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The association between the neighborhood social environment and obesity in Brazil varies by gender and neighborhood socioeconomic status: a multilevel study

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Complete List of Authors:	Chaparro, M. Pia; Tulane University School of Public Health and Tropical Medicine, Global Community Health and Behavioral Sciences Pina, Maria; Fundacao Oswaldo Cruz, Laboratory of Health and Environment Education; INEB - Instituto de Engenharia Biomédica, Universidade do Porto Cardoso, Letícia; Fundação Oswaldo Cruz., National School of Public Health Sergio Arouca Santos, Simone; Fundação Oswaldo Cruz., National School of Public Health Sergio Arouca Barreto, Sandhi; Hospital das Clinicas da Universidade Federal de Minas Gerais Giatti, Luana; Universidade Federal da Ouro Preto, School of Nutrition Matos, Sheila Maria; Universidade Federal da Bahia, Institute of Public Health Mendes da Fonseca, Maria ; Fundacao Oswaldo Cruz, National School of Public Health Sergio Arouca Chor, Dora; Oswaldo Cruz Foundation-National School of Public Health, Epidemiology Griep, Rosane Haerter; Fundacao Oswaldo Cruz, Laboratory of Health and Environment Education
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The association between the neighborhood social environment and obesity in Brazil varies by gender and neighborhood socioeconomic status: a multilevel study

M. Pia Chaparro,[1] M. Fatima Pina,[2-4] Leticia de Oliveira Cardoso,[5] Simone M. Santos,[5] Sandi Maria Barreto,[6] Luana Giatti Gonçalves,[7] Sheila M. Alvim de Matos,[8] Maria de Jesus Mendes da Fonseca,[5] Dóra Chor,[5] Rosane Härter Griep[2]

[1]Department of Global Community Health and Behavioral Sciences, School of Public Health and Tropical Medicine, Tulane University, New Orleans, LA, USA.

[2]Laboratory of Health and Environment Education, Oswaldo Cruz Institute, Fundação Oswaldo Cruz, Manguinhos, Rio de Janeiro, Brazil.

[3]Institute of Biomedical Engineering (INEB), University of Porto, Porto, Portugal.

[4]Institure of Research and Innovation in Health (i3s), University of Porto, Porto, Portugal.

[5]National School of Public Health Sergio Arouca, Fundação Oswaldo Cruz, Rio de Janeiro, Brazil.

[6]Medical School & Hospital das Clínicas, Federal University of Minas Gerais, Belo Horizonte, Minas Gerais, Brazil.

[7]School of Nutrition, Federal University of Ouro Preto, Ouro Preto, Minas Gerais, Brazil.

[8]Institute of Public Health, Federal University of Bahia, Salvador, Brazil.

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Corresponding author: M. Pia Chaparro, MS, PhD (corresponding author)

Department of Global Community Health and Behavioral Sciences

School of Public Health and Tropical Medicine

Tulane University

1440 Canal St., suite 2200-16, mail code #8319

New Orleans, LA 70112

Tel. (504) 988-4533

Email: pchaparro@tulane.edu

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ABSTRACT

Objective: To investigate the association between the neighborhood social environment, including social cohesion, perceived neighborhood safety, perceived neighborhood violence, and obesity in Brazil.

Setting: 6 state capitals in Brazil (Salvador, Vitoria, Belo Horizonte, Porto Alegre, Sao Paulo, and Rio de Janeiro)

Participants: Current or former employees of 5 federal universities and 1 research center in each of the 6 Brazilian state capitals who were participants of the baseline wave (2008-2010) of the Brazilian Longitudinal Study of Adult Health (N=11,456; 56% women; 56% White, 28% Brown, and 16% Black).

Primary outcome measure: Obesity, based on measured weight and height, and defined as having a body mass index (BMI) >30kg/m^2.

Results: No associations were found between the neighborhood social environment and obesity among men. In multilevel logistic regression models adjusted for age, education, and skin color, women living in the least socially cohesive neighborhoods and in those perceived as most violent had higher odds of obesity compared to their counterparts (OR=1.25, 95%CI=1.01-1.55; OR=1.35, 95%CI=1.10-1.66, respectively). When stratified by neighborhood SES, results for social cohesion and for violence remained only for women residing in high SES and low SES neighborhoods, respectively.

Conclusions: Neighborhood-level interventions to increase social cohesion and reduce violence may help in the prevention of obesity among women in Brazil.

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STRENGTHS AND LIMITATIONS OF THE STUDY

- This is one of the first studies investigating the association between the neighborhood social environment and obesity in Latin America
- The sample comes from a well-defined cohort study in six large and diverse cities in Brazil, using validated questionnaires and scales, as well as measured weight and height
- This study is based on civil-servants, which excludes the extremely poor and unemployed, limiting generalizability

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INTRODUCTION

Research on neighborhoods and their influence on obesity focus on the physical environment, including the food and physical activity environments, as well as the social environment,[1,2] which refers to the social interactions (or lack thereof) that occur in the neighborhood between neighbors. The social environment includes concepts like social cohesion and social ties, as well as exposure to crime and violence, all of which have been linked to obesity.[3] Given the hypothesized link between neighborhoods and obesity, neighborhood-level interventions may be effective ways of influencing individual weight-related behaviors and thus preventing obesity, particularly among vulnerable populations.[4]

To date most evidence linking neighborhoods and obesity come from high-income countries, with still a limited amount of evidence available for low- and middle-income countries like those in Latin America.[5] This is despite the exponential increase in obesity observed in the region in the past two decades, and the widespread search for effective ways to curb the epidemic.[6,7] Research in Latin America has mostly focused on the food and physical activity environments,[8-12] with fewer studies assessing the neighborhood social environment as it pertains to obesity. Of those studying the social environment, most focus on neighborhood safety/crime. For example, neighborhood rates of homicides have been linked to obesity in Cali, Colombia[13] and Belo Horizonte, Brazil,[14] whereas perceiving one's neighborhood as unsafe was associated with decreased physical activity in Curitiba, Brazil,[15] Sao Paulo, Brazil,[16] and Florianopolis, Brazil.[17] To our knowledge, no studies in Latin America have looked into neighborhood social interactions – measured by social cohesion or social ties – and obesity, but a study in Belo Horizonte, Brazil found that neighborhood social cohesion was positively associated with physical activity.[18]

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To fill-in such gaps in the literature and taking advantage of a rich and georeferenced dataset based on six large cities in Brazil, the aim of this study was to investigate if the neighborhood social environment – including social cohesion, perceived safety and violence – was associated with obesity among Brazilian adults, and to identify if this association varied by individual- and neighborhood-level socioeconomic status (SES).

METHODS

Data comes from the baseline of the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil), a multicenter cohort study designed to investigate the incidence and progression of cardiovascular disease and diabetes, as well as the biological, social, and environmental determinants of these conditions in the Brazilian population.[19] ELSA-Brasil data is collected among active and retired employees from universities/research centers located in six Brazilian state capitals: Salvador, Vitoria, Belo Horizonte, Porto Alegre, Sao Paulo, and Rio de Janeiro.[19]

Detailed data collection procedures are found elsewhere.[19] Briefly, participants were recruited via on-site and radio announcements, mailings, billboards, and phone calls. Eligible participants were also recruited using a list of employees stratified by age, gender, and occupation to ensure representativeness in key sub-groups. Baseline data collection occurred in 2008-2010, with a total sample of 15,105 (54% women), ages 35 to 74 years. Data collected relevant to the current study include measured weight and height, sociodemographic information (age, gender, educational attainment, self-reported skin color), and perceptions about participants' neighborhood.

Participants' residential addresses were georeferenced and aggregated at the neighborhood level. In Brazil, existing tracts used for census data collection are heterogenous in

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terms of size and composition; they are often too small to capture the collective social processes we are set to investigate, while also proving problematic for statistical analysis.[20] Therefore, neighborhoods were constructed by combining contiguous census tracts with similar sociodemographic composition based on four variables from the Brazilian Census 2010:[21] number of people per household, proportion of children 0-4 years, mean income, and percent of white residents, following the same methodology described by Santos et al. 2010.[20] Neighborhoods were defined with a minimum population size of 5,000 inhabitants, a number deemed appropriate to be able to distinguish between different socioeconomic patterns.[20] Our sample includes 11,456 individuals with complete data and valid neighborhood definitions, corresponding to 76% of the ELSA-Brasil participants; this sample lived in 1902 neighborhoods, with a mean population of 6.02 individuals per neighborhood (SD 9.82).

ELSA-Brasil research protocol was approved by the Research Ethics Committees of São Paulo University, Minas Gerais Federal University, Fundação Oswaldo Cruz, Espírito Santo Federal University, Bahia Federal University, Rio Grande do Sul Federal University, and the National Research Ethics Committee.

The outcome of this study was obesity, defined as having a body mass index (BMI)>30 kg/m^2, based on measured weight and height. Our exposure variables were self-reported measures of the neighborhood social environment, including social cohesion, perceived safety, and perceived violence. Social cohesion, defined as the willingness of neighbors to intervene for the good of the community,[22] was assessed with a 5-item scale: 1) this is a close-knit neighborhood; 2) people around here are willing to help their neighbors; 3) people in this neighborhood don't get along with each other; 4) people in this neighborhood do not share the same values; and 5) people in this neighborhood can be trusted. Participants were asked their

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agreement level for these items using a 5-point Likert scale ranging from 1="completely agree" to 5="completely disagree," with scores ranging from 5-25. Reverse coding was used as needed so that a higher score indicated a higher social cohesion.

Perceived neighborhood safety was assessed with a 3-item scale: 1) I feel safe walking in my neighborhood, day or night; 2) violence is a problem in my neighborhood; and 3) my neighborhood is safe from crime, with participants reporting their agreement level with these items following the same 5-point Likert scale as above. Individual scores ranged from 3-15. Items 1 and 3 were reverse coded so that a higher score indicated a higher perceived safety.

Perceived neighborhood violence was assessed based on 5 items, referring to the previous 6 months: 1) how often was there a fight in this neighborhood in which a weapon was used?; 2) how often was there a violent argument between neighbors?; 3) how often was there a gang fight?; 4) how often was there a sexual assault or rape?; and 5) how often was there a robbery or mugging?. Response options ranged from 1="frequently" to 4="never," with individual scores ranging from 5 to 20 and a higher score representing lower perceived violence.

For all these neighborhood scales, thus, a higher score meant something positive: higher social cohesion, higher perceived safety, and lower perceived violence. These three scales were cross-culturally adapted from existing validated ones,[22,23] including a translation and back-translation from English to Portuguese.[24] Test-retest reliability was assessed in a sub-sample of ELSA-Brasil participants to evaluate internal consistency and temporal stability of the measurements; the scales were found to have good internal consistency and very good reproducibility.[24]

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For all analyses, individual-level scores on social cohesion, perceived safety and perceived violence were each aggregated at the neighborhood level, so that all participants living in the same neighborhood would have the same level of exposure. Further, neighborhood-level scores were converted into tertiles to simplify interpretation as the three sets of scores followed different scales with different ranges of responses. Neighborhoods were then classified as being in the lowest, middle, or highest tertile of exposure for each neighborhood predictor.

Covariates included participants' age (continuous), gender, educational attainment (less than primary, primary, high school, and university), and self-reported skin color (White, Brown ["mixed race"], Black, Asian, and Indigenous; Asian and Indigenous were dropped from the analysis because of their small sample size).

Neighborhood SES was created based on the same four census variables used for neighborhood definition. A principal component analysis followed by a cluster analysis were used to classify neighborhoods into three SES categories. Two principal components emerged from the analysis, explaining 87% of the SES variability; the first component was composed by *number of people per household* and *proportion of children 0-4 years*, whereas the second component was composed by *median income* and *percent of white residents.* We forced these principal components into three clusters, which resulted in low, intermediate, and high neighborhood SES classifications.

Patient and public involvement

Patients were not involved in the development of this study.

Statistical analysis

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We ran gender-stratified 3-level hierarchical multilevel logistic regression models as individuals (level 1) were nested within neighborhoods (level 2) and within ELSA sites (level 3), and the outcome variable (obesity) was dichotomous. Model 1 was adjusted by age, Model 2 was further adjusted by education, and Model 3 was adjusted by age, education, and skin color. Further, we ran models stratified by neighborhood SES to see if it modified the association between the neighborhood social environment and obesity. For the latter models, neighborhood-level scores of our three neighborhood variables were reconverted into tertiles *within* each neighborhood SES category. All analyses were carried out in SAS v9.4 (SAS Institute Inc., Cary, NC, USA) with a p-value<0.05 denoting statistical significance.

RESULTS

Table 1 displays the sample characteristics sample by obesity. Obesity was more prevalent among women (23%) than men (20%) and among middle-aged participants. We observed social inequities based on education and skin color, with decreased obesity prevalence as education increased, and black participants having the highest prevalence of obesity compared to white participants (29% vs. 20%). We observed an obesity gradient for neighborhood social cohesion and perceived violence, indicating that residents of the least cohesive and most self-perceived violent neighborhoods had a higher prevalence of obesity than those in the most cohesive and least violent neighborhoods, respectively. Residents of the poorest neighborhoods had a higher obesity prevalence compared to those in the richest (26% vs. 19%).

Results of the multilevel logistic regression models predicting obesity by neighborhood social cohesion, perceived safety, and perceived violence are shown in Tables 2, 3, and 4,

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respectively. Neighborhood social cohesion was associated with obesity for women only, and this association remained after adjusting for age, education, and skin color. In fully adjusted models, women who lived in the least socially cohesive neighborhoods had 25% higher odds of being obese compared to women living in the most socially cohesive neighborhoods (Table 2). We observed no associations between perceived safety and obesity (Table 3). In turn, perceived violence was associated with obesity among women only: women living in the most violent neighborhoods had 35% higher odds of obesity compared to women who lived in the least violent neighborhoods, adjusting for age, education, and skin color (Table 4).

Table 5 displays the results of the analysis stratified by neighborhood SES. For social cohesion, our results remained only among women living in high SES neighborhoods: women in the least socially cohesive neighborhoods had 54% higher odds of obesity compared to women living in the most socially cohesive neighborhoods *within high SES neighborhoods*. Oppositely, our results with perceived violence remained for women in poor neighborhoods: *within low SES neighborhoods*, women living in the most violent neighborhoods had 73% higher odds of obesity compared to those living in the least violent neighborhoods. Associations also emerged in the intermediate SES category, suggesting a dose-response association between perceived violence and obesity by neighborhood SES.

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Table 1: Characteristics of the sub-sample of ELSA-Brasil participants included in the study, stratified by obesity status (N=11,456)

	Not obese (BMI<30 kg/m^2) Row %	Obese (BMI≥30 kg/m^2) Row %	Total N (%)
INDIVIDUAL-LEVEL VARIABLES			
Gender			
Women	76.6	23.4	6427 (56.1)
Men	80.1	19.9	5025 (43.9)
Age group (years)			
34-45	81.9	18.1	2841 (24.8)
46-55	76.9	23.1	4400 (38.4)
56-65	76.4	23.6	3077 (26.9)
>65	78.5	21.5	1134 (9.9)
Education			
Less than primary	72.0	28.0	522 (4.6)
Primary	73.8	26.2	646 (5.6)
Secondary	74.3	25.7	3543 (30.9)
University	81.1	18.9	6741 (58.9)
Skin color			
White	80.3	19.7	6127 (56.2)
Brown	77.3	22.7	3052 (28.0)
Black	70.6	29.4	1719 (15.8)
NEIGHBORHOOD-LEVEL VARIABLES			
Social cohesion (mean 17.3, SD 3.6)			
Lowest tertile	76.0	24.0	2156 (18.8)
Middle tertile	78.3	21.7	5671 (49.5)
Highest tertile	79.2	20.8	3629 (31.7)
Perceived safety (mean 9.5, SD 3.2)			
Lowest tertile	76.8	23.2	2899 (25.3)
Middle tertile	79.1	20.9	4648 (40.6)
Highest tertile	78.1	21.9	3909 (34.1)
Perceived violence (mean 16.8, SD 2.8)			
Lowest tertile	74.9	25.1	2584 (22.6)
Middle tertile	78.6	21.4	4783 (41.8)
Highest tertile	79.7	20.3	4089 (35.7)
Neighborhood SES			
Low	74.1	25.9	2812 (24.6)
Intermediate	76.9	23.1	3418 (29.8)
High	81.2	18.8	5225 (45.6)

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Table 2: Results from the multilevel logistic regression model predicting obesity (BMI>30 kg/m^2) by neighborhood social cohesion; gender-stratified (N= 6,104 women; 4,791 men)

	Model 1 OR (95%CI)		Model 2 OR (95%CI)		Model 3 OR (95%CI)	
	Women	**Men**	**Women**	**Men**	**Women**	**Men**
Social cohesion						
Lowest tertile	**1.38 (1.11-1.71)**	0.99 (0.78-1.26)	**1.28 (1.04-1.58)**	0.96 (0.76-1.22)	**1.25 (1.01-1.55)**	0.95 (0.75-1.21)
Middle tertile	1.11 (0.93-1.32)	0.97 (0.80-1.18)	1.09 (0.92-1.30)	0.96 (0.80-1.17)	1.08 (0.91-1.29)	0.97 (0.80-1.17)
Highest tertile	1.00	1.00	1.00	1.00	1.00	1.00
Age	**1.02 (1.01-1.03)**	1.00 (0.99-1.01)	**1.02 (1.01-1.03)**	1.00 (0.99-1.01)	**1.02 (1.01-1.03)**	1.00 (0.99-1.01)
Education						
Less than primary			**1.96 (1.40-2.75)**	1.33 (0.97-1.84)	**1.62 (1.15-2.29)**	1.21 (0.87-1.69)
Primary			**1.70 (1.27-2.27)**	1.10 (0.79-1.50)	**1.39 (1.03-1.87)**	1.00 (0.72-1.40)
Secondary			**1.68 (1.46-1.94)**	1.18 (0.99-1.41)	**1.47 (1.27-1.71)**	1.10 (0.92-1.33)
University			1.00	1.00	1.00	1.00
Skin color						
Black					**1.82 (1.50-2.21)**	**1.40 (1.08-1.82)**
Brown					**1.34 (1.13-1.61)**	1.11 (0.91-1.36)
White					1.00	1.00

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Table 3: Results from the multilevel logistic regression model predicting obesity (BMI>30 kg/m^2) by perceived neighborhood safety; gender-stratified (N= 6,104 women; 4,791 men)

