BMJ Open

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

M Pia Chaparro,[1] Maria Fátima Pina,[2,3] Letícia de Oliveira Cardoso,[4] Simone M Santos,[4] Sandhi M Barreto,[5] Luana Giatti Gonçalves,[5] Sheila M Alvim de Matos,[6] Maria de Jesus Mendes da Fonseca,[4] Dora Chor,[4] Rosane Haerter Griep[7]

To cite: Chaparro MP, Pina MF, de Oliveira Cardoso L, *et al*. The association between the neighbourhood social environment and obesity in Brazil: a cross-sectional analysis of the ELSA-Brasil study. *BMJ Open* 2019;**9**:e026800. doi:10.1136/bmjopen-2018-026800

► Prepublication history and additional material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2018-026800).

Received 25 September 2018
Revised 09 August 2019
Accepted 14 August 2019

For numbered affiliations see end of article.

Correspondence to
Dr M Pia Chaparro;
pchaparro@tulane.edu

Dr Rosane Haerter Griep;
rohgriep@ioc.fiocruz.br

ABSTRACT

Objective To investigate the association between the neighbourhood social environment, including social cohesion, perceived neighbourhood safety, perceived neighbourhood 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 five federal universities and one research centre in each of the six 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 ≥30 kg/m^2.

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

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

Strengths and limitations of the study

- This is one of the first studies investigating the association between the neighbourhood 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 generalisability.

INTRODUCTION

Research on neighbourhoods 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 neighbourhood between neighbours. 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] Neighbourhood social cohesion is hypothesised to work as a buffer for stress and, as such, to be protective of obesity,[5] whereas neighbourhood crime and violence may affect the likelihood of outdoor physical activity[6–8] and, through this mechanism, be detrimental for obesity. Given the hypothesised link between neighbourhoods and obesity, neighbourhood-level interventions may be effective ways of influencing individual weight-related behaviours and thus preventing obesity.[9]

To date most evidence linking neighbourhoods and obesity come from high-income countries, with still a limited amount of evidence available for low-income 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 neighbourhood social environment as it pertains to obesity. Of those studying the social environment, most focus on neighbourhood safety/crime. For example, neighbourhood rates of homicides have been linked to obesity in Cali, Colombia[19] and Belo Horizonte, Brazil,[20] whereas perceiving one's neighbourhood as unsafe was associated with decreased physical activity in Curitiba, Brazil,[6] Sao Paulo, Brazil,[21] and Florianopolis, Brazil.[7] To our knowledge, no studies in Latin America have looked into neighbourhood social interactions—measured by social cohesion or social ties—and obesity,[4] but a study in Belo Horizonte, Brazil found that neighbourhood 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 neighbourhood 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 neighbourhood characteristics are associated with obesity[5–8 19 20] and that neighbourhood environments affect women more than men[23 24]; therefore, we hypothesised that the neighbourhood social environment will be associated with obesity among Brazilian adults, particularly among women. Furthermore, we hypothesised that lower neighbourhood socioeconomic status (SES) could modify individuals' perceptions of their neighbourhood environment and, thus, influence obesity-related behaviours. Therefore, we also assessed if the association between the neighbourhood social environment and obesity varied by neighbourhood SES.

METHODS

Data come from the baseline of the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil), a multicentre 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 among active and retired employees from universities/research centres 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 onsite 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 subgroups. Baseline data collection occurred in 2008–2010, with a total sample of 15 105 (54% women), ages 35–74 years. Data collected relevant to the current study include measured weight and height, sociodemographic information (age, gender, educational attainment, self-reported skin colour) and perceptions about participants' neighbourhood.

Participants' residential addresses were georeferenced at the census tract level. In Brazil, existing tracts used for census data collection are heterogeneous 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, neighbourhoods 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 per cent of white residents, following an adaptation of the methodology described by Santos *et al* (2010).[26] In their study, Santos *et al* (2010)[26] utilised a spatial aggregation method based on SKATER (Spatial 'K'lustre 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 per cent of white residents, as available in the Brazilian Census 2000.[26] The Brazilian Census 2010 did not include questions regarding education,[27] so per cent of white residents was chosen as an adequate replacement variable based on principal component analysis.

