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ORIGINAL ARTICLE

The influence of area-level education on body mass index, waist circumference and obesity according to gender

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Abstract

Objectives The aim of this study was to analyze the association between area-level education and body mass index (BMI), waist circumference (WC) and obesity controlling for individual demographic and socioeconomic characteristics.

Methods A cross-sectional population-based study was carried out with 1720 adults aged 20–59 in southern Brazil. We used multilevel modeling techniques to test whether area-level education was associated with BMI, WC and obesity regardless of individual-level characteristics.

Results We observed a significant between-groups variance for both BMI and WC. Among women, area-level education explained 27.6 and 30.0 % of the between-groups variance of BMI and WC, respectively. In the fully adjusted model, the WC was 4.67 cm higher ($p < 0.05$) and the BMI was 1.12 kg/m^2 higher ($p < 0.05$) in the women residents of low education neighborhoods compared to the residents of high education areas. In the same group, the chance of central obesity and general obesity was, respectively, 2.05 (IC95 % 1.19–3.52) and 1.85 (IC95 % 1.04–3.29) times higher.

Conclusions The findings suggest that neighborhood characteristics play an important role in the distribution of obesity and must be addressed by policy makers.

Keywords Body mass index · Waist circumference · Obesity · Education · Socioeconomic factors · Multilevel analysis

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Introduction

Obesity is a major risk factor for the health of the world's population in the early twentieth century. Despite the well-established risk of obesity to health, its prevalence has increased sharply around the world, including high-income countries, and more recently, low- and middle-income countries (LMIC) (World Health Organization 2002, 2011). In 2008, 11 % of the world's adult population was obese and it is estimated that almost 3 million adults die each year as a result of being overweight or obese (World Health Organization 2014).

According to Malik et al. (2013), this increase in obesity prevalence in recent decades is related to global trade liberalization, economic growth, rapid urbanization and a reduction in physical activity. But it also expresses the difficulty that societies and policy makers have had in addressing this public health problem. Therefore, it is necessary to gain further knowledge on obesity epidemiology to develop more effective policies for obesity control (Caballero 2007; Black and Macinko 2008).

One criticism is that strategies and interventions against obesity have been carried out almost exclusively on an individual level. The main focus has been to make lifestyles changes, such as reducing the consumption of high-calorie foods and increasing physical activity levels

(Caballero 2007; Pearce and Witten 2010). While in some cases this strategy may be successful on an individual level, it has failed to reduce the epidemic levels of obesity on the population level (Black and Macinko 2008; Pearce and Witten 2010).

In this context, researchers have turned toward the contextual effect on health and empirical studies using multilevel methodology have demonstrated that obesity is not randomly distributed among neighborhoods. One important aspect of the variation that has been observed is the socioeconomic status of the neighborhoods. Analyzing data from US, Ludwig et al. (2011) reported a significant association between area poverty and obesity. Similar results have been reported in other studies, almost all of them carried out in rich countries (Robert and Reither 2004; Matheson et al. 2008; Leal et al. 2011). Nevertheless, it is not clear yet the mechanisms underlying these associations. Our hypothesis is that area-level education plays an important role and may explain at least part of the neighborhood variation in obesity. Although the association of education and obesity has been well described on the individual level, there are few studies exploring this association on an area-level approach (Ross et al. 2007; Fleischer et al. 2008; Mowafi et al. 2011).

High-educated neighborhoods may have more facilities for exercise and/or offer healthier food options in local food outlets. Besides that, high levels of education are usually associated with the acquisition of knowledge and engagement in healthy behaviors. It is also important to note that a high-educated neighborhood may have a spillover effect upon the residents with more people engaging in healthy habits regardless of individual socioeconomic characteristics.

One additional aspect that requires further investigation is the potential difference of the effect of area-level education on the prevalence of obesity among men and women. It is known that the neighborhood affects both differently; while men are less embedded in the neighborhood, women spend more time in the place where they live (Stafford et al. 2005). But many studies do not stratify the analysis by gender and the existence of this difference among men and women when analyzing the effect of area-level education on obesity is not clear.

This study contributes to this subject by analyzing the association between area-level education and BMI and WC net of individual demographic and socioeconomic characteristics in Brazil. We also aim to test whether the effect of socioeconomic status affect men and women differently. To our knowledge, this is the first study in Latin America analyzing data on this subject using objective measures of nutritional status and one of the few carried out in low- and middle-income countries.

