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Is food environment associated with body mass index, overweight and obesity? A study with adults and elderly subjects from southern Brazil

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ABSTRACT

The purpose of this article was to investigate the association of food environment variables with Body Mass Index (BMI), excess weight and obesity. This was a cross-sectional study determining the presence or absence of food establishments within a 100-m buffer zone from each sampled household. Individuals aged 18 years and older living in the urban area of Rio Grande, RS State, Brazil, in 2016, were considered eligible. A total of 1,139 individuals, with an average age of 46.5 years (SD 17.1), residing in the household for more than one year, were selected as a representative sample of the population. The mean BMI of study participants was 27.0 kg/m^2 (SD 4.8), and the prevalence of excess weight and obesity was 61.6% (95%CI: 58.9; 64.3) and 23.7% (95%CI: 21.3; 26.1), respectively. Living near a convenience store was associated with a higher BMI and a higher likelihood of being above normal weight and obese. In contrast, living near a restaurant was associated with a lower BMI and a lower likelihood of being above normal weight and obese. In addition, participants who lived close to fruit shops had lower BMI and a lower likelihood of being above normal weight. Concluding few associations were found between food environment and the health-related outcomes. Proximity to food establishments does not seem to significantly affect BMI, excess weight and obesity in the studied population.

1. Introduction

Excess weight may have serious health consequences ranging from premature death to the onset of noncommunicable diseases (World Health Organization, 2018). In 2015, excess weight accounted for approximately four million deaths, which corresponded to 7.1% of all death causes worldwide (GBD, 2015). In 2016, over 1.9 billion (39%) adults aged 18 years or older were above normal weight, of which 600 million (13%) were obese (World Health Organization, 2018). In 2018, the prevalence rates of excess weight and obesity in Brazil were as high as 55.7% and 19.8%, respectively (Ministério Da Saúde, 2019).

Obesity is a preventable disease (World Health Organization, 2018) resulting from an interaction between genetic, lifestyle and environmental factors (ABESO, 2016). Considered a pandemic, this condition has been related to the built environment (Bouchard, 2007), as individual biological and risk factors alone do not seem to fully explain the steady increase in the disease prevalence (Huang and Glass, 2008). A proper environment in terms of food accessibility and availability is known to positively influence one's choice for healthy foods, thereby avoiding overweight and obesity (World Health Organization, 2018). Therefore, while obesity is determined by a genetic background, a conducive environment – composed of perceived and objective components – is needed for phenotypic expression to occur (Egger et al., 1997). Yet, understanding how these factors drive one's healthy or obese status remains a very complex task (Lake and Townshend, 2006).

A recent review pointed out the impact of food environment on the onset of obesity and reinforced the need for further research in the field (Zhang and Yin, 2019). Food environment refers to the availability and accessibility of food products (Lake and Townshend, 2006; Elgaard Jensen et al., 2019) and to places where food can be purchased (*e.g.*, convenience stores, grocery stores, specialty food stores, restaurants, fruit shops and supermarkets) (Sallis and Glanz, 2009). Evidence suggests that individuals who live near establishments that sell healthy food, such as supermarkets, have a lower risk of being overweight and obese, unlike those who live near stores selling unhealthy food products, such as fast food outlets (Papas et al., 2007; Cobb et al., 2015).

The relationship between food environment and obesity has been more frequently studied in developed countries (*e.g.*, United States) (Yan et al., 2015; Morland and Evenson, 2009; Rundle et al., 2009; Bodor et al., 2010) as compared to developing countries (*e.g.*, Brazil), where

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research is more recent and incipient. A study carried out in a state capital city in Brazil showed the likelihood of being obese decreases as there is more availability of healthy food stores and restaurants (Matozinhos et al., 2015). In contrast, another study conducted in the same city did not find any significant association between the presence of healthy food stores (supermarkets, fruit/vegetable shops) nearby and excess weight (Velásquez-Meléndez et al., 2013). Therefore, the relationship between food environment and obesity remains largely unknown, particularly in Brazil, a country undergoing rapid socioeconomic and nutritional transitions (Jaime et al., 2011). Thus, this study investigated the association of food environment variables with Body Mass Index (BMI), excess weight and obesity among individuals aged 18 years or older residing in the urban area of a municipality in southern Brazil.

2. Methods

This was a cross-sectional population-based study with individuals aged 18 years or older, living in the municipality of Rio Grande, southern Brazil. This study is part of a major project entitled "*Riograndina Population Health Survey*", whose secondary objective is to georeference some health aspects of the population. The work described herein was carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) and was previously approved by the Research Ethics Committee at the Health Center of the Federal University of Rio Grande (FURG), under protocol no. 20/2016. Rio Grande has a population of approximately 200,000 inhabitants (2010 census), with 96% of them living in the urban area (Instituto Brasileiro de Geografia e Estatística, 2010).