Neighbourhoods were defined with a minimum population size of 5000 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 neighbourhood definitions, corresponding to 76% of the ELSA-Brasil participants; this sample lived in 1902 neighbourhoods, with a mean population of 6.02 individuals per neighbourhood (SD 9.82; median=3; min–max=1–139).

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 neighbourhood 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 subsample 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 and 0.71 for perceived violence) and very good reproducibility (assessed with intraclass correlation coefficients (CCs): 0.83 for social cohesion, 0.86 for perceived safety and

0.87 for perceived violence).[30] There was a low correlation between the social cohesion and the perceived safety (Pearson 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). CCs were similar for women and men.

Social cohesion, defined as the willingness of neighbours to intervene for the good of the community,[28] was assessed with a 5-item scale: (1) this is a close-knit neighbourhood; (2) people around here are willing to help their neighbours; (3) people in this neighbourhood don't get along with each other; (4) people in this neighbourhood do not share the same values and (5) people in this neighbourhood 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 to 25. Reverse coding was used as needed so that a higher score indicated a higher social cohesion.

Perceived neighbourhood safety was assessed with a 3-item scale: (1) I feel safe walking in my neighbourhood, day or night; (2) violence is a problem in my neighbourhood and (3) my neighbourhood 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 to 15. Items 1 and 3 were reverse coded so that a higher score indicated a higher perceived safety.

Perceived neighbourhood violence was assessed based on five items, referring to the previous 6 months: (1) how often was there a fight in this neighbourhood in which a weapon was used?; (2) how often was there a violent argument between neighbours?; (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 neighbourhood 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 neighbourhood level so that all participants living in the same neighbourhood would have the same level of exposure. Furthermore, neighbourhood-level scores were converted into tertiles to simplify interpretation as the three sets of scores followed different scales with different ranges of responses. Neighbourhoods were then classified as being in the lowest, middle or highest tertile of exposure for each neighbourhood predictor.

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

To classify the neighbourhoods by SES, we ran a principal component analysis to reduce the same four census variables used in the definition of neighbourhoods 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 *per cent 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 neighbourhoods 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 neighbourhoods into low, intermediate and high SES. Characteristics of these low, intermediate and high SES neighbourhoods are displayed in online 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 neighbourhoods (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 colour; 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 neighbourhood social cohesion, perceived safety and perceived violence as predictors, respectively. This latter adjustment allowed us to account for individual variations in neighbourhood perceptions and to obtain neighbourhood 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 neighbourhood social environment and obesity varied by neighbourhood SES, we further stratified our analysis by neighbourhood SES. For these models, neighbourhood-level scores of our three neighbourhood variables were reconverted into tertiles *within* each neighbourhood SES category. All analyses were carried out in SAS V.9.4 (SAS Institute, 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

Table 1 Characteristics of the subsample of ELSA-Brasil participants included in the study, stratified by obesity status (n=11 456)

	Non-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 colour			
White	80.3	19.7	6127 (56.2)
Brown	77.3	22.7	3052 (28.0)
Black	70.6	29.4	1719 (15.8)
Neighbourhood-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: 18–25; 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: 10–15; 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: 17.5–20; mean: 18.5, SD: 0.7)	79.7	20.3	4089 (35.7)
Neighbourhood 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)

BMI, body mass index; ELSA, Brazilian Longitudinal Study of Adult Health; SES, socioeconomic status.

majority of the sample (56%); compared with 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 colour, with decreased obesity prevalence as education increased, and black participants having the highest prevalence of obesity compared with white participants (29% vs 20%). We observed an obesity gradient for neighbourhood social cohesion and perceived violence, indicating that residents of the least cohesive and most self-perceived violent neighbourhoods had a higher prevalence of obesity than those in the most cohesive and least violent neighbourhoods, respectively.

Residents of the poorest neighbourhoods had a higher obesity prevalence compared with those in the richest (26% vs 19%).