Methods

Study population

A cross-sectional study was carried out in a population-based sample in Florianópolis, a medium-sized Southern Brazilian city. To investigate several health outcomes, 1720 adults aged 20–59 were interviewed in 2009/2010. The city is the capital of the Brazilian State of Santa Catarina and it has a population of approximately 400,000 inhabitants.

Sample size

The sample size was calculated considering the following parameters: 95 % confidence level, sample error of 3.5 % and design effect of 2—due to the cluster sample scheme. As several outcomes were investigated in the large research, an expected prevalence of the phenomenon of 50 % was used to obtain the largest sample size. Finally, an over-sample of 15 % was included for control of confounders in the study of associations and 10 % to compensate refusals. The final sample after estimation of each of the studied outcomes was 2016 people.

Data source and sampling design

The sample was selected in multiple stages. The primary sample units were the census tracts. According to the Brazilian Census performed in 2000, Florianopolis had 420 urban census tracts, which were organized according to the average income of the head of the household. The units where then stratified by deciles and 60 tracts were systematically drawn (sampling fraction equal to seven), totaling six tracts in each decile. All selected census tracts were visited to update the number of houses and residents in the selected clusters. As three census tracts presented an important increase in occupied houses from 2000 to 2009 each one was separated into two. Six census tracts had their number reduced and were merged into three clusters. 63 census tracts resulted from this process, which led to a reduced variability in the number of households in each census tract (coefficient of variation 32 %). In each census tract, a total of 18 households were systematically drawn. All the adults aged between 20 and 59 residing in these households at the time of interview were considered potential participants in the study. Exclusion criteria included amputees, bedridden individuals and those who were considered unable to answer the questionnaire.

The home visits included the administration of a face-to-face questionnaire applied with the use of a personal digital assistant. Thirty-five interviewers were intensively trained prior to field work; the questionnaire pre-testing was performed on 35 adults. The pilot study included 99 adults living in two census tracts not included in the sample. Data were collected from September 2009 to January 2010.

Visits were made to all eligible adults at least four times or until find them at home. At least one visit occurred at night and another on the weekend. If after that the interviewer was not able to locate the interviewee or the resident refused to participate, this was considered a loss. A no replacement sample scheme was adopted.

As data quality control, a short version of the questionnaire (10 questions) was applied through a telephone interview to 15 % of the whole sample ($n = 248$). The kappa values varied between 0.6 and 0.9.

Outcomes

Two outcomes were analyzed: general obesity and central obesity. General obesity was positive when the BMI (weight in kilograms/height in centimeters^2) was $\geq$30 kg/m^2 and central obesity was positive when waist circumference (WC) was $\geq$102 cm for men and $\geq$88 cm for women. BMI and WC were also analyzed as continuous variables.

Anthropometric measurements of body weight, height and waist circumference were taken as recommended by Lohman et al. (1988) Interviewees were measured twice and the average was used. The measurement of body weight was performed using a portable digital scale (GAMA Italy Professional®, HCM model 5110M), with a sensitivity of 100 g and a capacity of 150 kg. All the scales were calibrated before training and field work. Interviewees were wearing light clothes and the scales were placed on a level surface during the measurement.

Height was taken using a stadiometer specifically built for the study and used an inelastic metric tape with 1-mm resolution. The respondents were asked to take off their shoes and any accessories. They were placed in the orthostatic position, with the head in the Frankfurt position. Gluteal muscles, shoulders and heels were placed against the wall and the respondents were asked to take a deep breath at the moment in which the height measurement was taken.

Waist circumference was measured with a non-elastic anthropometric tape with a resolution of 1 mm (Sanny®). The measurement of waist circumference was performed with the respondents standing upright with feet slightly apart and arms slightly away from the body, with palms facing the thighs. Waist circumference was taken at the narrowest part of the trunk below the last rib. For individuals in whom it was not possible to find the narrowest part of the trunk circumference, the WC was measured at a midpoint between the iliac crest and the lowest rib. Pregnant women, women who had given birth in the 6 months prior to the survey and individuals unable to stay in the recommended position were excluded.

