

Association Between Perceived Neighborhood Characteristics and Carotid Artery Intima-Media Thickness

Cross-Sectional Results From the ELSA-Brasil Study



Clarissa Willets*, Itamar S. Santos[†], Paulo A. Lotufo[†], Isabela M. Benseñor[†], Claudia K. Suemoto^{†,‡}

São Paulo, São Paulo, Brazil

ABSTRACT

Background: Living in a neighborhood with a low socioeconomic context may increase the risk of coronary heart disease. However, few studies have explored the impact of neighborhood characteristics on subclinical atherosclerosis, and their role as a risk factor for cardiovascular disease has not yet been studied in poor countries.

Objectives: This study aimed to investigate the association between perceived neighborhood characteristics and subclinical atherosclerosis in a large sample of adults, using cross-sectional data from the ELSA-Brasil (Brazilian Longitudinal Study of Adult Health).

Methods: Participants free of clinical coronary artery disease answered a questionnaire designed to assess their perceptions regarding 6 neighborhood dimensions: social cohesion, walkability, availability of healthy food, safety, witnessed violence, and personal victimization. The scores of each domain were used as independent variables. Common carotid intima-media thickness (CCIMT) was used as a dependent variable. Then linear regression models, adjusted by demographic, socioeconomic, and cardiovascular factors, were used.

Results: A total of 9,923 adults (mean age = 51.5 ± 8.9 years, 44% male, 55% white) were examined. In the univariate analysis, better walkability ($\beta = -0.62$, 95% confidence interval [CI]: -1.01 to -0.23; $p = 0.002$) and low witnessed violence ($\beta = -1.95$; 95% CI: -2.96 to -0.94; $p < 0.0001$) were associated with lower CCIMT, whereas low personal victimization was associated with higher CCIMT ($\beta = 10.70$; 95% CI: 4.55 to 16.85; $p = 0.001$). A borderline interaction between neighborhood domain and sex was found. Better social cohesion may be associated with larger CCIMT among women, whereas better safety was associated with lower CCIMT among men. Multiple imputation for missing CCIMT data showed similar results.

Conclusions: The perception of living in a more walkable environment and in a neighborhood where people witness fewer violent episodes can provide protection on the early phases of the atherosclerosis process. Less stress and the practice of physical activity may explain the protection.

Atherosclerosis is a central phenomenon in the pathogenesis of cardiovascular disease (CVD), which continues to be the leading cause of death and a major source of health disparities worldwide [1]. Carotid artery intima-media thickness (CMT) is a noninvasive biomarker of subclinical atherosclerosis and presents a positive association with the risk of cardiovascular events, independent of all major risk factors [2]. However, a significant proportion of CMT variance is not explained by traditional demographic and cardiovascular risk factors, which highlights the need to study novel risk factors [3].

Growing evidence suggests that a neighborhood's socioeconomic context, such as a lack of resources for physical activity, violence, and low social interactions may influence the risk of CVD [4–7]. Rose [8] highlighted the

advantages of the “population strategy” regarding disease prevention. It attempts to control the determinants of disease, lower the mean level of risk factors, and shift the whole distribution of exposure in a favorable direction. It has the potential to truly remove the underlying causes of disease and has large potential for the population as a whole (and not only for individuals at high risk), whereas in the “high risk strategy,” the efforts lead to temporary results in high-risk people, as presumably in every generation there will be susceptible individuals and the approach would need to be sustained year after year. Understanding contextual risk factors help public health professional work based on the population strategy.

Few studies have explored the impact of neighborhoods on subclinical atherosclerosis [5,9]. In the MESA

The authors report no relationships that could be construed as a conflict of interest.

This work was supported by the Brazilian Ministry of Health and National Council for Scientific and Technological Development (grants n 01060010.00RS, 01060212.00BA, 01060300.00ES, 01060278.00MG, 01060115.00SP, 01060071.00RJ).

Supplementary data associated with this article can be found, in the online version, at <https://doi.org/10.1016/j.jheart.2019.09.002>.

From the *Center for Clinical and Epidemiological Research, University of São Paulo, São Paulo, São Paulo, Brazil; †Center for Clinical and Epidemiological Research, University of São Paulo, São Paulo, São Paulo, Brazil; and the ‡Division of Geriatrics, University of São Paulo Medical School, São Paulo, São Paulo, Brazil. Correspondence: C. K. Suemoto (cksuemoto@usp.br).