Results of the multilevel logistic regression models predicting obesity by neighbourhood social cohesion, perceived safety and perceived violence are shown in tables 2–4, respectively. Neighbourhood social cohesion was associated with obesity for women only, and this association remained after adjusting for age, education, skin colour and individual-level social cohesion scores. In fully adjusted models, women who lived in the least socially cohesive neighbourhoods had 25% higher odds of being obese compared with women living in the most socially cohesive neighbourhoods (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 neighbourhoods had 28% higher odds of obesity compared with women who lived in the least violent neighbourhoods, adjusting for age, education, skin colour and individual-level perceived violence scores (table 4).

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

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 neighbourhood 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 neighbourhood SES, the association between living in the least socially cohesive neighbourhoods and obesity remained only among women living in high SES

Table 2 Results from the multilevel logistic regression model predicting obesity (BMI ≥30 kg/m^2) by neighbourhood social cohesion; gender-stratified (n=6092 women; 4783 men)

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

Bold values indicate statistical significance at the p<0.05 level (OR does not include 1).
BMI, body mass index; ELSA, Brazilian Longitudinal Study of Adult Health.

Table 3 Results from the multilevel logistic regression model predicting obesity (BMI ≥30 kg/m^2) by perceived neighbourhood safety; gender-stratified (n=6092 women; 4783 men)

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

Bold values indicate statistical significance at the p<0.05 level (OR does not include 1).
BMI, body mass index; ELSA, Brazilian Longitudinal Study of Adult Health.

neighbourhoods, whereas the association between living in the most (perceived) violent neighbourhoods and obesity remained only for women residing in low SES neighbourhoods.

Studies in Latin America[19 20] and elsewhere[8] also report an association between neighbourhood violence and obesity among adults. The hypothesised 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 neighbourhood. There is support for both hypotheses in the literature, as neighbourhood 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 behaviours and by dysregulating the hypothalamic–pituitary–adrenal axis, leading to abdominal fat deposition.[33]

There are mixed results in relation to neighbourhood 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 neighbourhoods with lower collective efficacy—a concept highly linked to social cohesion—had higher BMIs in Los Angeles, CA, USA.[5] Burdette *et al* (2006), in turn, found no such association among women living in 20 US cities.[34]

Social cohesion is hypothesised to act as a buffer from neighbourhood-related stress and, through this mechanism, be protective of obesity.[5] Cohen *et al* (2006) also suggest that adults in neighbourhoods with higher social cohesion may be willing to intervene in aspects of the neighbourhood that influence weight-related behaviours; 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 neighbourhoods 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 neighbourhood social cohesion and perceived violence only influence the obesity risk of Brazilian women and not men. This finding that women are more affected by their neighbourhood environment, particularly the social one, is not new.[24 35 36] Rech *et al* (2012) found that perception of safety during the day was

Table 4 Results from the multilevel logistic regression model predicting obesity (BMI ≥30 kg/m^2) by perceived neighbourhood violence; gender-stratified (n=6092 women; 4783 men)

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

Bold values indicate statistical significance at the p<0.05 level (OR does not include 1).
*The perceived violence scale was constructed so that a higher score indicated a lower perceived violence. Therefore, the *lowest tertile* category represents neighbourhoods with the highest perceived violence.
BMI, body mass index; ELSA, Brazilian Longitudinal Study of Adult Health.

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, USA found that women living in high-poverty neighbourhoods exercised less than men, partly due to safety concerns associated with accessing outdoor parks.[36] Moreover, Guilcher *et al* (2017) found that a higher neighbourhood social cohesion was associated with lower odds of obesity only among women in a sample of adults in Toronto, Canada.[23] Reasons why neighbourhood effects may be stronger for women than men include differences in their neighbourhood perceptions (which is not the case in our sample), an increased exposure (ie, women spending more time in their residential neighbourhoods) or an increased vulnerability (ie, women being more impacted by their surroundings).[24] Furthermore, women are more often victims of sexual violence than men,[3 8] and this 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 neighbourhoods.