The relative technical error was calculated during training and the maximum values observed were considered satisfactory (waist circumference: intra-examiner 1.18; inter-examiner 1.86; height: intra-examiner 0.24; inter-examiner 1.67; weight: intra-examiner 0.36; inter-examiner 0.96).

Exposure

We used the average years of schooling of the head of the household in each census tract. Only the years successfully completed were considered. The data were gathered from the 2000 Brazilian census, carried out by the Brazilian Institute of Geography and Statistics. The variable was divided into three categories: 0–8 years of study, 9–11 years and 12 or more years.

Covariates

The individual-level variables were age (grouped into four categories: 20–29 years old, 30–39, 40–49 and 50–59), self-reported race/skin color (white, dark-skinned black, and light-skinned black), equalized household income (divided into tertiles), and years of successful studies (divided into three categories: 0–8 years of study, 9–11 and 12 or more).

Statistical analysis

First of all the sample distribution was examined. Then, the mean BMI and WC and the prevalence of central obesity and general obesity with respective 95 % confidence intervals were analyzed according to the variables included in the study.

This was followed by estimating a multilevel linear regression model having BMI and WC as continuous variables. The full multilevel model used was:

$$Y_{ij} = \beta_{0j} + \beta_{1j}X_{1ij} + \beta_{2j}X_{2ij} + \beta_{3j}X_{3ij} + \beta_{4j}X_{4ij} + e_{ij}, \quad (1)$$

where

$$\begin{aligned}&\beta_{0j} = \gamma_{00} + \gamma_{01}W_j + u_{0j};\ \beta_{1j} = \gamma_{10} + \gamma_{11}W_j + u_{1j};\\&\beta_{2j} = \gamma_{20} + \gamma_{21}W_j + u_{2j};\ \beta_{3j} = \gamma_{30} + \gamma_{31}W_j + u_{3j};\\&\beta_{4j} = \gamma_{40} + \gamma_{41}W_j + u_{4j}. \quad (2)\end{aligned}$$

In this equation, β_{0j} is the intercept, $\beta_{1j}\ldots\beta_{4j}$ are the regression coefficients for the individual explanatory variables and X_{1ij}, X_{2ij}, X_{3ij} and X_{4ij} are the explanatory variables on the individual level. Using variable labels, the notation reads:

$$\text{BMI (or WC)}_{ij} = \beta_{0j} + \beta_{1j}\text{age}_{ij} + \beta_{2j}\text{skin color}_{ij} + \beta_{3j}\text{individual} - \text{level education}_{ij} + \beta_{4j}\text{equalized household income}_{ij} + e_{ij}, \quad (3)$$

The symbol W_j refers to the level-two predictor, in our case, the area-level education, and γ_{00} refers to the overall intercept (population average of WC or BMI for those living in neighborhoods where area-level education is zero). The *u*-terms represent the residual error terms at the neighborhood level.

To estimate the proportion of total variance of BMI and WC that is due to differences between groups, the variance partition coefficient (VPC) was calculated, defined as:

$$\text{VPC} = \sigma_u^2 / (\sigma_u^2 + \sigma_e^2), \quad (4)$$

where σ_u^2 is the between-group variance and σ_e^2 is the within-group between-individual variance. The closer the VPC is to 1, the more the variance can be attributed to between-group differences.

To quantify the importance of the area-level education in predicting BMI and WC, the regression coefficients and standard deviations were estimated. Level of significance was defined at $p < 0.05$. Also, logistic multilevel analyses were run to test the association between central obesity and general obesity with area-level education. Odds ratio and respective $IC_{95\%}$ were reported. The following models were created both in linear and logistic regression: (i) unadjusted, (ii) adjusted for age and race/skin color, (iii) adjusted for age, race/skin color, individual-level education and equalized household income.

Potential cross-level interactions were examined between area-level education and individual-level education and equalized household income. All analyses were stratified by gender and carried out taking the weighted and clustered sample into account. The data were analyzed using the software Stata 9 (Stata Corp., College Station, TX, USA).

Ethical aspects

The project was approved by the Ethics Committee of Research with Human Beings of the Federal University of Santa Catarina (Process no 351/08). All participants signed an informed consent form.

Results

In total, 1720 people were interviewed (response rate of 85.3 %). The main characteristics of the sample are described in Table 1. The majority of the sample was women (55.5 %). In both genders, approximately 85 % of people were white, 3 out of 4 had more than 9 years of schooling and more than half were under 40 years of age (mean age for men: 37.2 years; among women: 38.1 years). The average area-level years of schooling was 9.5 years.

