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Spatial clusters of diabetes: individual and neighborhood characteristics in the ELSA-Brasil cohort study

Aglomerados espaciais de diabetes: características individuais e de vizinhança no estudo longitudinal ELSA-Brasil

Grupos espaciales de diabetes: características individuales y vecinales en el estudio longitudinal ELSA-Brasil

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Abstract

This study identified spatial clusters of type 2 diabetes mellitus among participants of the Brazilian Longitudinal Study of Adult Health *(ELSA-Brasil) residing in two cities and verified individual and neighborhood socioeconomic environmental characteristics associated with the spatial clusters. A cross-sectional study was conducted with 4,335 participants. Type 2 diabetes mellitus was defined as fasting blood glucose ≥ 126mg/dL (7.0mmol/L), oral glucose tolerance test ≥ 200mg/dL (11.1mmol/L), or glycated hemoglobin ≥ 6.5% (48mmol/L); by antidiabetic drug use; or by the self-reported medical diagnosis of type 2 diabetes mellitus. Neighborhood socioeconomic characteristics were obtained from the 2011 Brazilian census. A spatial data analysis was conducted with the SaTScan method to detect spatial clusters. Logistic regression models were fitted to estimate the magnitude of associations. In total, 336 and 343 participants had type 2 diabetes mellitus in Belo Horizonte, Minas Gerais State (13.5%) and Salvador, Bahia State (18.5%), respectively. Two cluster areas showing a high chance of type 2 diabetes mellitus were identified in Belo Horizonte and Salvador. In both cities, participants living in the high type 2 diabetes mellitus cluster area were more likely to be mixed-race or black and have a low schooling level and manual work; these were also considered low-income areas. On the other hand, participants in the low type 2 diabetes mellitus cluster area of Salvador were less likely to be black and have low schooling level (university degree) and live in a low-income area. More vulnerable individual and neighborhood socioeconomic characteristics were associated with living in clusters of higher type 2 diabetes mellitus occurrence , whereas better contextual profiles were associated with clusters of lower prevalence.*

Neighborhood; Cluster Analysis; Socioeconomic Factors

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Background

Diabetes is one of the main public health concerns globally and in 2016, it accounted for nearly 1.6 million deaths worldwide [1]. An estimated 8.8% of people have diabetes (425 million individuals), with this prevalence expected to increase to 9.9% by 2045 (629 million individuals). Brazil ranks fourth in the ranking of countries with the highest number of individuals with diabetes, 12.5 million people, with the possibility of reaching 20.3 million people in 2045 [1]. Type 2 diabetes mellitus is associated with a higher risk of cardiovascular diseases [2,3], chronic kidney disease [4], and poor clinical and functional outcomes [5,6], as well as higher healthcare costs [7]. Thus, type 2 diabetes mellitus also creates a great economic and social burden for countries [8].

Due to its magnitude, clinical repercussions, and economic and social impact, type 2 diabetes mellitus is an important contemporary public health problem. Therefore, understanding the spatial distribution of diabetes could be an important tool to guide public managers to design programs and rationally allocate resources for its prevention, control, and treatment [9]. Scientific evidence shows disparities in the geographic distribution of type 2 diabetes mellitus within communities, with areas of higher or lower frequencies of the disease identified in investigations conducted in Florida, Unietd States [9]; Kerala, India [10]; and Adelaide, Australia [11].

Built environment and socioeconomic characteristics differ significantly between areas with high or low frequencies of diseases, and this relationship seems to vary among populations. A study in Kerala found spatial clusters of diabetes and physical inactivity and, after comparing sociodemographic aspects between clusters, built environment characteristics proved to be relevant in Kerala's urban and rural areas [10]. In contrast, in an Australian study, an inverse relationship was observed between higher type 2 diabetes mellitus clusters and the socioeconomic status of the areas of spatial clusters [11]. However, the associations between the structural and socioeconomic conditions of the type 2 diabetes mellitus cluster areas observed in both studies were not independent and may be influenced by potential individual and environmental confounding factors [12].

Furthermore, it is important to highlight that the urban environment and the population's health conditions are interdependent and socially determined [13]. Therefore, these aspects need to be better explored in epidemiological studies.

Hence, studies that investigate spatial variability of the type 2 diabetes mellitus distribution must also analyze the individual characteristics of the residents of the areas with the highest and lowest chances of occurrence of disease, along with their structural and socioeconomic conditions [9]. For instance, previous findings of the *Brazilian Longitudinal Study of Adult Health* (ELSA-Brasil) showed that individuals living in economically segregated neighborhoods were more likely to have type 2 diabetes mellitus regardless of the income, schooling level, and other sociodemographic factors [14] suggesting inequalities when one considers the spatial distribution of type 2 diabetes mellitus. Furthermore, results from a study in the United States indicated that individual characteristics, such as being male, older age, being married, having a low income, insufficient practice of physical activity, overweight/obesity, as well as hypertension, hypercholesterolemia, or arthritis were independently associated with high cluster areas of type 2 diabetes mellitus [9].

This study aimed to identify spatial clusters of type 2 diabetes mellitus among participants of ELSA-Brasil residing in two cities and verify individual and neighborhood socioeconomic environmental characteristics associated with spatial clusters of type 2 diabetes mellitus.

Methods

This is a cross-section analysis of the ELSA-Brasil baseline (2008-2010), a multicenter, prospective cohort study consisting of 15,105 active and retired civil servants, aged from 35 to 74 years at baseline (2008-2010), from universities and research institutions. Its primary objective was to identify risk factors and natural history of diabetes and cardiovascular diseases. Data collection included face-to-face interviews, clinical examinations, and laboratory tests conducted by trained, certified professionals using standardized tools. The ELSA-Brasil study was approved by the Ethics Research Committees of all institutions involved [Minas Gerais Federal University (CAAE: 186/06); Bahia

Federal University (CAAE: 0017.1.069.000-06027/06); São Paulo University (CAAE: 0016.1.198.000-06669/06); Rio Grande do Sul Federal University (CAAE: 194/061); Oswaldo Cruz Foundation (CAAE: 0058.0.011.000-07343/06); Espírito Santo Federal University (CAAE: 0058.0.011.000-07343/06), and all participants signed an informed consent form. Details of the study design and the cohort profile have been previously described [14,15].

This study was developed with 3,115 participants living in the city of Belo Horizonte (Minas Gerais State) and 2,029 participants living in the city of Salvador (Bahia State) at baseline. Among them, those with missing geographic coordinates (n = 59), those with geographic coordinates out of the municipalities of Belo Horizonte and Salvador (n = 570 and n = 84, respectively), and participants who self-reported as Indigenous (n = 69), due to the very few observations, were excluded. The final sample size was 2,486 individuals for Belo Horizonte and 1,849 for Salvador.

Belo Horizonte is the state capital of Minas Gerais, with Human Development Index (HDI) of 0.810 [16] and an estimated population of 2,375,151 inhabitants, being the sixth most populous municipality in Brazil [17]. Salvador is the state capital of Bahia. with a 0.759 HDI [16] and an estimated population of 2,675,656 inhabitants, being the third most populous municipality in Brazil [17].

The data collection team at the ELSA-Brasil Research Centers was trained and certified for the collection of anthropometric measurements, blood samples, and application of questionnaires. Collection in all centers was standardly conducted according to the procedures described in the specific Operation Manuals for interviews and exams.