	Model 1 OR (95%CI)		Model 2 OR (95%CI)		Model 3 OR (95%CI)	
	Women	**Men**	**Women**	**Men**	**Women**	**Men**
Perceived safety						
Lowest tertile	1.18 (0.96-1.44)	1.05 (0.85-1.29)	1.16 (0.95-1.40)	1.04 (0.84-1.29)	1.15 (0.95-1.40)	1.03 (0.83-1.28)
Middle tertile	0.96 (0.80-1.15)	0.97 (0.80-1.17)	0.96 (0.81-1.14)	0.96 (0.80-1.17)	0.96 (0.81-1.14)	0.97 (0.80-1.17)
Highest tertile	1.00	1.00	1.00	1.00	1.00	1.00
Age	**1.02 (1.01-1.03)**	1.00 (0.99-1.01)	**1.02 (1.01-1.02)**	1.00 (0.99-1.01)	**1.02 (1.01-1.03)**	1.00 (1.00-1.01)
Education						
Less than primary			**2.00 (1.43-2.80)**	1.33 (0.96-1.83)	**1.64 (1.16-2.32)**	1.21 (0.87-1.69)
Primary			**1.73 (1.29-2.31)**	1.09 (0.79-1.50)	**1.40 (1.04-1.89)**	1.00 (0.72-1.39)
Secondary			**1.70 (1.47-1.96)**	1.17 (0.99-1.40)	**1.48 (1.28-1.72)**	1.10 (0.91-1.32)
University			1.00	1.00	1.00	1.00
Skin color						
Black					**1.83 (1.51-2.23)**	**1.40 (1.07-1.81)**
Brown					**1.36 (1.14-1.62)**	1.11 (0.91-1.36)
White					1.00	1.00

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Table 4: Results from the multilevel logistic regression model predicting obesity (BMI>30 kg/m^2) by perceived neighborhood violence; gender-stratified (N= 6,104 women; 4,791 men)

	Model 1 OR (95%CI)		Model 2 OR (95%CI)		Model 3 OR (95%CI)	
	Women	**Men**	**Women**	**Men**	**Women**	**Men**
Perceived violence[1]						
Lowest tertile	**1.61 (1.31-1.98)**	1.17 (0.94-1.46)	**1.41 (1.15-1.73)**	1.12 (0.89-1.40)	**1.35 (1.10-1.66)**	1.10 (0.87-1.38)
Middle tertile	1.12 (0.94-1.34)	1.02 (0.85-1.24)	1.06 (0.89-1.26)	1.00 (0.83-1.21)	1.06 (0.89-1.26)	1.00 (0.83-1.21)
Highest tertile	1.00	1.00	1.00	1.00	1.00	1.00
Age	**1.02 (1.01-1.03)**	1.00 (1.00-1.01)	**1.02 (1.01-1.02)**	1.00 (0.99-1.01)	**1.02 (1.01-1.03)**	1.00 (1.00-1.01)
Education						
Less than primary			**1.91 (1.36-2.68)**	1.30 (0.94-1.80)	**1.58 (1.12-2.24)**	1.19 (0.85-1.67)
Primary			**1.64 (1.23-2.20)**	1.07 (0.77-1.47)	**1.35 (1.00-1.82)**	0.98 (0.71-1.37)
Secondary			**1.64 (1.41-1.89)**	1.16 (0.97-1.38)	**1.44 (1.24-1.68)**	1.09 (0.90-1.31)
University			1.00	1.00	1.00	1.00
Skin color						
Black					**1.79 (1.47-2.18)**	**1.39 (1.07-1.80)**
Brown or *preto*					**1.34 (1.12-1.61)**	1.11 (0.90-1.36)
White					1.00	1.00

[1]The perceived violence scale was constructed so that a higher score indicated a lower perceived violence. Therefore, the *lowest tertile* category represents neighborhoods with the highest perceived violence.

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Table 5: Results from the multilevel logistic regression model predicting obesity (BMI>30 kg/m^2) by neighborhood social cohesion, perceived safety, and perceived violence; stratified by neighborhood socioeconomic status (SES) and gender[1]

	High SES OR (95%CI)		Intermediate SES OR (95%CI)		Low SES OR (95%CI)	
	Women	**Men**	**Women**	**Men**	**Women**	**Men**
Social cohesion						
Lowest tertile	**1.54 (1.14-2.10)**	1.10 (0.79-1.55)	0.85 (0.57-1.27)	0.91 (0.61-1.38)	1.36 (0.93-2.00)	0.95 (0.61-1.49)
Middle tertile	1.08 (0.82-1.41)	1.05 (0.78-1.41)	1.05 (0.76-1.43)	0.80 (0.56-1.14)	1.00 (0.72-1.38)	0.87 (0.58-1.29)
Highest tertile	1.00	1.00	1.00	1.00	1.00	1.00
Perceived safety						
Lowest tertile	1.03 (0.75-1.40)	1.00 (0.72-1.38)	0.87 (0.60-1.26)	0.94 (0.62-1.42)	1.30 (0.90-1.89)	1.12 (0.73-1.72)
Middle tertile	0.97 (0.73-1.30)	0.86 (0.64-1.17)	0.87 (0.63-1.20)	0.91 (0.63-1.30)	1.24 (0.90-1.70)	0.94 (0.64-1.39)
Highest tertile	1.00	1.00	1.00	1.00	1.00	1.00
Perceived violence[2]						
Lowest tertile	1.14 (0.83-1.56)	1.18 (0.82-1.68)	1.23 (0.84-1.81)	1.07 (0.71-1.63)	**1.73 (1.15-2.59)**	1.05 (0.66-1.68)
Middle tertile	0.92 (0.70-1.21)	1.07 (0.80-1.44)	1.00 (0.71-1.41)	0.86 (0.59-1.26)	**1.61 (1.14-2.26)**	1.03 (0.70-1.51)
Highest tertile	1.00	1.00	1.00	1.00	1.00	1.00

[1]Adjusted by age, education, and skin color

[2]The perceived violence scale was constructed so that a higher score indicated a lower perceived violence. Therefore, the *lowest tertile* category represents neighborhoods with the highest perceived violence.

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DISCUSSION

In this study based on a civil-servant sample of adults living in six large cities in Brazil, we found that living in a neighborhood with low social cohesion and high levels of self-perceived violence was associated with higher odds of obesity among women but not men. After stratifying by neighborhood SES, the association between living in the least socially cohesive neighborhoods and obesity remained only among women living in high SES neighborhoods, whereas the association between living in the most violent neighborhoods and obesity remained only for women residing in low SES neighborhoods.

Studies in Latin America[13,14] and elsewhere[25] also report an association between neighborhood violence and obesity among adults. The hypothesized mechanisms involved are a reduction in outdoor physical activity, related to the fear of being outdoors, as well as the direct stress caused by living in an unsafe neighborhood. There is support for both hypotheses in the literature, as neighborhood crime/violence is associated with a decreased physical activity,[15,17,25] and also with an increase in stress and a worse mental health.[26,27] Chronic stress, in turn, has been linked to an increased obesity risk due to its influence on weight-related behaviors and by dysregulating the hypothalamic-pituitary-adrenal axis, leading to abdominal fat deposition.[28]

There are mixed results in relation to neighborhood social cohesion and obesity in high-income countries[29-31] and, as far as the authors know, no previous studies have looked at this association in Latin America. Similar to our findings, Cohen et al. (2006) found that residents of neighborhoods with lower collective efficacy – a concept highly linked to social cohesion – had higher BMIs in Los Angeles, CA, U.S.[29]. Burdette et al. (2006), in turn, found no such association among women living in 20 U.S. cities.[30] Social cohesion is hypothesized to act as a buffer from neighborhood-related stress and, through this mechanism, be protective of obesity.

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Cohen et al. (2006) also suggest that adults in neighborhoods with higher social cohesion may be willing to intervene in aspects of the neighborhood that influence weight-related behaviors; for example, setting up sports leagues or influencing local food stores to carry healthier offerings.[29]

We found that the neighborhood social environment only influences obesity risk among Brazilian women and not men. This finding that women are more affected by their neighborhood environment, particularly the social one, is not new.[32-34] Rech et al. 2012 found that perception of safety during the day was associated with leisure walking among women but not men among a convenience sample of adults in Curitiba, Brazil.[15] Similarly, a study in Los Angeles, CA, U.S. found that women living in high-poverty neighborhoods exercised less than men, partly due to safety concerns associated with accessing outdoor parks.[33] Moreover, Guilcher et al. (2017) found that a higher neighborhood social cohesion was associated with lower odds of obesity only among women in a sample of adults in Toronto, Canada.[31] Reasons why neighborhood effects may be stronger for women than men include differences in their neighborhood perceptions, an increased exposure (i.e. women spending more time in their residential neighborhoods), or an increased vulnerability (i.e. women being more impacted by their surroundings).[32] Further, women are more often victims of sexual violence than men,[3,25] and this may influence the time they spend outdoors – and hence their physical activity levels – as well as their stress levels.

Finally, we found that the effect of social cohesion and perceived violence on obesity among women varied by neighborhood SES. Two studies of the neighborhood social environments in Brazil have found differential effects of these neighborhood variables on physical activity by *individual*-level SES. Andrade et al. (2015) reports a positive association between social cohesion and physical activity only among low-SES individuals in Belo Horizonte, Brazil.[18] This contradicts our findings that a lower social cohesion was associated

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with a higher obesity risk among women living in high-SES neighborhoods. In turn, Rech et al. (2012) found that negative associations between safety perceptions and physical inactivity in Curitiba, Brazil were only present among high-SES individuals.[15] We found that perceived neighborhood violence increased obesity risk among women in low-SES neighborhoods only. Future studies should investigate the interactions between individual-and neighborhood-level SES in the effects of social environments on obesity.

Our results suggest that neighborhood interventions to increase social cohesion and decrease violence perceptions may prevent obesity among women in Brazil. Effective neighborhood interventions designed to reduce violence may include the cleaning and greening of vacant lots, as well as the reduction of alcohol availability.[35] The greening of vacant lots may also work at increasing social cohesion and social interactions, based on evidence available from public gardening research.[36] Increasing access to safe public spaces may also help increase social cohesion and thus decrease obesity risk. Salvo et al.,[37] for example, found that residents of Bogota, Colombia and Cuernavaca, Mexico reported shopping malls and nightclubs as places where they engaged in physical activity with friends, highlighting that public places that allow for social interactions may be important for weight-related behaviors. Another option to potentially increase neighborhood trust and thus social cohesion while reducing crime is instituting neighborhood watches.[38] It can be argued, however, that participating in neighborhood watches may increase crime awareness and, thus, have a counteractive effect.[39]

Strengths and limitations

This study is based on civil-servants in six large cities in Brazil; therefore, our sample excludes the extremely poor and unemployed and so our results may only be generalizable to Brazilian

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adults with stable employment. However, the ELSA-Brasil sample is diverse in terms of sociodemographic characteristics, including diverse regions within Brazil. Moreover, data collection was based on validated questionnaires and scales, as well as direct body measurements which allowed us to estimate obesity based on measured weight and height as opposed to self-reports. The neighborhood social environment variables, however, are all self-reported and we did not have access to objective measures of crime/violence in the neighborhood. Another limitation includes the cross-sectional design, which prevents us from establishing the directionality of the associations. However, the ELSA-Brasil population is highly stable in terms of neighborhood residence, with an average of 15-year length of residence in their current neighborhood.

CONCLUSIONS

To our knowledge, this is one of the few studies in Latin America examining the association between the neighborhood social environment and obesity, providing key insights into the likelihood of success of neighborhood-level interventions addressing obesity in the Brazilian context, in particular. Our results suggest that an increase in neighborhood social cohesion and a reduction in the perception of neighborhood violence may be protective of obesity among Brazilian women, with the latter particularly true for women living in poverty. Further research is needed to test some of the proposed interventions in Brazil and other Latin American countries, with an aim to strengthen existing communities while improving the public's health. Future research should also clarify the reasons why the neighborhood social environment in both high and low- and middle-income countries seem to affect women more than men.

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DATA SHARING

The data used in this study are available for research proposals on request to the ELSA's Datacenter and to the ELSA's Publications Committee (publiELSA). Additional information can be obtained from the ELSA's Datacenter (estatisticaelsa@ufrgs.br) and from the ELSA Coordinator from the Research Center of Rio de Janeiro (rohgriep@ioc.fiocruz.br).

DISCLOSURE

The authors declared no conflict of interest.

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Page No	Recommendation
Title and abstract	1	1	(a) Indicate the study's design with a commonly used term in the title or the abstract *The term "a multilevel study" is included in the title*
		2	(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction			
Background/rationale	2	5	Explain the scientific background and rationale for the investigation being reported
Objectives	3	6	State specific objectives, including any prespecified hypotheses *Our study was exploratory, so objectives are included but no prespecified hypotheses.*
Methods			
Study design	4	6	Present key elements of study design early in the paper
Setting	5	6	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants
Variables	7	7-9	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	7-9	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	9	Describe any efforts to address potential sources of bias *Explained covariate adjustment to control for confounding*
	10	7	Explain how the study size was arrived at
Quantitative variables	11	7-9	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	10	(*a*) Describe all statistical methods, including those used to control for confounding (*b*) Describe any methods used to examine subgroups and interactions (*c*) Explain how missing data were addressed (*d*) If applicable, describe analytical methods taking account of sampling strategy (*e*) Describe any sensitivity analyses *No sensitivity analyses done*
Results			
Participants	13*	6-7	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
			(b) Give reasons for non-participation at each stage
			(c) Consider use of a flow diagram *Authors consider this unnecessary as data collection has been explained in previous publications at length (cited in this paper)*
Descriptive data	14*	10,12	(a) Give characteristics of study participants (eg demographic, clinical,

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			social) and information on exposures and potential confounders
			(b) Indicate number of participants with missing data for each variable of interest *Complete data analysis only*
Outcome data	15*	10,12	Report numbers of outcome events or summary measures
Main results	16	13-16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
			(*b*) Report category boundaries when continuous variables were categorized
			(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period *Not applicable*
Other analyses	17	11,16	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses *Subgroups analyses are explained; no sensitivity analyses reported*
Discussion			
Key results	18	17	Summarise key results with reference to study objectives
Limitations	19	19-20	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	19-20	Discuss the generalisability (external validity) of the study results
Other information			
Funding	22	21	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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The association between the neighborhood social environment and obesity in Brazil varies by gender and neighborhood socioeconomic status: a cross-sectional analysis of the ELSA-Brasil study

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Primary Subject Heading:	Global health
Secondary Subject Heading:	Nutrition and metabolism
Keywords:	obesity, neighborhood, Brazil, social environment

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The association between the neighborhood social environment and obesity in Brazil varies by gender and neighborhood socioeconomic status: a cross-sectional analysis of the ELSA-Brasil study

M. Pia Chaparro,[1] M. Fatima Pina,[2-4] Leticia de Oliveira Cardoso,[5] Simone M. Santos,[5] Sandhi Maria Barreto,[6] Luana Giatti Gonçalves,[7] Sheila M. Alvim de Matos,[8] Maria de Jesus Mendes da Fonseca,[5] Dóra Chor,[5] Rosane H. Griep[2]

[1]Department of Global Community Health and Behavioral Sciences, School of Public Health and Tropical Medicine, Tulane University, New Orleans, LA, USA.

[2]Laboratory of Health and Environment Education, Oswaldo Cruz Institute, Fundação Oswaldo Cruz, Manguinhos, Rio de Janeiro, Brazil.

[3]Institute of Biomedical Engineering (INEB), University of Porto, Porto, Portugal.

[4]Institure of Research and Innovation in Health (i3s), University of Porto, Porto, Portugal.

[5]National School of Public Health Sergio Arouca, Fundação Oswaldo Cruz, Rio de Janeiro, Brazil.

[6]Medical School & Hospital das Clínicas, Federal University of Minas Gerais, Belo Horizonte, Minas Gerais, Brazil.

[7]School of Nutrition, Federal University of Ouro Preto, Ouro Preto, Minas Gerais, Brazil.

[8]Institute of Public Health, Federal University of Bahia, Salvador, Brazil.

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Corresponding author: M. Pia Chaparro, MS, PhD (corresponding author)

Department of Global Community Health and Behavioral Sciences

School of Public Health and Tropical Medicine

Tulane University

1440 Canal St., suite 2200-16, mail code #8319

New Orleans, LA 70112

Tel. (504) 988-4533

Email: pchaparro@tulane.edu

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ABSTRACT

Objective: To investigate the association between the neighborhood social environment, including social cohesion, perceived neighborhood safety, perceived neighborhood violence, and obesity in Brazil.

Design: Cross-sectional study.

Setting: 6 state capitals in Brazil (Salvador, Vitoria, Belo Horizonte, Porto Alegre, Sao Paulo, and Rio de Janeiro)

Participants: Current or former employees of 5 federal universities and 1 research center in each of the 6 Brazilian state capitals who were participants of the baseline wave (2008-2010) of the Brazilian Longitudinal Study of Adult Health (N=11,456; 56% women; 56% White, 28% Brown, and 16% Black).

Primary outcome measure: Obesity, based on measured weight and height, and defined as having a body mass index (BMI) $\geq 30 kg/m^2$.

Results: No associations were found between the neighborhood social environment and obesity among men. In multilevel logistic regression models adjusted for age, education, skin color, and individual-level social cohesion and perceived violence scores, respectively, women living in the least socially cohesive neighborhoods and in those perceived as most violent had higher odds of obesity compared to their counterparts (OR=1.26, 95%CI=1.00-1.58; OR=1.27, 95%CI=1.01-1.59, respectively). When stratified by neighborhood SES – defined based on number of people per household, proportion of children 0-4 years, median income, and percent of white residents at the neighborhood level – results for social cohesion and for violence remained only for women residing in high SES and low SES neighborhoods, respectively.

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Conclusions: In this civil-servant sample in 6 large cities in Brazil, the neighborhood social environment was associated with obesity among women, but not men. Neighborhood-level interventions to increase social cohesion and reduce violence may help in the prevention of obesity among women in Brazil.