The mean BMI was 25.9 kg/m^2 among men, a value close to that observed among women (25.3 kg/m^2). The prevalence of general obesity was slightly higher among women (16.7 vs. 14.7 %). The waist circumference was significantly higher among men (88.1 cm), however, the prevalence of central obesity was much higher among women (11.2 % among men vs. 20.4 % among women). The distribution of the outcomes according to exploratory variables is described in Table 2.

When analyzing the waist circumference, it was found in the empty model that the between-group variance corresponded to 10.2 % of the total variance among men and to 14.2 % among women. When the outcome was BMI, the VPC was equal to 12.5 and 9.4 %, respectively. The area-level education explained 27.6 % of the level-two variance of BMI and 30.0 % of the level-two variance of WC among women. The inclusion of the individual-level variables did not substantially change the VPC. The contextual variable did not affect the VPC among men.

Table 3 shows the results of linear regression analyses. In the fully adjusted model, the waist circumference was 4.67 cm higher ($p < 0.05$) and the BMI was 1.12 kg/m^2 higher ($p < 0.05$) in the residents of low education neighborhoods net of individual characteristics. There was no association between area-level education and the outcomes among men.

Similar results were found in the multilevel logistic analyses (Table 4). No association was observed among men, but among women in the crude model the chance of central obesity and general obesity was, respectively, 3.08 and 2.73 times higher in the residents of low education neighborhoods. Even when adjusting for all the blocks of individual variables, the association remained statistically significant (central obesity, OR 2.05: $IC_{95\%}$ 1.19–3.52; general obesity, OR 1.85: $IC_{95\%}$ 1.04–3.29). There was no cross-level interaction between contextual education and individual-level socioeconomic variables.

Discussion

Three major findings can be highlighted in this study. First, we observed a significant between-group variance in waist circumference, body mass index and obesity for both men and women. Second, we found that contextual education explained more than 25 % of the area-level variation of the outcomes among women, but it was not significant among

Table 1 Sample distribution, mean body mass index, mean waist circumference, prevalence of general obesity and prevalence of central obesity