The study outcome was to live inside or outside a detected prevalence cluster of type 2 diabetes mellitus. This variable was fitted in two steps.

Participants were considered as having type 2 diabetes mellitus when they presented the following parameters: fasting blood glucose ≥ 126mg/dL (7.0mmol/L), oral glucose tolerance test (OGTT) ≥ 200mg/dL (11.1mmol/L), glycated hemoglobin (HbA1c) ≥ 6.5% (48mmol/L), or by antidiabetic drug use; or by the self-reported medical diagnosis of diabetes. Blood samples were collected after a 10 to 14-hour fasting, stored in a freezer at -80°C and sent to the certified central laboratory in São Paulo (Brazil). An OGTT was administered to all participants without a known diabetes diagnosis. Blood glucose level was measured using the enzymatic colorimetric method (ADVIA 1200, https://www.diamonddiagnostics.com), and HbA1c was measured using high-pressure chromatography (HPLC, https://www.bio-rad.com).

Initially, the database from ELSA-Brasil was obtained in georeferenced formats from the residential address informed at baseline. The census sectors were identified from the geographic coordinates (X and Y coordinates of the study participants) of each point of residence of the individuals in the study who were georeferenced in the census tract.

The first step to remove out-of-region points is defining the shape of each capital city, which in this case was defined as the shape obtained from the *geobr* R package (http://www.r-project.org) for each municipality, constituted of all the shapes of its census tracts.

After data preparation, a spatial data analysis was conducted with the SaTScan (http://www.satscan.org) method of cluster detection of punctual data, which tests for the existence of an area with multiple clusters of any size up to 20% of the total population for the outcome. The SaTScan detects a spatial cluster on different maps and computes its significance based on Monte Carlo simulations. The Bernoulli spatial scan statistic [18] was used to detect spatial clustering of tye 2 diabetes mellitus among the participants of ELSA-Brasil. Analyses were performed at the individual level to maximize spatial heterogeneity [19]. For statistical inference the null hypothesis of complete spatial randomness was rejected at a p-value ≤ 0.05.

The covariates of this study were divided into: individual characteristics of the participants and neighborhood characteristics of the area where the participants lived.

Individual characteristic variables included sex; age; race/skin color; schooling level; nature of occupation. This study also included tobacco use; alcohol consumption measured by the sum of doses of each type of alcoholic beverage consumed turned into grams, with excessive consumption being ≥ 210g/week of alcohol for men and ≥ 140g/week for women; leisure physical activity was assessed using the long-modified version of the *International Physical Activity Questionnaire* (IPAQ) and categorized according to time spent at different intensities of physical activity (light: < 600 MET-min/week; moderate: 600-3,000 MET-min/week; or vigorous: ≥ 3,000 MET-min/week) [20]; waist circumference (WC) measured at the midpoint between the last rib and the iliac crest, using a non-elastic anthropometric tape (Mabis, https://www.livehealthsmart.com) with 0.1cm precision; and abdominal obesity, which was classified according to IDF cut-off points: WC ≥ 90cm for men and WC ≥ 80cm for women [21].

The neighborhood socioeconomic environmental variables were obtained from the 2010 Brazilian *Demographic Census* [17]. The unit of analysis to build up neighborhood variables was the census tracts. This study included: (1) neighborhood household income per capita (in Brazilian Reais – BRL) stratified in tertiles, the highest area income was used as the reference in data analysis; (2) percentage of neighborhoods with adequate housing (dwellers living in properly identified adequate houses/dwellers in owned homes); (3) percentage of neighborhoods with litter (dwellers with an accumulation of litter on the public roads/dwellers in owned homes); (4) percentage of neighborhoods with sidewalks (dwellers that have sidewalks/dwellers in owned homes); due to the asymmetric distribution, these last three variables were divided according to the best possible statistical participation using two categories: low and high (cut-off points = 67th percentile for percentage of neighborhoods with adequate housing, 85th percentile for percentage of neighborhoods with littering, 66th percentile for percentage of neighborhoods with sidewalks in the city of Belo Horizonte). For the city of Salvador, the only variable with two categories was the percentage of neighborhoods with exposed trash (cut-off points = 80th percentile), with the others divided by tertiles.

Then, a frequency distribution of individuals and socioeconomic environmental characteristics was performed (Tables 1 and 2), fitting the logistic regression models to estimate the magnitude of the associations of the individuals and neighborhood characteristics between participants living inside and those living outside the clusters. The models were adjusted for sex, age, race/skin-color, schooling level, smoking, alcohol consumption, nature of occupation, leisure physical activity, waist circumference, and neighborhood socioeconomic environmental variables.

All analyses and plots presented and discussed in this study were produced using the R programming language version 3.5.1 with the RStudio IDE v1.3.125 and the SaTScan program version 9.6.0.

Results

Tables 1 and 2 describe individual and neighborhood socioeconomic characteristics. The characteristics that predominated in the study population were female sex, aged 41 to 60 years, self-reported race/skin color as white (Belo Horizonte) or mixed-race/black (Salvador), higher education, non-manual work, never smoked, moderate alcohol consumption, and light leisure physical activity. Prevalence of type 2 diabetes mellitus was higher among women, participants with manual jobs, and those with abdominal adiposity (Table 1). In Belo Horizonte, the prevalence of type 2 diabetes mellitus was higher in neighborhoods with low-income household and in neighborhoods with a high percentage of littering. In Salvador, the prevalence of type 2 diabetes mellitus was higher in neighborhoods with the poorest environmental socioeconomic characteristics for all indicators included in this study (Table 2).

Figure 1 shows the cluster area with the highest prevalence of type 2 diabetes mellitus in Belo Horizonte (circle; n = 132). This area was in the northeastern region of the city, with a 4.8km radius. The prevalence ratios of type 2 diabetes mellitus were 28.8% and 13.5%, respectively, among those who lived inside and outside the cluster area.

Figure 2 shows the cluster area with the highest prevalence of type 2 diabetes mellitus in Salvador (n = 355). This area was in the northern region of the city, with a 8.5km radius. The prevalence of type 2 diabetes mellitus was 27.6% and 18.5%, respectively, among those who lived inside and outside the cluster area. The Figure 2 also shows the cluster area with a low prevalence of type 2 diabetes mellitus (n = 71). This area was in the southern region of the city, with a 0.92km radius. The prevalence of type 2 diabetes mellitus was 1.4%.

Tables 3, 4, and 5 present the comparison of the individual characteristic of the participants who lived inside and outside the cluster area of type 2 diabetes mellitus.

After adjusting for covariables, living inside the cluster area with a high prevalence of type 2 diabetes mellitus was associated with increased odds of self-reporting mixed-race and, primarily, black

Table 1

Individual characteristics of the participants and type 2 diabetes mellitus prevalence. Belo Horizonte, Minas Gerais State (n = 2,486) and Salvador, Bahia State (n = 1,849), Brazil. ELSA-Brasil 2008/2010.