GLOBAL HEART
© 2019 World Heart Federation (Geneva). Published by Elsevier Ltd. All rights reserved.
VOL. 14, NO. 4, 2019
ISSN 2211-8160/\$36.00.
<https://doi.org/10.1016/j.jheart.2019.09.002>

(Multi-Ethnic Study of Atherosclerosis), Lemelin et al. [10] investigated the association of atherosclerosis with neighborhood socioeconomic position. Carotid atherosclerosis was patterned by exposure to neighborhood poverty in women, even after adjusting for race, childhood, and adulthood socioeconomic position [10]. Community disadvantage was associated with greater CIMT; plaque occurrence; and a poorer profile of hypertension, body mass index (BMI), smoking, and diabetes [11]. Most neighborhood studies to date investigate only 1 or 2 domains at the same time [12,13], and the role of neighborhood characteristics as a risk factor for subclinical CVD has not yet been studied in low-middle income countries [9,11,14,15].

The present study examines the association between subclinical atherosclerosis, measured by CIMT, and perceived neighborhood characteristics (PNC) at the baseline of the ELSA-Brasil (Brazilian Longitudinal Study of Adult Health).

METHODS

Participants

A detailed description of the ELSA-Brasil study can be found elsewhere [16]. Briefly, ELSA-Brasil is a cohort study of 15,105 civil servants, 35 to 74 years of age at enrollment (2008 to 2010), from 6 state capitals in Brazil (Belo Horizonte, Porto Alegre, Rio de Janeiro, Salvador, São Paulo, and Vitória). The baseline interview collected information about sociodemographics, clinical history, occupational exposure, family history of diseases, access to health care, lifestyle factors, mental health, anthropometrics, and laboratory and imaging measurements. All individuals signed an informed consent form, and the local institutional review boards approved the study.

For this cross-sectional analysis, we used data from the baseline examination. We excluded participants who reported coronary artery disease or stroke. We also excluded participants with incomplete data on neighborhood questionnaire or covariates. Finally, we excluded people who did not have an evaluation of common carotid intima-media thickness (CCIMT) (Figure 1). For the multiple imputation analysis, the participants with missing values for carotid ultrasound evaluation were not excluded (Online Figure 1).

Assessment of subclinical atherosclerosis

Of the total cohort, 13,205 of the study participants (87.4%) underwent CIMT evaluation for both common carotid arteries (CCA). The losses in image acquisitions were mainly due to local availability to perform the exam in the same day of the other baseline procedures. All study centers used a Toshiba ultrasound machine (Aplio XGTM; Toshiba Corp., Tokyo, Japan) with a 7.5-MHz linear transducer to measure CIMT in the outer walls of both left and right CCA, within an area of 1 cm in length, 1 cm below the carotid bifurcation, during 3 complete cardiac

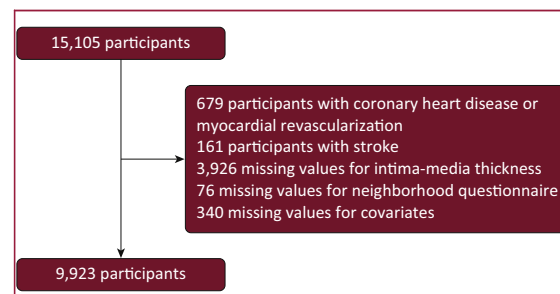


FIGURE 1. Flowchart of study participants.

cycles. The images acquired were sent to a centralized reading center in São Paulo. Only participants with high-quality images were included. The criteria for a valid image were clear visualization of both left and right CCA and their anatomic references, identification of the interfaces between the lumen and the far vessel wall, and identification of the interfaces between the media and the adventitia layers of the far vessel wall [17]. We used the MIA software (Mia-Software, Paris, France) to standardize the readings and interpretation of the carotid images. The maximal measure between the left and right CCA was considered the dependent variable for this study. From the 13,205 participants with CIMT evaluation for both CCA, 10,943 (82.9%) had high-quality valid CIMT measurements for both CCA. The complete protocol for the CCIMT measurement can be found elsewhere [18]. For this study, we present the results of the measurement in micrometers.