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STRENGTHS AND LIMITATIONS OF THE STUDY

- This is one of the first studies investigating the association between the neighborhood social environment and obesity in Latin America
- The sample comes from a well-defined cohort study in six large and diverse cities in Brazil, using validated questionnaires and scales, as well as measured weight and height
- This study is based on civil-servants, which excludes the extremely poor and unemployed, limiting generalizability

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INTRODUCTION

Research on neighborhoods and their influence on obesity focus on the physical environment, including the food and physical activity environments, as well as the social environment,[1,2] which refers to the social interactions (or lack thereof) that occur in the neighborhood between neighbors. The social environment includes concepts like social cohesion and social ties, as well as exposure to crime and violence, all of which have been linked to obesity.[3,4] Neighborhood social cohesion is hypothesized work as a buffer for stress and, as such, be protective of obesity,[5] whereas neighborhood crime and violence may affect the likelihood of outdoor physical activity[6-8] and, through this mechanism, be detrimental for obesity. Given the hypothesized link between neighborhoods and obesity, neighborhood-level interventions may be effective ways of influencing individual weight-related behaviors and thus preventing obesity.[9]

To date most evidence linking neighborhoods and obesity come from high-income countries, with still a limited amount of evidence available for low- and middle-income countries like those in Latin America.[10] This is despite the exponential increase in obesity observed in the region in the past two decades, and the widespread search for effective ways to curb the epidemic.[11,12] In Brazil, for example, obesity among women has increased from 12.1% in 2006 to 19.6% in 2016, and for men the corresponding numbers are 11.4% and 18.1%.[13] Research in Latin America has mostly focused on the food and physical activity environments,[14-18] with fewer studies assessing the neighborhood social environment as it pertains to obesity. Of those studying the social environment, most focus on neighborhood safety/crime. For example, neighborhood rates of homicides have been linked to obesity in Cali, Colombia[19] and Belo Horizonte, Brazil,[20] whereas perceiving one's neighborhood as unsafe was associated with decreased physical activity in Curitiba, Brazil,[6] Sao Paulo, Brazil,[21] and Florianopolis, Brazil.[7]

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To our knowledge, no studies in Latin America have looked into neighborhood social interactions – measured by social cohesion or social ties – and obesity,[4] but a study in Belo Horizonte, Brazil found that neighborhood social cohesion was positively associated with physical activity.[22]

To fill-in such gaps in the literature and taking advantage of a rich and georeferenced dataset based on six large cities in Brazil, the aim of this study was to investigate if the neighborhood social environment – including social cohesion, perceived safety and violence – was associated with obesity among Brazilian adults, and to identify if this association varied by individual- and neighborhood-level socioeconomic status (SES). We hypothesized that the neighborhood social environment will be associated with obesity among Brazilian adults, more so in women than men, and that this association will be stronger among those living in low SES neighborhoods.

METHODS

Data comes from the baseline of the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil), a multicenter cohort study designed to investigate the incidence and progression of cardiovascular disease and diabetes, as well as the biological, social, and environmental determinants of these conditions in the Brazilian population.[23] ELSA-Brasil data are collected among active and retired employees from universities/research centers located in six Brazilian state capitals: Salvador, Vitoria, Belo Horizonte, Porto Alegre, Sao Paulo, and Rio de Janeiro.[23]

Detailed data collection procedures are found elsewhere.[23] Briefly, participants were recruited via on-site and radio announcements, mailings, billboards, and phone calls. Eligible participants were also recruited using a list of employees stratified by age, gender, and

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occupation to ensure representativeness in key sub-groups. Baseline data collection occurred in 2008-2010, with a total sample of 15,105 (54% women), ages 35 to 74 years. Data collected relevant to the current study include measured weight and height, sociodemographic information (age, gender, educational attainment, self-reported skin color), and perceptions about participants' neighborhood.

Participants' residential addresses were georeferenced at the census tract level. In Brazil, existing tracts used for census data collection are heterogenous in terms of size and composition; they are often too small to capture the collective social processes we are set to investigate, while also proving problematic for statistical analysis.[24] Therefore, neighborhoods were constructed by combining contiguous census tracts with similar sociodemographic composition based on four variables from the Brazilian Census 2010:[25] number of people per household, proportion of children 0-4 years, mean income, and percent of white residents, following the same methodology described by Santos et al. 2010.[24] Neighborhoods were defined with a minimum population size of 5,000 inhabitants, a number deemed appropriate to be able to distinguish between different socioeconomic patterns. [24] Our sample includes 11,456 individuals with complete data and valid neighborhood definitions, corresponding to 76% of the ELSA-Brasil participants; this sample lived in 1902 neighborhoods, with a mean population of 6.02 individuals per neighborhood (SD 9.82; median=3; min-max=1-139).

ELSA-Brasil research protocol was approved by the Research Ethics Committees of São Paulo University, Minas Gerais Federal University, Fundação Oswaldo Cruz, Espírito Santo Federal University, Bahia Federal University, Rio Grande do Sul Federal University, and the National Research Ethics Committee.

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The outcome of this study was obesity, defined as having a body mass index (BMI)>30 kg/m^2, based on measured weight and height. Our exposure variables were self-reported measures of the neighborhood social environment, including social cohesion, perceived safety, and perceived violence. The three scales used to measure social cohesion, perceived safety, and perceived violence were cross-culturally adapted from existing validated ones,[26,27] including a translation and back-translation from English to Portuguese.[28] Test-retest reliability was assessed in a sub-sample of ELSA-Brasil participants to evaluate internal consistency and temporal stability of the measurements; the scales were found to have good internal consistency (assessed with Cronbach's alpha: 0.60 for social cohesion, 0.67 for perceived safety, 0.71 for perceived violence) and very good reproducibility (assessed with intraclass correlation coefficients: 0.83 for social cohesion, 0.86 for perceived safety, 0.87 for perceived violence).[28] There was a low correlation between the social cohesion and the perceived safety (Pearson correlation coefficient [CC]=0.24) and the perceived violence (CC=0.26) scales in our sample, and a moderate correlation between the perceived safety and perceived violence scales (CC=0.46). Correlation coefficients were similar for women and men.

Social cohesion, defined as the willingness of neighbors to intervene for the good of the community,[26] was assessed with a 5-item scale: 1) this is a close-knit neighborhood; 2) people around here are willing to help their neighbors; 3) people in this neighborhood don't get along with each other; 4) people in this neighborhood do not share the same values; and 5) people in this neighborhood can be trusted. Participants were asked their agreement level for these items using a 5-point Likert scale ranging from 1="completely agree" to 5="completely disagree," with scores ranging from 5-25. Reverse coding was used as needed so that a higher score indicated a higher social cohesion.

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Perceived neighborhood safety was assessed with a 3-item scale: 1) I feel safe walking in my neighborhood, day or night; 2) violence is a problem in my neighborhood; and 3) my neighborhood is safe from crime, with participants reporting their agreement level with these items following the same 5-point Likert scale as above. Individual scores ranged from 3-15. Items 1 and 3 were reverse coded so that a higher score indicated a higher perceived safety.

Perceived neighborhood violence was assessed based on 5 items, referring to the previous 6 months: 1) how often was there a fight in this neighborhood in which a weapon was used?; 2) how often was there a violent argument between neighbors?; 3) how often was there a gang fight?; 4) how often was there a sexual assault or rape?; and 5) how often was there a robbery or mugging?. Response options ranged from 1="frequently" to 4="never," with individual scores ranging from 5 to 20 and a higher score representing lower perceived violence. For all these neighborhood scales, thus, a higher score meant something positive: higher social cohesion, higher perceived safety, and lower perceived violence. For all analyses, individual-level scores on social cohesion, perceived safety and perceived violence were each aggregated at the neighborhood level, so that all participants living in the same neighborhood would have the same level of exposure. Further, neighborhood-level scores were converted into tertiles to simplify interpretation as the three sets of scores followed different scales with different ranges of responses. Neighborhoods were then classified as being in the lowest, middle, or highest tertile of exposure for each neighborhood predictor.

Covariates included participants' age (continuous), gender, educational attainment (up to primary, secondary, and university), and self-reported skin color (White, Brown ["mixed race"], Black, Asian, and Indigenous; Asian and Indigenous were dropped from the analysis because of their small sample size).

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Neighborhood SES was created based on the same four census variables used for neighborhood definition. A principal component analysis followed by a cluster analysis were used to classify neighborhoods into three SES categories. Two principal components emerged from the analysis, explaining 87% of the SES variability; the first component was composed by *number of people per household* and *proportion of children 0-4 years*, whereas the second component was composed by *median income* and *percent of white residents.* We forced these principal components into three clusters, which resulted in low, intermediate, and high neighborhood SES classifications. Characteristics of these low, intermediate, and high SES neighborhoods are displayed in Supplementary Table S1.

Patient and public involvement

Patients were not involved in the development of this study.

Statistical analysis

We ran gender-stratified 3-level hierarchical multilevel logistic regression models as individuals (level 1) were nested within neighborhoods (level 2) and within ELSA sites (level 3), and the outcome variable (obesity) was dichotomous. Model 1 was minimally adjusted by age while Model 2 was adjusted by age, education, and skin color, as well as by individual-level scores on the social cohesion, perceived safety, and perceived violence scales for the models with neighborhood social cohesion, perceived safety, and perceived violence as outcomes, respectively. This latter adjustment allowed us to account for individual variations in neighborhood perceptions and to obtain neighborhood effects above and beyond individual effects.

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Further, we ran models stratified by neighborhood SES to see if it modified the association between the neighborhood social environment and obesity. For these models, neighborhood-level scores of our three neighborhood variables were reconverted into tertiles *within* each neighborhood SES category. All analyses were carried out in SAS v9.4 (SAS Institute Inc., Cary, NC, USA) with a p-value<0.05 denoting statistical significance.

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RESULTS

Table 1 displays the sample characteristics for the whole sample and by obesity status. Women comprised the majority of the sample (56%); compared to men in the sample, women had a higher education and were more likely to be black. Obesity was more prevalent among women (23%) than men (20%) and among middle-aged participants (46-65 years). We observed social inequities based on education and skin color, with decreased obesity prevalence as education increased, and black participants having the highest prevalence of obesity compared to white participants (29% vs. 20%). We observed an obesity gradient for neighborhood social cohesion and perceived violence, indicating that residents of the least cohesive and most self-perceived violent neighborhoods had a higher prevalence of obesity than those in the most cohesive and least violent neighborhoods, respectively. Residents of the poorest neighborhoods had a higher obesity prevalence compared to those in the richest (26% vs. 19%).

Results of the multilevel logistic regression models predicting obesity by neighborhood social cohesion, perceived safety, and perceived violence are shown in Tables 2, 3, and 4, respectively. Neighborhood social cohesion was associated with obesity for women only, and this association remained after adjusting for age, education, skin color, and individual-level

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social cohesion scores. In fully adjusted models, women who lived in the least socially cohesive neighborhoods had 26% higher odds of being obese compared to women living in the most socially cohesive neighborhoods (Table 2). We observed no associations between perceived safety and obesity (Table 3). In turn, perceived violence was associated with obesity among women only: women living in the most violent neighborhoods had 27% higher odds of obesity compared to women who lived in the least violent neighborhoods, adjusting for age, education, skin color, and individual-level perceived violence scores (Table 4).

Table 5 displays the results of the analysis stratified by neighborhood SES. For social cohesion, our results remained only among women living in high SES neighborhoods: women in the least socially cohesive neighborhoods had 52% higher odds of obesity compared to women living in the most socially cohesive neighborhoods *within high SES neighborhoods*. Oppositely, our results with perceived violence remained for women in poor neighborhoods: *within low SES neighborhoods*, women living in the most violent neighborhoods had 84% higher odds of obesity compared to those living in the least violent neighborhoods. Associations also emerged in the intermediate SES category, suggesting a dose-response association between perceived violence and obesity for those in low SES neighborhoods.

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Table 1: Characteristics of the sub-sample of ELSA-Brasil participants included in the study, stratified by obesity status (N=11,456)

	Not obese (BMI<30 kg/m²) Row %	Obese (BMI≥30 kg/m²) Row %	Total N (%)
INDIVIDUAL-LEVEL VARIABLES			
Gender			
Women	76.6	23.4	6427 (56.1)
Men	80.1	19.9	5025 (43.9)
Age group (years)			
34-45	81.9	18.1	2841 (24.8)
46-55	76.9	23.1	4400 (38.4)
56-65	76.4	23.6	3077 (26.9)
>65	78.5	21.5	1134 (9.9)
Education			
Less than primary	72.0	28.0	522 (4.6)
Primary	73.8	26.2	646 (5.6)
Secondary	74.3	25.7	3543 (30.9)
University	81.1	18.9	6741 (58.9)
Skin color			
White	80.3	19.7	6127 (56.2)
Brown	77.3	22.7	3052 (28.0)
Black	70.6	29.4	1719 (15.8)
NEIGHBORHOOD-LEVEL VARIABLES			
Social cohesion (mean 17.3, SD 3.6)			
Lowest tertile (range 5-16.3; mean 14.3, SD 2.0)	76.0	24.0	2156 (18.8)
Middle tertile (range 16.3-18; mean 17.1, SD 0.4)	78.3	21.7	5671 (49.5)
Highest tertile (range 18-25; mean 19.4, SD 1.5)	79.2	20.8	3629 (31.7)
Perceived safety (mean 9.5, SD 3.2)			
Lowest tertile (range 3-8.4; mean 6.5, SD 7.0)	76.8	23.2	2899 (25.3)
Middle tertile (range 8.4-10; mean 9.2, SD 0.4)	79.1	20.9	4648 (40.6)
Highest tertile (range 10-15; mean 11.3, SD 1.3)	78.1	21.9	3909 (34.1)
Perceived violence (mean 16.8, SD 2.8)			
Lowest tertile (range 7-16; mean 13.8, SD 1.8)	74.9	25.1	2584 (22.6)
Middle tertile (range 16-17.5; mean 16.7, SD 0.5)	78.6	21.4	4783 (41.8)
Highest tertile (range 17.5-20; mean 18.5, SD 0.7)	79.7	20.3	4089 (35.7)
Neighborhood SES			
Low	74.1	25.9	2812 (24.6)
Intermediate	76.9	23.1	3418 (29.8)
High	81.2	18.8	5225 (45.6)

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Table 2: Results from the multilevel logistic regression model predicting obesity (BMI≥30 kg/m^2) by neighborhood social cohesion; gender-stratified (N= 6,107 women; 4,791 men)

	Model 1 OR (95%CI)		Model 2 OR (95%CI)	
	Women	**Men**	**Women**	**Men**
Neighborhood Social cohesion				
Lowest tertile	**1.38 (1.11-1.71)**	0.99 (0.78-1.26)	**1.26 (1.00-1.58)**	0.90 (0.70-1.16)
Middle tertile	1.11 (0.93-1.32)	0.97 (0.80-1.18)	1.08 (0.91-1.29)	0.97 (0.80-1.17)
Highest tertile	1.00	1.00	1.00	1.00
Age	**1.02 (1.01-1.03)**	1.00 (0.99-1.01)	**1.02 (1.01-1.03)**	1.00 (0.99-1.01)
Individual-level social cohesion			1.00 (0.98-1.02)	0.99 (0.97-1.01)
Education				
Primary or less			**1.47(1.14-1.89)**	1.10 (0.84-1.44)
Secondary			**1.48 (1.26-1.73)**	1.10 (0.90-1.34)
University			1.00	1.00
Skin color				
Black			**1.82 (1.50-2.21)**	**1.40 (1.08-1.82)**
Brown			**1.35 (1.13-1.61)**	1.11 (0.91-1.36)
White			1.00	1.00

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Table 3: Results from the multilevel logistic regression model predicting obesity (BMI≥30 kg/m^2) by perceived neighborhood safety; gender-stratified (N= 6,107 women; 4,791 men)

	Model 1 OR (95%CI)		Model 2 OR (95%CI)	
	Women	**Men**	**Women**	**Men**
Neighborhood Perceived safety				
Lowest tertile	1.18 (0.96-1.44)	1.05 (0.85-1.29)	1.14 (0.92-1.41)	1.04 (0.82-1.32)
Middle tertile	0.96 (0.80-1.15)	0.97 (0.80-1.17)	0.95 (0.80-1.14)	0.98 (0.80-1.19)
Highest tertile	1.00	1.00	1.00	1.00
Age	**1.02 (1.01-1.03)**	1.00 (0.99-1.01)	**1.02 (1.01-1.03)**	1.00 (1.00-1.01)
Individual-level perceived safety			1.00 (0.94-1.02)	1.00 (0.98-1.03)
Education				
Primary or less			**1.50 (1.16-1.93)**	1.10 (0.84-1.43)
Secondary			**1.49 (1.27-1.74)**	1.10 (0.90-1.33)
University			1.00	1.00
Skin color				
Black			**1.83 (1.51-2.23)**	**1.40 (1.08-1.81)**
Brown			**1.36 (1.14-1.63)**	1.11 (0.91-1.36)
White			1.00	1.00

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Table 4: Results from the multilevel logistic regression model predicting obesity (BMI≥30 kg/m^2) by perceived neighborhood violence; gender-stratified (N= 6,107 women; 4,791 men)

	Model 1 OR (95%CI)		Model 2 OR (95%CI)	
	Women	**Men**	**Women**	**Men**
Neighborhood Perceived violence[1]				
Lowest tertile	**1.61 (1.31-1.98)**	1.17 (0.94-1.46)	**1.27 (1.01-1.59)**	1.06 (0.82-1.36)
Middle tertile	1.12 (0.94-1.34)	1.02 (0.85-1.24)	1.03 (0.86-1.23)	0.99 (0.82-1.20)
Highest tertile	1.00	1.00	1.00	1.00
Age	**1.02 (1.01-1.03)**	1.00 (1.00-1.01)	**1.02 (1.01-1.03)**	1.00 (1.00-1.01)
Individual-level perceived violence			0.98 (0.96-1.00)	0.99 (0.96-1.02)
Education				
Primary or less			**1.44 (1.11-1.86)**	1.09 (0.83-1.42)
Secondary			**1.44 (1.23-1.68)**	1.09 (0.89-1.32)
University			1.00	1.00
Skin color				
Black			**1.79 (1.47-2.18)**	**1.39 (1.07-1.81)**
Brown			**1.34 (1.12-1.61)**	1.11 (0.90-1.36)
White			1.00	1.00

[1]The perceived violence scale was constructed so that a higher score indicated a lower perceived violence. Therefore, the *lowest tertile* category represents neighborhoods with the highest perceived violence.

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Table 5: Results from the multilevel logistic regression model predicting obesity (BMI≥30 kg/m^2) by neighborhood social cohesion, by perceived safety, and by perceived violence independently, and stratified by neighborhood socioeconomic status (SES) and gender[1]

	High SES OR (95% CI)		Intermediate SES OR (95%CI)		Low SES OR (95%CI)	
	Women	**Men**	**Women**	**Men**	**Women**	**Men**
Social cohesion						
N	2799	2144	1882	1371	1410	1268
Lowest tertile	**1.52 (1.10-2.10)**	1.01 (0.71-1.43)	0.90 (0.59-1.37)	0.96 (0.62-1.50)	1.42 (0.92-2.18)	0.91 (0.55-1.50)
Middle tertile	1.07 (0.81-1.42)	0.99 (0.73-1.34)	1.07 (0.78-1.48)	0.82 (0.57-1.18)	1.00 (0.72-1.41)	0.85 (0.57-1.28)
Highest tertile	1.00	1.00	1.00	1.00	1.00	1.00
Perceived safety						
N	2804	2148	1882	1371	1413	1269
Lowest tertile	1.03 (0.73-1.44)	0.96 (0.67-1.37)	0.82 (0.55-1.22)	1.06 (0.68-1.66)	1.30 (0.84-2.00)	1.12 (0.68-1.84)
Middle tertile	0.97 (0.72-1.30)	0.85 (0.62-1.15)	0.85 (0.61-1.18)	0.96 (0.66-1.40)	1.24 (0.89-1.73)	0.94 (0.63-1.40)
Highest tertile	1.00	1.00	1.00	1.00	1.00	1.00
Perceived violence						
N	2799	2139	1875	1369	1412	1269
Lowest tertile	0.98 (0.70-1.37)	1.16 (0.79-1.71)	1.25 (0.83-1.89)	1.01 (0.64-1.60)	**1.84 (1.17-2.91)**	0.98 (0.57-1.68)
Middle tertile	0.87 (0.65-1.15)	1.06 (0.78-1.42)	1.02 (0.72-1.44)	0.83 (0.56-1.22)	**1.66 (1.16-2.37)**	1.00 (0.67-1.50)
Highest tertile	1.00	1.00	1.00	1.00	1.00	1.00

[1]All models adjusted by age, education, and skin color, as well as by individual-level social cohesion, perceived safety, and perceived violence scores for the neighbohood social cohesion, perceived safety, and perceived violence models, respectively.
[2]The perceived violence scale was constructed so that a higher score indicated a lower perceived violence. Therefore, the *lowest tertile* category represents neighborhoods with the highest perceived violence.

