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Spatial inequalities of retail food stores may determine availability of healthful food choices in a Brazilian metropolis

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Abstract

Objective: To examine the association between economic residential segregation and food environment.

Design: Ecological: Food stores categorised according to the NOVA classification were geocoded, and absolute availability was calculated for each neighbourhood. Segregation was measured using local G_i^* statistic, a measure of the SD between the economic composition of a neighbourhood (the proportion of heads of households in neighbourhoods earn monthly income of 0 to 3 minimum wages) and larger metropolitan area, weighted by the economic composition of surrounding neighbourhoods. Segregation was categorised as high (most segregated), medium (integrated) and low (less segregated or integrated). A proportional odds models were used to model the association between segregation and food environment.

Setting: Belo Horizonte, Brazil.

Participants: Food stores.

Results: After adjustment for covariates, neighbourhoods characterised by high economic segregation had fewer food stores overall compared with neighbourhoods characterised by low segregation (OR = 0·56; 95 % CI (0·45, 0·69)). In addition, high segregated neighbourhoods were 49 % (OR = 0·51; 95 % CI (0·42, 0·61)) and 45 % (OR = 0·55; 95 % CI (0·45, 0·67)) less likely to have a high number of food stores that predominantly marketed ultra-processed foods and mixed food stores, respectively, as compared with their counterparts.

Conclusions: Economic segregation is associated with differences in the distribution of food stores. Both low and high segregation territories should be prioritised by public policies to ensure healthy and adequate nutrition as a right for all communities. The former must continue to be protected from access to unhealthy commercial food outlets, while the latter must be the locus of actions that limit the availability of unhealthy commercial food store.

Keywords
Urban Health
Residential segregation
Food Environment
Brazil

As proposed by the Brazilian Dietary Guidelines, considered one of the best sets of nutritional guidelines worldwide, choosing unprocessed or minimally processed foods and freshly made dishes and meals instead of ultra-processed foods is one of the golden rules for changing the population's dietary patterns. This choice will help promote good health and prevent diseases[1,2]. This choice, however, is not only a matter of individual behavior but also of context, a finding supported by a large body of empirical evidence.

The availability of different types of food stores varies according to neighbourhood characteristics, and some evidence of disparities has consistently been described in the literature[3–6]. These disparities are not random and have

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been identified both at community and consumer levels of local food environments. Economic residential segregation, a multidimensional phenomenon, may occur when two or more groups of people who are categorised by income live separately from one another in different parts of an urban environment, due in large part to public policies and corporate practices that restrict the residential mobility of economically disadvantaged individuals[7]. The resulting living conditions of the neighbourhood promote a wide range of exposure and could represent the spatial manifestation of inequalities[8]. Spatial inequalities in the availability of unhealthy food, for example, suggest that the adherence to eating unprocessed and minimally processed food intake may be harder for residents, depending on the level of segregation[9–11].

For example, studies in the USA demonstrate that racially segregated and economically disadvantaged neighbourhoods have a lower availability of stores selling reasonably priced healthy food; more expensive healthy options although with poorer quality and a greater availability of fast-food outlets compared with more affluent areas[11–17]. Such results also coincide with findings from New Zealand, Australia and Sweden in addition to the USA–Mexico border[18,19]. An inverse relationship was found in some studies carried out in Canada, the United Kingdom, Denmark and Brazil in which economically disadvantaged neighbourhoods tend to have a lower availability of stores selling unhealthy foods[20–23]. Other studies have been incapable of finding any clear patterns or gradient or any significant associations between neighbourhood characteristics and food environments[24–26]. Nevertheless, it is important to note that lower availability of stores selling unhealthy foods does not necessarily imply lower exposure to unhealthy food environments. For instance, the number of unhealthy food stores can be lower, but food stores can be further away than in affluent areas (impacting people's access to both healthy and unhealthy foods). In one study, conducted in Brazil, access to unhealthy food was found to be lower in economically disadvantaged neighbourhoods than in affluent ones, and both unhealthy and healthy food stores were more distant and less concentrated in disadvantaged neighbourhoods than in affluent one[27].

In contrast to what has been found in other countries, scientific evidence has revealed that Brazilian areas with the lowest social deprivation present a higher density of all types of establishments selling predominantly unhealthy foods and a lower density of supermarkets/shops selling fruits and vegetables[3,5,6,28,29].

Although these findings have shown an association between economic disadvantages and food environments, these findings may not produce the same results when considering segregation as an exposure for several reasons: (1) the main studies were conducted in less socially unequal countries compared with Brazil[30] or even in those with distinct cultures and dietary patterns[31]; (2) most studies on segregation and food environments have been conducted in the USA and tend to focus on racial/ethnic segregation[32–35] and (3) it is unclear if the mechanisms underlying racial segregation in the USA are similar to those related to economic segregation in the Brazilian context. However, previous evidence has revealed that economically segregated areas, located in some Brazilian cities, have a higher prevalence of blacks and browns when compared with more affluent areas[36].

To address the gaps in the literature concerning food segregation as described above, the current study examined the association between economic residential segregation and community food environments. Findings from the current study may be helpful in determining recommendations for public health policies and interventions.

Methods

Study area and geographic unit

The current study was an ecological study on the spatial distribution of retail food stores in economically segregated urban neighbourhoods of Belo Horizonte. Located in the southwest region of Brazil, Belo Horizonte is the sixth most populous city with a population of 2 375 151 inhabitants[37]. Belo Horizonte is the capital of the State of Minas Gerais and is divided into nine administrative regions. This municipality presents a high value on the Municipal Human Development Index (IDHM, expressed in Portuguese) of 0·810. IDHM is a measure of indicators of three dimensions of human development: (1) longevity; (2) education and (3) income. The index values range from 0 to 1. The value close to 1 indicates greater human development. A total of approximately 18·9 % of the census sectors in the city were highly segregated as reported in previous study[8]. In the city, the wealthier regions are located at the south-central area, which has the highest per capita income (R$ 3915) and IDHM (0·910) of the city. Poorer communities are found on the outskirts of the city (North, Venda Nova and Barreiro) with a per capita income of ≤ R$ 80 000[8,38].

The census tract was used to represent the community (area) level unit used in this study. Census tracts are administrative areas defined by the Brazilian Census Bureau for census data collection and include an average of 1000 residents per area[37].

Data sources

The names, addresses, National Register of Legal Entities number and the National Classification of Economic Activities, which is a national standardised instrument used by the Brazilian tax administration[39], of all food stores located in Belo Horizonte in 2015 were obtained from

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the government offices of Minas Gerais State Finance Secretariat and Deputy Municipal Inspection Secretariat. Since no single directory of food stores in Belo Horizonte exists, this study's data were obtained and combined from these two secondary sources.