Assessment of perceived neighborhood characteristics

A structured questionnaire to access the participants' perceptions regarding the characteristics of their neighborhood was applied in ELSA-Brasil [19]. Based on prior studies [20–22], 6 neighborhood dimensions were evaluated: social cohesion; walkability; availability of healthy food; safety; witnessed violence; and personal victimization (Online Table 1). These aspects of the neighborhood environment were conceptually linked to a higher risk of CVD [23]. The validity and transcultural adaptation of the neighborhood questionnaire for Brazilian reality was performed with good reproducibility and consistency (Cronbach α = between 0.60 and 0.84) [24].

For social cohesion, walkability, availability of healthy food, and safety domains, a Likert scale was used for each question, with responses ranging from 1 to 5 (1 = strongly agree; 2 = agree; 3 = neither agree nor disagree; 4 = disagree; and 5 = strongly disagree). Some of the scores were reverse-coded so that high scores represented better neighborhood perception. The scores for each domain varied depending on how many questions the domain had (Table 1). For the witnessed violence domain, a frequency score varying from 1 (frequently) to 4 (never) was applied. Personal victimization was evaluated by a single question,

TABLE 1. Perceived neighborhood characteristics (N = 9,923)

Neighborhood Domain	Questions in Domain	Response Types	Domain Value Range	
Social cohesion	5	Likert 1–5	5–25	117.2 ± 3.6
Walkability	9	Likert 1–5	9–45	32.9 ± 7.3
Availability of healthy food	4	Likert 1–5	4–20	15 ± 2.7
Safety	3	Likert 1–5	3–15	9.5 ± 3.1
Low witnessed violence	5	Frequency scale 1–4	5–20	17 (15–19)*
Low personal victimization	1	Binary	Yes or no	67.7

Values are n, mean ± SD, median (interquartile range), or %.
 IQR, interquartile range.
 *Not normal distribution.

with a “yes or no” possible response, asking the participants whether they, or a member of their household, had ever been subjected to violence in the neighborhood (Online Table 1).

Other variables

We evaluated possible confounders on the association between PNC and CCIMT: age; sex; education (high school

or less vs. college); race (white, brown, black, other); monthly income (categorized in tertiles); hypertension (previous use of antihypertensive drugs, systolic blood pressure ≥140 mm Hg, or diastolic blood pressure ≥90 mm Hg); diabetes (defined by medical diagnosis, use of oral hypoglycemic drugs or insulin, fasting plasma glucose ≥126 mg/dl, 2-h post-prandial 75-g glucose test ≥200 mg/dl, or glycosylated hemoglobin ≥6.5%);

TABLE 2. Association between CCIMT* with demographic and clinical variables adjusted for age and sex (N = 9,923)

		β (95% CI)*
Age, yrs	51.5 ± 8.9	8.54 (8.22 to 8.86)
Male	44	45.79 (39.34 to 52.24)
Race		
White	55.8	0 (Ref.)
Brown	25.4	17.17 (10.42 to 23.91)
Black	15.1	50.81 (42.66 to 58.97)
Other	3.80	7.75 (–7.12 to 22.62)
Education		
High school or less	47.5	0 (Ref.)
College or more	53.5	–34.10 (–39.74 to –28.47)
Monthly income in US\$		
<968.2	37	0 (Ref.)
968.2–1,971	33.7	–20.23 (–26.94 to –13.51)
>2,074.5	29.3	–31.27 (–38.39 to –24.52)
Hypertension	32	73.19 (66.00 to 79.38)
Diabetes	18	54.32 (46.84 to 61.80)
Dyslipidemia		
LDL	131.3 ± 34.2	0.42 (0.34 to 0.50)
HDL	57.2 ± 14.7	–1.32 (–1.53 to –1.12)
Alcohol abuse [†]	6.9	16.05 (4.76 to 27.33)
Smoking		
Never	57.5	0 (Ref.)
Former	29.3	16.88 (10.34 to 23.41)
Current	13.2	30.99 (22.36 to 39.61)
Physically active	23.3	–14.6 (–22.31 to –8.89)
BMI, kg/m ²	26.8 ± 4.6	8.34 (7.75 to 8.94)

Values are mean ± SD or %. Simple linear regression model. BMI, body mass index; CCIMT, common carotid intima-thickness; CI, confidence interval; HDL, high-density lipoprotein; LDL, low-density lipoprotein.

*Expressed in micrometers.