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DISCUSSION

In this study based on a civil-servant sample of adults living in six large cities in Brazil, we found that living in a neighborhood with low social cohesion and high levels of self-perceived violence was associated with higher odds of obesity among women but not men. After stratifying by neighborhood SES, the association between living in the least socially cohesive neighborhoods and obesity remained only among women living in high SES neighborhoods, whereas the association between living in the most violent neighborhoods and obesity remained only for women residing in low SES neighborhoods.

Studies in Latin America[19,20] and elsewhere[8] also report an association between neighborhood violence and obesity among adults. The hypothesized mechanisms involved are a reduction in outdoor physical activity, related to the fear of being outdoors, as well as the direct stress caused by living in an unsafe neighborhood. There is support for both hypotheses in the literature, as neighborhood crime/violence is associated with a decreased physical activity,[6-8] and also with an increase in stress and a worse mental health.[29,30] Chronic stress, in turn, has been linked to an increased obesity risk due to its influence on weight-related behaviors and by dysregulating the hypothalamic-pituitary-adrenal axis, leading to abdominal fat deposition.[31]

There are mixed results in relation to neighborhood social cohesion and obesity in high-income countries,[5,32,33] though most studies have found protective effects.[4] As far as the authors know, no previous studies have looked at this association in Latin America. Similar to our findings, Cohen et al. (2006) found that residents of neighborhoods with lower collective efficacy – a concept highly linked to social cohesion – had higher BMIs in Los Angeles, CA, U.S.[5] Burdette et al. (2006), in turn, found no such association among women living in 20 U.S. cities.[32]

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Social cohesion is hypothesized to act as a buffer from neighborhood-related stress and, through this mechanism, be protective of obesity. Cohen et al. (2006) also suggest that adults in neighborhoods with higher social cohesion may be willing to intervene in aspects of the neighborhood that influence weight-related behaviors; for example, setting up sports leagues or influencing local food stores to carry healthier offerings.[5] However, the opposite can also be true, with residents in high-social-cohesion neighborhoods uniting for negative things as they pertain to obesity, for example, standing against soda taxation or against bans of unhealthy vending machines.[4]

We found that neighborhood social cohesion and perceived violence only influences the obesity risk of Brazilian women and not men, even though there were no gender differences in the social cohesion, perceived safety, and perceived violence average individual scores. This finding that women are more affected by their neighborhood environment, particularly the social one, is not new.[34-36] Rech et al. 2012 found that perception of safety during the day was associated with leisure walking among women but not men among a convenience sample of adults in Curitiba, Brazil.[6] Similarly, a study in Los Angeles, CA, U.S. found that women living in high-poverty neighborhoods exercised less than men, partly due to safety concerns associated with accessing outdoor parks.[35] Moreover, Guilcher et al. (2017) found that a higher neighborhood social cohesion was associated with lower odds of obesity only among women in a sample of adults in Toronto, Canada.[33] Reasons why neighborhood effects may be stronger for women than men include differences in their neighborhood perceptions (which is not the case in our sample), an increased exposure (i.e. women spending more time in their residential neighborhoods), or an increased vulnerability (i.e. women being more impacted by their surroundings).[34] Further, women are more often victims of sexual violence than men,[3,8] and this

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may influence the time they spend outdoors – and hence their physical activity levels – as well as their stress levels, particularly among women in low SES neighborhoods.

A previous study conducted in the south of Brazil found neighborhood-level variations in obesity prevalence for both men and women; however, neighborhood-level education was only associated with obesity among women in the sample.[37] Another study using ELSA-Brasil data found that the food and physical activity neighborhood environments were associated with obesity among women but not men.[38] The results of these studies and our own suggest that the neighborhood environment may matter for men's obesity risk, but the neighborhood factors studied to date are relevant only for women. Future studies should further investigate which neighborhood factors, if any, affect obesity risk among men in Brazil and other Latin American settings, as well as the reason why neighborhood factors may affect women's and men's obesity risk differently.

Finally, we found that the effect of social cohesion and perceived violence on obesity among women varied by neighborhood SES. Two studies of the neighborhood social environments in Brazil have found differential effects of these neighborhood variables on physical activity by *individual*-level SES. Andrade et al. (2015) reports a positive association between social cohesion and physical activity only among low-SES individuals in Belo Horizonte, Brazil.[22] This contradicts our findings that a lower social cohesion was associated with a higher obesity risk among women living in high-SES neighborhoods. In turn, Rech et al. (2012) found that negative associations between safety perceptions and physical inactivity in Curitiba, Brazil were only present among high-SES individuals.[6] We found that perceived neighborhood violence increased obesity risk among women in low-SES neighborhoods only.

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Even though we found minimal variations in perceived violence scores by neighborhood SES in our sample (Supplementary Table S1), women living in low SES neighborhoods may be more impacted by their perceived neighborhood violence than those living in high SES neighborhoods. For example, residents of high SES neighborhoods may be more likely to have cars and access (monetary and physical) to indoor places for exercising (e.g. gyms). This would mean that high-SES neighborhood residents could more effectively avoid spending time outdoors in their neighborhoods without this having a severe impact on their physical activity behaviors and/or stress, the suggested mechanisms linking perceived violence and obesity. Scores of neighborhood social cohesion are also similar in our sample across neighborhood SES categories (Supplementary Table S1). Why social cohesion would be associated with obesity only among women residing in high-SES neighborhoods requires further investigation.

Our results suggest that neighborhood interventions to increase social cohesion and decrease violence perceptions may prevent obesity among women in Brazil. Effective neighborhood interventions designed to reduce violence may include the cleaning and greening of vacant lots, as well as the reduction of alcohol availability.[39] Though the effect of these kinds of interventions on *perceived* violence is unknown, research suggests that *fear of crime* may be negatively influenced by neglected and run-down neighborhood spaces.[40] The greening of vacant lots may also work at increasing social cohesion and social interactions, based on evidence available from public gardening research.[41] Increasing access to safe public spaces may also help increase social cohesion and thus decrease obesity risk. Salvo et al.,[42]for example, found that residents of Bogota, Colombia and Cuernavaca, Mexico reported shopping malls and nightclubs as places where they engaged in physical activity with friends, highlighting that public places that allow for social interactions may be important for weight-related behaviors. Another option

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to potentially increase neighborhood trust and thus social cohesion while reducing crime is instituting neighborhood watches.[43] It can be argued, however, that participating in neighborhood watches may increase crime awareness and, thus, have a counteractive effect.[40]

Strengths and limitations

This study is based on civil-servants in six large cities in Brazil; therefore, our sample excludes the extremely poor and unemployed and so our results may only be generalizable to Brazilian adults with stable employment. However, the ELSA-Brasil sample is diverse in terms of sociodemographic characteristics, including diverse regions within Brazil. Moreover, whereas the ELSA-Brasil sample has, on average, a higher income and social class than the residents of the six included cities,[25,44] the ELSA-Brasil sample has a similar prevalence of obesity and obesity-related behaviors (i.e. diet and physical activity patterns) than the Brazilian population at large.[45]

Data collection was based on validated questionnaires and scales, as well as direct body measurements which allowed us to estimate obesity based on measured weight and height as opposed to self-reports. The neighborhood social environment variables, however, are all self-reported and we did not have access to objective measures of crime/violence in the neighborhood. Another limitation includes the cross-sectional design, which prevents us from establishing the directionality of the associations. However, the ELSA-Brasil population is highly stable in terms of neighborhood residence, with an average of 15-year length of residence in their current neighborhood.

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CONCLUSIONS

To our knowledge, this is one of the few studies in Latin America examining the association between the neighborhood social environment and obesity, providing key insights into the likelihood of success of neighborhood-level interventions addressing obesity in the Brazilian context, in particular. Our results suggest that an increase in neighborhood social cohesion and a reduction in the perception of neighborhood violence may be protective of obesity among Brazilian women, with the latter particularly true for women living in poverty. Further research is needed to test some of the proposed interventions in Brazil and other Latin American countries, with an aim to strengthen existing communities while improving the public's health. Future research should also clarify the reasons why the neighborhood social environment in both high and low- and middle-income countries seem to affect women more than men.

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DATA SHARING

The data used in this study are available for research proposals on request to the ELSA's Datacenter and to the ELSA's Publications Committee (publiELSA). Additional information can be obtained from the ELSA's Datacenter (estatisticaelsa@ufrgs.br) and from the ELSA Coordinator from the Research Center of Rio de Janeiro (rohgriep@ioc.fiocruz.br).

DISCLOSURE

The authors declared no conflict of interest.

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SUPPLEMENTARY TABLE

Supplementary Table S1: Neighborhood characteristics by SES cluster (N=1902 neighborhoods where the sample lived)

	Low SES N=753			Intermediate SES N=550			High SES N=598		
	Mean	SD	IQR	Mean	SD	IQR	Mean	SD	IQR
Proportion of children 0-4 years	6.85	1.17	6.03-7.62	5.29	0.98	4.62-5.90	3.93	1.04	3.26-4.48
Number of people per household	3.27	0.19	3.15-3.37	3.02	0.18	2.90-3.14	2.59	0.31	2.35-2.81
% White	32.11	15.07	16.31-43.10	59.70	13.79	50.68-69.04	81.24	10.14	74.79-89.11
Median income ($R)	946.56	292.02	733.13-1102.92	1916.65	750.63	1395.50-2209.20	4758.85	2290.00	3003.02-6001.70
Social capital	16.79	2.96	15.25-18.40	17.17	2.62	16.00-18.75	17.45	1.93	16.40-18.62
Perceived safety	8.84	2.61	7.00-10.50	9.35	2.49	8.00-11.00	9.51	1.96	8.25-10.75
Perceived violence	15.68	2.53	14.20-17.50	16.71	2.06	15.81-18.00	17.04	1.67	16.33-18.00

Abbreviations: SES=socioeconomic status; SD=standard deviation; IQR= interquartile range
Note: The perceived violence scale was constructed so that a higher score indicated a lower perceived violence.

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Page No	Recommendation
Title and abstract	1	1	*(*a) Indicate the study's design with a commonly used term in the title or the abstract *The term "cohort study" is included in the title*
		3	(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction			
Background/rationale	2	6-7	Explain the scientific background and rationale for the investigation being reported
Objectives	3	7	State specific objectives, including any prespecified hypotheses
Methods			
Study design	4	7	Present key elements of study design early in the paper
Setting	5	7	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	7	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants
Variables	7	8-11	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	8-11	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	10	Describe any efforts to address potential sources of bias *Explained covariate adjustment to control for confounding*
	10	8	Explain how the study size was arrived at
Quantitative variables	11	8-12	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	11-12	(*a*) Describe all statistical methods, including those used to control for confounding (*b*) Describe any methods used to examine subgroups and interactions (*c*) Explain how missing data were addressed (*d*) If applicable, describe analytical methods taking account of sampling strategy (*e*) Describe any sensitivity analyses *No sensitivity analyses done*
Results			
Participants	13*	8	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
			(b) Give reasons for non-participation at each stage
			(c) Consider use of a flow diagram *Authors consider this unnecessary as data collection has been explained in previous publications at length (cited in this paper)*
Descriptive data	14*	12 Table1	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
			(b) Indicate number of participants with missing data for each variable of

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			interest *WOMEN max sample = 8218 (all have age and education)* *8218 – 395 with missing skin color = 7823* *7823 – 3 missing obesity = 7820* *7820 – 1713 missing neighborhood (and hence, all neighborhood values) = 6107 → ANALYTICAL SAMPLE* *MEN max sample = 6887 (all have age and education)* *6887 – 320 with missing skin color = 6567* *6567 – 3 missing obesity = 6564* *6564 – 1773 missing neighborhood (and hence, all neighborhood values) = 4791 → ANALYTICAL SAMPLE*
Outcome data	15*	12 Table1	Report numbers of outcome events or summary measures
Main results	16	12,13 Tables 2-5	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
			(*b*) Report category boundaries when continuous variables were categorized
			(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period *Not applicable*
Other analyses	17	13 Table5	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses *Subgroups analyses are explained; no sensitivity analyses reported*
Discussion			
Key results	18	19	Summarise key results with reference to study objectives
Limitations	19	23	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	24	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	23	Discuss the generalisability (external validity) of the study results
Other information			
Funding	22	25	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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The association between the neighborhood social environment and obesity in Brazil varies by gender and neighborhood socioeconomic status: a cross-sectional analysis of the ELSA-Brasil study

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Keywords:	obesity, neighborhood, Brazil, social environment

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The association between the neighborhood social environment and obesity in Brazil varies by gender and neighborhood socioeconomic status: a cross-sectional analysis of the ELSA-Brasil study

M. Pia Chaparro,[1] M. Fatima Pina,[2-4] Leticia de Oliveira Cardoso,[5] Simone M. Santos,[5] Sandhi Maria Barreto,[6] Luana Giatti Gonçalves,[7] Sheila M. Alvim de Matos,[8] Maria de Jesus Mendes da Fonseca,[5] Dóra Chor,[5] Rosane H. Griep[2]

[1]Department of Global Community Health and Behavioral Sciences, School of Public Health and Tropical Medicine, Tulane University, New Orleans, LA, USA.

[2]Laboratory of Health and Environment Education, Oswaldo Cruz Institute, Fundação Oswaldo Cruz, Manguinhos, Rio de Janeiro, Brazil.

[3]Institute of Biomedical Engineering (INEB), University of Porto, Porto, Portugal.

[4]Institure of Research and Innovation in Health (i3s), University of Porto, Porto, Portugal.

[5]National School of Public Health Sergio Arouca, Fundação Oswaldo Cruz, Rio de Janeiro, Brazil.

[6]Medical School & Hospital das Clínicas, Federal University of Minas Gerais, Belo Horizonte, Minas Gerais, Brazil.

[7]School of Nutrition, Federal University of Ouro Preto, Ouro Preto, Minas Gerais, Brazil.

[8]Institute of Public Health, Federal University of Bahia, Salvador, Brazil.

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Corresponding author: M. Pia Chaparro, MS, PhD (corresponding author)

Department of Global Community Health and Behavioral Sciences

School of Public Health and Tropical Medicine

Tulane University

1440 Canal St., suite 2200-16, mail code #8319

New Orleans, LA 70112

Tel. (504) 988-4533

Email: pchaparro@tulane.edu

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ABSTRACT

Objective: To investigate the association between the neighborhood social environment, including social cohesion, perceived neighborhood safety, perceived neighborhood violence, and obesity in Brazil.

Design: Cross-sectional study.

Setting: 6 state capitals in Brazil (Salvador, Vitoria, Belo Horizonte, Porto Alegre, Sao Paulo, and Rio de Janeiro)

Participants: Current or former employees of 5 federal universities and 1 research center in each of the 6 Brazilian state capitals who were participants of the baseline wave (2008-2010) of the Brazilian Longitudinal Study of Adult Health (N=11,456; 56% women; 56% White, 28% Brown, and 16% Black).

Primary outcome measure: Obesity, based on measured weight and height, and defined as having a body mass index (BMI) $\geq 30 kg/m^2$.

Results: No associations were found between the neighborhood social environment and obesity among men. In multilevel logistic regression models adjusted for age, education, skin color, state of residence, and individual-level social cohesion and perceived violence scores, respectively, women living in the least socially cohesive neighborhoods and in those perceived as most violent had higher odds of obesity compared to their counterparts (OR=1.25, 95%CI=1.02-1.53; OR=1.28, 95%CI=1.04-1.56, respectively). When stratified by neighborhood SES – defined based on number of people per household, proportion of children 0-4 years, median income, and percent of white residents at the neighborhood level – results for social cohesion and for violence remained only for women residing in high SES and low SES neighborhoods, respectively.

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Conclusions: In this civil-servant sample in 6 large cities in Brazil, the neighborhood social environment was associated with obesity among women, but not men. Neighborhood-level interventions to increase social cohesion and reduce violence may help in the prevention of obesity among women in Brazil.

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STRENGTHS AND LIMITATIONS OF THE STUDY

- This is one of the first studies investigating the association between the neighborhood social environment and obesity in Latin America
- The sample comes from a well-defined cohort study in six large and diverse cities in Brazil, using validated questionnaires and scales, as well as measured weight and height
- This study is based on civil-servants, which excludes the extremely poor and unemployed, limiting generalizability

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INTRODUCTION

Research on neighborhoods and their influence on obesity focus on the physical environment, including the food and physical activity environments, as well as the social environment,[1,2] which refers to the social interactions (or lack thereof) that occur in the neighborhood between neighbors. The social environment includes concepts like social cohesion and social ties, as well as exposure to crime and violence, all of which have been linked to obesity.[3,4] Neighborhood social cohesion is hypothesized to work as a buffer for stress and, as such, to be protective of obesity,[5] whereas neighborhood crime and violence may affect the likelihood of outdoor physical activity[6-8] and, through this mechanism, be detrimental for obesity. Given the hypothesized link between neighborhoods and obesity, neighborhood-level interventions may be effective ways of influencing individual weight-related behaviors and thus preventing obesity.[9]

To date most evidence linking neighborhoods and obesity come from high-income countries, with still a limited amount of evidence available for low- and middle-income countries like those in Latin America.[10] This is despite the exponential increase in obesity observed in the region in the past two decades, and the widespread search for effective ways to curb the epidemic.[11,12] In Brazil, for example, obesity among women has increased from 12.1% in 2006 to 19.6% in 2016, and for men the corresponding numbers are 11.4% and 18.1%.[13] Research in Latin America has mostly focused on the food and physical activity environments,[14-18] with fewer studies assessing the neighborhood social environment as it pertains to obesity. Of those studying the social environment, most focus on neighborhood safety/crime. For example, neighborhood rates of homicides have been linked to obesity in Cali, Colombia[19] and Belo Horizonte, Brazil,[20] whereas perceiving one's neighborhood as unsafe was associated with decreased physical activity in Curitiba, Brazil,[6] Sao Paulo, Brazil,[21] and Florianopolis, Brazil.[7]

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To our knowledge, no studies in Latin America have looked into neighborhood social interactions – measured by social cohesion or social ties – and obesity,[4] but a study in Belo Horizonte, Brazil found that neighborhood social cohesion was positively associated with physical activity.[22]

To fill-in such gaps in the literature and taking advantage of a rich and georeferenced dataset based on six large cities in Brazil, the aim of this study was to investigate if the neighborhood social environment – including social cohesion, perceived safety and violence – was associated with obesity among Brazilian adults, and to identify if this association varied by gender. Previous studies have found that social neighborhood characteristics are associated with obesity[5-8,19,20] and that neighborhood environments affect women more than men;[23,24]therefore, we hypothesized that the neighborhood social environment will be associated with obesity among Brazilian adults, particularly among women. Furthermore, we hypothesized that lower neighborhood socioeconomic status (SES) could modify individuals' perceptions of their neighborhood environment and, thus, influence obesity-related behaviors. Therefore, we also assessed if the association between the neighborhood social environment and obesity varied by neighborhood SES.