Characteristics	Belo Horizonte		Salvador	
	Total sample n (%)	Type 2 diabets mellitus n (%)	Total sample n (%)	Type 2 diabets mellitus n (%)
Sex				
Female	1,352 (54.4)	146 (10.8)	1,094 (59.2)	183 (16.7)
Male	1,134 (45.6)	190 (16.8)	755 (40.8)	160 (21.2)
Age (years)				
31-40	221 (8.9)	9 (4.1)	135 (7.3)	2 (1.5)
41-50	850 (34.2)	61 (7.2)	615 (33.3)	54 (8.8)
51-60	915 (36.8)	138 (15.1)	651 (35.2)	146 (22.4)
61-70	410 (16.5)	101 (24.6)	382 (20.7)	122 (31.9)
71-80	90 (3.6)	27 (30.0)	66 (3.6)	19 (28.8)
Race/Skin color				
White	1,323 (53.2)	156 (11.8)	361 (19.5)	44 (12.2)
Yellow	53 (2.1)	10 (18.9)	23 (1.2)	5 (21.7)
Mixed-race	836 (33.6)	117 (14.0)	839 (45.4)	141 (16.8)
Black	274 (11.0)	53 (19.3)	626 (33.9)	153 (24.4)
Schooling level				
Higher education	1,613 (64.9)	175 (10.9)	878 (47.0)	97 (11.0)
High school	701 (28.2)	115 (16.4)	714 (39.0)	161 (22.5)
Complete elementary school	89 (3.6)	23 (25.8)	157 (8.0)	44 (28.0)
Incomplete elementary school	83 (3.3)	23 (27.7)	100 (5.0)	41 (41.0)
Tobacco use				
Never smoked	1,482 (59.6)	167 (11.3)	1,215 (65.7)	201 (16.5)
Former smoker	281 (11.3)	43 (15.3)	132 (7.1)	25 (18.9)
Smoker	723 (29.1)	126 (17.4)	502 (27.2)	117 (23.3)
Alcohol consumption				
No	610 (24.5)	101 (16.6)	635 (34.4)	139 (21.9)
Moderate	1,654 (66.4)	193 (11.7)	1,059 (57.3)	164 (15.5)
Excessive	219 (9.0)	41 (18.7)	152 (8.2)	39 (25.7)
ND	3 (0.1)	1 (0.33)	3 (0.1)	1 (0.33)
Type of occupation				
Non-manual	2,247 (90.4)	282 (12.6)	1,597 (86.4)	264 (16.5)
Manual	239 (9.6)	54 (22.6)	252 (13.6)	79 (31.3)
Leisure physical activity				
Light	1,786 (72.0)	242 (13.5)	1,509 (81.7)	291 (19.3)
Moderate	478 (19.0)	69 (14.4)	241 (13.0)	47 (19.5)
Vigorous	204 (8.3)	24 (11.8)	97 (5.2)	4 (4.1)
ND	18 (0.7)	1 (5.5)	2 (0.1)	
Waist circumference				
Normal	800 (32.2)	47 (5.9)	528 (28.6)	45 (8.5)
Abdominal adiposity	1,686 (67.8)	289 (17.1)	1,321 (71.4)	298 (22.6)

ND: no data.

Note: abdominal adiposity: waist circumference – WC ≥ 90cm for men and WC ≥ 80cm for women (Alberti et al. [21]).

Table 2

Socioeconomic environmental characteristics from census tracts where the participants lived and type 2 diabetes mellitus prevalence. Belo Horizonte, Minas Gerais State (n = 2,486) and Salvador, Bahia (n = 1,849), Brazil. ELSA-Brasil 2008/2010.

Characteristics	Belo Horizonte		Salvador	
	Total sample n (%)	Type 2 diabetes mellitus n (%)	Total sample n (%)	Type 2 diabetes mellitus n (%)
Area income				
High	831 (33.4)	89 (10.8)	615 (33.3)	75 (12.2)
Middle	826 (33.3)	92 (11.1)	617 (33.3)	122 (19.8)
Low	829 (33.3)	155 (18.7)	617 (33.4)	146 (23.7)
Neighborhoods with adequate housing				
High	1,657 (66.5)	215 (13.0)	616 (33.3)	97 (15.7)
Middle	-	-	616 (33.3)	109 (17.7)
Low	829 (33.5)	121 (14.6)	617 (33.4)	137 (22.2)
Neighborhoods with litter				
Low	2,123 (85.4)	274 (12.9)	1,492 (80.7)	264 (17.7)
High	363 (14.6)	62 (17.1)	357 (19.3)	79 (22.1)
Neighborhoods with sidewalks				
High	1,651 (66.4)	218 (13.2)	615 (33.3)	95 (15.4)
Middle	-	-	617 (33.3)	116 (18.8)
Low	835 (33.6)	118 (14.1)	617 (33.4)	132 (21.4)

race/skin color, a lower education level, and manual work occupation than those living outside the cluster (Tables 3 and 4).

Table 6 shows the comparison of the socioeconomic neighborhood environmental characteristics, after adjustment for all covariables, from the area inside and outside of the type 2 diabetes mellitus cluster area.

In Belo Horizonte, 90.1% of the area within the cluster presented low-income neighborhoods. Thus, this location is characterized as an impoverished area, which is the only socioeconomic environmental factor independently related to the cluster type 2 diabetes mellitus area. In Salvador, the cluster with the highest prevalence of type 2 diabetes mellitus had a substantial and high variation in odds ratio (OR) estimated for each covariable (area income, neighborhoods with adequate housing, neighborhoods with litter, and neighborhoods with sidewalks). In the same municipality, participants living inside the cluster areas with a low prevalence of type 2 diabetes mellitus had lower odds of reporting mixed-race or black race/skin color and a lower schooling level, and higher odds of excessive alcohol consumption than participants living inside, after adjusting for covariables (Table 5). When we analyzed the OR, the cluster with a low prevalence of type 2 diabetes mellitus in Salvador exhibited geographical areas with higher incomes.

Discussion

This study used spatial scan methods to identify clusters of type 2 diabetes mellitus and verified individual and neighborhood characteristics associated with spatial clusters of type 2 diabetes mellitus in ELSA-Brasil participants living in Belo Horizonte and Salvador. One spatial cluster of type 2 diabetes mellitus was found in Belo Horizonte (higher prevalence of type 2 diabetes mellitus), whereas two spatial clusters of type 2 diabetes mellitus were found in Salvador (higher and lower prevalence of

Table 3

Individual characteristics of the participants who live inside and outside the cluster with higher chance of type 2 diabetes mellitus and their association. Belo Horizonte, Minas Gerais State, Brazil. ELSA-Brasil 2008/2010 (n = 2,486).