[†]Men ≥210 g/alcohol/week; women ≥140 g/alcohol/week.

low-density lipoprotein cholesterol level; high-density lipoprotein cholesterol level; excessive alcohol intake (men ≥ 210 g alcohol per week; women ≥ 140 g alcohol per week); smoking (classified as current smoker, past smoker, or never smoker); leisure time physical activity (mild, moderate, or vigorous); and measured BMI (calculated by dividing the weight in kilograms by the square of the height in meters). We also considered how many years each participant had lived in the neighborhood.

Statistical analysis

The dependent variable CCIMT was used as a continuous variable. The main independent variable was each domain score of the neighborhood questionnaire. We described the association of CCIMT with the scores in each neighborhood domain, using linear regression models following a hierarchical approach. First, we adjusted the linear models for age, sex, and years of residence. Second, we added income, education, and race to the models. Finally, we further adjusted the models to the cardiovascular risk factors (hypertension, diabetes, dyslipidemia, smoking, alcohol abuse, physical activity, and BMI). We also performed a stratified analysis by years of residence, using the 25th percentile as the cutoff (5 years of residence). In addition, we tested for interactions between sex and each neighborhood domain based on previous evidence that this association may be different between men and women [10,14,15]. Finally, we tried to minimize a possible impact of missing data for CCIMT by using multiple imputation, which has been shown to provide more accurate estimates of associations than other methods of handling missing data [25]. The statistical analyses were performed in Stata version 15 (StataCorp LP, College Station, TX). We used the *mi* command to generate the imputed data [26]. All tests were 2-tailed, and the α level was set at 5%.

RESULTS

Among 15,105 ELSA-Brasil participants, 9,923 met the criteria for this study (Figure 1). The mean age of the sample was 51.5 ± 8.9 years, 44% were male, 55% were white, and 53% had at least college education (Table 2). The participants' mean scores in each domain are presented in Table 1.

In the analysis adjusted for age, sex, and years of residence, better walkability ($\beta = -0.62$; 95% confidence interval [CI]: -1.01 to -0.23 ; $p = 0.002$) and low witnessed violence ($\beta = -1.95$; 95% CI: -2.96 to -0.94 ; $p < 0.0001$) were associated with lower CCIMT (Table 3). On the other hand, low personal victimization was associated with higher CCIMT ($\beta = 10.70$; 95% CI: 4.55 to 16.85 ; $p = 0.001$). When race and socioeconomic factors were added to the model, only low personal victimization showed a borderline association with higher CCIMT ($\beta = 6.12$; 95% CI: -0.01 to 12.24 ; $p = 0.05$). When we adjusted the model further for cardiovascular risk factors, no association was found between PNC and CCIMT.

Among participants living in the neighborhood for more than 5 years, better walkability and low witnessed violence were associated with lower CCIMT, whereas low personal victimization showed an association with higher CCIMT in the analysis adjusted for age and sex (Table 4). When race and socioeconomic variables were added, only walkability was associated with lower CCIMT among those who had lived in the neighborhood for more than 5 years. Among those who had lived in the neighborhood for 5 years or less, only low witnessed violence showed a negative association with CCIMT. No association remained significant when cardiovascular risk factors were added, both in those who had lived less or more than 5 years in the neighborhood. We also included interaction terms of each neighborhood domain with sex (Table 5). We found a borderline interaction of sex with social cohesion (p value for the interaction = 0.06), and safety ($p = 0.08$). Better social cohesion may be associated with larger CCIMT among women, and a better safety was associated with lower CCIMT among men. The interaction term between sex and social cohesion ($p = 0.06$) suggests a stronger association among women. However, we probably did not have enough power to demonstrate that this association is significant among women in the stratified analyses ($p = 0.085$).

When we imputed CCIMT data using multiple imputations, better walkability ($\beta = -0.46$; 95% CI: -0.85 to -0.06 ; $p = 0.024$) and low witnessed violence ($\beta = -1.52$; 95% CI: -2.50 to -0.55 ; $p = 0.002$) were associated with lower CCIMT in the analysis adjusted for age, sex, and years of residence in the neighborhood (Online Tables 2 and 3). On the other hand, low personal victimization was associated with higher CCIMT ($\beta = 7.78$; 95% CI: 2.09 to 13.46 ; $p = 0.007$). When we adjusted for race, socioeconomic factors, and cardiovascular risk factors, no association was found between PNC and CCIMT.