METHODS

Data comes from the baseline of the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil), a multicenter cohort study designed to investigate the incidence and progression of cardiovascular disease and diabetes, as well as the biological, social, and environmental determinants of these conditions in the Brazilian population.[25] ELSA-Brasil data are collected

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among active and retired employees from universities/research centers located in six Brazilian state capitals: Salvador, Vitoria, Belo Horizonte, Porto Alegre, Sao Paulo, and Rio de Janeiro.[25]

Detailed data collection procedures are found elsewhere.[25] Briefly, participants were recruited via on-site and radio announcements, mailings, billboards, and phone calls. Eligible participants were also recruited using a list of employees stratified by age, gender, and occupation to ensure representativeness in key sub-groups. Baseline data collection occurred in 2008-2010, with a total sample of 15,105 (54% women), ages 35 to 74 years. Data collected relevant to the current study include measured weight and height, sociodemographic information (age, gender, educational attainment, self-reported skin color), and perceptions about participants' neighborhood.

Participants' residential addresses were georeferenced at the census tract level. In Brazil, existing tracts used for census data collection are heterogenous in terms of size and composition; they are often too small to capture the collective social processes we are set to investigate, while also proving problematic for statistical analysis.[26] Therefore, neighborhoods were constructed by combining contiguous census tracts with similar sociodemographic composition based on four variables from the Brazilian Census 2010:[27] number of people per household, proportion of children 0-4 years, mean income, and percent of white residents, following an adaptation of the methodology described by Santos et al. (2010).[26] In their study, Santos et al. (2010)[26] utilized a spatial aggregation method based on SKATER (Spatial 'K'luster Analysis by Tree Edge Removal at TerraView software) to create clusters of contiguous census tracts based on the same sociodemographic characteristics listed above but with educational attainment instead of percent of white residents, as available in the Brazilian Census 2000.[26] The Brazilian Census 2010 did

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not include questions regarding education,[27] so percent of white residents was chosen as an adequate replacement variable based on principal component analysis.

Neighborhoods were defined with a minimum population size of 5,000 inhabitants, a number deemed appropriate to be able to distinguish between different socioeconomic patterns.[26] Our sample includes 11,456 individuals with complete data and valid neighborhood definitions, corresponding to 76% of the ELSA-Brasil participants; this sample lived in 1902 neighborhoods, with a mean population of 6.02 individuals per neighborhood (SD 9.82; median=3; min-max=1-139).

ELSA-Brasil research protocol was approved by the Research Ethics Committees of São Paulo University, Minas Gerais Federal University, Fundação Oswaldo Cruz, Espírito Santo Federal University, Bahia Federal University, Rio Grande do Sul Federal University, and the National Research Ethics Committee.

The outcome of this study was obesity, defined as having a body mass index (BMI)>30 kg/m^2, based on measured weight and height. Our exposure variables were self-reported measures of the neighborhood social environment, including social cohesion, perceived safety, and perceived violence. The three scales used to measure social cohesion, perceived safety, and perceived violence were cross-culturally adapted from existing validated ones,[28,29] including a translation and back-translation from English to Portuguese.[30] Test-retest reliability was assessed in a sub-sample of ELSA-Brasil participants to evaluate internal consistency and temporal stability of the measurements; the scales were found to have good internal consistency (assessed with Cronbach's alpha: 0.60 for social cohesion, 0.67 for perceived safety, 0.71 for perceived violence) and very good reproducibility (assessed with intraclass correlation coefficients: 0.83 for social cohesion, 0.86 for perceived safety, 0.87 for perceived violence).[30] There was a low

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correlation between the social cohesion and the perceived safety (Pearson correlation coefficient [CC]=0.24) and the perceived violence (CC=0.26) scales in our sample, and a moderate correlation between the perceived safety and perceived violence scales (CC=0.46). Correlation coefficients were similar for women and men.

Social cohesion, defined as the willingness of neighbors to intervene for the good of the community,[28] was assessed with a 5-item scale: 1) this is a close-knit neighborhood; 2) people around here are willing to help their neighbors; 3) people in this neighborhood don't get along with each other; 4) people in this neighborhood do not share the same values; and 5) people in this neighborhood can be trusted. Participants were asked their agreement level for these items using a 5-point Likert scale ranging from 1="completely agree" to 5="completely disagree," with scores ranging from 5-25. Reverse coding was used as needed so that a higher score indicated a higher social cohesion.

Perceived neighborhood safety was assessed with a 3-item scale: 1) I feel safe walking in my neighborhood, day or night; 2) violence is a problem in my neighborhood; and 3) my neighborhood is safe from crime, with participants reporting their agreement level with these items following the same 5-point Likert scale as above. Individual scores ranged from 3-15. Items 1 and 3 were reverse coded so that a higher score indicated a higher perceived safety.

Perceived neighborhood violence was assessed based on 5 items, referring to the previous 6 months: 1) how often was there a fight in this neighborhood in which a weapon was used?; 2) how often was there a violent argument between neighbors?; 3) how often was there a gang fight?; 4) how often was there a sexual assault or rape?; and 5) how often was there a robbery or mugging?. Response options ranged from 1="frequently" to 4="never," with individual scores ranging from 5 to 20 and a higher score representing lower perceived violence. For all these

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neighborhood scales, thus, a higher score meant something positive: higher social cohesion, higher perceived safety, and lower perceived violence. For all analyses, individual-level scores on social cohesion, perceived safety and perceived violence were each aggregated at the neighborhood level, so that all participants living in the same neighborhood would have the same level of exposure. Further, neighborhood-level scores were converted into tertiles to simplify interpretation as the three sets of scores followed different scales with different ranges of responses. Neighborhoods were then classified as being in the lowest, middle, or highest tertile of exposure for each neighborhood predictor.

Covariates included participants' age (continuous), gender, educational attainment (up to primary, secondary, and university), and self-reported skin color (White, Brown ["mixed race"], Black, Asian, and Indigenous; Asian and Indigenous were dropped from the analysis because of their small sample size).

In order to classify the neighborhoods by SES, we ran a principal component analysis to reduce the same four census variables used in the definition of neighborhoods into two non-correlated principal components. The first component was composed of *number of people per household* and *proportion of children 0-4 years*, whereas the second component was composed of *median income* and *percent of white residents*, explaining 87% of the data variability. We then forced these two principal components into three hierarchical clusters, using the Ward's method, to identify groups of neighborhoods with similar characteristics. The authors' empirical knowledge of the area and the interpretation of the scores of each principal component within each cluster allowed for the classification of the neighborhoods into low, intermediate, and high SES. Characteristics of these low, intermediate, and high SES neighborhoods are displayed in Supplementary Table S1.

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Patient and public involvement

Patients were not involved in the development of this study.

Statistical analysis

Hierarchical multilevel logistic regression models were ran as individuals (level 1) were nested within neighborhoods (level 2), and the outcome variable (obesity) was dichotomous. Model 1 included our independent variable of interest (social cohesion, perceived safety, or perceived violence) and age, while Model 2 was further adjusted by gender; education; skin color; ELSA sites; an interaction term between gender and social cohesion, perceived safety, or perceived violence; as well as individual-level scores on the social cohesion, perceived safety, and perceived violence scales for the models with neighborhood social cohesion, perceived safety, and perceived violence as predictors, respectively. This latter adjustment allowed us to account for individual variations in neighborhood perceptions and to obtain neighborhood effects above and beyond individual effects. Given that gender interactions for two out of our three independent variables of interest were significant (social cohesion interaction p-value=0.0077; perceived safety p-value=0.3569; perceived violence p-value=0.0363), we re-ran all models stratified by gender.

To identify if the association between the neighborhood social environment and obesity varied by neighborhood SES, we further stratified our analysis by neighborhood SES. For these models, neighborhood-level scores of our three neighborhood variables were reconverted into tertiles *within* each neighborhood SES category. All analyses were carried out in SAS v9.4 (SAS Institute Inc., Cary, NC, USA) with a p-value<0.05 denoting statistical significance.

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RESULTS

Table 1 displays the sample characteristics for the whole sample and by obesity status. Women comprised the majority of the sample (56%); compared to men in the sample, women had a higher education and were more likely to be black. Obesity was more prevalent among women (23%) than men (20%) and among middle-aged participants (46-65 years). We observed social inequities based on education and skin color, with decreased obesity prevalence as education increased, and black participants having the highest prevalence of obesity compared to white participants (29% vs. 20%). We observed an obesity gradient for neighborhood social cohesion and perceived violence, indicating that residents of the least cohesive and most self-perceived violent neighborhoods had a higher prevalence of obesity than those in the most cohesive and least violent neighborhoods, respectively. Residents of the poorest neighborhoods had a higher obesity prevalence compared to those in the richest (26% vs. 19%).

Results of the multilevel logistic regression models predicting obesity by neighborhood social cohesion, perceived safety, and perceived violence are shown in Tables 2, 3, and 4, respectively. Neighborhood social cohesion was associated with obesity for women only, and this association remained after adjusting for age, education, skin color, and individual-level social cohesion scores. In fully adjusted models, women who lived in the least socially cohesive neighborhoods had 25% higher odds of being obese compared to women living in the most socially cohesive neighborhoods (Table 2). We observed no associations between perceived safety and obesity (Table 3). In turn, perceived violence was associated with obesity among women only: women living in the most violent neighborhoods had 28% higher odds of obesity compared to women who lived in the least violent neighborhoods, adjusting for age, education, skin color, and individual-level perceived violence scores (Table 4).

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Table 1: Characteristics of the sub-sample of ELSA-Brasil participants included in the study, stratified by obesity status (N=11,456)

	Not obese (BMI<30 kg/m²) Row %	Obese (BMI≥30 kg/m²) Row %	Total N (%)
INDIVIDUAL-LEVEL VARIABLES			
Gender			
Women	76.6	23.4	6427 (56.1)
Men	80.1	19.9	5025 (43.9)
Age group (years)			
34-45	81.9	18.1	2841 (24.8)
46-55	76.9	23.1	4400 (38.4)
56-65	76.4	23.6	3077 (26.9)
>65	78.5	21.5	1134 (9.9)
Education			
Less than primary	72.0	28.0	522 (4.6)
Primary	73.8	26.2	646 (5.6)
Secondary	74.3	25.7	3543 (30.9)
University	81.1	18.9	6741 (58.9)
Skin color			
White	80.3	19.7	6127 (56.2)
Brown	77.3	22.7	3052 (28.0)
Black	70.6	29.4	1719 (15.8)
NEIGHBORHOOD-LEVEL VARIABLES			
Social cohesion (mean 17.3, SD 3.6)			
Lowest tertile (range 5-16.3; mean 14.3, SD 2.0)	76.0	24.0	2156 (18.8)
Middle tertile (range 16.3-18; mean 17.1, SD 0.4)	78.3	21.7	5671 (49.5)
Highest tertile (range 18-25; mean 19.4, SD 1.5)	79.2	20.8	3629 (31.7)
Perceived safety (mean 9.5, SD 3.2)			
Lowest tertile (range 3-8.4; mean 6.5, SD 7.0)	76.8	23.2	2899 (25.3)
Middle tertile (range 8.4-10; mean 9.2, SD 0.4)	79.1	20.9	4648 (40.6)
Highest tertile (range 10-15; mean 11.3, SD 1.3)	78.1	21.9	3909 (34.1)
Perceived violence (mean 16.8, SD 2.8)			
Lowest tertile (range 7-16; mean 13.8, SD 1.8)	74.9	25.1	2584 (22.6)
Middle tertile (range 16-17.5; mean 16.7, SD 0.5)	78.6	21.4	4783 (41.8)
Highest tertile (range 17.5-20; mean 18.5, SD 0.7)	79.7	20.3	4089 (35.7)
Neighborhood SES			
Low	74.1	25.9	2812 (24.6)
Intermediate	76.9	23.1	3418 (29.8)
High	81.2	18.8	5225 (45.6)

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Table 2: Results from the multilevel logistic regression model predicting obesity (BMI≥30 kg/m^2) by neighborhood social cohesion; gender-stratified (N= 6,092 women; 4,783 men)

	Model 1 OR (95%CI)		Model 2 OR (95%CI)	
	Women	**Men**	**Women**	**Men**
Neighborhood Social cohesion				
Lowest tertile	**1.43 (1.18-1.72)**	0.99 (0.81-1.21)	**1.25 (1.02-1.53)**	0.90 (0.72-1.13)
Middle tertile	1.14 (0.97-1.32)	0.96 (0.82-1.13)	1.07 (0.92-1.26)	0.95 (0.80-1.13)
Highest tertile	1.00	1.00	1.00	1.00
Age	**1.02 (1.01-1.03)**	1.00 (0.99-1.01)	**1.02 (1.01-1.03)**	1.00 (1.00-1.01)
Individual-level social cohesion			1.00 (0.98-1.02)	0.99 (0.97-1.01)
Education				
Primary or less			**1.46 (1.16-1.83)**	1.10 (0.87-1.40)
Secondary			**1.48 (1.28-1.70)**	1.10 (0.92-1.30)
University			1.00	1.00
Skin color				
Black			**1.86 (1.56-2.21)**	**1.45 (1.15-1.82)**
Brown			**1.38 (1.18-1.62)**	1.13 (0.95-1.36)
White			1.00	1.00
ELSA site				
Bahia			**0.62 (0.50-0.76)**	**0.56 (0.44-0.72)**
Espirito Santo			**0.70 (0.51-0.96)**	0.88 (0.63-1.23)
Minas Gerais			**0.75 (0.62-0.91)**	0.91 (0.74-1.11)
Rio de Janeiro			0.89 (0.71-1.11)	1.06 (0.84-1.33)
Rio Grande do Sul			0.91 (0.74-1.12)	0.91 (0.72-1.16)
Sao Paulo			1.00	1.00

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Table 3: Results from the multilevel logistic regression model predicting obesity (BMI≥30 kg/m^2) by perceived neighborhood safety; gender-stratified (N= 6,092 women; 4,783 men)

	Model 1 OR (95%CI)		Model 2 OR (95%CI)	
	Women	**Men**	**Women**	**Men**
Neighborhood Perceived safety				
Lowest tertile	1.16 (0.97-1.38)	0.98 (0.82-1.18)	1.15 (0.95-1.39)	1.06 (0.86-1.30)
Middle tertile	0.94 (0.80-1.10)	0.92 (0.78-1.08)	0.96 (0.82-1.12)	0.98 (0.83-1.17)
Highest tertile	1.00	1.00	1.00	1.00
Age	**1.02 (1.01-1.03)**	1.00 (0.99-1.01)	**1.02 (1.01-1.03)**	1.00 (1.00-1.01)
Individual-level perceived safety			0.99 (0.97-1.02)	1.00 (0.98-1.03)
Education				
Primary or less			**1.48 (1.18-1.86)**	1.10 (0.87-1.39)
Secondary			**1.49 (1.30-1.71)**	1.09 (0.92-1.30)
University			1.00	1.00
Skin color				
Black			**1.87 (1.57-2.23)**	**1.44 (1.14-1.81)**
Brown			**1.39 (1.19-1.63)**	1.13 (0.95-1.36)
White			1.00	1.00
ELSA site				
Bahia			**0.59 (0.48-0.73)**	**0.56 (0.43-0.72)**
Espirito Santo			**0.66 (0.48-0.90)**	0.89 (0.64-1.24)
Minas Gerais			**0.71 (0.59-0.86)**	0.92 (0.75-1.12)
Rio de Janeiro			0.84 (0.67-1.05)	1.05 (0.83-1.32)
Rio Grande do Sul			0.87 (0.71-1.07)	0.92 (0.72-1.17)
Sao Paulo			1.00	1.00

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Table 4: Results from the multilevel logistic regression model predicting obesity (BMI≥30 kg/m^2) by perceived neighborhood violence; gender-stratified (N= 6,092 women; 4,783 men)

	Model 1 OR (95%CI)		Model 2 OR (95%CI)	
	Women	**Men**	**Women**	**Men**
Neighborhood Perceived violence				
Lowest tertile	**1.51 (1.27-1.80)**	1.08 (0.90-1.30)	**1.28 (1.04-1.56)**	1.07 (0.86-1.34)
Middle tertile	1.07 (0.91-1.25)	0.98 (0.83-1.15)	1.03 (0.88-1.20)	0.99 (0.84-1.18)
Highest tertile	1.00	1.00	1.00	1.00
Age	**1.02 (1.01-1.03)**	1.00 (0.99-1.01)	**1.02 (1.01-1.03)**	1.00 (1.00-1.01)
Individual-level perceived violence			0.98 (0.96-1.00)	0.99 (0.96-1.02)
Education				
Primary or less			**1.42 (1.13-1.78)**	1.08 (0.86-1.38)
Secondary			**1.44 (1.25-1.66)**	1.08 (0.91-1.29)
University			1.00	1.00
Skin color				
Black			**1.82 (.153-2.17)**	**1.43 (1.13-1.81)**
Brown			**1.37 (1.17-1.61)**	1.13 (0.94-1.35)
White			1.00	1.00
ELSA site				
Bahia			**0.56 (0.45-0.70)**	**0.54 (0.42-0.70)**
Espirito Santo			**0.67 (0.49-0.92)**	0.89 (0.64-1.23)
Minas Gerais			**0.70 (0.58-0.84)**	0.92 (0.75-1.11)
Rio de Janeiro			0.81 (0.65-1.02)	1.02 (0.81-1.29)
Rio Grande do Sul			0.84 (0.68-1.03)	0.90 (0.71-1.15)
Sao Paulo			1.00	1.00

[1]The perceived violence scale was constructed so that a higher score indicated a lower perceived violence. Therefore, the *lowest tertile* category represents neighborhoods with the highest perceived violence.