Characteristics	Diabetes cluster		Crude OR (95%CI)	Adjusted OR * (95%CI)
	Yes n (%)	No n (%)		
Sex				
Female				
Male	57 (43.2)	1,077 (45.8)	0.90 (0.63; 1.28)	0.82 (0.54; 1.25)
Age (years)				
31-40	11 (8.3)	210 (8.9)	1.00 (Reference)	1.00 (Reference)
41-50	59 (44.7)	791 (33.6)	1.42 (0.74; 2.76)	1.10 (0.55; 2.20)
51-60	46 (34.9)	869 (36.9)	1.01 (0.52; 1.99)	0.74 (0.36; 1.53)
61-70	13 (9.8)	397 (16.9)	0.63 (0.28; 1.42)	0.49 (0.20; 1.21)
71-80	3 (2.3)	87 (3.7)	0.66 (0.18; 2.42)	0.52 (0.13; 2.05)
Race/Skin color				
White	35 (26.5)	1,288 (54.7)	1.00 (Reference)	1.00 (Reference)
Yellow	3 (2.3)	50 (2.1)	2.21 (0.66; 7.42)	1.25 (0.36; 4.37)
Mixed-race	59 (44.7)	777 (33.0)	2.79 (1.82; 4.28)	1.79 (1.13; 2.83)
Black	35 (26.5)	239 (10.2)	5.39 (3.31; 8.78)	2.64 (1.55; 4.50)
Schooling level				
Higher education	36 (27.3)	1,577 (67.0)	1.00 (Reference)	1.00 (Reference)
High school	71 (53.8)	630 (26.8)	4.94 (3.27; 7.45)	3.28 (2.07; 5.18)
Complete elementary school	14 (10.6)	75 (3.2)	8.18 (4.22; 15.81)	4.96 (2.30; 10.67)
Incomplete elementary school	11 (8.3)	72 (3.0)	6.69 (3.27; 13.69)	3.60 (1.46; 8.81)
Tobacco use				
Never smoked	75 (56.8)	1,407 (59.8)	1.00 (Reference)	1.00 (Reference)
Former smoker	19 (14.4)	262 (11.1)	1.36 (0.81; 2.29)	0.94 (0.53; 1.68)
Smoker	38 (28.8)	685 (29.1)	1.04 (0.70; 1.55)	0.99 (0.64; 1.55)
Alcohol consumption				
No	45 (34.1)	565 (24.0)	1.00 (Reference)	1.00 (Reference)
Moderate	72 (54.5)	1,582 (67.2)	0.57 (0.39; 0.84)	0.85 (0.56; 1.29)
Excessive	14 (10.6)	205 (8.7)	0.86 (0.46; 1.59)	1.03 (0.51; 2.06)
ND	1 (0.8)	2 (0.1)	-	-
Type of occupation				
Non-manual	95 (72.0)	2,152 (91.4)	1.00 (Reference)	1.00 (Reference)
Manual	37 (28.0)	202 (8.6)	4.15 (2.76; 6.23)	1.76 (1.04; 2.97)
Leisure physical activity				
Light	111 (84.1)	1,675 (71.2)	1.00 (Reference)	1.00 (Reference)
Moderate	15 (11.4)	463 (19.7)	0.49 (0.28; 0.85)	0.62 (0.35; 1.08)
Vigorous	5 (3.8)	199 (8.4)	0.38 (0.15; 0.94)	0.66 (0.26; 1.68)
ND	1 (0.7)	17 (0.7)	-	-
Waist circumference				
Normal	38 (28.8)	762 (32.4)	1.00 (Reference)	1.00 (Reference)
Abdominal adiposity	94 (71.2)	1,592 (67.6)	1.18 (0.80; 1.74)	1.08 (0.71; 1.63)

95%CI: 95% confidence interval; ND: no data; OR: odds ratio.

Note: abdominal adiposity: waist circumference – WC ≥ 90cm for men and WC ≥ 80cm for women (Alberti et al. [21]).

* Adjusted for sex, age, race/skin color, schooling level, tobacco use, alcohol consumption, type of occupation, leisure physical activity, and waist circumference.

Table 4

Individual characteristics of the participants who lived inside and outside the cluster with higher chance of type 2 diabetes mellitus and their association. Salvador, Bahia State, Brazil. ELSA-Brasil 2008/2010 (n = 1,849)

Characteristics	Diabetes cluster		Crude OR (95%CI)	Adjusted OR * (95%CI)
	Yes n (%)	No n (%)		
Sex				
Female	192 (54.1)	902 (60.4)	1.00 (Reference)	1.00 (Reference)
Male	163 (45.9)	592 (39.6)	1.29 (1.02; 1.63)	1.31 (0.99; 1.72)
Age (years)				
31-40	24 (6.8)	111 (7.4)	1.00 (Reference)	1.00 (Reference)
41-50	105 (29.6)	510 (34.1)	0.95 (0.58; 1.55)	0.59 (0.34; 1.01)
51-60	128 (36.0)	523 (35.0)	1.13 (0.70; 1.83)	0.72 (0.42; 1.25)
61-70	81 (22.8)	301 (20.2)	1.24 (0.75; 2.06)	0.74 (0.42; 1.32)
71-80	17 (4.8)	49 (3.3)	1.60 (0.79; 3.25)	0.93 (0.42; 2.04)
Race/Skin color				
White	23 (6.5)	338 (22.6)	1.00 (Reference)	1.00 (Reference)
Yellow	8 (2.3)	15 (1.0)	7.84 (3.01; 20.40)	5.89 (2.14; 16.22)
Mixed-race	153 (43.0)	686 (45.9)	3.28 (2.07; 5.18)	2.24 (1.39; 3.59)
Black	171 (48.2)	455 (30.5)	5.52 (3.49; 8.73)	3.23 (2.00; 5.23)
Schooling level				
Higher education	76 (21.4)	802 (53.7)	1.00 (Reference)	1.00 (Reference)
High school	202 (56.9)	512 (34.3)	4.16 (3.13; 5.54)	3.46 (2.54; 4.72)
Complete elementary school	42 (11.8)	115 (7.7)	3.85 (2.52; 5.89)	2.63 (1.60; 4.33)
Incomplete elementary school	35 (9.9)	65 (4.3)	5.68 (3.54; 9.12)	3.39 (1.89; 6.09)
Tobacco use				
Never smoked	238 (67.0)	977 (65.4)	1.00 (Reference)	1.00 (Reference)
Former smoker	32 (9.0)	100 (6.7)	1.31 (0.86; 2.00)	1.09 (0.68; 1.73)
Smoker	85 (24.0)	417 (27.9)	0.84 (0.64; 1.10)	0.79 (0.59; 1.07)
Alcohol consumption				
No	132 (37.2)	503 (33.7)	1.00 (Reference)	1.00 (Reference)
Moderate	190 (53.5)	869 (58.2)	0.83 (0.65; 1.07)	1.03 (0.79; 1.35)
Excessive	32 (9.0)	120 (8.1)	1.02 (0.66; 1.57)	0.91 (0.56; 1.47)
ND	1 (0.3)	-	-	-
Type of occupation				
Non-manual	273 (76.9)	1,324 (88.6)	1.00 (Reference)	1.00 (Reference)
Manual	82 (23.1)	170 (11.4)	2.34 (1.74; 3.14)	1.29 (0.88; 1.89)
Leisure physical activity				
Light	302 (85.0)	1207 (80.8)	1.00 (Reference)	1.00 (Reference)
Moderate	35 (9.9)	206 (13.8)	0.68 (0.46; 0.99)	0.78 (0.52; 1.16)
Vigorous	18 (5.1)	79 (5.3)	0.91 (0.54; 1.54)	1.09 (0.61; 1.95)
ND	-	2 (0.1)	-	-
Waist circumference				
Normal	97 (27.3)	431 (28.9)	1.00 (Reference)	1.00 (Reference)
Abdominal adiposity	258 (72.7)	1,063 (71.1)	1.08 (0.83; 1.40)	0.93 (0.70; 1.24)

95%CI: 95% confidence interval; ND: no data; OR: odds ratio.