A previous study conducted in the south of Brazil found neighbourhood-level variations in obesity prevalence for both men and women; however, neighbourhood-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 neighbourhood environments were associated with obesity among women but not men.[38] The results of these studies and our own suggest that the neighbourhood environment may matter for men's obesity risk, but the neighbourhood factors studied to date are relevant only for women. Future studies should further investigate which neighbourhood factors, if any, affect obesity risk among men in Brazil and other Latin American settings, as well as the reason why neighbourhood 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 neighbourhood SES. Two studies of the neighbourhood social environments in Brazil have found differential

Table 5 Results from the multilevel logistic regression model predicting obesity (BMI ≥30 kg/m^2) by neighbourhood social cohesion, by perceived safety and by perceived violence independently, and stratified by neighbourhood SES and gender*

	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 to 1.99)**	1.03 (0.76 to 1.42)	0.86 (0.59 to 1.26)	0.95 (0.63 to 1.45)	1.43 (0.98 to 2.10)	0.92 (0.59 to 1.44)
Middle tertile	1.06 (0.82 to 1.37)	1.05 (0.80 to 1.38)	1.03 (0.77 to 1.37)	0.83 (0.59 to 1.16)	0.98 (0.73 to 1.33)	0.83 (0.58 to 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 to 1.48)	1.01 (0.73 to 1.40)	0.81 (0.57 to 1.16)	1.11 (0.74 to 1.66)	1.38 (0.93 to 2.02)	1.19 (0.76 to 1.86)
Middle tertile	1.00 (0.77 to 1.30)	0.87 (0.66 to 1.14)	0.84 (0.63 to 1.13)	0.98 (0.70 to 1.37)	1.27 (0.94 to 1.71)	0.99 (0.69 to 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 to 1.37)	1.21 (0.85 to 1.72)	1.22 (0.84 to 1.76)	1.03 (0.68 to 1.56)	**1.92 (1.28 to 2.90)**	1.02 (0.63 to 1.66)
Middle tertile	0.87 (0.67 to 1.12)	1.08 (0.83 to 1.40)	1.01 (0.75 to 1.38)	0.86 (0.60 to 1.22)	**1.70 (1.23 to 2.34)**	1.03 (0.72 to 1.49)
Highest tertile	1.00	1.00	1.00	1.00	1.00	1.00

Bold values indicate statistical significance at the p<0.05 level (OR does not include 1).
*All models adjusted by age, education, skin colour, ELSA site, as well as by individual-level social cohesion, perceived safety and perceived violence scores for the neighbourhood social cohesion, perceived safety and perceived violence models, respectively.
†The perceived violence scale was constructed so that a higher score indicated a lower perceived violence. Therefore, the lowest tertile category represents neighbourhoods with the highest perceived violence.
BMI, body mass index; ELSA, Brazilian Longitudinal Study of Adult Health; SES, socioeconomic status.

effects of these neighbourhood variables on physical activity by *individual*-level SES. Andrade *et al* (2015) report 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 neighbourhoods. 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 neighbourhood violence increased obesity risk among women in low-SES neighbourhoods only.

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

Our results suggest that neighbourhood interventions to increase social cohesion and decrease violence perceptions may prevent obesity among women in Brazil. Effective neighbourhood 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 neighbourhood 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 behaviours. Another option to potentially increase neighbourhood trust and thus social cohesion while reducing crime is instituting neighbourhood watches.[43] It can be argued, however, that participating in neighbourhood 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 generalisable 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 behaviours (ie, 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 neighbourhood 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 neighbourhood. 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 neighbourhood boundaries, results may vary if neighbourhoods were to be defined in a different manner. Similarly, using a different way to categorise neighbourhoods into low, middle, and high levels of social cohesion, perceived safety 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 neighbourhood level so that all participants in the same neighbourhood 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 neighbourhood 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 neighbourhood-level variables with health outcomes due to people self-selecting into neighbourhoods,[46] the ELSA-Brasil population is highly stable, with an average length of residence in their current neighbourhood of 15 years.