The data were geo-referenced, combined, de-duplicated, cleaned and verified through the Google Street View tool on the basis of matching. National Classification of Economic Activities errors were also resolved using the Google Street View tool. Informal food stores, i.e. stores without legal registration that probably do not issue tax notes and whose employees may not have formal contracts, present in the database were also analysed.

After undertaking the above procedures, the database of geo-coded food stores consisted of 15 454 establishments and included twelve different types of registered food stores. For this study, in particular, some units of the Food and Nutrition Security Programs of Belo Horizonte were included in the database (such as popular restaurants and municipal farmers' markets, known as ABasteCer and Direto da Roça). In contrast, department stores and pharmacies, which do not have the sale of food as their main focus, were excluded. Likewise, food stores whose location could not be verified using the Google Street View tool (location inside private institutions, such as schools and universities) and those that did not have a fixed marketing place were excluded. Moreover, 267 stores located in census tracts for which calculation of segregation was impossible due to the omission of income data from the 2010 Census were also excluded. Thus, the final database consisted of 15 187 establishments.

Measures

Defining neighbourhood economic residential segregation

The Getis-Ord Local G_i^* statistic (or G_i^* statistic) is a spatially weighted *Z*-score and is a measure of the SD between the economic composition of the neighbourhoods (the proportion of heads of household in neighbourhoods that earn a monthly income within 0 to 3 SDs of the minimum wage) and the makeup of the surrounding neighbourhood. This tool represents how much the income makeup of a neighbourhood deviates from a larger area, for example, from the city. The local G_i^* statistic was used to evaluate the spatial clustering of high or low values among census tracts. Higher positive G_i^* *Z*-scores (*Z*-scores > 1·96) indicate higher income segregation (over-representation of the high proportion of heads of households in a neighbourhood earning a monthly income of 0 to 3 minimum wage) or clustering of a high proportion of heads of households in a neighbourhood earning a monthly income of 0 to 3 minimum wage. Scores near 0 (*Z*-scores = 0) indicate income integration or no segregation. Lower negative scores (Z-scores ≤ −1·96) suggest lower income representation (under-representation of the high proportion of heads of households in a neighbourhood earning a monthly income of 0 to 3 minimum wage)[40,41].

G_i^* scores were calculated using the Hot Spot Analysis Tool in ArcGIS, version 10.3 and based on the following equation:

$$Gi^* = \frac{\sum_{j=1}^{n} w_{ij}x_j - \bar{x}\sum_{j=1}^{n} w_{ij}}{s\sqrt{\frac{\left[N\sum_{j=1}^{n} w_{ij}^2 - \left(\sum_{j=1}^{n} w_{ij}\right)^2\right]}{N-1}}}$$

in which x_j represents the proportion of households with 0 to 3 minimum wage for neighbourhood *j*, w_{ij} is the spatial weight between features *i* and *j*, *n* is the total number of neighbourhoods within Belo Horizonte, *X* is the mean proportion of households with 0 to 3 minimum wages for Belo Horizonte and *S* is the SD.

Data from the 2010 Brazilian Census were used to determine the proportion of heads of households in a neighbourhood earning a monthly income within 0–3 minimum wage (approximately US$ 0·00–US$ 900·00 in 2010). The cut-off point, 0–3 minimum wage, was based on prior studies of economic segregation in Brazil[36] and corresponded to an average monthly income of a Brazilian worker in 2015, the year in which the database was created[42].

A total of 3936 census tracts were identified in Belo Horizonte. Census tracts in which the population was zero (*n* 41) and whose income data were omitted by 2010 Brazilian Census for safety reasons (*n* 62) were excluded.

Census tracts were weighted using a first-order rook spatial weight matrix. Higher, positive scores represented census tracts that are more segregated (for example, a higher proportion of households within incomes of 0 to 3 minimum wage), while lower, negative scores account for less segregated census tracts (for example, a lower proportion of households with incomes of 0 to 3 minimum wage).

Three categories of segregation were created: (1) High: G_i^* statistic ≥ 1·96; (2) Medium: G_i^* statistic between 0 and 1·96 and (3) Low: G_i^* statistic < 0 according to the distribution of the *Z*-score. The high segregation category corresponds to a statistically significant clustering of high values ($\alpha = 0{\cdot}05$), so it is the most segregated neighbourhood. Medium corresponds to the absence of segregation (integrated neighbourhood), and the low category corresponds to the absence of any clustering (integrated neighbours) or less segregated neighbourhood with a clustering of low values. A small number of census tract had $G_i^* < -1{\cdot}96$; thus, we used a cut point of 0 for the low segregation category, as a result that category corresponds to integrated neighbours or less segregated neighbourhood[43]. See Appendix 1 in the Supplementary Material 1 for further details on the segregation measurements.

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Classification of food stores

To assess food environments, categories of food retailers were proposed based on the extent and purpose of industrial processing of food predominantly marketed by them according to the NOVA classification as proposed by Inter-ministerial Chamber for Food and Nutritional Security (CAISAN). CAISAN is based on analysis of the profile of food retail establishments in Brazil that are listed in a national home survey, the Survey of Family Budgets 2008–2009 (POF, in Portuguese)[1,44]. Therefore, as suggested by CAISAN, our study categorised food stores as one of three types: (1) Predominantly markets with unprocessed and/or minimally processed foods in which the purchase of fresh or minimally processed food, such as butcher shops, fish markets, fairs and greengrocers, accounts for more than 50 % of the total acquisition; (2) predominantly markets with ultra-processed foods in which the acquisition of ultra-processed food represents more than 50 % of the total acquisition (such as candy shops, cafés, bars and fast-food restaurants) and (3) mixed establishments in which a predominance of the acquisition of culinary preparations and/or processed foods can be found or in which no predominance of food purchases of unprocessed/minimally processed foods or ultra-processed foods exists (such as supermarkets, hypermarkets, restaurant, bakeries, mini-markets and dairy shops)[44]. Supermarkets and hypermarkets were not classified as sources of healthy food. For details of the types of food stores included in each category, see online Supplemental Material 2 and for the CAISAN classification process, see Brazil, 2018[44].