Table 5 displays the results of the analysis stratified by neighborhood SES. For social cohesion, our results remained only among women living in high SES neighborhoods: women in the least socially cohesive neighborhoods had 48% higher odds of obesity compared to women living in the most socially cohesive neighborhoods *within high SES neighborhoods*. Oppositely, our results with perceived violence remained for women in poor neighborhoods: *within low SES neighborhoods*, women living in the most (perceived)s violent neighborhoods had almost twice the odds of obesity compared to those living in the least (perceived) violent neighborhoods. Associations also emerged in the intermediate SES category, suggesting a dose-response association between perceived violence and obesity for those in low SES neighborhoods.

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Table 5: Results from the multilevel logistic regression model predicting obesity (BMI≥30 kg/m^2) by neighborhood social cohesion, by perceived safety, and by perceived violence independently, and stratified by neighborhood socioeconomic status (SES) and gender[1]

	High SES OR (95% CI)		Intermediate SES OR (95%CI)		Low SES OR (95%CI)	
	Women	**Men**	**Women**	**Men**	**Women**	**Men**
Social cohesion						
N	2799	2144	1882	1371	1410	1268
Lowest tertile	**1.48 (1.10-1.99)**	1.03 (0.76-1.42)	0.86 (0.59-1.26)	0.95 (0.63-1.45)	1.43 (0.98-2.10)	0.92 (0.59-1.44)
Middle tertile	1.06 (0.82-1.37)	1.05 (0.80-1.38)	1.03 (0.77-1.37)	0.83 (0.59-1.16)	0.98 (0.73-1.33)	0.83 (0.58-1.20)
Highest tertile	1.00	1.00	1.00	1.00	1.00	1.00
Perceived safety						
N	2797	2144	1881	1371	1408	1268
Lowest tertile	1.09 (0.80-1.48)	1.01 (0.73-1.40)	0.81 (0.57-1.16)	1.11 (0.74-1.66)	1.38 (0.93-2.02)	1.19 (0.76-1.86)
Middle tertile	1.00 (0.77-1.30)	0.87 (0.66-1.14)	0.84 (0.63-1.13)	0.98 (0.70-1.37)	1.27 (0.94-1.71)	0.99 (0.69-1.43)
Highest tertile	1.00	1.00	1.00	1.00	1.00	1.00
Perceived violence						
N	2792	2134	1873	1369	1406	1267
Lowest tertile	1.00 (0.73-1.37)	1.21 (0.85-1.72)	1.22 (0.84-1.76)	1.03 (0.68-1.56)	**1.92 (1.28-2.90)**	1.02 (0.63-1.66)
Middle tertile	0.87 (0.67-1.12)	1.08 (0.83-1.40)	1.01 (0.75-1.38)	0.86 (0.60-1.22)	**1.70 (1.23-2.34)**	1.03 (0.72-1.49)
Highest tertile	1.00	1.00	1.00	1.00	1.00	1.00

[1]All models adjusted by age, education, skin color, ELSA site, as well as by individual-level social cohesion, perceived safety, and perceived violence scores for the neighborhood social cohesion, perceived safety, and perceived violence models, respectively.
[2]The perceived violence scale was constructed so that a higher score indicated a lower perceived violence. Therefore, the *lowest tertile* category represents neighborhoods with the highest perceived violence.

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DISCUSSION

In this study based on a civil-servant sample of adults living in six large cities in Brazil, we found that living in a neighborhood with low social cohesion and high levels of self-perceived violence was associated with higher odds of obesity among women but not men. After stratifying by neighborhood SES, the association between living in the least socially cohesive neighborhoods and obesity remained only among women living in high SES neighborhoods, whereas the association between living in the most (perceived) violent neighborhoods and obesity remained only for women residing in low SES neighborhoods.

Studies in Latin America[19,20] and elsewhere[8] also report an association between neighborhood violence and obesity among adults. The hypothesized mechanisms involved are a reduction in outdoor physical activity, related to the fear of being outdoors, as well as the direct stress caused by living in an unsafe neighborhood. There is support for both hypotheses in the literature, as neighborhood crime/violence is associated with a decreased physical activity,[6-8] and also with an increase in stress and a worse mental health.[31,32] Chronic stress, in turn, has been linked to an increased obesity risk due to its influence on weight-related behaviors and by dysregulating the hypothalamic-pituitary-adrenal axis, leading to abdominal fat deposition.[33]

There are mixed results in relation to neighborhood social cohesion and obesity in high-income countries,[5,23,34] though most studies have found protective effects.[4] As far as the authors know, no previous studies have looked at this association in Latin America. Similar to our findings, Cohen et al. (2006) found that residents of neighborhoods with lower collective efficacy – a concept highly linked to social cohesion – had higher BMIs in Los Angeles, CA, U.S.[5] Burdette et al. (2006), in turn, found no such association among women living in 20 U.S. cities.[34]

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Social cohesion is hypothesized to act as a buffer from neighborhood-related stress and, through this mechanism, be protective of obesity.[5] Cohen et al. (2006) also suggest that adults in neighborhoods with higher social cohesion may be willing to intervene in aspects of the neighborhood that influence weight-related behaviors; for example, setting up sports leagues or influencing local food stores to carry healthier offerings.[5] However, the opposite can also be true, with residents in high-social-cohesion neighborhoods uniting for negative things as they pertain to obesity, for example, standing against soda taxation or against bans of unhealthy vending machines.[4]

We found that neighborhood social cohesion and perceived violence only influences the obesity risk of Brazilian women and not men. This finding that women are more affected by their neighborhood environment, particularly the social one, is not new.[24,35,36] Rech et al. 2012 found that perception of safety during the day was associated with leisure walking among women but not men among a convenience sample of adults in Curitiba, Brazil.[6] Similarly, a study in Los Angeles, CA, U.S. found that women living in high-poverty neighborhoods exercised less than men, partly due to safety concerns associated with accessing outdoor parks.[36] Moreover, Guilcher et al. (2017) found that a higher neighborhood social cohesion was associated with lower odds of obesity only among women in a sample of adults in Toronto, Canada.[23] Reasons why neighborhood effects may be stronger for women than men include differences in their neighborhood perceptions (which is not the case in our sample), an increased exposure (i.e. women spending more time in their residential neighborhoods), or an increased vulnerability (i.e. women being more impacted by their surroundings).[24] Further, women are more often victims of sexual violence than men,[3,8] and this may influence the time they spend outdoors – and hence

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their physical activity levels – as well as their stress levels, particularly among women in low SES neighborhoods.

A previous study conducted in the south of Brazil found neighborhood-level variations in obesity prevalence for both men and women; however, neighborhood-level education was only associated with obesity among women in the sample.[37] Another study using ELSA-Brasil data found that the food and physical activity neighborhood environments were associated with obesity among women but not men.[38] The results of these studies and our own suggest that the neighborhood environment may matter for men's obesity risk, but the neighborhood factors studied to date are relevant only for women. Future studies should further investigate which neighborhood factors, if any, affect obesity risk among men in Brazil and other Latin American settings, as well as the reason why neighborhood factors may affect women's and men's obesity risk differently.

Finally, we found that the effect of social cohesion and perceived violence on obesity among women varied by neighborhood SES. Two studies of the neighborhood social environments in Brazil have found differential effects of these neighborhood variables on physical activity by *individual*-level SES. Andrade et al. (2015) reports a positive association between social cohesion and physical activity only among low-SES individuals in Belo Horizonte, Brazil.[22] This contradicts our findings that a lower social cohesion was associated with a higher obesity risk among women living in high-SES neighborhoods. In turn, Rech et al. (2012) found that negative associations between safety perceptions and physical inactivity in Curitiba, Brazil were only present among high-SES individuals.[6] We found that perceived neighborhood violence increased obesity risk among women in low-SES neighborhoods only.

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Even though we found minimal variations in perceived violence scores by neighborhood SES in our sample (Supplementary Table S1), women living in low SES neighborhoods may be more impacted by their perceived neighborhood violence than those living in high SES neighborhoods. For example, residents of high SES neighborhoods may be more likely to have cars and access (monetary and physical) to indoor places for exercising (e.g. gyms). This would mean that high-SES neighborhood residents could more effectively avoid spending time outdoors in their neighborhoods without this having a severe impact on their physical activity behaviors and/or stress, the suggested mechanisms linking perceived violence and obesity. Scores of neighborhood social cohesion are also similar in our sample across neighborhood SES categories (Supplementary Table S1). Why social cohesion would be associated with obesity only among women residing in high-SES neighborhoods requires further investigation.

Our results suggest that neighborhood interventions to increase social cohesion and decrease violence perceptions may prevent obesity among women in Brazil. Effective neighborhood interventions designed to reduce violence may include the cleaning and greening of vacant lots, as well as the reduction of alcohol availability.[39] Though the effect of these kinds of interventions on *perceived* violence is unknown, research suggests that *fear of crime* may be negatively influenced by neglected and run-down neighborhood spaces.[40] The greening of vacant lots may also work at increasing social cohesion and social interactions, based on evidence available from public gardening research.[41] Increasing access to safe public spaces may also help increase social cohesion and thus *may* decrease obesity risk. Salvo et al.,[42]for example, found that residents of Bogota, Colombia and Cuernavaca, Mexico reported shopping malls and nightclubs as places where they engaged in physical activity with friends, highlighting that public places that allow for social interactions may be important for weight-related behaviors.

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Another option to potentially increase neighborhood trust and thus social cohesion while reducing crime is instituting neighborhood watches.[43] It can be argued, however, that participating in neighborhood watches may increase crime awareness and, thus, have a counteractive effect.[40]

Strengths and limitations

This study is based on civil-servants in six large cities in Brazil; therefore, our sample excludes the extremely poor and unemployed and so our results may only be generalizable to Brazilian adults with stable employment. However, the ELSA-Brasil sample is diverse in terms of sociodemographic characteristics, including diverse regions within Brazil. Moreover, whereas the ELSA-Brasil sample has, on average, a higher income and social class than the residents of the six included cities,[27,44] the ELSA-Brasil sample has a similar prevalence of obesity and obesity-related behaviors (i.e. diet and physical activity patterns) than the Brazilian population at large.[45]

Data collection was based on validated questionnaires and scales, as well as direct body measurements which allowed us to estimate obesity based on measured weight and height as opposed to self-reports. The neighborhood social environment variables, however, are all self-reported and we did not have access to objective measures of crime/violence in the neighborhood. Moreover, we aggregated individual-level scores from the social cohesion, perceived safety, and perceived violence scales to the neighborhood level so that all participants in the same neighborhood would have the same level of exposure. While this is standard procedure for the use of these scales,[28,29] the aggregate values are based only on the ELSA-Brasil sample and not on a representative sample of neighborhood residents. Another limitation

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includes the cross-sectional design, which prevents us from establishing the directionality of the associations. While some researchers question the validity of associating neighborhood-level variables with health outcomes due to people self-selecting into neighborhoods,[46] the ELSA-Brasil population is highly stable, with an average length of residence in their current neighborhood of 15 years.

CONCLUSIONS

To our knowledge, this is one of the few studies in Latin America examining the association between the neighborhood social environment and obesity, providing key insights into the likelihood of success of neighborhood-level interventions addressing obesity in the Brazilian context, in particular. Our results suggest that an increase in neighborhood social cohesion and a reduction in the perception of neighborhood violence may be protective of obesity among Brazilian women, with the latter particularly true for women living in poor neighborhoods. Further research is needed to test some of the proposed interventions in Brazil and other Latin American countries, with an aim to strengthen existing communities while improving the public's health. Future research should also clarify the reasons why the neighborhood social environment in both high and low- and middle-income countries seem to affect women more than men.

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DATA SHARING

The data used in this study are available for research proposals on request to the ELSA's Datacenter and to the ELSA's Publications Committee (publiELSA). Additional information can be obtained from the ELSA's Datacenter (estatisticaelsa@ufrgs.br) and from the ELSA Coordinator from the Research Center of Rio de Janeiro (rohgriep@ioc.fiocruz.br).

DISCLOSURE

The authors declared no conflict of interest.

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SUPPLEMENTARY TABLE

Supplementary Table S1: Neighborhood characteristics by SES cluster (N=1902 neighborhoods where the sample lived)

	Low SES N=753			Intermediate SES N=550			High SES N=598		
	Mean	SD	IQR	Mean	SD	IQR	Mean	SD	IQR
Proportion of children 0-4 years	6.85	1.17	6.03-7.62	5.29	0.98	4.62-5.90	3.93	1.04	3.26-4.48
Number of people per household	3.27	0.19	3.15-3.37	3.02	0.18	2.90-3.14	2.59	0.31	2.35-2.81
% White	32.11	15.07	16.31-43.10	59.70	13.79	50.68-69.04	81.24	10.14	74.79-89.11
Median income ($R)	946.56	292.02	733.13-1102.92	1916.65	750.63	1395.50-2209.20	4758.85	2290.00	3003.02-6001.70
Social capital	16.79	2.96	15.25-18.40	17.17	2.62	16.00-18.75	17.45	1.93	16.40-18.62
Perceived safety	8.84	2.61	7.00-10.50	9.35	2.49	8.00-11.00	9.51	1.96	8.25-10.75
Perceived violence	15.68	2.53	14.20-17.50	16.71	2.06	15.81-18.00	17.04	1.67	16.33-18.00

Abbreviations: SES=socioeconomic status; SD=standard deviation; IQR= interquartile range
Note: The perceived violence scale was constructed so that a higher score indicated a lower perceived violence.

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Page No	Recommendation
Title and abstract	1	1	*(*a) Indicate the study's design with a commonly used term in the title or the abstract *The term "cohort study" is included in the title*
		3	(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction			
Background/rationale	2	6-7	Explain the scientific background and rationale for the investigation being reported
Objectives	3	7	State specific objectives, including any prespecified hypotheses
Methods			
Study design	4	7	Present key elements of study design early in the paper
Setting	5	7	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	7	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants
Variables	7	8-11	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	8-11	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	10	Describe any efforts to address potential sources of bias *Explained covariate adjustment to control for confounding*
	10	8	Explain how the study size was arrived at
Quantitative variables	11	8-12	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	11-12	(*a*) Describe all statistical methods, including those used to control for confounding (*b*) Describe any methods used to examine subgroups and interactions (*c*) Explain how missing data were addressed (*d*) If applicable, describe analytical methods taking account of sampling strategy (*e*) Describe any sensitivity analyses *No sensitivity analyses done*
Results			
Participants	13*	8	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
			(b) Give reasons for non-participation at each stage
			(c) Consider use of a flow diagram *Authors consider this unnecessary as data collection has been explained in previous publications at length (cited in this paper)*
Descriptive data	14*	12 Table1	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
			(b) Indicate number of participants with missing data for each variable of

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			interest *WOMEN max sample = 8218 (all have age and education)* *8218 – 395 with missing skin color = 7823* *7823 – 3 missing obesity = 7820* *7820 – 1713 missing neighborhood (and hence, all neighborhood values) = 6107 → ANALYTICAL SAMPLE* *MEN max sample = 6887 (all have age and education)* *6887 – 320 with missing skin color = 6567* *6567 – 3 missing obesity = 6564* *6564 – 1773 missing neighborhood (and hence, all neighborhood values) = 4791 → ANALYTICAL SAMPLE*
Outcome data	15*	12 Table1	Report numbers of outcome events or summary measures
Main results	16	12,13 Tables 2-5	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
			(*b*) Report category boundaries when continuous variables were categorized
			(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period *Not applicable*
Other analyses	17	13 Table5	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses *Subgroups analyses are explained; no sensitivity analyses reported*
Discussion			
Key results	18	19	Summarise key results with reference to study objectives
Limitations	19	23	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	24	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	23	Discuss the generalisability (external validity) of the study results
Other information			
Funding	22	25	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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The association between the neighborhood social environment and obesity in Brazil: a cross-sectional analysis of the ELSA-Brasil study

M. Pia Chaparro,[1] M. Fatima Pina,[2-4] Leticia de Oliveira Cardoso,[5] Simone M. Santos,[5] Sandhi Maria Barreto,[6] Luana Giatti Gonçalves,[7] Sheila M. Alvim de Matos,[8] Maria de Jesus Mendes da Fonseca,[5] Dóra Chor,[5] Rosane H. Griep[2]

[1]Department of Global Community Health and Behavioral Sciences, School of Public Health and Tropical Medicine, Tulane University, New Orleans, LA, USA.

[2]Laboratory of Health and Environment Education, Oswaldo Cruz Institute, Fundação Oswaldo Cruz, Manguinhos, Rio de Janeiro, Brazil.

[3]Institute of Biomedical Engineering (INEB), University of Porto, Porto, Portugal.

[4]Institure of Research and Innovation in Health (i3s), University of Porto, Porto, Portugal.

[5]National School of Public Health Sergio Arouca, Fundação Oswaldo Cruz, Rio de Janeiro, Brazil.

[6]Medical School & Hospital das Clínicas, Federal University of Minas Gerais, Belo Horizonte, Minas Gerais, Brazil.

[7]School of Nutrition, Federal University of Ouro Preto, Ouro Preto, Minas Gerais, Brazil.

[8]Institute of Public Health, Federal University of Bahia, Salvador, Brazil.

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Corresponding author: M. Pia Chaparro, MS, PhD (corresponding author)

Department of Global Community Health and Behavioral Sciences

School of Public Health and Tropical Medicine

Tulane University

1440 Canal St., suite 2200-16, mail code #8319

New Orleans, LA 70112

Tel. (504) 988-4533

Email: pchaparro@tulane.edu

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ABSTRACT

Objective: To investigate the association between the neighborhood social environment, including social cohesion, perceived neighborhood safety, perceived neighborhood violence, and obesity in Brazil.

Design: Cross-sectional study.

Setting: 6 state capitals in Brazil (Salvador, Vitoria, Belo Horizonte, Porto Alegre, Sao Paulo, and Rio de Janeiro)

Participants: Current or former employees of 5 federal universities and 1 research center in each of the 6 Brazilian state capitals who were participants of the baseline wave (2008-2010) of the Brazilian Longitudinal Study of Adult Health (N=11,456; 56% women; 56% White, 28% Brown, and 16% Black).

Primary outcome measure: Obesity, based on measured weight and height, and defined as having a body mass index (BMI) $\geq 30 kg/m^2$.

Results: No associations were found between the neighborhood social environment and obesity among men. In multilevel logistic regression models adjusted for age, education, skin color, state of residence, and individual-level social cohesion and perceived violence scores, respectively, women living in the least socially cohesive neighborhoods and in those perceived as most violent had higher odds of obesity compared to their counterparts (OR=1.25, 95%CI=1.02-1.53; OR=1.28, 95%CI=1.04-1.56, respectively). When stratified by neighborhood SES – defined based on number of people per household, proportion of children 0-4 years, median income, and percent of white residents at the neighborhood level – results for social cohesion and for violence remained only for women residing in high SES and low SES neighborhoods, respectively.