CONCLUSIONS

To our knowledge, this is one of the few studies in Latin America examining the association between the neighbourhood social environment and obesity, providing key insights into the likelihood of success of neighbourhood-level interventions addressing obesity in the Brazilian context, in particular. Our results suggest that an increase in neighbourhood social cohesion and a reduction in the perception of neighbourhood violence may be protective of obesity among Brazilian women, with the latter particularly true for women living in poor neighbourhoods. Further research is needed to test some of the proposed interventions (eg, greening of vacant lots, increasing access to public spaces, instituting neighbourhood 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 neighbourhood social environment in both high-income and low-income and middle-income countries seem to affect women more than men.

Author affiliations
[1]Department of Global Community Health and Behavioral Sciences, Tulane University School of Public Health and Tropical Medicine, New Orleans, Louisiana, USA
[2]Institute for Communication and Information on Health, Fundacao Oswaldo Cruz, Rio de Janeiro, Rio de Janeiro, Brazil
[3]INEB - Instituto de Engenharia Biomédica, Universidade do Porto, Porto, Portugal
[4]Department of Epidemiology and Quantitative Methods, National School of Public Health Sergio Arouca, Fundacao Oswaldo Cruz, Rio de Janeiro, Rio de Janeiro, Brazil
[5]School of Medicine & Clinical Hospital, Universidad Federal de Minas Gerais, Belo Horizonte, Minas Gerais, Brazil
[6]Institute of Collective Health, Universidade Federal da Bahia, Salvador, Brazil
[7]Laboratory of Health and Environment Education, Fundacao Oswaldo Cruz, Rio de Janeiro, Brazil

Acknowledgements We thank all ELSA-Brasil participants for their invaluable contribution to this study.

Contributors MFP, LOC, SMS, SMB, LGG, SMAM, MJMF, DC and RHG were involved with data acquisition; MPC and MFP were in charge of data analysis with guidance from LOC, SMS, DC and RHG; all authors were involved in data interpretation; MPC drafted the manuscript; all authors edited the manuscript and approved the final version for submission. All authors take responsibility for the contents of this manuscript and agree to be accountable for all aspects of the work.

Funding This study was funded by the Brazilian Ministry of Health (Department of Science and Technology) and the Brazilian Ministry of Science, Technology and Innovation (FINEP, Financiadora de Estudos e Projetos and CNPq, National Research Council), Grant No 01 06 0010.00, 01 06 0212.00, 01 06 0300.00, 01 06 0278.00, 01 06 0115.00 and 01 06 0071.00. DC, LG, RHG, SMB and SMAM are research fellows of the National Research Council (CNPq). DC, LOC and RHG are supported by a research grant (Cientistas do Nosso Estado) from the Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro - FAPERJ, Brazil. MPC received a COR Research Fellowship from the Tulane University Senate Committee on Research and the Tulane Provost's Office, which funded her travels to Brazil.

Competing interests None declared.

Patient consent for publication Not required.

Ethics approval 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.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request.