Note: abdominal adiposity: waist circumference – WC ≥ 90cm for men and WC ≥ 80cm for women (Alberti et al. [21]).

* Adjusted for sex, age, race/skin color, schooling level, tobacco use, alcohol consumption, type of occupation, leisure physical activity, and waist circumference.

Table 5

Individual characteristics of the participants who lived inside and outside the cluster with low chance of type 2 diabetes mellitus and their association. Salvador, Bahia State, Brazil. ELSA-Brasil 2008/2010 (n = 1,849).

Characteristics	Diabetes cluster		Crude OR (95%CI)	Adjusted OR * (95%CI)
	Yes n (%)	No n (%)		
Sex				
Female	43 (60.6)	1,051 (59.1)	1.00 (Reference)	1.00 (Reference)
Male	28 (39.4)	727 (40.9)	0.94 (0.58; 1.53)	0.80 (0.48; 1.35)
Age (years)				
31-40	9 (12.7)	126 (7.1)	1.00 (Reference)	1.00 (Reference)
41-50	24 (33.8)	591 (33.2)	0.57 (0.26; 1.25)	0.81 (0.36; 1.84)
51-60	23 (32.4)	628 (35.3)	0.51 (0.23; 1.13)	0.73 (0.31; 1.74)
61-70	13 (18.3)	369 (20.8)	0.49 (0.21; 1.18)	0.86 (0.33; 2.20)
71-80	2 (2.8)	64 (3.6)	0.44 (0.10; 2.08)	0.76 (0.15; 3.88)
Race/Skin color				
White	28 (39.4)	333 (18.7)	1.00 (Reference)	1.00 (Reference)
Yellow	0 (0.0)	23 (1.3)	**	**
Mixed-race	31 (43.7)	808 (45.4)	0.46 (0.27; 0.77)	0.61 (0.35; 1.06)
Black	12 (16.9)	614 (34.6)	0.23 (0.12; 0.46)	0.38 (0.18; 0.78)
Schooling level				
Higher education	56 (78.9)	822 (46.2)	1.00 (Reference)	1.00 (Reference)
High school	10 (14.1)	704 (39.6)	0.21 (0.11; 0.41)	0.28 (0.14; 0.58)
Complete elementary school	4 (5.6)	153 (8.6)	0.38 (0.14; 1.07)	0.65 (0.20; 2.12)
Incomplete elementary school	1 (1.4)	99 (5.6)	0.15 (0.02; 1.08)	0.33 (0.04; 2.98)
Tobacco use				
Never smoked	45 (63.4)	1,170 (65.8)	1.00 (Reference)	1.00 (Reference)
Former smoker	6 (8.4)	126 (7.1)	1.23 (0.52; 2.96)	1.31 (0.51; 3.33)
Smoker	20 (28.2)	482 (27.1)	1.08 (0.63; 1.85)	1.01 (0.56; 1.82)
Alcohol consumption				
No	15 (21.1)	620 (34.9)	1.00 (Reference)	1.00 (Reference)
Moderate	45 (63.4)	1,014 (57.0)	1.83 (1.01; 3.32)	1.39 (0.75; 2.57)
Excessive	11 (15.5)	141 (7.9)	3.22 (1.45; 7.17)	3.82 (1.61; 9.10)
ND	-	3 (0.2)	-	-
Type of occupation				
Non-manual	68 (95.8)	1,529 (86.0)	1.00 (Reference)	1.00 (Reference)
Manual	3 (4.2)	249 (14.0)	0.27 (0.08; 0.87)	0.49 (0.12; 1.98)
Leisure physical activity				
Light	55 (77.5)	1,454 (81.8)	1.00 (Reference)	1.00 (Reference)
Moderate	9 (12.7)	232 (13.05)	1.03 (0.50; 2.10)	0.89 (0.42; 1.87)
Vigorous	7 (9.8)	92 (5.05)	2.06 (0.91; 4.64)	1.59 (0.67; 3.74)
ND	-	2 (0.1)	-	-
Waist circumference				
Normal	26 (36.6)	502 (28.2)	1.00 (Reference)	1.00 (Reference)
Abdominal adiposity	45 (63.4)	1,276 (71.8)	0.68 (0.42; 1.12)	0.74 (0.44; 1.26)

95%CI: 95% confidence interval; ND: no data; OR: odds ratio.

Note: abdominal adiposity: waist circumference – WC ≥ 90cm for men and WC ≥ 80cm for women (Alberti et al. [21]).

*Adjusted for sex, age, race/skin color, schooling level, tobacco use, alcohol consumption, type of occupation, leisure physical activity and waist circumference;

** No participants were in this category.

Table 6

Neighborhood socioeconomic environmental characteristics from census tracts of participants who lived inside and outside the clusters and their association. Belo Horizonte, Minas Gerais State and Salvador, Bahia State, Brazil. ELSA-Brasil 2008/2010.

Characteristics	Diabetes cluster		Crude OR (95%CI)	Adjusted OR * (95%CI)
	Yes n (%)	No n (%)		
Belo Horizonte [cluster (n = 132) with higher chance]				
Neighborhood income per capita				
High	3 (2.3)	828 (35.2)	1.00 (Reference)	1.00 (Reference)
Middle	10 (7.6)	816 (34.7)	3.38 (0.93; 12.34)	2.64 (0.79; 11.94)
Low	119 (90.1)	710 (30.1)	46.26 (14.64; 146.11)	26.18 (9.12; 110.80)
Neighborhoods with adequate housing				
High	67 (50.8)	1,590 (67.5)	1.00 (Reference)	1.00 (Reference)
Low	65 (49.2)	764 (32.5)	2.02 (1.42; 2.87)	0.82 (0.55; 1.21)
Neighborhoods with litter				
Low	98 (74.2)	2,025 (86.0)	1.00 (Reference)	1.00 (Reference)
High	34 (25.8)	329 (14.0)	2.14 (1.42; 3.21)	0.96 (0.61; 1.50)
Neighborhoods with sidewalks				
High	63 (47.7)	1,588 (67.5)	1.00 (Reference)	1.00 (Reference)
Low	69 (52.3)	766 (32.5)	2.27 (1.60; 3.23)	1.17 (0.79; 1.72)
Salvador [cluster (n = 355) with higher chance]				
Neighborhood income per capita				
High	4 (1.2)	611 (40.9)	1.00 (Reference)	1.00 (Reference)
Middle	75 (21.1)	542 (36.3)	21.14 (7.68; 58.16)	17.20 (6.86; 57.79)
Low	276 (77.7)	341 (22.8)	123.63 (45.68; 334.64)	136.10 (53.16; 463.62)
Neighborhoods with adequate housing				
High	44 (12.4)	572 (38.3)	1.00 (Reference)	1.00 (Reference)
Middle	116 (32.7)	500 (33.5)	3.02 (2.09; 4.35)	1.55 (1.01; 2.41)
Low	195 (54.9)	422 (28.2)	6.01 (4.23; 8.53)	2.56 (1.63; 4.07)
Neighborhoods with litter				
Low	267 (75.2)	1,225 (82.0)	1.00 (Reference)	1.00 (Reference)
High	88 (24.8)	269 (18.0)	1.50 (1.14; 1.97)	1.31 (0.93; 1.83)
Neighborhoods with sidewalks				
High	54 (15.2)	561 (37.5)	1.00 (Reference)	1.00 (Reference)
Middle	120 (33.8)	497 (33.3)	2.51 (1.78; 3.53)	0.83 (0.53; 1.28)
Low	181 (51.0)	436 (29.2)	4.31 (3.11; 5.99)	0.30 (0.18; 0.48)
Salvador [cluster (n = 71) with low chance]				
Neighborhood income per capita				
High	60 (84.5)	555 (31.2)	1.00 (Reference)	1.00 (Reference)
Middle	4 (5.6)	613 (34.5)	0.06 (0.02; 0.17)	0.06 (0.02; 0.18)
Low	7 (9.9)	610 (34.3)	0.11 (0.05; 0.23)	0.12 (0.03; 0.36)
Neighborhoods with adequate housing				
High	49 (69.0)	567 (31.9)	1.00 (Reference)	1.00 (Reference)
Middle	10 (14.1)	606 (34.1)	0.19 (0.10; 0.38)	0.31 (0.14; 0.60)
Low	12 (16.9)	605 (34.0)	0.23 (0.12; 0.44)	0.46 (0.18; 1.08)

