closely associated with objective measures of crime, they were independent predictors of physical activity (McGinn et al., 2008). In this study, stress and physical activity were gathered from self-report and susceptible to same source bias, however, BMI and HbA1c measures were gathered from EMR. Future studies with this cohort will examine any relationships between neighborhood safety/crime relationship and changes in BMI and/or HbA1c.

Finally, while we controlled for several sociodemographic variables in our study, we cannot rule out residual confounding. In studies involving neighborhood exposures, controlling for all individual characteristics that account for self-selection to neighborhoods may not be possible; therefore, we are unable to distinguish whether the positive findings we identified were attributable to who moves into neighborhoods with exposure to perceived crime versus the perceived crime exposure causing changes in these health outcomes. We were unable to control for medications that can increase or decrease weight and 13% of our sample was missing income which may be an important confounder to our findings. Our current study was a non-random sample, selected from an existing survey follow-up study of diabetes patients; all subjects in our study had responded to the original cohort study survey and a second sub-study survey. While participants were sampled from the larger cohort study, non-English speaking and people living in rural areas were excluded and people from poorer food environments were oversampled limiting our generalizability and external validity of our findings to the larger cohort or other similar populations.

Despite these limitations, this study adds to the literature examining area-based risk factors for health. We found an association between unsafe neighborhoods and increased BMI and obesity, but detected no relationships for stress, physical activity, and glycemic control (HbA1c). More study is needed to identify the mechanisms that may explain the observed crime-obesity relationship and whether those mechanisms are modifiable, or whether the relationship was secondary or artifactual. Nationally, the prevalence of diabetes is growing and identifying modifiable environmental influences have policy implications.

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