The categorises foods according to the extent and purpose of food processing, and not in terms of nutrients in the NOVA classification, categorises foods according to the extent and purpose of food processing rather than in terms of nutrients in: (i) Unprocessed foods are edible parts of plants (fruits, vegetables, leaves and roots) or animals (such as muscle, offal, eggs and milk), and also fungi, algae and water, after separation from nature; (ii) minimally processed foods are natural foods that are altered by various processes, such as removal of inedible or unwanted parts, drying, crushing, grinding, fractioning, filtering, roasting, boiling, pasteurisation, refrigeration, freezing, placing in containers, vacuum packaging and/or non-alcoholic fermentation; (iii) processed culinary ingredients are substances directly obtained from unprocessed foods or from nature by processes such as pressing, refining, grinding, milling and spray drying and (iv) ultra-processed food and drink products are industrial formulations that typically contain many ingredients, such as sugar, oils, fats, salt, anti-oxidants, stabilisers and preservatives. Ingredients only found in ultra-processed products include substances not commonly used in culinary preparations and additives whose purpose is to imitate sensory qualities[1].

Calculating absolute availability

For this study, the absolute availability indicates the number (0, 1, 2 or 3+) of food stores within a census tract that predominantly marketed unprocessed and/or minimally processed foods, those that predominantly marketed ultra-processed foods or mixed establishments.

Statistical analysis

The present study's analysis was conducted in two steps. First, descriptive analysis was done to calculate the distribution of food stores that predominantly marketed unprocessed and/or minimally processed foods, those that predominantly market ultra-processed foods and mixed establishments. Accordingly, the absolute availability was divided into four categories: (1) none (0); (2) one; (3) two and (4) three or more food stores. We then calculated the percent of tracts in each economic segregation category (high, medium and low) containing none, one, two or three or more food stores for each store type category and for all types of stores (regardless of the predominant category of marketed food). An example of how the percentage of census sectors classified as high segregation and that had one establishment of mixed foods was calculated: number of total high segregation census tracts in Belo Horizonte-MG that has one mixed establishment/ number of total high segregation census tracts in Belo Horizonte-MG. Comparison of the 95 % CI was used to identify any differences between percentage of categories of economic residential segregation areas (high, medium and low).

Second, a regression-based approach was implemented in order to determine the association between economic residential segregation and the different levels of food store availability adjusted by population in increments of 100 people. The total population at the census tract level was obtained from the 2010 Brazilian Census. The number of people in a given area could be associated with the distribution of food stores, mainly because the number of food stores tended to be higher in more densely populated areas[36].

The partial proportional odds model was selected for the current study due to the dependent variable (a four-category ordinal outcome) in which the proportional odds assumption is often violated (see online Supplemental Material 3, Table 1). The brand statistic test was used to determine if a predictor violates the proportional odds assumption ($P < 0{\cdot}05$). The tests indicate that we violated the assumption of proportional probabilities; thus, it was necessary to run partial proportional odds models rather than a proportional odd one.

An ordered logistic model is equivalent to a series of binary logistic regressions in which the different levels or group ranks of the dependent variable are combined and contrasted[45]. In this case, four ordinal levels of food store availability were found (none, one, two and three or more food stores) in which none was compared with levels 1, 2

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Table 1 Levels of availability of food store by neighbourhood economic residential segregation in Belo Horizonte-Minas Gerais, Brazil, 2015

	Total (*n* 3833)	Residential economical segregation			
		High (*n* 725)	Medium (*n* 1574)	Low (*n* 1534)	
	%				*P*-value*
Food store†					
Any type of food store					
None	24·86	29·79	26·75	20·6	<0·001
1	15·81	19·59	16·07	13·75	
2	13·41	14·07	14·29	12·19	
3 or more	45·92	36·55	42·88	53·46	
Predominantly market unprocessed and/or minimally processed foods‡					
None	77·62	76·69	76·18	79·53	0·034
1	13·46	12·28	14·55	12·91	
2	5·35	7·45	4·89	7·82	
3 or more	3·57	3·59	4·38	2·74	
Predominantly market ultraprocessed foods§					
None	41·4	50·21	42·06	36·57	<0·001
1	22·15	25·79	22·74	19·82	
2	13·51	11·03	14·17	14·02	
3 or more	22·93	12·97	21·03	29·60	
Mixed establishments‖					
None	31·72	37·24	33·93	26·86	<0·001
1	19·46	24·41	16·93	16·95	
2	14·58	13·93	15·12	14·34	
3 or more	34·23	24·41	31·32	41·85	

†The percent of tracts in each residential segregation category (high, medium and low) containing none, 1, 2 or 3+ food stores for each store-type category (unprocessed and/or minimally processed foods; ultraprocessed foods; mixed) and all types of food store.
‡Establishments where the purchase of fresh or minimally processed food accounts for more than 50 % of the total acquisition (e.g. butcher shops, fish markets, fairs and greengrocers).
§Establishments where the acquisition of ultra-processed food represents more 50 % of the total acquisition (e.g. bar, candy shops, cafés and fast-food restaurants).
‖Establishments where there is a predominance of the acquisition of culinary preparations or processed foods or where there is no predominance of food purchases in natura/minimally processed foods or ultraprocessed foods (e.g. supermarkets, hypermarkets, restaurant, bakeries, mini markets and dairy shops).
*χ^2 test for linear tendency.
Bold denotes significantly different.
Residential segregation was measured for study defined neighbourhoods using the local G_i^* statistic.
Categories of segregation were defined as follows: High: $G_i^* > 1{\cdot}96$; Medium: $0 > G_i^* < 1{\cdot}96$ and Low: $G_i^* < 0$.

and 3 or more foods stores combined, none and one food stores combined *v.* levels 2 and 3 or more foods stores and levels 0, 1 and 2 food stores combined *v.* level 3 or more food stores. Levels 1, 2 and 3 or more foods stores when combined refers to more food stores in given area. Three coefficients were returned.

Eight unique partial proportional odds models divided into four groups were estimated: (1) Models 1 and 2 = any type of food store as a response; (2) Models 3 and 4 = predominantly marketed unprocessed/or minimally processed foods as a response; (3) Models 5 and 6 = predominantly marketed ultra-processed foods as a response and (4) Models 7 and 8 = mixed establishments as a response. Odd-numbered statistical models were unadjusted, and even-numbered statistical models were adjusted by population in increments of 100 people.

When interpreting the models, it was necessary to consider two groups of variables: (1) those for which the proportional probability assumption was verified and (2) those for which the assumption was not. For the first group, the association of the variable was constant across all categories of segregation, and only one parameter was estimated. For the others, a coefficient was estimated for each category combination. In the footnotes of the table, our study highlighted which variables violated the proportional odds assumption.

All analyses were performed using the Stata software, version 14 (Stata Corp.), considering a significance level of 5 %.