DISCUSSION

In a large sample of Brazilian middle-aged adults, CCIMT was negatively associated with perception of good walkability and low witnessed violence, and positively correlated with perception of low personal victimization in the analyses adjusted for demographic variables. These associations were no longer significant after adjusting for race, individual socioeconomic factors, and cardiovascular risk factors. The stratified analyses by years of residency confirmed these results among participants living in the neighborhood for 5 years or more. A multiple imputation model for missing CCIMT data reinforced the same findings.

Walkability and low witnessed violence: Associated with lower CCIMT

We found evidence of association of better walkability and low witnessed violence with lower CCIMT, meaning that the perception of living in a more walkable environment

TABLE 3. Coefficients and 95% CI for CCIMT,* according to PNC (N = 9,923)

	Social Cohesion	Walkability	Availability of Healthy Food	Safety	Low Witnessed Violence	Low Personal Victimization
Crude						
β (95% CI)	0.97 (0.08 to 1.86)	0.28 (−0.15 to 0.72)	3.04 (1.87 to 4.21)	1.80 (0.78 to 2.8)	0.83 (−0.31 to 1.97)	8.36 (1.46 to 15.26)
Model 1						
β (95% CI)	−0.65 (−1.44 to 0.14)	−0.62 (−1.01 to −0.23)	0.27 (−0.74 to 1.32)	−0.13 (−1.02 to 0.76)	−1.95 (−2.96 to −0.94)	10.70 (4.55 to 16.85)
Model 2						
β (95% CI)	−0.09 (−0.87 to 0.70)	−0.26 (−0.65 to 0.13)	0.62 (−0.40 to 1.64)	−0.35 (−1.23 to 0.54)	−0.96 (−1.97 to 0.06)	6.12 (−0.01 to 12.24)
Model 3						
β (95% CI)	0.17 (−0.57 to 0.91)	−0.09 (−0.46 to 0.28)	0.66 (−0.31 to 1.62)	−0.62 (−1.46 to 0.22)	−0.54 (−1.50 to 0.42)	3.02 (−2.67 to 8.71)

Model 1: Linear regression model, adjusted for age, sex, and years of residence. Model 2: Linear regression model, adjusted for age, sex, race, income, education, and years of residence. Model 3: Linear regression model, adjusted for age, sex, race, income, education, hypertension, diabetes, dyslipidemia, smoking, alcohol use, physical activity, BMI, and years of residence. PNC, perceived neighborhood characteristics; other abbreviations as in [Tables 1 and 2](#).

*Expressed in micrometers.

and in a neighborhood where people witness fewer episodes of fights, violent arguments, assaults, rapes, or robberies can provide protection on early phases of the atherosclerosis process. In prior study, perceived walkability was independently associated with the practice of physical activity, which may explain the protection role of this domain [12]. The perception of living in a neighborhood with low rates of these violent episodes may as well

stimulate healthy behaviors such as exercising and may reduce stress.

Social cohesion, healthy food, and safety: No association found

We hypothesized that a favorable perception of social cohesion in the community would bring protection against high

TABLE 4. Coefficients and 95% CI for CCIMT,* according to PNC, stratified by years of residence (N = 9,923)

	Model 1 β (95% CI)	Model 2 β (95% CI)	Model 3 β (95% CI)
Social cohesion			
<5	−0.65 (−2.12 to 0.83)	−0.15 (−1.63 to 1.32)	0.23 (−1.18 to 1.63)
>5	−0.64 (−1.57 to 0.28)	−0.04 (−0.97 to 0.88)	0.14 (−0.75 to 1.01)
Walkability			
<5	0.24 (−0.47 to 0.95)	0.57 (−0.15 to 1.28)	0.76 (0.07 to 1.44)
>5	−1.00 (−1.46 to −0.54)	−0.59 (−1.05 to −0.12)	−0.40 (−0.84 to 0.03)
Availability of healthy food			
<5	−0.67 (−2.53 to 1.19)	−0.44 (−2.28 to 1.41)	−0.18 (−1.93 to 1.58)
>5	0.62 (−0.61 to 1.85)	1.05 (−0.17 to 2.27)	0.96 (−0.19 to 1.12)
Sense of safety			
<5	−0.56 (−2.22 to 1.10)	−0.52 (−2.17 to 1.13)	−0.89 (−2.46 to 0.67)
>5	−0.03 (−1.09 to 1.02)	−0.34 (−1.39 to 0.70)	−0.57 (−1.56 to 0.42)
Low witnessed violence			
<5	−3.05 (−4.99 to −1.12)	−2.19 (−4.15 to −0.24)	−1.36 (−3.23 to 0.50)
>5	−1.80 (−2.98 to −0.62)	−0.66 (−1.85 to 0.52)	−0.33 (−1.45 to 0.79)
Low personal victimization			
<5	−1.26 (−15.11 to 12.58)	−1.57 (−15.35 to 12.21)	−4.27 (−17.38 to 8.85)
>5	11.08 (4.16 to 17.99)	5.97 (−0.92 to 12.85)	3.91 (−2.60 to 10.42)