Variables ($n = 1720$)	Male					Female				
	Sample distribution	Mean ($IC_{95\ \%}$)		Prevalence ($IC_{95\ \%}$)		Sample distribution	Mean ($IC_{95\ \%}$)		Prevalence ($IC_{95\ \%}$)	
	n (%)	BMI (kg/m^2)	WC (cm)	General obesity	Central obesity	*n* (%)	BMI (kg/m^2)	WC (cm)	General obesity	Central obesity
Age (years)										
20–29	260 (34.2)	24.5 (24.0–25.1)	82.7 (81.3–84.0)	9.3 (8.7–9.4)	5.5 (3.1–7.9)	280 (29.2)	23.7 (23.0–24.3)	73.5 (71.9–75.0)	9.7 (5.7–13.8)	9.2 (5.2–13.3)
30–39	172 (22.6)	26.2 (25.5–27.0)	88.6 (86.8–90.5)	16.0 (9.8–22.2)	10.0 (5.2–14.8)	220 (22.9)	24.6 (23.8–25.4)	78.1 (75.8–80.4)	15.9 (9.4–22.4)	19.7 (13.2–26.2)
40–49	181 (23.8)	26.8 (26.2–27.5)	91.6 (90.2–93.0)	18.3 (11.6–25.0)	14.9 (10.2–19.6)	257 (26.8)	26.1 (25.5–26.3)	81.0 (79.2–82.9)	18.2 (13.8–22.7)	19.6 (14.4–24.3)
50–59	148 (19.4)	26.9 (26.1–27.6)	93.1 (90.7–95.4)	18.5 (11.2–25.9)	18.7 (11.4–26.0)	202 (21.1)	27.5 (26.7–28.2)	85.5 (83.3–87.8)	25.6 (18.7–32.5)	38.7 (31.4–45.9)
Skin color										
White	642 (85.6)	26.1 (25.7–26.4)	88.7 (87.7–89.6)	15.4 (12.3–18.4)	12.3 (9.6–14.9)	802 (86.4)	25.2 (24.8–25.7)	78.7 (77.3–80.1)	16.2 (12.9–19.5)	19.9 (16.3–23.4)
Lighter-skinned black	74 (9.9)	25.0 (24.1–25.9)	85.0 (82.7–87.3)	12.7 (4.3–21.1)	6.0 (0.6–11.3)	73 (7.9)	25.6 (24.2–26.8)	79.1 (75.8–82.4)	19.1 (10.5–27.7)	20.1 (11.4–28.7)
Dark-skinned black	34 (4.5)	25.0 (23.8–26.1)	85.5 (80.4–90.5)	8.7 (0.3–17.1)	4.7 (0.0–10.7)	53 (5.7)	25.6 (23.9–27.2)	82.0 (76.8–87.2)	15.3 (3.5–27.0)	21.5 (10.5–32.5)
Individual educational level (years of successful studies)										
≤4	69 (9.1)	26.7 (25.3–28.0)	90.8 (87.2–94.5)	24.4 (12.4–36.4)	17.2 (7.2–27.1)	89 (9.3)	28.1 (27.0–29.1)	86.0 (83.4–88.6)	28.4 (20.0–36.6)	38.8 (27.7–50.0)
5–8	108 (14.2)	25.7 (24.8–26.6)	88.0 (85.5–90.6)	17.0 (7.9–26.1)	7.0 (1.9–12.2)	145 (15.1)	26.7 (25.9–27.6)	82.9 (80.5–85.2)	25.5 (18.3–32.7)	31.7 (22.4–41.1)
9–11	263 (34.7)	25.9 (25.2–26.6)	87.8 (86.1–89.6)	13.6 (9.7–17.7)	12.6 (8.8–16.4)	305 (31.8)	25.6 (25.0–26.3)	79.7 (77.8–81.5)	17.6 (12.6–22.7)	21.2 (16.1–26.3)
≥12	318 (42.0)	25.8 (25.2–26.4)	87.8 (86.3–89.2)	13.0 (8.2–17.9)	10.0 (6.3–13.7)	419 (43.8)	24.1 (23.6–24.7)	75.9 (74.4–77.3)	10.8 (7.1–14.6)	12.4 (9.0–15.9)
Equalized household income (tertiles)										
Poorest	228 (30.0)	25.7 (25.0–26.4)	86.9 (85.1–88.6)	15.5 (10.6–20.5)	10.1 (6.0–14.2)	346 (36.2)	26.1 (25.5–26.7)	81.2 (79.4–83.1)	20.0 (16.0–24.0)	27.7 (22.9–32.4)
Intermediate	267 (35.1)	26.4 (25.7–27.0)	90.0 (88.1–92.0)	18.5 (13.2–23.8)	16.2 (10.9–21.5)	306 (31.9)	25.5 (24.7–26.3)	78.5 (76.6–80.4)	20.1 (14.5–25.7)	20.5 (15.6–25.3)
Richest	266 (34.9)	25.7 (25.1–26.2)	87.3 (85.7–88.9)	10.5 (6.0–14.9)	7.5 (4.2–10.7)	306 (31.9)	24.4 (23.8–25.0)	77.1 (75.3–78.9)	9.9 (6.1–13.8)	12.5 (7.7–17.2)
Area-level education (years of successful studies) (63 census tracts)										
≥12	175 (23.0)	25.6 (24.6–26.5)	87.6 (85.3–90.0)	8.8 (2.5–15.0)	8.0 (3.5–12.6)	252 (26.3)	24.3 (23.8–24.8)	76.0 (74.2–77.8)	9.9 (6.1–13.8)	12.3 (8.9–15.6)
9–11	335 (44.0)	25.8 (25.3–26.4)	87.8 (86.2–89.4)	15.6 (11.7–19.5)	12.0 (8.5–15.5)	406 (42.3)	25.2 (24.5–25.8)	78.4 (76.6–80.2)	15.9 (11.8–19.9)	19.0 (14.2–23.9)
≤8	251 (33.0)	26.2 (25.7–26.8)	88.9 (87.5–90.3)	17.8 (13.7–22.0)	12.5 (8.0–17.1)	301 (31.4)	26.6 (26.0–27.1)	82.7 (80.5–84.9)	24.4 (19.6–29.1)	30.1 (24.4–35.8)
All	761 (100.0)	25.9 (25.5–26.3)	88.1 (87.1–89.1)	14.7 (11.8–17.5)	11.2 (8.8–13.6)	959 (100.0)	25.3 (24.9–25.8)	79.0 (77.6–80.4)	16.7 (13.7–19.6)	20.4 (17.1–23.7)