Results

The present study analysed 3833 census tracts in Belo Horizonte. Segregation scores ranged from −6·64 to 3·92. The total sample included 18·9 % high segregation areas (*Z*-score ≥ 1·96 and *P*-value ≤ 0·05), 41·1 % medium and 40·0 % low segregation areas. The availability of at least one food store in the neighbourhood (i.e. census tract) by economic residential segregation is shown in Fig. 1.

As shown in Fig. 1, the low segregation area had the greatest percentage of census tracts with at least one food store, regardless of the type (Low = 79·40 %, Medium = 73·26 % and High = 70·21 %). Overall, the percentage of census tracts that had at least one food store that predominantly marketed ultra-processed processed foods was (58·60 %, 95 % CI (57·02, 60·14)), which was lower among highly segregated areas (49·79 %; 95 % CI (46·16, 53·43)). Likewise, the percentage of tracts that had at least one

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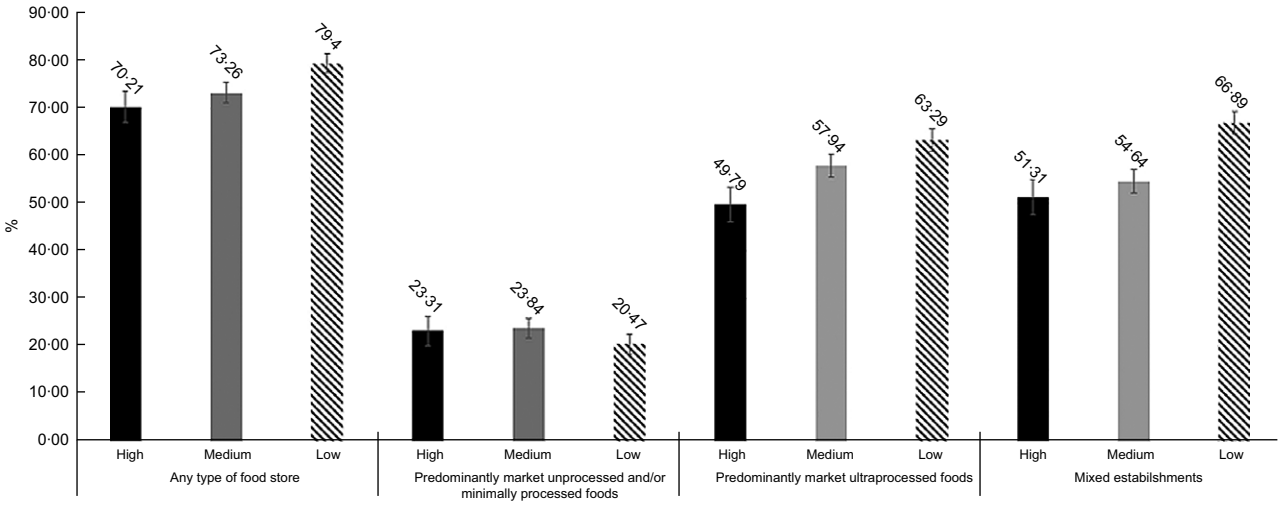

Fig. 1 Availability of at least one food store by neighbourhood economic residential segregation in Belo Horizonte-Minas Gerais, Brazil, 2015

mixed establishment was lower in high segregation neighbourhoods as compared with low segregation neighbourhoods (51·31 %; 95 % CI (47·67, 54·93) *v.* 66·88 %; 95 % CI (64·48, 69·20)). No statistically significant differences between economic segregation and percentage of tracts that had at least one food store predominantly marketing unprocessed and/or minimally processed foods were found (Fig. 1).

The percentage of census tracts containing at least one food store of any type was significantly higher in low segregation neighbourhoods. The percentage of census tracts containing three or more stores that predominantly marketed unprocessed and/or minimally processed foods was significantly lower in low segregation areas. The census tracts in which food stores that predominantly marketed unprocessed and/or minimally processed foods were mainly located in the medium segregation neighbourhoods. In contrast, the percentage of census tracts containing three or more food stores that predominantly marketed ultra-processed foods and mixed establishments were higher in low segregation areas (Table 1).

Modelling results

Medium and high residential economic segregation variables were associated with lower odds for a higher number (levels 1 + 2 + 3 or more) of food stores that predominantly marketed ultra-processed foods and mixed establishments. These trends were generally sustained with the addition of the population variable into the models, demonstrating a constant association across all levels of comparison (Table 2).

High segregation neighbourhoods, when compared with low segregated neighbourhoods, were 44 % less likely to be in an area with a higher number (1 + 2 + 3 or more) of any type of food store ($P < 0·001$). In addition, highly segregated neighbourhoods were 49 % and 45 % less likely to be in an area with a higher number (1 + 2 + 3 or more) of food stores that predominantly market ultra-processed foods and mixed food stores, respectively, as compared with their counterparts from the lower segregated neighbourhoods ($P < 0·001$), as shown in Table 2.

After comparing high and low segregation neighbourhoods, no statistically significant differences were found between the prevalence of food stores that predominantly marketed unprocessed and/or minimally processed foods. In contrast, that integrated neighbourhoods (medium segregation areas) were 19 % more likely to be an area with a higher number of food stores that predominantly marketed unprocessed and/or minimally processed foods as compared with their counterparts from the lower segregated neighbourhoods ($P = 0·044$), as shown in Table 2.

Across the three comparisons (none *v.* 1 + 2 + 3 or more, none +1 *v.* 2 + 3 or more and none +1 + 2 *v.* 3 or more), all types of food stores tended to present the same association of segregation and population.

Discussion

In our study examining the association between economic residential segregation and the local retail food environment in a large Brazilian metropolis, we found that neighbourhoods with high levels of economic segregation have fewer unhealthy food stores or mixed establishments compared with more affluent areas. Moreover, economic segregation was not associated with the availability of food stores that predominantly marketed unprocessed and/or minimally processed foods.