Model 1: Linear regression model, adjusted for age and sex. Model 2: Linear regression model, adjusted for age, sex, race, income, and education. Model 3: Linear regression model, adjusted for age, sex, race, income, education, hypertension, diabetes, dyslipidemia, smoking, alcohol use, physical activity, and BMI. Abbreviations as in [Tables 1 to 3](#).

*Expressed in micrometers.

TABLE 5. Coefficients and 95% CI for CCIMT,* according to PNC, stratified by sex (N = 9,923)

	Men	Women	<i>p</i> Value for Interaction
	β (95% CI)	β (95% CI)	
Social cohesion	−0.70 (−1.95 to 0.55)	0.79 (−0.11 to 1.68)	0.057
Walkability	0.09 (−0.54 to 0.72)	−0.20 (−0.64 to 0.25)	0.487
Availability of healthy food	−0.33 (−2.00 to 1.33)	1.28 (0.13 to 2.43)	0.179
Safety	−1.57 (−2.97 to −0.16)	0.14 (−0.88 to 1.15)	0.076
Low witnessed violence	−0.64 (−2.24 to 0.96)	−0.48 (−1.65 to 0.69)	0.844
Low personal victimization	3.34 (−6.47 to 13.15)	4.08 (−2.93 to 11.09)	0.770

The *p* value for the interaction between each neighborhood domain and sex on the association between each domain and CCIMT. Linear regression model adjusted for age, race, income, education, hypertension, diabetes, dyslipidemia, smoking, alcohol abuse, physical activity, BMI, and years of residence. Abbreviations as in [Tables 1 to 3](#).

*Expressed in micrometers.

CCIMT, through a stress-reduction mechanism, as lack of social cohesion has been associated with mental illness processes [13] and with myocardial infarction and coronary artery calcification [15]. But the study in which atherosclerosis was associated with low social cohesion measured the association 5 years later than the exposure. Our results suggest that the perception of these aspects of the current neighborhood may not be a central phenomenon in early stages of the atherosclerosis process.

The perception of availability of healthy food in our findings also was not associated with CCIMT, although it has been associated with better dietary habits in the same population, which could be associated with lower CCIMT [12]. Our results are in line with a prior work from MESA, where increases in the density of healthy food stores around residences were related to decrease in subclinical atherosclerosis as characterized by coronary calcium but not with survey measures [21]. It has been argued that survey-based measures may not reflect objective locational data [27].

We also hypothesized that perceiving a safer community would protect against CCIMT, but no association was found between the safety domain and CCIMT, contrasting with low witnessed violence domain findings. The safety domain questions access the perceptions of community without asking about having witnessed specific events ([Online Table 1](#)). The perception of safety when it is accessed with open questions may reveal that violence can be naturalized. Sometimes when people perceive their neighborhood as safe from crime, they may actually be naturalizing the violence and be in fact exercising less and be under very stressful situations.

Low personal victimization: Associated with higher CCIMT

This domain showed a counterintuitive positive association with CCIMT. We believe this finding can be result of multiple test problem (type I error). Another possibility is

that this domain is made of a single question that asks whether the participant or her households have been being victim of violent episodes ([Online Table 1](#)). As violence is more common among young people, many who answered positively may be the fathers or mothers of young victims, with higher odds of having a partner, which is known to provide protection against health problems.

Although prior studies have found differences between sexes [10,14,15], we found only 1 borderline interaction of sex with social cohesion and safety. In the stratified analysis, only men showed a protective CCIMT association with better safety. Previous studies found that perceived safety was associated with lower systolic blood pressure and more frequent physical activity [28,29]. Interestingly, perceived safety was associated with a decrease in BMI and waist circumference among men and an increase in waist circumference among women [30]. The fact that the multivariate models were not significant after adjustment for sociodemographic and clinical variables suggests that these variables may be moderators in the relationship between neighborhood perception and CCIMT.