REFERENCES

1. Diez Roux AV, Mair C. Neighborhoods and health. *Ann N Y Acad Sci* 2010;1186:125–45.
2. Gee GC, Payne-Sturges DC. Environmental health disparities: a framework integrating psychosocial and environmental concepts. *Environ Health Perspect* 2004;112:1645–53.
3. Suglia SF, Shelton RC, Hsiao A, *et al*. Why the neighborhood social environment is critical in obesity prevention. *J Urban Health* 2016;93:206–12.
4. Carrillo-Álvarez E, Kawachi I, Riera-Romaní J. Neighbourhood social capital and obesity: a systematic review of the literature. *Obes Rev* 2019;20:119–41.
5. Cohen DA, Finch BK, Bower A, *et al*. Collective efficacy and obesity: the potential influence of social factors on health. *Soc Sci Med* 2006;62:769–78.
6. Rech CR, Reis RS, Hino AAF, *et al*. Neighborhood safety and physical inactivity in adults from Curitiba, Brazil. *Int J Behav Nutr Phys Act* 2012;9.
7. Weber Corseuil M, Hallal PC, Xavier Corseuil H, *et al*. Safety from crime and physical activity among older adults: a population-based study in Brazil. *J Environ Public Health* 2012;2012:1–7.
8. Yu E, Lippert AM. Neighborhood crime rate, weight-related behaviors, and obesity: a systematic review of the literature. *Sociol Compass* 2016;10:187–207.
9. Lovasi GS, Hutson MA, Guerra M, *et al*. Built environments and obesity in disadvantaged populations. *Epidemiol Rev* 2009;31:7–20.
10. Kline L, Jones-Smith J, Jaime Miranda J, *et al*. A research agenda to guide progress on childhood obesity prevention in Latin America. *Obes Rev* 2017;18 Suppl 2:19–27.
11. Rivera Juan Ángel, de Cossío TG, Pedraza LS, *et al*. Childhood and adolescent overweight and obesity in Latin America: a systematic review. *Lancet Diabetes Endocrinol* 2014;2:321–32.
12. Pérez-Escamilla R, Lutter CK, Rabadan-Diehl C, *et al*. Prevention of childhood obesity and food policies in Latin America: from research to practice. *Obes Rev* 2017;18 Suppl 2:28–38.
13. Brazilian Ministry of Health. VIGITEL Brasil 2016. Habits of Brazilians affect the growth in obesity and the increased prevalence of diabetes and hypertension, 2017. Available: http://portalarquivos.saude.gov.br/images/pdf/2017/abril/17/Vigitel.pdf [Accessed 15 Feb 2019].
14. Molina M, Serván-Mori E, Quezada AD, *et al*. Is there a link between availability of food and beverage establishments and BMI in Mexican adults? *Public Health Nutr* 2017;20:3326–32.
15. Chor D, Cardoso LO, Nobre AA, *et al*. Association between perceived neighbourhood characteristics, physical activity and diet quality: results of the Brazilian longitudinal study of adult health (ELSA-Brasil). *BMC Public Health* 2016;16:751.
16. Hino AAF, Rech CR, Gonçalves PB, *et al*. Perceived neighborhood environment and leisure time physical activity among adults from Curitiba, Brazil. *Rev Bras Cineantropom Desempenho Hum* 2017;19:596–607.
17. Mendonça G, Florindo AA, Rech CR, *et al*. Perceived neighborhood environmental characteristics and different types of physical activity among Brazilian adolescents. *J Sports Sci* 2018;36:1068–75.
18. Gómez LF, Parra DC, Buchner D, *et al*. Built environment attributes and walking patterns among the elderly population in Bogotá. *Am J Prev Med* 2010;38:592–9.
19. Martínez L, Prada S, Estrada D. Homicides, public goods, and population health in the context of high urban violence rates in Cali, Colombia. *J Urban Health* 2018;95:391–400.
20. Mendes LL, Nogueira H, Padez C, *et al*. Individual and environmental factors associated for overweight in urban population of Brazil. *BMC Public Health* 2013;13:988–9.
21. Florindo AA, Salvador EP, Reis RS, *et al*. Perception of the environment and practice of physical activity by adults in a low socioeconomic area. *Rev Saude Publica* 2011;45:302–10.
22. Andrade ACdeS, Peixoto SV, Friche AAdeL, *et al*. Social context of neighborhood and socioeconomic status on leisure-time physical activity in a Brazilian urban center: the BH health study. *Cad Saude Publica* 2015;31 Suppl 1:136–47.
23. Guilcher SJT, Kaufman-Shriqui V, Hwang J, *et al*. The association between social cohesion in the neighborhood and body mass index (BMI): an examination of gendered differences among urban-dwelling Canadians. *Prev Med* 2017;99:293–8.