In general, international literature has revealed that highly segregated neighbourhoods, especially those that are ethnically/racially segregated, and economically disadvantaged areas tend to have a lower availability of stores selling

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Table 2 Results of the final partial proportional odds model, according of different types of food store response, in Belo Horizonte-Minas Gerais, Brazil, 2015

				(None) *v.* (1 + 2 + 3 or more)			(None + 1) *v.* (2 + 3 or more)			(None + 1 + 2) *v.* (3 or more)		
				OR			OR			OR		
		Co-variable	Categories	Estimative	95 % CI	*P*-value	Estimative	95 % CI	*P*-value	Estimative	95 % CI	*P*-value
Any type of food store	Model 1	Residential economical segregation	Low	1·00			1·00			1·00		
			Medium	0·67	0·59, 0·77	<0·001	0·67	0·59, 0·77	<0·001	0·67	0·59, 0·77	<0·001
			High	0·54	0·46, 0·63	<0·001	0·54	0·46, 0·63	<0·001	0·54	0·46, 0·63	<0·001
	Model 2	Residential economical segregation	Low	1·00			1·00			1·00		
			Medium	0·74	0·63, 0·88	<0·001	0·69	0·59, 0·80	<0·001	0·60	0·52, 0·70	<0·001
			High	0·56	0·45, 0·69	<0·001	0·46	0·38, 0·56	<0·001	0·40	0·34, 0·49	<0·001
		Population*		1·24	1·21, 1·26	<0·001	1·24	1·21, 1·26	<0·001	1·24	1·21, 1·26	<0·001
Unprocessed/or minimally processed foods	Model 3	Residential economical segregation	Low	1·00			1·00			1·00		
			Medium	1·22	1·03, 1·44	0·019	1·22	1·03, 1·45	0·019	1·22	1·03, 1·45	0·019
			High	1·18	0·96, 1·46	0·116	1·50	1·13, 1·98	0·005	1·12	0·72, 1·74	0·625
	Model 4	Residential economical segregation	Low	1·00			1·00			1·00		
			Medium	1·19	1·01, 1·41	0·044	1·19	1·01, 1·41	0·044	1·19	1·01, 1·41	0·004
			High	1·06	0·86, 1·32	0·576	1·37	1·03, 1·82	0·029	1·07	0·68, 1·68	0·758
		Population*		1·14	1·11, 1·17	<0·001	1·11	1·07, 1·15	<0·001	1·06	1·00, 1·13	0·053
Ultraprocessed foods	Model 5	Residential economical segregation	Low	1·00			1·00			1·00		
			Medium	0·79	0·69, 092	0·002	0·70	0·61, 0·81	<0·001	0·63	0·54, 0·74	<0·001
			High	0·57	0·48, 0·68	<0·001	0·41	0·33, 0·50	<0·001	0·35	0·28, 0·45	<0·001
	Model 6	Residential economical segregation	Low	1·00			1·00			1·00		
			Medium	0·80	0·69, 0·93	0·004	0·68	0·59, 0·78	<0·001	0·60	0·51, 0·71	<0·001
			High	0·51	0·42, 0·61	<0·001	0·35	0·28, 0·42	<0·001	0·31	0·24, 0·39	<0·001
		Population*		1·19	1·16, 1·22	<0·001	1·19	1·16, 1·22	<0·001	1·16	1·13, 1·19	<0·001
Mixed establishment	Model 7	Residential economical segregation	Low	1·00			1·00			1·00		
			Medium	0·67	0·59, 0·76	<0·001	0·67	0·59, 0·76	<0·001	0·67	0·59, 0·76	<0·001
			High	0·60	0·50, 0·72	<0·001	0·48	0·40, 0·58	<0·001	0·46	0·38, 0·56	<0·001
	Model 8	Residential economical segregation	Low	1·00			1·00			1·00		
			Medium	0·72	0·62, 0·85	<0·001	0·64	0·55, 0·74	<0·001	0·57	0·49, 0·66	<0·001
			High	0·55	0·45, 0·67	<0·001	0·40	0·33, 0·49	<0·001	0·34	0·29, 0·44	<0·001
		Population*		1·23	1·20, 1·25	<0·001	1·23	1·20, 1·25	<0·001	1·23	1·20, 1·25	<0·001

Categories of segregation were defined as follows: High: $G_i^* > 1{\cdot}96$; Medium: $0 > G_i^* < 1{\cdot}96$ and Low: $G_i^* < 0$.
*In increments of 100 people. Odd-numbered statistical models are unadjusted and even-numbered statistical models are adjusted for population.
Model 2 = The proportional odds assumption was violated for medium and high residential economical segregation.
Model 4 = The proportional odds assumption was violated for high residential economical segregation and population.
Model 6 = The proportional odds assumption was violated for medium and high residential economical segregation and population.
Model 8 = The proportional odds assumption was violated for medium and high residential economical segregation.

healthy foods and a greater availability of unhealthy food stores as compared with more affluent areas[11,18,32,35,46–48]. However, this relationship may not necessarily be true in Brazil if we consider the methods and the scales of groups (race, ethnicity, skin colour or socio-economic status) used to assess residential segregation[36] and the distinct dietary and purchase patterns of Brazilians. In Brazil, more than half (53·4 %) of the consumed energies are obtained from fresh or minimally processed foods, 15·6 % from processed culinary ingredients, 11·3 % from processed foods and 19·7 % from ultra-processed foods. In addition, the frequency of food consumption outside the home is ~35 %[31,49,50].

The present study's findings concerning the percentage of census tracts containing food stores that predominantly market ultra-processed foods, which tends to be lower in the highly segregated areas, suggest that the wealthier and lower segregation areas in middle-income regions are more likely to have access to unhealthy food than other areas.

In contrast, the low percentage of census tracts containing mixed establishments, such as supermarkets and hypermarkets in highly segregated areas as compared with their counterparts, may be considered a spatial inequality, given that residents of highly segregated or disadvantaged areas may be disproportionately do not have the opportunity to benefit from lower prices, good quality and wide variety of the products offered by supermarkets or hypermarkets[3,6,11]. Brazilian studies reveal that supermarkets are responsible for a large share of the acquisition of culinary preparations or processed foods and are more characterised by lower prices and healthier items than are local grocery stores and convenience stores[3,6,49].

This may in fact reflect the patterns of expansion adopted by some food stores, urban planning or even discriminatory investment. This finding may also reflect cultural, economic and/or political disparities and even possible differences of natural resources between Brazil and other countries (especially the USA). Disadvantaged areas with precarious infrastructure and fewer consumers with purchasing power may also not be attractive to commercial establishments[3,6]. Thus, wealthier neighbourhoods that provide many/all services and most likely present access to specific types of food stores are directly related to the population's average income and the store's strategy to obtain a higher return[51]. Another reason for this finding may be that this area converges upon the largest and most important road corridors in the city with the highest concentration of most of the commercial activities[52]. On the other hand, poor and economically segregated areas can be intertwined with informal facilities that do not contain proper electricity or sanitation systems thus leading to a worse quality of food offered in the region[53].

The accelerated speed of changes in urbanisation, economic growth, technological changes for work, leisure and in the global Food System repercuss on different stages of nutritional transition observed in the world. In Brazil, as in other low- and middle-income countries, in contrast to the USA, ultra-processed foods are expensive in comparison with processed culinary ingredients and unprocessed or minimally processed foods[54,55]. Thus, even with the increase in access to ultra-processed foods and successive price reductions that have occurred since the early 2000s, prices of these types of foods are still restrictive for Brazilians with low socio-economic status. Although Brazilian supermarkets may have lower prices, a 1 % increase in the price of ultra-processed foods implies a 0·59 % reduction in their actual purchases[54].