Florianopolis, Brazil, 2009–2010

BMI body mass index, *WC* waist circumference, *General obesity* body mass index ≥30 kg/m^2, *Central obesity* waist circumference ≥102 cm for men and ≥88 cm for women

Table 2 Variance estimates from multilevel models of waist circumference (WC) and body mass index (BMI) and area-level education adjusted by individual variables

Variables	Male				Female			
	Empty model coefficient (SE)	Model 1 coefficient (SE)	Model 2 coefficient (SE)	Model 3 coefficient (SE)	Empty model coefficient (SE)	Model 1 coefficient (SE)	Model 2 coefficient (SE)	Model 3 coefficient (SE)
Waist circumference								
Level-two variance	14.10	13.98	13.05	13.21	24.66	17.84	15.54	15.69
Level-one variance	124.60	124.60	108.82	107.19	149.46	149.46	134.22	132.47
VPC (%)	10.17	10.09	10.71	10.97	14.16	10.66	10.38	10.59
BMI								
Level-two variance	2.48	2.42	2.39	2.42	2.40	1.68	1.42	1.49
Level-one variance	17.32	17.32	16.39	16.32	23.10	23.10	21.16	20.65
VPC (%)	12.53	12.26	12.73	12.91	9.41	6.78	6.29	6.73

Florianopolis, Brazil, 2009–2010

Model 1 area-level education, *Model 2* model 1 + age and skin color, *Model 3* model 2 + individual-level education and equalized household income, *VPC* variance partition coefficient

Table 3 Fixed parameters from multilevel linear regression of waist circumference (WC) and body mass index (BMI) and area-level education adjusted by individual variables

Variables	Male				Female			
	Empty model coefficient (SE)	Model 1 coefficient (SE)	Model 2 coefficient (SE)	Model 3 coefficient (SE)	Empty model coefficient (SE)	Model 1 coefficient (SE)	Model 2 coefficient (SE)	Model 3 coefficient (SE)
Waist circumference								
Intercept	88.27	87.86	82.00	83.01	79.18	76.25	70.29	75.06
Area-level education (mean years of schooling)								
≥12	Reference	Reference	Reference		Reference	Reference	Reference	Reference
9–11		0.38 (1.33)	1.39 (1.24)	0.74 (1.26)		2.41 (1.26)	2.60 (1.12)*	1.56 (1.23)
≤8		0.89 (1.34)	1.25 (1.38)	0.56 (1.45)		6.72 (1.28)**	6.58 (1.37)**	4.67 (1.56)*
BMI								
Intercept	25.97	25.66	24.21	24.62	25.35	24.39	22.75	25.11
Area-level education (mean years of schooling)								
≥12	Reference	Reference	Reference		Reference	Reference	Reference	Reference
9–11		0.29 (0.51)	0.56 (0.49)	0.40 (0.50)		0.81 (0.40)*	0.76 (0.36)*	0.22 (0.42)
≤8		0.64 (0.59)	0.74 (0.61)	0.58 (0.63)		2.17 (0.36)**	2.09 (0.39)**	1.12 (0.53)*

Florianopolis, Brazil, 2009–2010

* <0.05; ** <0.001

men. Finally, we identified that women who live in lower education neighborhoods were approximately twice as likely to be obese than those who live in neighborhoods with higher education.

The negative association between obesity and area-level socioeconomic status observed in our study is consistent with findings from studies carried out in rich countries, such as the US (Robert and Reither 2004), Australia (King et al. 2006), the Netherlands (van Lenthe and Mackenbach 2002), Scotland (Ellaway et al. 1997) and France (Leal et al. 2011).