The present study has many strengths. It is the largest study to investigate the associations between contextual factors and subclinical atherosclerosis, which allowed us to examine interactions with sex and perform stratified analyses by time of residence. We investigated a large number of different contextual neighborhood domains. Our study is the first to study the association between CCIMT and PNC in a low- and middle-income country and it is consistent with those from high-income countries. Information from developing countries is important due to the high burden of CVD and the high prevalence of risk factors in these countries [31,32]. A final strength of our study is that we used CCIMT to access subclinical atherosclerosis, which may detect early phases of plaque formation, when there may be greater opportunities for intervention [10,11,14,15,21,33]. But our study has several limitations. Our sample was obtained from a civil servants cohort that was not representative of Brazilian population regarding

socioeconomic status, which can limit the generalizability of our findings. However, it is important to highlight that the ELSA-Brasil sample, when compared with the Brazilian population, has similar frequency of cardiovascular risk and lifestyle factors. We did not have information on whether the participants actually used the nearby resources. Workplace context may be more relevant. We accessed information at a single time point in adulthood, which may have resulted in inaccurate estimates of social patterning, as the risk of chronic diseases is thought to accumulate over the life course. Another limitation was that CCIMT measures were missing in 26% of the original ELSA-Brasil sample due to technical issues. We ran sensitivity analyses using multiple imputations for CIMT missing data and found similar results in these analyses.

We found that better walkability, lower witnessed violence, and less personal victimization were associated with subclinical atherosclerosis in Brazilian adults. Future research should examine the longitudinal association between neighborhood characteristics and the incidence of atherosclerotic disease in individuals from low- and middle-income countries.