Ultra-processed food purchases and consumption were shown to be greater among higher-income classes in Brazil[48,56,57], and food stores tend to be concentrated in areas in which a demand for them exists. It is concluded that the location of these stores in Brazil may be different from other countries, which may justify the different results and more likely explain the higher percentage of that type of store in low segregated neighbourhoods.

The lack of association between availability of unprocessed and minimally processed food stores and economic residential segregation found in our study also shows a new hypothesis when compared with past research conducted in countries with less economic inequalities and cultural differences than Brazil[32,34,35]. The observed trend of a lower prevalence of healthy establishments in low segregation areas, compared with integrated areas (no segregation neighbourhoods), reinforces the benefits of living in integrated areas and reveals the possible risks experienced in more economically affluent areas, including lower availability of healthy foods stores *v.* greater availability of unhealthy foods stores. However, the classification of establishments adopted in the current study may differ from others. In the present study, supermarkets and hypermarkets were not classified as health food stores, which is different from other studies that tend to classify them as health food stores[58–60]. Furthermore, we hypothesised that butcher shops and fish markets should be classified as stores that offer healthy food; however, in this study, they appeared to be less attractive establishments for the wealthier areas of the city, and therefore may not represent healthy food stores for those living in these areas. Probably that they appear as stores with specific segments: only meat or seafood. So, it can be not convenient for the customer, because it requires more time to purchase foods. Another important aspect can be related to sanitary issues. Butchers and fish markets sell perishable products. And individuals who live in more affluent areas may prefer to buy them in larger stores which they can judge as greater sanitary control than others.

Furthermore, the innovative classification of food based on the extent and the purpose of industrial processing is relatively new (2009); a Brazilian proposal to classify stores based on the results of a national survey of food acquisition in the country is recent (2018) and perhaps for this reason not yet fully covered by previous studies.

Although a better scenario was identified in Brazil for the highly segregated areas, these areas may still be

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unaffordable with minimal access to healthy foods. On the other hand, the proximity and density may not be sufficient to ensure healthy food choices or consumption[9,11,13]. At the same time, the scenario observed for the areas of low segregation is worrisome. Thus, programmes and actions should protect highly segregated areas from the advancement of stores predominantly selling ultra-processed foods and also maintain or even increase the availability of food stores with healthy food in all types of areas.

Limitations and strengths

First, methodological limitations of the current study mainly concern the selection of study areas, which are administrative areas that do not reflect the true character of a neighbourhood. Despite this shortcoming, an important number of studies use census tracts to define neighbourhood boundaries, and small areas have been consistent with how residents perceive and define their neighbourhood[61].

Second, absolute availability does not necessarily translate into access, and counting the number of establishments may not capture all aspects of physical availability. Many residents may choose to shop outside the census tract. Another limitation is the lack of information on store quality and price in addition to street connectivity. These factors require further investigation as the results may also reflect the organisation of trade based on the existence of major and more interconnected streets.

Other limitations include potential store misclassification and geocoded errors; however, the combination of two secondary sources and the verification through the Google Street View tool are likely to have caused a reduction in these errors. Furthermore, the possibility of not including some existing establishments as they are informal and not registered in any of the requested banks exists. We hypothesise that establishments that represent true negatives occur more often in more economically vulnerable locations, which may have led to differential losses and/or the underestimation of the number of stores in segregated areas[62,63]. In addition, non-inclusion of those food stores that did not have a fixed location may have underestimated the number of unhealthy establishments in the selected study areas and may have impacted the results as these deprived areas tend to have higher exposure to informal vendors. These problems could be remedied by conducting the onsite observations since the current study evaluated only one of the dimensions of the food environment, namely, the community food environment. However, it would be unfeasible to apply this method for the entire city of Belo Horizonte due to its large territorial extension, considering that onsite observations were recommended for small geographic areas[64].

With the impossibility of collecting data in loco even in a sub-sample, we highlight that in general, the quality of information from secondary databases for informal and smaller establishments shows a worse in performance compared with large chain stores[65–68]. A study that sought to validate an innovative tool for automatic data capture from Google Earth food environment for the cities of Rio de Janeiro and Belo Horizonte showed that the performance of this tool for smaller and independent food outlets is worse than other similar tools[69].

An important strength of the present study is inclusion of neighbourhood data from the totality of residential addresses found in a large Brazilian city.

Second, the current study showed the availability of stores according to the NOVA classification, an innovative food classification based on the extent and the purpose of industrial processing. The classification of these stores was also conducted by a large national study involving results from major national surveys[44]. Finally, even though several segregation-related indices are available, we applied a novel spatial approach, the Getis-Ord Local G_i^* statistic. To the best of our knowledge, no other study has ever examined the relationship between different scenarios of community-level food environments and economic residential segregation in Brazil.

Conclusion

Our study demonstrates a link between economic residential segregation and inequalities in the distribution of retail food stores in a Brazilian metropolis and reveal that low and high segregated territories should be targeted by public policies. The first policy must continue to protect residents from access to unhealthy foods while the second must represent the locus of nutritional interventions and actions, given that healthy and appropriate nutrition is the right of everyone. Both territories should also benefit from the expansion of essentially healthy establishments. In this context, the present study addresses a gap in the food environment literature in low- and middle-income countries.

Additional research is warranted to investigate informal establishments and to explore consumer nutritional environments in order to underline the differences in variety, price and quality of foods among economically segregated neighbourhoods. Complex system approaches can help promote understanding of the implications of complex systems for nutrition policies. Finally, efforts to improve the availability of healthy products in the city may encourage consumers to purchase and consume them, thus reducing dietary and access inequalities.