(continues)

Table 6 (continued)

Characteristics	Diabetes cluster		Crude OR (95%CI)	Adjusted OR * (95%CI)
	Yes n (%)	No n (%)		
Neighborhoods with litter				
Low	13 (18.3)	344 (19.3)	1.00 (Reference)	1.00 (Reference)
High	58 (81.7)	1,434 (80.7)	0.93 (0.51; 1.72)	1.54 (0.76; 2.94)
Neighborhoods with sidewalks				
High	40 (56.3)	575 (32.4)	1.00 (Reference)	1.00 (Reference)
Middle	19 (26.7)	598 (33.6)	0.46 (0.26; 0.80)	1.11 (0.59; 2.03)
Low	12 (17.0)	605 (34.0)	0.28 (0.15; 0.55)	2.16 (0.73; 6.17)

95%CI: 95% confidence interval; ND: no data; OR: odds ratio.

Note: no participants were in this category living inside the cluster area of type 2 diabetes.

* Ajusted for sex, age, race/skin color, schooling level, tobacco use, alcohol consumption, type of occupation, leisure physical activity, waist circumference, and each socioeconomic environmental characteristic.

type 2 diabetes mellitus). At the individual level, black and mixed-race individuals and lower schooling levels were associated with greater chances of belonging to the cluster area with a high prevalence of type 2 diabetes mellitus in Belo Horizonte and Salvador, even after adjustments for the individual covariables. In the cluster identified with a low prevalence of type 2 diabetes mellitus in Salvador, this study found a minimal chance of black and low schooling level participants living in this area. In both cities, the low levels of neighborhood income per capita were related to high spatial clusters of type 2 diabetes mellitus. In Salvador, the best level of these variables (neighborhood income per capita and pertcentage of neighborhoods with adequate housing) were associated with the low spatial cluster of type 2 diabetes mellitus.

Our findings indicate a high prevalence of type 2 diabetes mellitus in participants of ELSA-Brasil from Belo Horizonte (13.5%) and Salvador (18.5%). In Belo Horizonte and Salvador, the occurrence of type 2 diabetes mellitus was greater in the cluster areas located, respectively, in the northeastern and northern regions compared to other areas. These cluster areas were characterized as being impoverished locations, with lower neighborhood income and higher proportions of mixed-race/black people, lower schooling levels, and manual work occupations. By contrast, the southern region of Salvador was a cluster area with a lower chance of type 2 diabetes mellitus. This area was characterized as a wealthier location, with a higher neighborhood income, and with a high schooling level and low proportion of black people . Finally, in both cities, we identified that, regardless of the individual characteristics, poor socioeconomic status of neighborhoods increased the chance of type 2 diabetes mellitus (low income, low percentage of adequate housing, high percentage of litter, and low percentage of sidewalks).

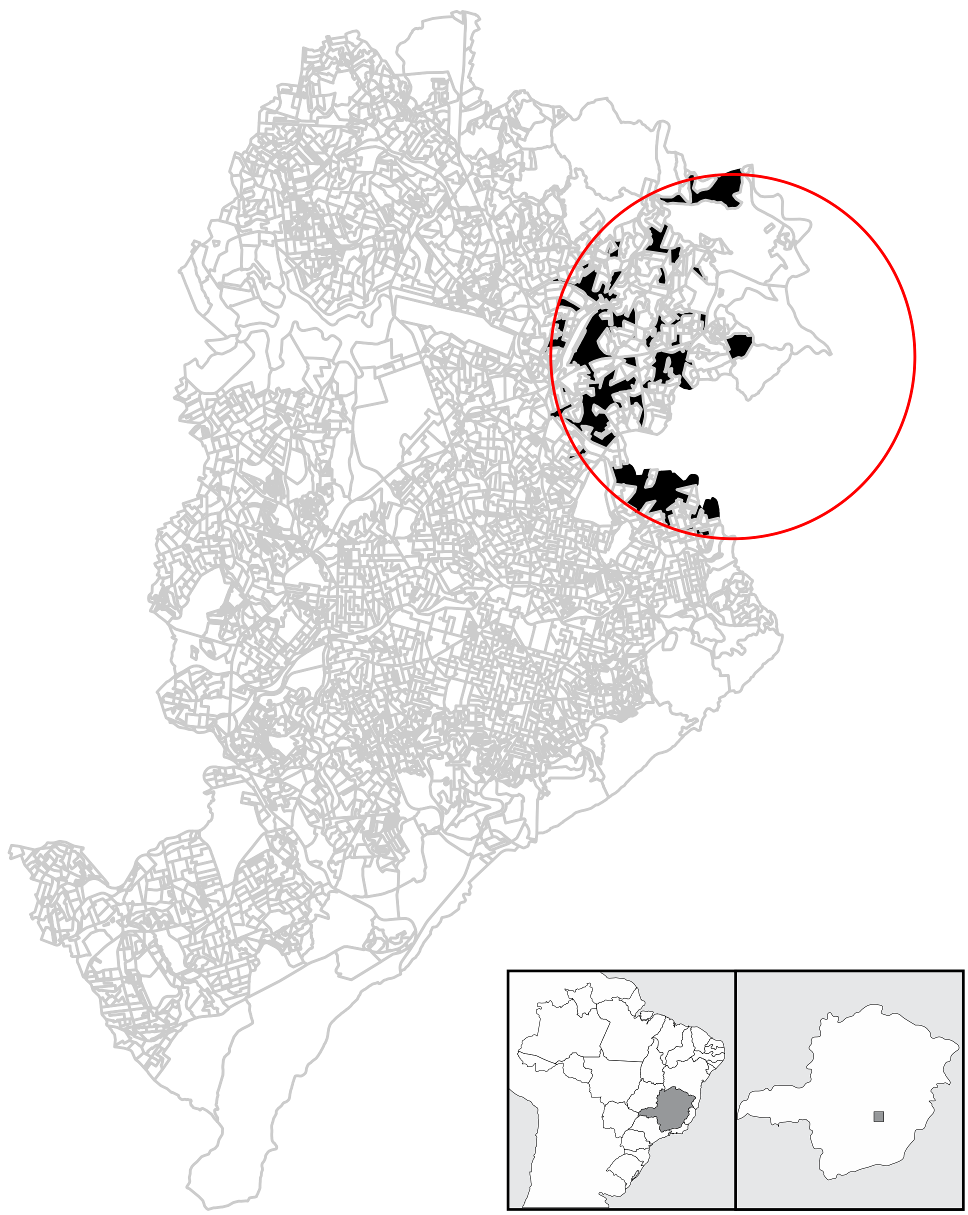
In summary, our results showed a relationship between poverty and social inequality and type 2 diabetes mellitus. Poorer people are more exposed to illness from NCDs, including type 2 diabetes mellitus, and to the worsening of their clinical conditions, due to the difficulty in meeting their health demands [22]. Furthermore, low schooling levels make it difficult to understand health promotion, disease prevention, and treatment actions, limiting the subject's empowerment regarding self-care [22,23].