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Conclusions: In this civil-servant sample in 6 large cities in Brazil, the neighborhood social environment was associated with obesity among women, but not men. Neighborhood-level interventions to increase social cohesion and reduce violence may help in the prevention of obesity among women in Brazil.

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STRENGTHS AND LIMITATIONS OF THE STUDY

- This is one of the first studies investigating the association between the neighborhood social environment and obesity in Latin America
- The sample comes from a well-defined cohort study in six large and diverse cities in Brazil, using validated questionnaires and scales, as well as measured weight and height
- This study is based on civil-servants, which excludes the extremely poor and unemployed, limiting generalizability

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INTRODUCTION

Research on neighborhoods and their influence on obesity focus on the physical environment, including the food and physical activity environments, as well as the social environment,[1,2] which refers to the social interactions (or lack thereof) that occur in the neighborhood between neighbors. The social environment includes concepts like social cohesion and social ties, as well as exposure to crime and violence, all of which have been linked to obesity.[3,4] Neighborhood social cohesion is hypothesized to work as a buffer for stress and, as such, to be protective of obesity,[5] whereas neighborhood crime and violence may affect the likelihood of outdoor physical activity[6-8] and, through this mechanism, be detrimental for obesity. Given the hypothesized link between neighborhoods and obesity, neighborhood-level interventions may be effective ways of influencing individual weight-related behaviors and thus preventing obesity.[9]

To date most evidence linking neighborhoods and obesity come from high-income countries, with still a limited amount of evidence available for low- and middle-income countries like those in Latin America.[10] This is despite the exponential increase in obesity observed in the region in the past two decades, and the widespread search for effective ways to curb the epidemic.[11,12] In Brazil, for example, obesity among women has increased from 12.1% in 2006 to 19.6% in 2016, and for men the corresponding numbers are 11.4% and 18.1%.[13] Research in Latin America has mostly focused on the food and physical activity environments,[14-18] with fewer studies assessing the neighborhood social environment as it pertains to obesity. Of those studying the social environment, most focus on neighborhood safety/crime. For example, neighborhood rates of homicides have been linked to obesity in Cali, Colombia[19] and Belo Horizonte, Brazil,[20] whereas perceiving one's neighborhood as unsafe was associated with decreased physical activity in Curitiba, Brazil,[6] Sao Paulo, Brazil,[21] and Florianopolis, Brazil.[7]

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To our knowledge, no studies in Latin America have looked into neighborhood social interactions – measured by social cohesion or social ties – and obesity,[4] but a study in Belo Horizonte, Brazil found that neighborhood social cohesion was positively associated with physical activity.[22]

To fill-in such gaps in the literature and taking advantage of a rich and georeferenced dataset based on six large cities in Brazil, the aim of this study was to investigate if the neighborhood social environment – including social cohesion, perceived safety and violence – was associated with obesity among Brazilian adults, and to identify if this association varied by gender. Previous studies have found that social neighborhood characteristics are associated with obesity[5-8,19,20] and that neighborhood environments affect women more than men;[23,24]therefore, we hypothesized that the neighborhood social environment will be associated with obesity among Brazilian adults, particularly among women. Furthermore, we hypothesized that lower neighborhood socioeconomic status (SES) could modify individuals' perceptions of their neighborhood environment and, thus, influence obesity-related behaviors. Therefore, we also assessed if the association between the neighborhood social environment and obesity varied by neighborhood SES.

METHODS

Data comes from the baseline of the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil), a multicenter cohort study designed to investigate the incidence and progression of cardiovascular disease and diabetes, as well as the biological, social, and environmental determinants of these conditions in the Brazilian population.[25] ELSA-Brasil data are collected

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among active and retired employees from universities/research centers located in six Brazilian state capitals: Salvador, Vitoria, Belo Horizonte, Porto Alegre, Sao Paulo, and Rio de Janeiro.[25]

Detailed data collection procedures are found elsewhere.[25] Briefly, participants were recruited via on-site and radio announcements, mailings, billboards, and phone calls. Eligible participants were also recruited using a list of employees stratified by age, gender, and occupation to ensure representativeness in key sub-groups. Baseline data collection occurred in 2008-2010, with a total sample of 15,105 (54% women), ages 35 to 74 years. Data collected relevant to the current study include measured weight and height, sociodemographic information (age, gender, educational attainment, self-reported skin color), and perceptions about participants' neighborhood.

Participants' residential addresses were georeferenced at the census tract level. In Brazil, existing tracts used for census data collection are heterogenous in terms of size and composition; they are often too small to capture the collective social processes we are set to investigate, while also proving problematic for statistical analysis.[26] Therefore, neighborhoods were constructed by combining contiguous census tracts with similar sociodemographic composition based on four variables from the Brazilian Census 2010:[27] number of people per household, proportion of children 0-4 years, mean income, and percent of white residents, following an adaptation of the methodology described by Santos et al. (2010).[26] In their study, Santos et al. (2010)[26] utilized a spatial aggregation method based on SKATER (Spatial 'K'luster Analysis by Tree Edge Removal at TerraView software) to create clusters of contiguous census tracts based on the same sociodemographic characteristics listed above but with educational attainment instead of percent of white residents, as available in the Brazilian Census 2000.[26] The Brazilian Census 2010 did

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not include questions regarding education,[27] so percent of white residents was chosen as an adequate replacement variable based on principal component analysis.

Neighborhoods were defined with a minimum population size of 5,000 inhabitants, a number deemed appropriate to be able to distinguish between different socioeconomic patterns.[26] Our sample includes 11,456 individuals with complete data and valid neighborhood definitions, corresponding to 76% of the ELSA-Brasil participants; this sample lived in 1902 neighborhoods, with a mean population of 6.02 individuals per neighborhood (SD 9.82; median=3; min-max=1-139).

ELSA-Brasil research protocol was approved by the Research Ethics Committees of São Paulo University, Minas Gerais Federal University, Fundação Oswaldo Cruz, Espírito Santo Federal University, Bahia Federal University, Rio Grande do Sul Federal University, and the National Research Ethics Committee.

The outcome of this study was obesity, defined as having a body mass index (BMI)≥30 kg/m^2, based on measured weight and height. Our exposure variables were self-reported measures of the neighborhood social environment, including social cohesion, perceived safety, and perceived violence. The three scales used to measure social cohesion, perceived safety, and perceived violence were cross-culturally adapted from existing validated ones,[28,29] including a translation and back-translation from English to Portuguese.[30] Test-retest reliability was assessed in a sub-sample of ELSA-Brasil participants to evaluate internal consistency and temporal stability of the measurements; the scales were found to have good internal consistency (assessed with Cronbach's alpha: 0.60 for social cohesion, 0.67 for perceived safety, 0.71 for perceived violence) and very good reproducibility (assessed with intraclass correlation coefficients: 0.83 for social cohesion, 0.86 for perceived safety, 0.87 for perceived violence).[30] There was a low

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correlation between the social cohesion and the perceived safety (Pearson correlation coefficient [CC]=0.24) and the perceived violence (CC=0.26) scales in our sample, and a moderate correlation between the perceived safety and perceived violence scales (CC=0.46). Correlation coefficients were similar for women and men.

Social cohesion, defined as the willingness of neighbors to intervene for the good of the community,[28] was assessed with a 5-item scale: 1) this is a close-knit neighborhood; 2) people around here are willing to help their neighbors; 3) people in this neighborhood don't get along with each other; 4) people in this neighborhood do not share the same values; and 5) people in this neighborhood can be trusted. Participants were asked their agreement level for these items using a 5-point Likert scale ranging from 1="completely agree" to 5="completely disagree," with scores ranging from 5-25. Reverse coding was used as needed so that a higher score indicated a higher social cohesion.

Perceived neighborhood safety was assessed with a 3-item scale: 1) I feel safe walking in my neighborhood, day or night; 2) violence is a problem in my neighborhood; and 3) my neighborhood is safe from crime, with participants reporting their agreement level with these items following the same 5-point Likert scale as above. Individual scores ranged from 3-15. Items 1 and 3 were reverse coded so that a higher score indicated a higher perceived safety.

Perceived neighborhood violence was assessed based on 5 items, referring to the previous 6 months: 1) how often was there a fight in this neighborhood in which a weapon was used?; 2) how often was there a violent argument between neighbors?; 3) how often was there a gang fight?; 4) how often was there a sexual assault or rape?; and 5) how often was there a robbery or mugging?. Response options ranged from 1="frequently" to 4="never," with individual scores ranging from 5 to 20 and a higher score representing lower perceived violence. For all these

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neighborhood scales, thus, a higher score meant something positive: higher social cohesion, higher perceived safety, and lower perceived violence. These three scales were designed to measure aggregate contextual characteristics; therefore, individual-level scores on social cohesion, perceived safety and perceived violence were each aggregated at the neighborhood level, so that all participants living in the same neighborhood would have the same level of exposure. Further, neighborhood-level scores were converted into tertiles to simplify interpretation as the three sets of scores followed different scales with different ranges of responses. Neighborhoods were then classified as being in the lowest, middle, or highest tertile of exposure for each neighborhood predictor.

Covariates included participants' age (continuous), gender, educational attainment (up to primary, secondary, and university), and self-reported skin color (White, Brown ["mixed race"], Black, Asian, and Indigenous; Asian and Indigenous were dropped from the analysis because of their small sample size).

In order to classify the neighborhoods by SES, we ran a principal component analysis to reduce the same four census variables used in the definition of neighborhoods into two non-correlated principal components. The first component was composed of *number of people per household* and *proportion of children 0-4 years*, whereas the second component was composed of *median income* and *percent of white residents*, explaining 87% of the data variability. We then forced these two principal components into three hierarchical clusters, using the Ward's method, to identify groups of neighborhoods with similar characteristics. The authors' empirical knowledge of the area and the interpretation of the scores of each principal component within each cluster allowed for the classification of the neighborhoods into low, intermediate, and high

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SES. Characteristics of these low, intermediate, and high SES neighborhoods are displayed in Supplementary Table S1.

Patient and public involvement

Patients were not involved in the development of this study.

Statistical analysis

Hierarchical multilevel logistic regression models were ran as individuals (level 1) were nested within neighborhoods (level 2), and the outcome variable (obesity) was dichotomous. Model 1 included our independent variable of interest (social cohesion, perceived safety, or perceived violence) and age, while Model 2 was further adjusted by gender; education; skin color; ELSA sites; an interaction term between gender and social cohesion, perceived safety, or perceived violence; as well as individual-level scores on the social cohesion, perceived safety, and perceived violence scales for the models with neighborhood social cohesion, perceived safety, and perceived violence as predictors, respectively. This latter adjustment allowed us to account for individual variations in neighborhood perceptions and to obtain neighborhood effects above and beyond individual effects. Given that gender interactions for two out of our three independent variables of interest were significant (social cohesion interaction p-value=0.0077; perceived safety p-value=0.3569; perceived violence p-value=0.0363), we re-ran all models stratified by gender.

To identify if the association between the neighborhood social environment and obesity varied by neighborhood SES, we further stratified our analysis by neighborhood SES. For these models, neighborhood-level scores of our three neighborhood variables were reconverted into

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tertiles *within* each neighborhood SES category. All analyses were carried out in SAS v9.4 (SAS Institute Inc., Cary, NC, USA) with a p-value<0.05 denoting statistical significance.

RESULTS

Table 1 displays the sample characteristics for the whole sample and by obesity status. Women comprised the majority of the sample (56%); compared to men in the sample, women had a higher education and were more likely to be black. Obesity was more prevalent among women (23%) than men (20%) and among middle-aged participants (46-65 years). We observed social inequities based on education and skin color, with decreased obesity prevalence as education increased, and black participants having the highest prevalence of obesity compared to white participants (29% vs. 20%). We observed an obesity gradient for neighborhood social cohesion and perceived violence, indicating that residents of the least cohesive and most self-perceived violent neighborhoods had a higher prevalence of obesity than those in the most cohesive and least violent neighborhoods, respectively. Residents of the poorest neighborhoods had a higher obesity prevalence compared to those in the richest (26% vs. 19%).

Results of the multilevel logistic regression models predicting obesity by neighborhood social cohesion, perceived safety, and perceived violence are shown in Tables 2, 3, and 4, respectively. Neighborhood social cohesion was associated with obesity for women only, and this association remained after adjusting for age, education, skin color, and individual-level social cohesion scores. In fully adjusted models, women who lived in the least socially cohesive neighborhoods had 25% higher odds of being obese compared to women living in the most socially cohesive neighborhoods (Table 2). We observed no associations between perceived safety and obesity (Table 3). In turn, perceived violence was associated with obesity among

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women only: women living in the most violent neighborhoods had 28% higher odds of obesity compared to women who lived in the least violent neighborhoods, adjusting for age, education, skin color, and individual-level perceived violence scores (Table 4).

Table 1: Characteristics of the sub-sample of ELSA-Brasil participants included in the study, stratified by obesity status (N=11,456)

	Not obese (BMI<30 kg/m²) Row %	Obese (BMI≥30 kg/m²) Row %	Total N (%)
INDIVIDUAL-LEVEL VARIABLES			
Gender			
Women	76.6	23.4	6427 (56.1)
Men	80.1	19.9	5025 (43.9)
Age group (years)			
34-45	81.9	18.1	2841 (24.8)
46-55	76.9	23.1	4400 (38.4)
56-65	76.4	23.6	3077 (26.9)
>65	78.5	21.5	1134 (9.9)
Education			
Less than primary	72.0	28.0	522 (4.6)
Primary	73.8	26.2	646 (5.6)
Secondary	74.3	25.7	3543 (30.9)
University	81.1	18.9	6741 (58.9)
Skin color			
White	80.3	19.7	6127 (56.2)
Brown	77.3	22.7	3052 (28.0)
Black	70.6	29.4	1719 (15.8)
NEIGHBORHOOD-LEVEL VARIABLES			
Social cohesion (mean 17.3, SD 3.6)			
Lowest tertile (range 5 to <16.3; mean 14.3, SD 2.0)	76.0	24.0	2156 (18.8)
Middle tertile (range 16.3 to <18; mean 17.1, SD 0.4)	78.3	21.7	5671 (49.5)
Highest tertile (range 18 to 25; mean 19.4, SD 1.5)	79.2	20.8	3629 (31.7)
Perceived safety (mean 9.5, SD 3.2)			
Lowest tertile (range 3 to <8.4; mean 6.5, SD 7.0)	76.8	23.2	2899 (25.3)
Middle tertile (range 8.4 to <10; mean 9.2, SD 0.4)	79.1	20.9	4648 (40.6)
Highest tertile (range 10 to 15; mean 11.3, SD 1.3)	78.1	21.9	3909 (34.1)
Perceived violence (mean 16.8, SD 2.8)			
Lowest tertile (range 7 to <16; mean 13.8, SD 1.8)	74.9	25.1	2584 (22.6)
Middle tertile (range 16 to <17.5; mean 16.7, SD 0.5)	78.6	21.4	4783 (41.8)
Highest tertile (range 17.5 to 20; mean 18.5, SD 0.7)	79.7	20.3	4089 (35.7)
Neighborhood SES			
Low	74.1	25.9	2812 (24.6)
Intermediate	76.9	23.1	3418 (29.8)
High	81.2	18.8	5225 (45.6)

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Table 2: Results from the multilevel logistic regression model predicting obesity (BMI≥30 kg/m^2) by neighborhood social cohesion; gender-stratified (N= 6,092 women; 4,783 men)

	Model 1 OR (95%CI)		Model 2 OR (95%CI)	
	Women	**Men**	**Women**	**Men**
Neighborhood Social cohesion				
Lowest tertile	**1.43 (1.18-1.72)**	0.99 (0.81-1.21)	**1.25 (1.02-1.53)**	0.90 (0.72-1.13)
Middle tertile	1.14 (0.97-1.32)	0.96 (0.82-1.13)	1.07 (0.92-1.26)	0.95 (0.80-1.13)
Highest tertile	1.00	1.00	1.00	1.00
Age	**1.02 (1.01-1.03)**	1.00 (0.99-1.01)	**1.02 (1.01-1.03)**	1.00 (1.00-1.01)
Individual-level social cohesion			1.00 (0.98-1.02)	0.99 (0.97-1.01)
Education				
Primary or less			**1.46 (1.16-1.83)**	1.10 (0.87-1.40)
Secondary			**1.48 (1.28-1.70)**	1.10 (0.92-1.30)
University			1.00	1.00
Skin color				
Black			**1.86 (1.56-2.21)**	**1.45 (1.15-1.82)**
Brown			**1.38 (1.18-1.62)**	1.13 (0.95-1.36)
White			1.00	1.00
ELSA site				
Bahia			**0.62 (0.50-0.76)**	**0.56 (0.44-0.72)**
Espirito Santo			**0.70 (0.51-0.96)**	0.88 (0.63-1.23)
Minas Gerais			**0.75 (0.62-0.91)**	0.91 (0.74-1.11)
Rio de Janeiro			0.89 (0.71-1.11)	1.06 (0.84-1.33)
Rio Grande do Sul			0.91 (0.74-1.12)	0.91 (0.72-1.16)
Sao Paulo			1.00	1.00

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Table 3: Results from the multilevel logistic regression model predicting obesity (BMI≥30 kg/m^2) by perceived neighborhood safety; gender-stratified (N= 6,092 women; 4,783 men)

	Model 1 OR (95%CI)		Model 2 OR (95%CI)	
	Women	**Men**	**Women**	**Men**
Neighborhood Perceived safety				
Lowest tertile	1.16 (0.97-1.38)	0.98 (0.82-1.18)	1.15 (0.95-1.39)	1.06 (0.86-1.30)
Middle tertile	0.94 (0.80-1.10)	0.92 (0.78-1.08)	0.96 (0.82-1.12)	0.98 (0.83-1.17)
Highest tertile	1.00	1.00	1.00	1.00
Age	**1.02 (1.01-1.03)**	1.00 (0.99-1.01)	**1.02 (1.01-1.03)**	1.00 (1.00-1.01)
Individual-level perceived safety			0.99 (0.97-1.02)	1.00 (0.98-1.03)
Education				
Primary or less			**1.48 (1.18-1.86)**	1.10 (0.87-1.39)
Secondary			**1.49 (1.30-1.71)**	1.09 (0.92-1.30)
University			1.00	1.00
Skin color				
Black			**1.87 (1.57-2.23)**	**1.44 (1.14-1.81)**
Brown			**1.39 (1.19-1.63)**	1.13 (0.95-1.36)
White			1.00	1.00
ELSA site				
Bahia			**0.59 (0.48-0.73)**	**0.56 (0.43-0.72)**
Espirito Santo			**0.66 (0.48-0.90)**	0.89 (0.64-1.24)
Minas Gerais			**0.71 (0.59-0.86)**	0.92 (0.75-1.12)
Rio de Janeiro			0.84 (0.67-1.05)	1.05 (0.83-1.32)
Rio Grande do Sul			0.87 (0.71-1.07)	0.92 (0.72-1.17)
Sao Paulo			1.00	1.00

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Table 4: Results from the multilevel logistic regression model predicting obesity (BMI≥30 kg/m^2) by perceived neighborhood violence; gender-stratified (N= 6,092 women; 4,783 men)

	Model 1 OR (95%CI)		Model 2 OR (95%CI)	
	Women	**Men**	**Women**	**Men**
Neighborhood Perceived violence				
Lowest tertile	**1.51 (1.27-1.80)**	1.08 (0.90-1.30)	**1.28 (1.04-1.56)**	1.07 (0.86-1.34)
Middle tertile	1.07 (0.91-1.25)	0.98 (0.83-1.15)	1.03 (0.88-1.20)	0.99 (0.84-1.18)
Highest tertile	1.00	1.00	1.00	1.00
Age	**1.02 (1.01-1.03)**	1.00 (0.99-1.01)	**1.02 (1.01-1.03)**	1.00 (1.00-1.01)
Individual-level perceived violence			0.98 (0.96-1.00)	0.99 (0.96-1.02)
Education				
Primary or less			**1.42 (1.13-1.78)**	1.08 (0.86-1.38)
Secondary			**1.44 (1.25-1.66)**	1.08 (0.91-1.29)
University			1.00	1.00
Skin color				
Black			**1.82 (.153-2.17)**	**1.43 (1.13-1.81)**
Brown			**1.37 (1.17-1.61)**	1.13 (0.94-1.35)
White			1.00	1.00
ELSA site				
Bahia			**0.56 (0.45-0.70)**	**0.54 (0.42-0.70)**
Espirito Santo			**0.67 (0.49-0.92)**	0.89 (0.64-1.23)
Minas Gerais			**0.70 (0.58-0.84)**	0.92 (0.75-1.11)
Rio de Janeiro			0.81 (0.65-1.02)	1.02 (0.81-1.29)
Rio Grande do Sul			0.84 (0.68-1.03)	0.90 (0.71-1.15)
Sao Paulo			1.00	1.00

[1]The perceived violence scale was constructed so that a higher score indicated a lower perceived violence. Therefore, the *lowest tertile* category represents neighborhoods with the highest perceived violence.