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Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980021002706

References

1. Monteiro CA, Cannon G, Lawrence M *et al.* (2019) *Ultra-Processed Foods, Diet Quality, and Health Using the NOVA Classification System*. Rome: FAO.
2. Swinburn BA, Kraak VI, Allender S *et al.* (2019) The global syndemic of obesity, undernutrition, and climate change: the Lancet Commission report. *Lancet* **393**, 791–846.
3. Leite MA, Assis MM, Carmo ASD *et al.* (2019) Is neighbourhood social deprivation in a Brazilian city associated with the availability, variety, quality and price of food in supermarkets? *Public Health Nutr* **29**, 1–10.
4. Borges CA, Cabral-Miranda W & Jaime PC (2018) Urban food sources and the challenges of food availability according to the Brazilian dietary guidelines recommendations. *Sustainability* **10**, 4643.
5. Lopes ACS, Menezes MC & Araújo ML (2017) Food environment and access to fruits and vegetables: "A metropolis into perspective". *Saúde Soc* **26**, 764–773.
6. Duran AC, Roux AVD, Maria do Rosario DO *et al.* (2013) Neighborhood socioeconomic characteristics and differences in the availability of healthy food stores and restaurants in Sao Paulo, Brazil. *Health Place* **23**, 39–47.
7. Massey DS & Denton N (1988) The dimensions of residential segregation. *Soc Forces* **67**, 281–315.
8. Lopes MS, Caiaffa WT, Andrade ACS *et al.* (2020) Disparities in food consumption between economically segregated urban neighbourhoods. *Public Health Nutr* **23**, 525–537.
9. Menezes MC, Diez Roux AV, Costa BVL *et al.* (2018) Individual and food environment factors: association with diet. *Public Health Nutr* **15**, 2782–2792.
10. Mendonça RD, Lopes MS, Freitas PP *et al.* (2019) Monotony in the consumption of fruits and vegetables and food environment characteristics. *Rev Saúde Pública* **53**, 63.
11. Gosliner W, Brown DM, Sun BC *et al.* (2018) Availability, quality and price of produce in low-income neighbourhood food stores in California raise equity issues. *Public Health Nutr* **21**, 1639–1648.
12. Rimkus L, Isgor Z, Ohri-Vachaspati P *et al.* (2015) Disparities in the availability and price of low-fat and higher-fat milk in US food stores by community characteristics. *J Acad Nutr Diet* **115**, 1975–1985.
13. Gustafson A, Hankins S & Jilcott S (2012) Measures of the consumer food store environment: a systematic review of the evidence 2000–2011. *J Community Health* **37**, 897–911.
14. Schuetz J, Kolko J & Meltzer R (2012) Are poor neighborhoods "retail deserts"? *Reg Sci Urban Econ* **42**, 269–285.
15. Richardson AS, Boone-Heinonen J, Popkin BM *et al.* (2011) Neighborhood fast food restaurants and fast food consumption: a national study. *BMC Public Health* **11**, 543.
16. Ohri-Vachaspati P, DeWeese RS, Acciai F *et al.* (2019) Healthy food access in low-income high-minority communities: a longitudinal assessment-2009 – 2017. *Int J Environ Res Public Health* **13**, 2354.
17. Hallum S, Hughey S, Wende ME *et al.* (2020) Healthy and unhealthy food environments are linked with neighbourhood socio-economic disadvantage: an innovative geospatial approach to understanding food access inequities. *Public Health Nutr* **17**, 3190–3196.
18. Sushil Z, Vandevijvere S, Exeter DJ *et al.* (2017) Food swamps by area socioeconomic deprivation in New Zealand: a national study. *Int J Public Health* **62**, 869–877.
19. Kawakami N, Winkleby M, Skog L *et al.* (2011) Differences in neighborhood accessibility to health-related resources: a nationwide comparison between deprived and affluent neighborhoods in Sweden. *Health Place* **17**, 132–139.
20. Jones J, Terashima M & Rainham D (2009) Fast food and deprivation in Nova Scotia. *Can J Public Health* **100**, 32–35.
21. Black JL, Carpiano RM, Fleming S *et al.* (2011) Exploring the distribution of food stores in British Columbia: associations with neighbourhood socio-demographic factors and urban form. *Health Place* **17**, 961–970.
22. Svastisalee CM, Nordahl H & Glümer C (2011) Supermarket and fast-food outlet exposure in Copenhagen: associations with socio-economic and demographic characteristics. *Public Health Nutr* **14**, 1618–1626.
23. Correa EN, Padez CMP, De Abreu AH *et al.* (2017) Geographic and socioeconomic distribution of food vendors: a case study of a municipality in the Southern Brazil. *Cad Saúde Pública* **33**, e00145015.
24. Cushon J, Creighton T, Kershaw T *et al.* (2013) Deprivation and food access and balance in Saskatoon, Saskatchewan. *Chronic Dis Inj Canada* **33**, 146–159.
25. Hill JL, Chau C, Luebbering CR *et al.* (2012) Does availability of physical activity and food outlets differ by race and income? Findings from an enumeration study in a health disparate region. *Int J Behav Nutr Phys Act* **9**, 105.
26. Costa BVL, Menezes MC, Oliveira CDL *et al.* (2019) Does access to healthy food vary according to socioeconomic status and to food store type? An ecologic study. *BMC Public Health* **19**, 775.