In middle-income countries the results are more mixed. As far as we know, only three studies conducted in middle-

Table 4 Association between area-level education and central obesity and general obesity adjusted by individual variables

Variables	Male			Female		
	Crude model OR ($IC_{95\ \%}$)	Model 1 OR ($IC_{95\ \%}$)	Model 2 OR ($IC_{95\ \%}$)	Crude model OR ($IC_{95\ \%}$)	Model 1 OR ($IC_{95\ \%}$)	Model 2 OR ($IC_{95\ \%}$)
Central obesity						
Area-level education (mean years of schooling)						
≥12	Reference	Reference	Reference	Reference	Reference	Reference
9–11	1.52 (0.82–2.83)	1.82 (0.96–3.42)	1.48 (0.75–2.92)	1.66 (1.05–2.61)	1.60 (1.00–2.58)	1.27 (0.77–2.09)
≤8	1.66 (0.88–3.16)	1.76 (0.92–3.40)	1.43 (0.67–3.63)	3.08 (1.95–4.86)	3.12 (1.93–5.03)	2.05 (1.19–3.52)
General obesity						
Area-level education (mean years of schooling)						
≥12	Reference	Reference	Reference	Reference	Reference	Reference
9–11	1.73 (0.97–3.10)	1.94 (1.07–3.52)	1.74 (0.93–3.27)	1.68 (1.02–2.75)	1.57 (0.94–2.60)	1.28 (0.75–2.17)
≤8	2.03 (1.12–3.68)	2.12 (1.15–3.90)	1.75 (0.88–3.49)	2.73 (1.66–4.48)	2.62 (1.57–4.35)	1.85 (1.04–3.29)

Florianopolis, Brazil, 2009–2010

Model 1 adjusted by age and skin color, *Model 2* model 1 + individual-level education and equalized household income, *Central obesity* ≥102 cm for men and ≥88 cm for women, *General obesity* body mass index ≥30 kg/m^2

income countries analyzed area-level education as the socioeconomic variable. In Argentina (Fleischer et al. 2008) and in Egypt (Mowafi et al. 2011), a higher prevalence of obesity was found among people who live in lower education neighborhood, which is what was discovered in our study. A different result was reported in China, where Le et al. (2007) analyzed data from rural communities and found no association between contextual education and BMI. But the authors identified an inverse association of the outcome with area income.

Another two studies carried out in middle-income countries reported higher levels of obesity or BMI among people living in wealthier neighborhoods. In the Philippines, Colchero and Bishai (2008) found that the average BMI among women living in neighborhoods with telephones, electricity, mail delivery and newspapers (a proxy of socioeconomic status) was higher than the values observed among women living in places with up to two of these public amenities. In India, data from 3 204 neighborhoods in 26 states showed a positive association between neighborhood socioeconomic status and BMI (Ackerson et al. 2008). Finally, analyzing data from a low-income country—Burkina Faso, Ouédraogo et al. (2008) reported a positive association between obesity and living in structured and high building-density areas.

Brazil has experienced an accelerated urbanization process and a rapid growth of the obesity epidemic. Differences in the demographic and nutritional characteristics may help to explain the discordant results observed in our study compared to studies carried out in Burkina Faso, the Philippines and India. An example is that since the 1980s overweight/obesity exceeds underweight in Brazil (Monteiro et al. 2002). Besides that, different from the observed by Neuman et al. (2011) and Subramanian et al. (2011) in pooled analyses of women from LMIC, a shift toward increased prevalence of obesity among the poor has been described in Brazil. According to Monteiro et al. (2007), obesity rates among men in lower-income group increased 3.3 times between 1975 and 1989 and 2.5 times between 1989 and 2003. Among men in high-income groups, the values were 1.5 and 1.4, respectively. The differences among women were even higher. While in the lower-income group the prevalence of obesity increased 40 % between 1989 and 2003, there was a reduction in the rates among the richest group.

In our study area-level education explained an important proportion of the between-group variance among women. The association between education and obesity on an individual level is well documented, but our findings suggest that exclusively analyzing individual education underestimates the overall effect of education on obesity.

Studies have shown that the presence of highly educated people in the neighborhoods has the potential to positively impact health indicators (a spillover effect) (Galea and Ahern 2005). People with a higher level of education may have greater capacity to bring public and private facilities to the neighborhood which are beneficial to health and/or contribute to the improvement of these facilities. In addition, people with higher education may be more likely to make positive lobbies for improvements in the area (Galea and Ahern 2005), such as trigger actions that make it safer, more walkable and with better physical structure. Econometric studies have also shown that regions with higher education may lead to an increase in the average income of the region (Moretti 2004). Finally, high levels of education are usually associated with the acquisition of knowledge and engagement in healthy behaviors, and the interaction of people with different levels of education may allow the sharing and dissemination of knowledge and skills with potential positive effect on the health of everyone.