Regarding skin color, some studies have suggested that the racial and ethnic disparities observed in type 2 diabetes mellitus may reflect differences in socioeconomic factors associated with skin color rather than genetic issues [24,25].

Furthermore, our results indicated that the areas with the highest and lowest chance of the occurrence of type 2 diabetes mellitus had territorial characteristics that highlighted social inequities. The areas with the highest concentration of people with type 2 diabetes mellitus had higher percentages of low-income families and neighborhoods with litter, and lower percentages of neighborhoods with adequate housing and neighborhoods with sidewalks. This profile was the opposite in the area with

Figure 1

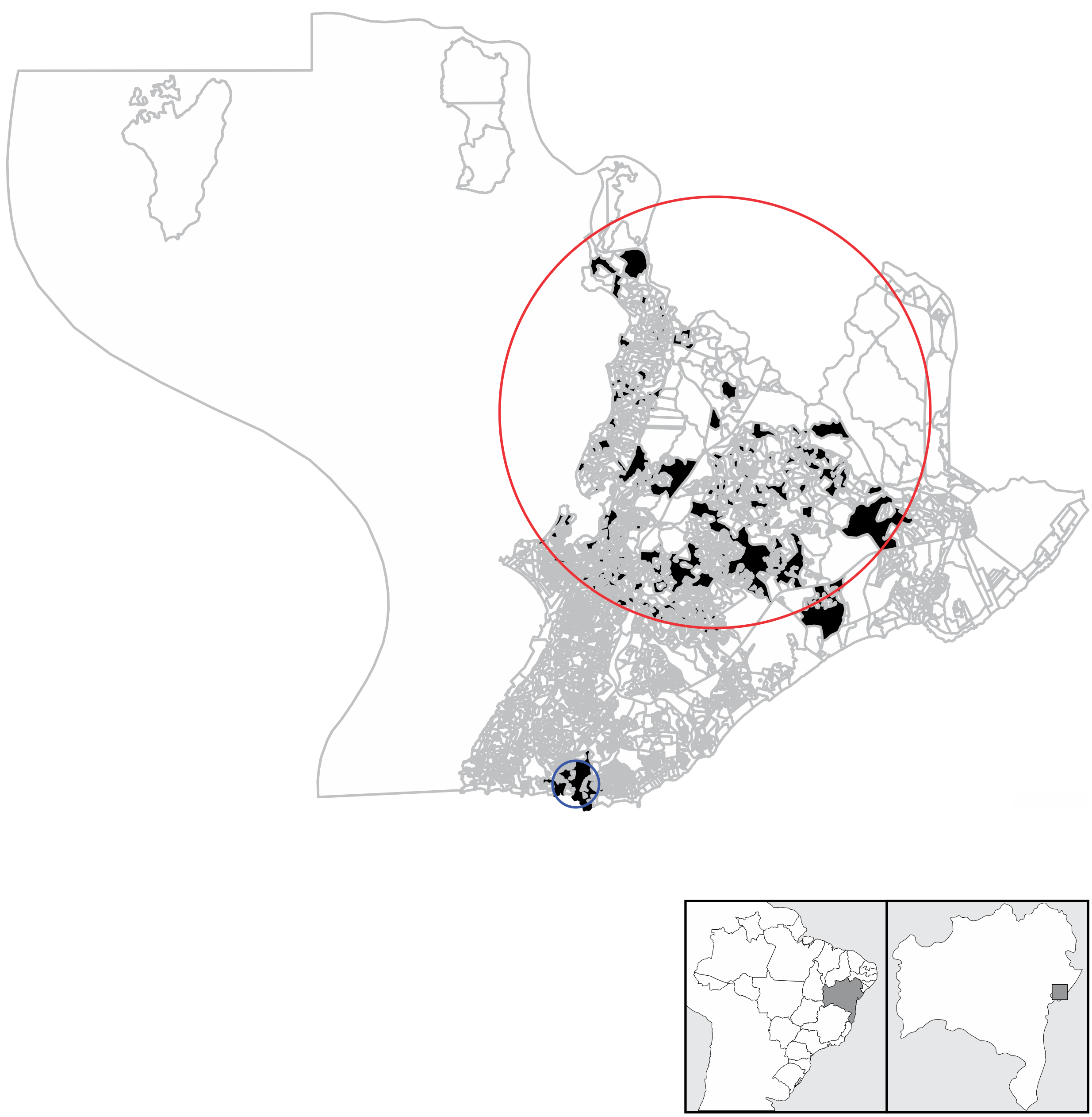
The probable cluster with a high chance (red circle) of the presence of type 2 diabetes mellitus by the circular spatial scan statistic of punctual data. Belo Horizonte, Minas Gerais State, Brazil. ELSA-Brasil 2008/2010.



Note: the black areas inside of the detected clusters are census tracts defined from Brazilian Institute of Geography and Statistics (IBGE) that belong to the participants of the ELSA-Brasil study.

Figure 2

The probable clusters of high (red circle) and low (blue circle) chances of the presence of type 2 diabetes mellitus by the circular spatial scan statistic of punctual data. Salvador, Bahia State, Brazil. ELSA-Brasil 2008/2010.



Note: the black areas inside of the detected clusters are census tracts defined from Brazilian Institute of Geography and Statistics (IBGE) that belong to the participants of the ELSA-Brasil study.

the lowest concentration of people with type 2 diabetes mellitus. Previous studies corroborate our findings, as they also showed that the areas with the greatest chance of the occurrence of type 2 diabetes mellitus were characterized as areas with worse socioeconomic conditions [9,11]. A survey conducted in Argentina found that the diabetes mortality rate was higher in provinces with low socioeconomic development. Such results could be a consequence of structural problems and health service coverage [26].

The distribution of population and economic activities in the urban space of cities is not homogeneous, but rather very uneven in several aspects. This article exemplifies this spatial inequality, associated with the prevalence of type 2 diabetes mellitus. The literature on regional and urban economics indicates two major forces that act on this distribution of economic activities [27]. The first is a specific hierarchy in the complexity of products and services offered in urban environments.

The effect on land rent, or rents, in this spatial distribution of economic activities on urban space will also affect the spatial location of the residences or dwellings of a city's population. Homes with more space available and more equipment associated with quality of life and leisure will be attracted to the proximity to these centers and the "concentric rings" formed in their surroundings. This trend will be reproduced by real estate developers who seek to maximize the income earned from the land they develop. Thus, the supply of high-standard housing is usually not homogeneous across space, but similar to economic activities concentrated in neighborhoods close to urban centers and constituents of so-called noble areas [28].