27. Leite FHM, Oliveira MA, Cremm EC *et al.* (2012) Availability of processed foods in the perimeter of public schools in urban areas. *J Pediatr* **88**, 328–334.
28. Assis MM, Leite MA, Carmo AS *et al.* (2019) Food environment, social deprivation and obesity among students from Brazilian public schools. *Public Health Nutr* **22**, 1920–1927.
29. Fortes MF, Borges CA, de Miranda WC *et al.* (2018) Mapping socioeconomic inequalities in the distribution of local food retail trade. *Segur Aliment Nutr* **25**, 45–58.
30. Organization for Economic Co-Operation and Development (2021) Income inequality (indicator). https://doi.org/10.1787/459aa7f1-en (accessed September 2019).
31. Brasil, Ministério da Saúde, Secretaria de Atenção à Saúde *et al.* (2015) *Brazilian Regional Food*, 2nd ed. Brasília: Ministério da Saúde.
32. Morland K & Filomena S (2007) Disparities in the availability of fruits and vegetables between racially segregated urban neighbourhoods. *Public Health Nutr* **10**, 1481–1489.
33. Winkler MR, Lenk KM, Caspi CE *et al.* (2019) Variation in the food environment of small and non-traditional stores across racial segregation and corporate status. *Public Health Nutr* **22**, 1624–1634.
34. Mendez DD, Kim KH, Hardaway CR *et al.* (2016) Neighborhood racial and socioeconomic disparities in the food and alcohol environment: are there differences by commercial data sources? *J Racial Ethnic Health Disparities* **3**, 108–116.
35. Bower KM, Thorpe RJ Jr, Rohde C *et al.* (2014) The intersection of neighborhood racial segregation, poverty, and urbanicity and its impact on food store availability in the United States. *Prev Med* **58**, 33–39.
36. Barber S, Roux AVD, Cardoso L *et al.* (2018) At the intersection of place, race, and health in Brazil: residential segregation and cardio-metabolic risk factors in the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil). *Soc Sci Med* **17**, S0277–S9536.
37. Instituto Brasileiro de Geografia e Estatística (IBGE) (2011) *Base de informações do Censo Demográfico 2010: Resultados do Universo por Setor Censitário*. Rio de Janeiro: Instituto Brasileiro de Geografia e Estatística.
38. PNUD, IPEA & FJP (2013) *Brazil's Human Development Atlas 2013*. http://www.atlasbrasil.org.br/2013 (accessed January 2021).
39. Instituto Brasileiro de Geografia e Estatística (2013) *National Classification Commission. National Classification of Economic Activities*. http://www.cnae.ibge.gov.br (accessed March 2019).
40. Getis A & Ord JK (1995) Local spatial autocorrelation statistics: distributional issues and an application. *Geogr Anal* **27**, 286–306.
41. Getis A & Ord JK (1992) The analysis of spatial association by use of distance statistics. *Geogr Anal* **24**, 189–206.
42. Instituto Brasileiro de Geografia e Estatística (2016) *Pesquisa Nacional Por Amostra De Domicílios: Síntese de Indicadores. Coordenação de Trabalho e Rendimento*. Rio de Janeiro: IBGE.
43. Kershaw KN & Albrecht SS (2015) Racial/ethnic residential segregation and cardiovascular disease risk. *Curr Cardiovasc Risk Rep* **9**, 10.
44. Brasil (2018) *Secretaria-Executiva da Câmara Interministerial de Segurança Alimentar e Nutricional Ministério do Desenvolvimento Social/MDS. Estudo Técnico Mapeamento dos Desertos Alimentares no Brasil*. https://aplicacoes.mds.gov.br/sagirmps/noticias/arquivos/files/Estudo_T%C3%A9cnico_Mapeamento_Desertos_Alimentares_Final_30_10_2019(1).pdf (accessed March 2019).
45. Williams R (2006) Generalized ordered logit/partial proportional odds models for ordinal dependent variables. *Stata J* **6**, 58–82.
46. Williams DR & Collins C (2001) Racial residential segregation: a fundamental cause of racial disparities in health. *Public Health Rep* **116**, 404–416.
47. Meltzer R & Schuetz J (2012) Bodegas or bagel shops? Neighborhood differences in retail and household services. *Econ Dev Q* **26**, 73–94.
48. Simões BDS, Barreto SM, Molina MDCB *et al.* (2018) Consumption of ultra-processed foods and socioeconomic position: a cross-sectional analysis of the Brazilian Longitudinal Study of Adult Health. *Cad Saude Publica* **34**, e00019717.
49. Machado PP, Claro RM, Canella DS *et al.* (2017) Price and convenience: the influence of supermarkets on consumption of ultra-processed foods and beverages in Brazil. *Appetite* **1**, 381–388.
50. Brasil (2020) *Pesquisa de Orçamentos Familiares 2017–2018: Análise do Consume Alimentar Pessoal No Brasil/IBGE, Coordenação de Trabalho e Rendimento*. Rio de Janeiro: IBGE.
51. Reardon T & Timmer CP (2012) The economics of the food system revolution. *Annu Rev Resour Econ* **4**, 225–264.
52. Belo Horizonte (2008) *Urban Studies: Belo Horizonte 2008: Recent Transformations in Urban Structure*. Belo Horizonte: City Hall of Belo Horizonte.
53. Organization for Economic Co-operation and Development (2018) Divided Cities: Understanding Intra-urban Inequalities. https://doi.org/10.1787/9789264300385-en (accessed July 2018).
54. Maia EG Passos CM, Levy RB *et al.* (2020) What to expect from the price of healthy and unhealthy foods over time? The case from Brazil. *Public Health Nutr* **1**, 1–10.
55. Claro RM, Maia EG, Costa BVL *et al.* (2016) Food prices in Brazil: prefer cooking to ultra-processed foods. *Cad Saúde Pública* **32**, 8.
56. Brazil (2019) *Family Budget Survey 2017–2018: First Results/IBGE, Coordination of Work and Income*. Rio de Janeiro: IBGE.
57. Martins APB, Levy RB, Claro RM *et al.* (2013) Increased contribution of ultra-processed food products in the Brazilian diet (1987–2009). *Rev Saúde Públic* **47**, 656–665.
58. Diez Roux AV & Mair C (2010) Neighborhoods and health. *Ann NY Acad Sci* **1186**, 125–145.
59. Brown HS & Yarnell LM (2013) The price of access: capitalization of neighborhood contextual factors. *Int J Behav Nutr Phys Act* **10**, 95.
60. Andreyeva T, Blumenthal DM, Schwartz MB *et al.* (2008) Availability and prices of foods across stores and neighborhoods: the case of New Haven, Connecticut. *Health Aff* **27**, 1381–1388.
61. Almeida FC, Friche AAL, Jennings MZ *et al.* (2018) Contextual characteristics associated with the perceived neighbourhood scale in a cross-sectional study in a large urban centre in Brazil. *BMJ Open* **8**, 1–9.
62. Clary CM & Kestens Y (2013) Field validation of secondary data sources: a novel measure of representativity applied to a Canadian food outlet database. *Int J Behav Nutr Phys Act* **10**, 77.
63. Fleischhacker SE, Rodriguez DA, Evenson KR *et al.* (2012) Evidence for validity of five secondary data sources for enumerating retail food outlets in seven American Indian Communities in North Carolina. *Int J Behav Nutr Phys Act* **9**, 137.
64. Lucan SC (2015) Concerning limitations of food-environment research: a narrative review and commentary framed around obesity and diet-related diseases in youth. *J Acad Nutr Diet* **115**, 205–212.
65. Wilkins EL, Radley D & Morris MA (2017) Examining the validity and utility of two secondary sources of food environment data against street audits in England. *Nutr J* **16**, 1.

https://doi.org/10.1017/S1368980021002706 Published online by Cambridge University Press

66. Rummo PE, Albrecht SS & Gordon-Larsen P (2015) Field validation of food outlet databases: the Latino food environment in North Carolina, USA. *Public Health Nutr* **18**, 977–982.
67. Burgoine T & Harrison F (2013) Comparing the accuracy of two secondary food environment data sources in the UK across socio-economic and urban/rural divides. *Int J Health Geogr* **12**, 2.
68. Liese AD, Barnes TL, Lamichhane AP *et al.* (2013) Characterizing the food retail environment: impact of count, type, and geospatial error in 2 secondary data sources. *J Nutr Educ Behav* **45**, 435–442.
69. Menezes MC, de Matos VP, de Pina M *et al.* (2020) A web data mining: validity of data from Google earth for food retail evaluation. *J Urban Health Bull NY Acad Med* **1**, 1.

https://doi.org/10.1017/S1368980021002706 Published online by Cambridge University Press