As people create places, places create people (Macintyre and Ellaway 2003). Besides the aforementioned ways by which people can influence a neighborhood (and other people), the area also influences the residents. In this context, studies have shown that healthier choices are easier made by residents of more affluent neighborhoods. A multilevel analysis carried out in Brazil by Duran et al. (2013) showed that supermarkets and full service restaurants are more likely found in rich areas, whereas fast food restaurants are more common in low socioeconomic status neighborhoods. Similarly, the UŚs most deprived neighborhoods were reported to have fewer physical activity facilities (Estabrooks et al. 2003). In other words, it seems to be easier to engage in healthy behaviors when a person lives in more affluent areas.

It must be highlighted that in our study area-level education was associated with WC, BMI and obesity only among women. This result is different from the findings reported by Fleischer et al. (2008) in Argentina and by Mowafi et al. (2011) in Egypt. In both countries, the association between area-level education and obesity did not vary by gender. Other studies carried out in LMIC did not analyze the association of obesity and area-socioeconomic status stratified by gender (Le et al. 2007; Colchero and Bishai 2008; Ackerson et al. 2008; Ouédraogo et al. 2008). But studies conducted in the US (Robert and Reither 2004) and Australia (King et al. 2006) also found an association between neighborhood socioeconomic status and obesity exclusively among women.

In the developed societies, especially for women, there is a stigmatization of obesity and a social vision that the ideal body is slim (Matheson et al. 2006). Besides this, it is known that women expresses more body consciousness and are more dissatisfied with their bodies than men (Tiggemann and Rothblum 1988; Algars et al. 2009). Living in high education neighborhoods may place women more strongly into this social vision and also makes it easier to engage in diets and physical activity (Matheson et al. 2008; Sobal and Stunkard 1989). Furthermore, as food acquisition and preparation are strongly linked to the role of women in society and considering that women spend more time at home than men they are especially sensitive to obesogenic areas (Matheson et al. 2008).

According to Harrington and Elliot (2009), area-level education can be considered a proxy of social support within the neighborhood. As women may be especially sensitive to social support for healthy living, it can explain the differential effect of area-level education over obesity by gender. A last consideration is that women are more embedded in the neighborhood. They know, talk to and visit neighbors more than men do. As a consequence they are more affected by the cultural, social and economic environment (Stafford et al. 2005).

This aside, it was observed that ICC for men is also quite high, which indicates that the residential environment is important for both genders. But the fact is that among men area-level education could not explain this between-groups variation. Thus, further studies are necessary to determine what other contextual variables are associated with obesity among men. Men differ in the importance given to different aspects of the environment. For instance, physical quality of the neighborhood was reported to be more important for men whereas women are more affected by social aspects of the area (Molinari et al. 1998). Men spend less time at home, in the residential area and may use different spaces and facilities of the neighborhood. Their friendships are more task/activity oriented and they are less dependent upon social support (Flaherty and Richman 1989; Shye et al. 1995). Differences in the way men interact with the neighborhood compared to women can explain the absence of association between area-level education and obesity among them.

This study had some limitations. First, as this was a cross-sectional study it was not possible to attribute causality. Second, there may be other individual-level confounders not included in this analyses that could attenuate the area-level effect. Third, this study took place in Florianópolis, Brazil, and it may not be possible to generalize to other settings. Fourth, in the vast majority of the sample, waist circumference was taken at the narrowest part of the trunk below the last rib, but we measured the waist circumference using two different methods. When the first option was not possible to be performed, the WC was measured at the midpoint between the iliac crest and the lowest rib. Considering that waist circumference measures taken at different sites tend to differ in magnitude, this methodological option must be considered a limitation. Strengths of the study include a high response rate that was similar in all the income deciles of the census tracts. The proportion of interviews according to gender and age was similar to the values reported by the Brazilian Institute of Geography and Statistics (IGBE) for the city in 2009. Finally, anthropometric measurements were taken according to international standards and there was high reproducibility of the interviewers to perform such measurements.

The results of this study show that policies to control obesity cannot be restricted to an individual approach and must be gender responsive. Neighborhood characteristics play an important role in the distribution of obesity and must be addressed by policy makers.

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