REFERENCES

- Benjamin EJ, Blaha MJ, Chiuve SE, et al. Heart disease and stroke statistics—2017 update: a report from the American Heart Association. *Circulation* 2017;135:e146–603.
- Lorenz MW, Polak JF, Kavousi M, et al., for the PROG-IMT Study Group. Carotid intima-media thickness progression to predict cardiovascular events in the general population (the PROG-IMT collaborative project): a meta-analysis of individual participant data. *Lancet* 2012;379:2053–62.
- Santos IS, Alencar AP, Rundek T, et al. Low impact of traditional risk factors on carotid intima-media thickness: the ELSA-Brasil cohort. *Arterioscler Thromb Vasc Biol* 2015;35:2054–9.
- Mobley LR, Root ED, Finkelstein EA, Khavjou O, Farris RP, Will JC. Environment, obesity, and cardiovascular disease risk in low-income women. *Am J Prev Med* 2006;30:327–32.
- Diez Roux AV, Mujahid MS, Hirsch JA, Moore K, Moore LV. The impact of neighborhoods on CV risk. *Glob Heart* 2016;11:353–63.
- Mujahid MS, Moore LV, Petito LC, Kershaw KN, Watson K, Diez Roux AV. Neighborhoods and racial/ethnic differences in ideal cardiovascular health (the Multi-Ethnic Study of Atherosclerosis). *Health Place* 2017;44:61–9.
- Winkleby M, Sundquist K, Cubbin C. Inequities in CHD incidence and case fatality by neighborhood deprivation. *Am J Prev Med* 2007;32:97–106.
- Rose G. Sick individuals and sick populations: 1985. *Bull World Health Organ* 2001;79:990–6.
- Dragano N, Hoffmann B, Stang A, et al., for the Recall Study Investigative Group. Subclinical coronary atherosclerosis and neighbourhood deprivation in an urban region. *Eur J Epidemiol* 2009;24:25–35.
- Lemelin ET, Diez Roux AV, Franklin TG, et al. Life-course socioeconomic positions and subclinical atherosclerosis in the Multi-Ethnic Study of Atherosclerosis. *Soc Sci Med* 2009;68:444–51.
- Petersen KL, Bleil ME, McCaffery J, et al. Community socioeconomic status is associated with artery atherosclerosis in untreated, hypertensive men. *Am J Hypertens* 2006;19:560–6.
- Chor D, Cardoso LO, Nobre AA, et al. Association between perceived neighbourhood characteristics, physical activity and diet quality: results of the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil). *BMC Public Health* 2016;16:751.
- Secretti T, Nunes MAA, Schmidt MI, Stein MC, Santos SM. Characteristics of neighborhood environment (social cohesion and safety) and common mental disorders in ELSA-Brasil study: a multilevel analysis. *Cad Saude Publica* 2019;35:e00197017.
- Murray ET, Diez Roux AV, Carnethon M, Lutsey PL, Ni H, O'Meara ES. Trajectories of neighborhood poverty and associations with subclinical atherosclerosis and associated risk factors: the Multi-Ethnic Study of Atherosclerosis. *Am J Epidemiol* 2010;171:1099–108.
- Kim D, Diez Roux AV, Kiefe CI, Kawachi I, Liu K. Do neighborhood socioeconomic deprivation and low social cohesion predict coronary calcification? The CARDIA study. *Am J Epidemiol* 2010;172:288–98.
- Schmidt MI, Duncan BB, Mill JG, et al. Cohort profile: Longitudinal Study of Adult Health (ELSA-Brasil). *Int J Epidemiol* 2015;44:68–75.
- Santos IS, Bittencourt MS, Oliveira IRS, et al. Carotid intima-media thickness value distributions in the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil). *Atherosclerosis* 2014;237:227–35.
- Mill JG, Pinto K, Griep RH, et al. Medical assessments and measurements in ELSA-Brasil. *Rev Saude Publica* 2013;47:54–62.
- Chor D, Alves MG, Giatti L, et al. [Questionnaire development in ELSA-Brasil: challenges of a multidimensional instrument]. *Rev Saude Publica* 2013;47:27–36.
- Mujahid MS, Diez Roux AV, Morenoff JD, Raghunathan T. Assessing the measurement properties of neighborhood scales: from psychometrics to econometrics. *Am J Epidemiol* 2007;165:858–67.
- Wing JJ, August E, Adar SD, et al. Change in neighborhood characteristics and change in coronary artery calcium: a longitudinal investigation in the MESA (Multi-Ethnic Study of Atherosclerosis) cohort. *Circulation* 2016;134:504–13.
- Echeverria SE, Diez Roux AV, Link BG. Reliability of self-reported neighborhood characteristics. *J Urban Health* 2004;81:682–701.
- Diez Roux AV. Residential environments and cardiovascular risk. *J Urban Health* 2003;80:569–89.
- Santos SM, Griep RH, Cardoso LO, et al. [Cross-cultural adaptation and reliability of measurements on self-reported neighborhood characteristics in ELSA-Brasil]. *Rev Saude Publica* 2013;47:122–30.
- Little RJA, Rubin DB. *Statistical Analysis With Missing Data*. 2nd edition. Hoboken, NJ: Wiley, 2002.
- StataCorp. *Multiple-Imputation Reference Manual*, Release 13. College Station, TX: StataCorp LP, 2013.
- Diez Roux AV. Neighborhoods and health: where are we and where do we go from here? *Rev Epidemiol Sante Publique* 2007;55:13–21.
- Mayne SL, Moore KA, Powell-Wiley TM, Evenson KR, Block R, Kershaw KN. Longitudinal associations of neighborhood crime and perceived safety with blood pressure: the Multi-Ethnic Study of Atherosclerosis (MESA). *Am J Hypertens* 2018;31:1024–32.
- Evenson KR, Block R, Diez Roux AV, McGinn AP, Wen F, Rodriguez DA. Associations of adult physical activity with perceived safety and police-recorded crime: the Multi-ethnic Study of Atherosclerosis. *Int J Behav Nutr Phys Act* 2012;9:146.
- Powell-Wiley TM, Moore K, Allen N, et al. Associations of neighborhood crime and safety and with changes in body mass index and waist circumference: the Multi-Ethnic Study of Atherosclerosis. *Am J Epidemiol* 2017;186:280–8.
- Schmidt MI, Duncan BB, Azevedo e Silva G, et al. Chronic non-communicable diseases in Brazil: burden and current challenges. *Lancet* 2011;377:1949–61.
- Danaei G, Singh GM, Paciorek CJ, et al., for the Global Burden of Metabolic Risk Factors of Chronic Disease Collaborating Group. The global cardiovascular risk transition: associations of four metabolic risk factors with national income, urbanization, and Western diet in 1980 and 2008. *Circulation* 2013;127:1493–502, 1502e1–1502e8.
- Bentzon JF, Otsuka F, Virmani R, Falk E. Mechanisms of plaque formation and rupture. *Circ Res* 2014;114:1852–66.