Table 5 displays the results of the analysis stratified by neighborhood SES. For social cohesion, our results remained only among women living in high SES neighborhoods: women in the least socially cohesive neighborhoods had 48% higher odds of obesity compared to women living in the most socially cohesive neighborhoods *within high SES neighborhoods*. Oppositely, our results with perceived violence remained for women in poor neighborhoods: *within low SES neighborhoods*, women living in the most (perceived)s violent neighborhoods had almost twice the odds of obesity compared to those living in the least (perceived) violent neighborhoods. Associations also emerged in the intermediate SES category, suggesting a dose-response association between perceived violence and obesity for those in low SES neighborhoods.

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Table 5: Results from the multilevel logistic regression model predicting obesity (BMI≥30 kg/m^2) by neighborhood social cohesion, by perceived safety, and by perceived violence independently, and stratified by neighborhood socioeconomic status (SES) and gender[1]

	High SES OR (95% CI)		Intermediate SES OR (95%CI)		Low SES OR (95%CI)	
	Women	**Men**	**Women**	**Men**	**Women**	**Men**
Social cohesion						
N	2799	2144	1882	1371	1410	1268
Lowest tertile	**1.48 (1.10-1.99)**	1.03 (0.76-1.42)	0.86 (0.59-1.26)	0.95 (0.63-1.45)	1.43 (0.98-2.10)	0.92 (0.59-1.44)
Middle tertile	1.06 (0.82-1.37)	1.05 (0.80-1.38)	1.03 (0.77-1.37)	0.83 (0.59-1.16)	0.98 (0.73-1.33)	0.83 (0.58-1.20)
Highest tertile	1.00	1.00	1.00	1.00	1.00	1.00
Perceived safety						
N	2797	2144	1881	1371	1408	1268
Lowest tertile	1.09 (0.80-1.48)	1.01 (0.73-1.40)	0.81 (0.57-1.16)	1.11 (0.74-1.66)	1.38 (0.93-2.02)	1.19 (0.76-1.86)
Middle tertile	1.00 (0.77-1.30)	0.87 (0.66-1.14)	0.84 (0.63-1.13)	0.98 (0.70-1.37)	1.27 (0.94-1.71)	0.99 (0.69-1.43)
Highest tertile	1.00	1.00	1.00	1.00	1.00	1.00
Perceived violence						
N	2792	2134	1873	1369	1406	1267
Lowest tertile	1.00 (0.73-1.37)	1.21 (0.85-1.72)	1.22 (0.84-1.76)	1.03 (0.68-1.56)	**1.92 (1.28-2.90)**	1.02 (0.63-1.66)
Middle tertile	0.87 (0.67-1.12)	1.08 (0.83-1.40)	1.01 (0.75-1.38)	0.86 (0.60-1.22)	**1.70 (1.23-2.34)**	1.03 (0.72-1.49)
Highest tertile	1.00	1.00	1.00	1.00	1.00	1.00

[1]All models adjusted by age, education, skin color, ELSA site, as well as by individual-level social cohesion, perceived safety, and perceived violence scores for the neighborhood social cohesion, perceived safety, and perceived violence models, respectively.
[2]The perceived violence scale was constructed so that a higher score indicated a lower perceived violence. Therefore, the *lowest tertile* category represents neighborhoods with the highest perceived violence.

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DISCUSSION

In this study based on a civil-servant sample of adults living in six large cities in Brazil, we found that living in a neighborhood with low social cohesion and high levels of self-perceived violence was associated with higher odds of obesity among women but not men. After stratifying by neighborhood SES, the association between living in the least socially cohesive neighborhoods and obesity remained only among women living in high SES neighborhoods, whereas the association between living in the most (perceived) violent neighborhoods and obesity remained only for women residing in low SES neighborhoods.

Studies in Latin America[19,20] and elsewhere[8] also report an association between neighborhood violence and obesity among adults. The hypothesized mechanisms involved are a reduction in outdoor physical activity, related to the fear of being outdoors, as well as the direct stress caused by living in an unsafe neighborhood. There is support for both hypotheses in the literature, as neighborhood crime/violence is associated with a decreased physical activity,[6-8] and also with an increase in stress and a worse mental health.[31,32] Chronic stress, in turn, has been linked to an increased obesity risk due to its influence on weight-related behaviors and by dysregulating the hypothalamic-pituitary-adrenal axis, leading to abdominal fat deposition.[33]

There are mixed results in relation to neighborhood social cohesion and obesity in high-income countries,[5,23,34] though most studies have found protective effects.[4] As far as the authors know, no previous studies have looked at this association in Latin America. Similar to our findings, Cohen et al. (2006) found that residents of neighborhoods with lower collective efficacy – a concept highly linked to social cohesion – had higher BMIs in Los Angeles, CA, U.S.[5] Burdette et al. (2006), in turn, found no such association among women living in 20 U.S. cities.[34]

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Social cohesion is hypothesized to act as a buffer from neighborhood-related stress and, through this mechanism, be protective of obesity.[5] Cohen et al. (2006) also suggest that adults in neighborhoods with higher social cohesion may be willing to intervene in aspects of the neighborhood that influence weight-related behaviors; for example, setting up sports leagues or influencing local food stores to carry healthier offerings.[5] However, the opposite can also be true, with residents in high-social-cohesion neighborhoods uniting for negative things as they pertain to obesity, for example, standing against soda taxation or against bans of unhealthy vending machines.[4]

We found that neighborhood social cohesion and perceived violence only influences the obesity risk of Brazilian women and not men. This finding that women are more affected by their neighborhood environment, particularly the social one, is not new.[24,35,36] Rech et al. 2012 found that perception of safety during the day was associated with leisure walking among women but not men among a convenience sample of adults in Curitiba, Brazil.[6] Similarly, a study in Los Angeles, CA, U.S. found that women living in high-poverty neighborhoods exercised less than men, partly due to safety concerns associated with accessing outdoor parks.[36] Moreover, Guilcher et al. (2017) found that a higher neighborhood social cohesion was associated with lower odds of obesity only among women in a sample of adults in Toronto, Canada.[23] Reasons why neighborhood effects may be stronger for women than men include differences in their neighborhood perceptions (which is not the case in our sample), an increased exposure (i.e. women spending more time in their residential neighborhoods), or an increased vulnerability (i.e. women being more impacted by their surroundings).[24] Further, women are more often victims of sexual violence than men,[3,8] and this may influence the time they spend outdoors – and hence

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their physical activity levels – as well as their stress levels, particularly among women in low SES neighborhoods.

A previous study conducted in the south of Brazil found neighborhood-level variations in obesity prevalence for both men and women; however, neighborhood-level education was only associated with obesity among women in the sample.[37] Another study using ELSA-Brasil data found that the food and physical activity neighborhood environments were associated with obesity among women but not men.[38] The results of these studies and our own suggest that the neighborhood environment may matter for men's obesity risk, but the neighborhood factors studied to date are relevant only for women. Future studies should further investigate which neighborhood factors, if any, affect obesity risk among men in Brazil and other Latin American settings, as well as the reason why neighborhood factors may affect women's and men's obesity risk differently.

Finally, we found that the effect of social cohesion and perceived violence on obesity among women varied by neighborhood SES. Two studies of the neighborhood social environments in Brazil have found differential effects of these neighborhood variables on physical activity by *individual*-level SES. Andrade et al. (2015) reports a positive association between social cohesion and physical activity only among low-SES individuals in Belo Horizonte, Brazil.[22] This contradicts our findings that a lower social cohesion was associated with a higher obesity risk among women living in high-SES neighborhoods. In turn, Rech et al. (2012) found that negative associations between safety perceptions and physical inactivity in Curitiba, Brazil were only present among high-SES individuals.[6] We found that perceived neighborhood violence increased obesity risk among women in low-SES neighborhoods only.

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Even though we found minimal variations in perceived violence scores by neighborhood SES in our sample (Supplementary Table S1), women living in low SES neighborhoods may be more impacted by their perceived neighborhood violence than those living in high SES neighborhoods. For example, residents of high SES neighborhoods may be more likely to have cars and access (monetary and physical) to indoor places for exercising (e.g. gyms). This would mean that high-SES neighborhood residents could more effectively avoid spending time outdoors in their neighborhoods without this having a severe impact on their physical activity behaviors and/or stress, the suggested mechanisms linking perceived violence and obesity. Scores of neighborhood social cohesion are also similar in our sample across neighborhood SES categories (Supplementary Table S1). Why social cohesion would be associated with obesity only among women residing in high-SES neighborhoods requires further investigation.

Our results suggest that neighborhood interventions to increase social cohesion and decrease violence perceptions may prevent obesity among women in Brazil. Effective neighborhood interventions designed to reduce violence may include the cleaning and greening of vacant lots, as well as the reduction of alcohol availability.[39] Though the effect of these kinds of interventions on *perceived* violence is unknown, research suggests that *fear of crime* may be negatively influenced by neglected and run-down neighborhood spaces.[40] The greening of vacant lots may also work at increasing social cohesion and social interactions, based on evidence available from public gardening research.[41] Increasing access to safe public spaces may also help increase social cohesion and thus *may* decrease obesity risk. Salvo et al.,[42]for example, found that residents of Bogota, Colombia and Cuernavaca, Mexico reported shopping malls and nightclubs as places where they engaged in physical activity with friends, highlighting that public places that allow for social interactions may be important for weight-related behaviors.

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Another option to potentially increase neighborhood trust and thus social cohesion while reducing crime is instituting neighborhood watches.[43] It can be argued, however, that participating in neighborhood watches may increase crime awareness and, thus, have a counteractive effect.[40]

Strengths and limitations

This study is based on civil-servants in six large cities in Brazil; therefore, our sample excludes the extremely poor and unemployed and so our results may only be generalizable to Brazilian adults with stable employment. However, the ELSA-Brasil sample is diverse in terms of sociodemographic characteristics, including diverse regions within Brazil. Moreover, whereas the ELSA-Brasil sample has, on average, a higher income and social class than the residents of the six included cities,[27,44] the ELSA-Brasil sample has a similar prevalence of obesity and obesity-related behaviors (i.e. diet and physical activity patterns) than the Brazilian population at large.[45]

Data collection was based on validated questionnaires and scales, as well as direct body measurements which allowed us to estimate obesity based on measured weight and height as opposed to self-reports. Even though the neighborhood social environment variables were obtained from these validated scales, they are still self-reported, and we did not have access to objective measures of crime/violence in the neighborhood. Moreover, the internal consistency of these scales, particularly for social cohesion (Cronbach's alpha=0.60)[30] was not ideal. In terms of the analysis, as most research using artificial neighborhood boundaries, results may vary if neighborhoods were to be defined in a different manner. Similarly, using a different way to categorize neighborhoods into low, middle, and high levels of social cohesion, perceived safety,

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and perceived violence instead of tertiles may lead to different results. We aggregated individual-level scores from the social cohesion, perceived safety, and perceived violence scales to the neighborhood level so that all participants in the same neighborhood would have the same level of exposure. While this is standard procedure for the use of these scales,[28,29] the aggregate values are based only on the ELSA-Brasil sample and not on a representative sample of neighborhood residents. Another limitation includes the cross-sectional design, which prevents us from establishing the directionality of the associations. While some researchers question the validity of associating neighborhood-level variables with health outcomes due to people self-selecting into neighborhoods,[46] the ELSA-Brasil population is highly stable, with an average length of residence in their current neighborhood of 15 years.

CONCLUSIONS

To our knowledge, this is one of the few studies in Latin America examining the association between the neighborhood social environment and obesity, providing key insights into the likelihood of success of neighborhood-level interventions addressing obesity in the Brazilian context, in particular. Our results suggest that an increase in neighborhood social cohesion and a reduction in the perception of neighborhood violence may be protective of obesity among Brazilian women, with the latter particularly true for women living in poor neighborhoods. Further research is needed to test some of the proposed interventions (e.g. greening of vacant lots, increasing access to public spaces, instituting neighborhood watches) in Brazil and other Latin American countries, with an aim to strengthen existing communities while improving the public's health. Future research should also clarify the reasons why the neighborhood social

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environment in both high and low- and middle-income countries seem to affect women more than men.

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DATA SHARING

The data used in this study are available for research proposals on request to the ELSA's Datacenter and to the ELSA's Publications Committee (publiELSA). Additional information can be obtained from the ELSA's Datacenter (estatisticaelsa@ufrgs.br) and from the ELSA Coordinator from the Research Center of Rio de Janeiro (rohgriep@ioc.fiocruz.br).

DISCLOSURE

The authors declared no conflict of interest.

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SUPPLEMENTARY TABLE

Supplementary Table S1: Neighborhood characteristics by SES cluster (N=1902 neighborhoods where the sample lived)

	Low SES N=753			Intermediate SES N=550			High SES N=598		
	Mean	SD	IQR	Mean	SD	IQR	Mean	SD	IQR
Proportion of children 0-4 years	6.85	1.17	6.03-7.62	5.29	0.98	4.62-5.90	3.93	1.04	3.26-4.48
Number of people per household	3.27	0.19	3.15-3.37	3.02	0.18	2.90-3.14	2.59	0.31	2.35-2.81
% White	32.11	15.07	16.31-43.10	59.70	13.79	50.68-69.04	81.24	10.14	74.79-89.11
Median income ($R)	946.56	292.02	733.13-1102.92	1916.65	750.63	1395.50-2209.20	4758.85	2290.00	3003.02-6001.70
Social capital	16.79	2.96	15.25-18.40	17.17	2.62	16.00-18.75	17.45	1.93	16.40-18.62
Perceived safety	8.84	2.61	7.00-10.50	9.35	2.49	8.00-11.00	9.51	1.96	8.25-10.75
Perceived violence	15.68	2.53	14.20-17.50	16.71	2.06	15.81-18.00	17.04	1.67	16.33-18.00

Abbreviations: SES=socioeconomic status; SD=standard deviation; IQR= interquartile range
Note: The perceived violence scale was constructed so that a higher score indicated a lower perceived violence.

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Page No	Recommendation
Title and abstract	1	1	*(*a) Indicate the study's design with a commonly used term in the title or the abstract *The term "cohort study" is included in the title*
		3	(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction			
Background/rationale	2	6-7	Explain the scientific background and rationale for the investigation being reported
Objectives	3	7	State specific objectives, including any prespecified hypotheses
Methods			
Study design	4	7	Present key elements of study design early in the paper
Setting	5	7	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	7	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants
Variables	7	8-11	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	8-11	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	10	Describe any efforts to address potential sources of bias *Explained covariate adjustment to control for confounding*
	10	8	Explain how the study size was arrived at
Quantitative variables	11	8-12	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	11-12	(*a*) Describe all statistical methods, including those used to control for confounding (*b*) Describe any methods used to examine subgroups and interactions (*c*) Explain how missing data were addressed (*d*) If applicable, describe analytical methods taking account of sampling strategy (*e*) Describe any sensitivity analyses *No sensitivity analyses done*
Results			
Participants	13*	8	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
			(b) Give reasons for non-participation at each stage
			(c) Consider use of a flow diagram *Authors consider this unnecessary as data collection has been explained in previous publications at length (cited in this paper)*
Descriptive data	14*	12 Table1	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
			(b) Indicate number of participants with missing data for each variable of

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			interest *WOMEN max sample = 8218 (all have age and education)* *8218 – 395 with missing skin color = 7823* *7823 – 3 missing obesity = 7820* *7820 – 1713 missing neighborhood (and hence, all neighborhood values) = 6107 → ANALYTICAL SAMPLE* *MEN max sample = 6887 (all have age and education)* *6887 – 320 with missing skin color = 6567* *6567 – 3 missing obesity = 6564* *6564 – 1773 missing neighborhood (and hence, all neighborhood values) = 4791 → ANALYTICAL SAMPLE*
Outcome data	15*	12 Table1	Report numbers of outcome events or summary measures
Main results	16	12,13 Tables 2-5	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
			(*b*) Report category boundaries when continuous variables were categorized
			(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period *Not applicable*
Other analyses	17	13 Table5	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses *Subgroups analyses are explained; no sensitivity analyses reported*
Discussion			
Key results	18	19	Summarise key results with reference to study objectives
Limitations	19	23	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	24	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	23	Discuss the generalisability (external validity) of the study results
Other information			
Funding	22	25	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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