24. Stafford M, Cummins S, Macintyre S, *et al*. Gender differences in the associations between health and neighbourhood environment. *Soc Sci Med* 2005;60:1681–92.
25. Aquino EML, Barreto SM, Bensenor IM, *et al*. Brazilian longitudinal study of adult health (ELSA-Brasil): objectives and design. *Am J Epidemiol* 2012;175:315–24.
26. Santos SM, Chor D, Werneck GL. Demarcation of local neighborhoods to study relations between contextual factors and health. *Int J Health Geogr* 2010;9:34.
27. Instituto Brasileiro de Geografia e Estatistica (IBGE). 2010 population census, 2017. Available: https://ww2.ibge.gov.br/english/estatistica/populacao/censo2010/default.shtm [Accessed 3 Aug 2017].
28. Sampson RJ, Raudenbush SW, Earls F. Neighborhoods and violent crime: a multilevel study of collective efficacy. *Science* 1997;277:918–24.
29. Mujahid MS, Diez Roux AV, Morenoff JD, *et al*. Assessing the measurement properties of neighborhood scales: from psychometrics to ecometrics. *Am J Epidemiol* 2007;165:858–67.
30. Santos SM, Griep RH, Cardoso LO, *et al*. [Cross-cultural adaptation and reliability of measurements on self-reported neighborhood characteristics in ELSA-Brasil]. *Rev Saude Publica* 2013;47 Suppl 2:122–30.
31. Stockdale SE, Wells KB, Tang L, *et al*. The importance of social context: neighborhood stressors, stress-buffering mechanisms, and alcohol, drug, and mental health disorders. *Soc Sci Med* 2007;65:1867–81.
32. Stafford M, Chandola T, Marmot M. Association between fear of crime and mental health and physical functioning. *Am J Public Health* 2007;97:2076–81.
33. Björntorp P. Do stress reactions cause abdominal obesity and comorbidities? *Obes Rev* 2001;2:73–86.
34. Burdette HL, Wadden TA, Whitaker RC. Neighborhood safety, collective efficacy, and obesity in women with young children. *Obesity* 2006;14:518–25.
35. Boing AF, Subramanian SV. The influence of area-level education on body mass index, waist circumference and obesity according to gender. *Int J Public Health* 2015;60:727–36.
36. Derose KP, Han B, Williamson S, *et al*. Gender disparities in Park use and physical activity among residents of high-poverty neighborhoods in Los Angeles. *Womens Health Issues* 2018;28:6–13.
37. Astell-Burt T, Feng X, Kolt GS, *et al*. Does rising crime lead to increasing distress? longitudinal analysis of a natural experiment with dynamic objective neighbourhood measures. *Soc Sci Med* 2015;138:68–73.
38. Pereira de Castro OC, Arauji Nobre A, Ribeiro de Castro IR, *et al*. Does context influence the body mass index of Brazilian workers? results from the ELSA-Brasil study baseline.
39. Kondo MC, Andreyeva E, South EC, *et al*. Neighborhood interventions to reduce violence. *Annu Rev Public Health* 2018;39:253–71.
40. Lorenc T, Clayton S, Neary D, *et al*. Crime, fear of crime, environment, and mental health and wellbeing: mapping review of theories and causal pathways. *Health Place* 2012;18:757–65.
41. Armstrong D. A survey of community gardens in upstate New York: implications for health promotion and community development. *Health Place* 2000;6:319–27.
42. Salvo D, Sarmiento OL, Reis RS, *et al*. Where Latin Americans are physically active, and why does it matter? findings from the IPEN-adult study in Bogota, Colombia; Cuernavaca, Mexico; and Curitiba, Brazil. *Prev Med* 2017;103:S27–S33.
43. Bennett T, Holloway K, Farrington DP. Does neighborhood Watch reduce crime? A systematic review and meta-analysis. *J Exp Criminol* 2007;2:437–58.
44. Camilo de Oliveira AMH, Furlan Antigo M, Rabelo A. Occupational typologies applied to the socioeconomic analysis of the ELSA sample. Report for CEDEPLAR/UFMG; 2013.
45. Schmidt MI, Duncan BB, Mill JG, *et al*. Cohort profile: longitudinal study of adult health (ELSA-Brasil). *Int J Epidemiol* 2015;44:68–75.
46. Hedman L, van Ham M. Understanding neighbourhood effects: Selection bias and residential mobility. In: van Ham M, Manley D, Bailey N, *et al*, eds. *Neighbourhood effects research: new perspectives*. Springer, 2012: 79–99.