The constitution of this "urban fabric" produces a socioeconomic segregation not only by income level but is also reproduced in the urban space. The families with the highest income are in the same neighborhoods and regions, which, due to the logic of distribution of economic activities, are the neighborhoods closest to complex and diversified urban services. This dynamic creates a differentiation in the quality of life of these populations compared to those who live in peripheral areas [28,29].

Contemplating policies that do not consider this socioeconomic segregation indicated by the spatial distribution reinforce the tendency of increasing spatial heterogeneity associated with the occurrence of chronic diseases [30].

This study used the circular scan statistic of Kulldorff [18] to indicate the spatial structure of the point process associated with type 2 diabetes mellitus. This is a well-known tool in spatial analysis, able to handle the major problems that have been faced by scan-type statistics in general: multiple hypothesis tests associated with a scanning window that moves through many regions of varying shapes and sizes, and the presence of non-negligible spatial correlations in the underlying point process. In fact, statistical inference under these circumstances tends to be problematic: the correlations that arise between the different tests due to factors such as proximity and adjacency invalidate standard procedures such as Bonferroni-type corrections for p-values. The method proposed by Kulldorff [18] solves both problems by considering a maximum likelihood ratio test based on a single p-value associated with the most likely cluster area. From an inferential point of view, this is an important advantage of this approach and one of the main reasons for it becoming a standard in investigations such as the one we presented here.

The cross-sectional design of this study limits the possibility of establishing temporal relation between variables. The association observed between the neighborhood and individual characteristics with type 2 diabetes mellitus inside and outside the clusters may be subject to unmeasured sources of confounding factors. However, generalization in epidemiological studies may also be based on the plausibility of associations [31] to guide, for example, prevention and control programs to the different areas identified.

Conclusion

In conclusion, individual and neighborhood socioeconomic characteristics influenced the geographic distribution of participants with type 2 diabetes mellitus, leading to cluster areas with higher and lower chances of the occurrence of diabetes, characterized as poor and wealthy areas, respectively.

Contributors

F. L. P. Oliveira contributed to the study conception and design, data acquisition, analysis, and interpretation, and writing; and approved the final version. A. M. Pimenta contributed to the study conception and design, data acquisition and analysis, and writing; and approved the final version. B. B. Duncan contributed to the study conception and design, data acquisition and analysis, and writing; and approved the final version. R. H. Griep contributed to the study conception and design, data acquisition and analysis, and writing; and approved the final version. G. Souza contributed to the study conception and design, data acquisition and analysis, and writing; and approved the final version. S. M. Barreto contributed to the study conception and design, data acquisition and analysis, and writing; and approved the final version. L. Giatti contributed to the study conception and design, data acquisition and analysis, and writing; and approved the final version.

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Resumo

Este estudo identificou aglomerados espaciais de diabetes mellitus tipo 2 entre participantes do Estudo Longitudinal de Saúde do Adulto no Brasil *(ELSA-Brasil) em duas cidades e verificou características socioeconômicas ambientais individuais e de vizinhança associadas aos aglomerados espaciais. Se trata de um estudo transversal com 4.335 participantes. Diabetes mellitus tipo 2 foi definido com base em glicemia de jejum ≥ 126mg/dL (7,0mmol/L); teste oral de tolerância à glicose ≥ 200mg/dL (11,1mmol/L); hemoglobina glicada ≥ 6,5% (48mmol/L); uso de drogas antidiabéticas; ou pelo autodiagnóstico médico de diabetes mellitus tipo 2. As características socioeconômicas do bairro foram obtidas a partir do censo brasileiro de 2011. A análise dos dados espaciais foi realizada pelo método SaTScan para detectar os aglomerados espaciais. Os modelos de regressão logística foram ajustados para estimar a magnitude das associações. Um total de 336 e 343 participantes apresentaram diabetes mellitus tipo 2 em Belo Horizonte, Minas Gerais (13,5%) e Salvador, Bahia (18,5%), respectivamente. Foram identificadas duas áreas de aglomerados com alta probabilidade de diabetes mellitus tipo 2 em Belo Horizonte e Salvador. Em ambas as cidades, os participantes residentes nos aglomerados com alta taxa de diabetes mellitus tipo 2 tinham maior probabilidade de relatar cor de pele parda ou preta, baixa escolaridade e ocupação de trabalho manual; essas áreas também foram consideradas de baixa renda. Por outro lado, os participantes do aglomerado com baixa taxa de diabetes mellitus tipo 2 de Salvador tinham menor probabilidade de serem negros e maior probabilidade de terem diploma universitário, além de morarem em áreas de alta renda. Características socioeconômicas individuais e de vizinhança mais vulneráveis estavam associadas à residência em aglomerados de maior ocorrência de diabetes mellitus tipo 2, enquanto o oposto foi observado para perfis contextuais melhores.*

Vizinhança; Análise de Conglomerados; Fatores Socioeconômicos

Resumen

Este estudio identificó grupos espaciales de diabetes mellitus tipo 2 entre los participantes del Estudio Longitudinal de Salud del Adulto en Brasil *(ELSA-Brasil) en dos ciudades y verificó las características socioeconómicas ambientales individuales y de vecindario asociadas con los grupos espaciales. Se trata de un estudio transversal con 4.335 participantes. La diabetes mellitus tipo 2 se definió en base a glucosa en ayunas ≥ 126mg/dL (7,0mmol/L); prueba de tolerancia oral a la glucosa ≥ 200mg/dL (11,1mmol/L); hemoglobina glicosilada ≥ 6,5% (48mmol/L); uso de medicamentos antidiabéticos; o por autodiagnóstico médico de diabetes mellitus tipo 2. Las características socioeconómicas del barrio se obtuvieron a partir del censo brasileño de 2011. El análisis de datos espaciales se realizó utilizando el método SaTScan para detectar grupos espaciales. Los modelos de regresión logística se ajustaron para estimar la magnitud de las asociaciones. Un total de 336 y 343 participantes presentaron diabetes mellitus tipo 2 en Belo Horizonte, Minas Gerais (13,5%) y Salvador, Bahia (18,5%), respectivamente. Se identificaron dos áreas de grupos con alta probabilidad de diabetes mellitus tipo 2 en Belo Horizonte y Salvador. En ambas ciudades, los participantes que residían en las áreas del grupo con una alta tasa de diabetes mellitus tipo 2 tenían más probabilidades de informar el color de piel pardo o negro, la baja educación y la ocupación del trabajo manual; estas áreas también se consideraron de bajos ingresos. Por el contrario, los participantes en el área del grupo con baja tasa de diabetes mellitus tipo 2 de Salvador tenían menos probabilidades de ser negros y más probabilidades de tener un título universitario, además de vivir en áreas de altos ingresos. Las características socioeconómicas individuales y de vecindario más vulnerables se asociaron con la residencia en grupos de mayor incidencia de diabetes mellitus tipo 2, mientras que se observó lo contrario para mejores perfiles contextuales.*

Vecindario; Análisis de Conglomerados; Factores Socioeconómicos

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