The sample of the *Riograndina Population Health Survey* was composed of individuals aged 18 years or older, living in the urban area, whom were not admitted to nursing homes, hospitals or prisons, and whom had physical and mental capacity to answer the study questionnaire. The sample size was calculated considering a 95% confidence level, 80% statistical power, 10% prevalence of outcome, 20 to 60% frequency of exposure and a prevalence ratio (PR) of 2.0, totaling 784 individuals. An additional 50% was included for the sample design effect and 15% for confounding factors, totaling 1,294 individuals. Another 10% was also included for sample dropouts, totaling a final sample size of 1,423 individuals. The sampling process was carried out in multiple stages and was based on the 2010 Demographic Census (Instituto Brasileiro de Geografia e Estatística, 2010), in which census tracts were selected first, followed by selection of households.

The first phase of this study corresponded to face-to-face interviews in the households selected between April and July 2016 through the sampling process. Standardized questionnaires, which had been previously tested by trained interviewers, were administered at the participants' households. Geographic coordinates of the households were obtained through GPS (Global Positioning System) technology after face-to-face interview. Further details of the sampling procedure as well as the fieldwork logistics were described elsewhere (Dumith et al., 2018).

The second part of this study consisted of georeferencing the households, collecting environmental variables from Rio Grande Treasury Department, and geocoding the data using ArcGIS 10.4 (ArcMap) software (Environmental Systems Research Institute, Redlands, United States; http://www.esri.com/software/arcgis/index.html). The data were processed at the Federal Institute of Education, Science and Technology of the South - Rio Grande Campus, from February 2018 to January 2019. Another study investigated the influence of the environment on physical activity practice in this population (Borchardt et al., 2019).

Three outcomes of interest were considered, namely: BMI, excess weight and obesity. BMI was calculated using the individual's weight in kilograms divided by the square of their height in meters (kg/m^2) (World Health Organization, 2018). Excess weight and obesity were dichotomized according to the World Health Organization (WHO) criteria. Individuals were considered to be above normal weight or obese when their BMI values were $\geq$25 kg/m^2 and $\geq$30 kg/m^2, respectively, regardless of sex (World Health Organization, 2018). Weight and height data were self-reported.

Food environment variables (Table 1) were obtained from a list with food service establishment permits provided by the Municipality of Rio Grande. Google Street View (https://www.google.com.br/intl/pt/streetview/) and Google search engine (https://www.google.com.br, "search" field) were used to update information based on the establishments' addresses. In doing so, we found out that the data obtained from the Municipality of Rio Grande overestimated the number of food establishments as when compared to the Google platform.

Circular buffers sized 50, 100, 250, 500, 800, 1600, and 3200 m were created for each household. The number of establishments present in each buffer was computed based on the buffer size, and the data were tabulated into Microsoft Office Excel spreadsheets. All buffers were analyzed, but no statistically significant associations were found for the 250, 500, 800, 1600 and 3200-meter buffers, whereas similar associations were observed for 50 and 100-meter buffers. Of note, as the buffer size was enlarged, the association measures became less significant. Thus, this article reports only the 100-meter buffer as a dichotomous variable, that is, the presence or absence of each type of food establishment.

The intervening variables used for sample adjustment and description were as follows: sex (male/female), age (in complete years), skin color (white/mixed/black/other), marital status (single/married/divorced or widowed), education (in years), asset index (z-score), demographic density (number of inhabitants/sector area in km^2 for each census tract) and dwelling time in the neighborhood (in years). The asset index considered 11 items, including household characteristics (*e.g.*, number of bathrooms in the house) and household goods (e.g., landline). An analysis of the main components was performed by extracting the first component, which explained 31% of the variability of all items (Filmer and Pritchett, 2001).

The data were exported to Stata 13.0 software for statistical analysis. Individuals residing for one year or less in the selected households were excluded from the analysis because it was a short exposure time. First, the means and prevalence rates of the outcomes for each food establishment were analyzed descriptively. Then, unadjusted and adjusted analyses were carried out using linear regression (BMI, data expressed as

Table 1
Description of different types of located in the municipality of Rio Grande, RS, Brazil, 2018.

Variable	Description
Street fair	Product sale and exhibition, especially food, momentarily held in a public place. Food products include "*in natura*"/fresh produce (vegetables, grains, fruits, tubers, cereals, herbs, meat, fish and eggs), processed items (cold cuts, jams, breads, spices, cheese, among others). Non-food products can be natural (flowers, seeds, vegetable soil etc.) and manufactured (products made with fabric, leather, metals, ceramics, wood, among others).
Fruit shop	Retail store of fresh produce (fruits and vegetables).
Snack bar	Snack bar, fast food, pastry shop, tea/juice/similar shop, ice cream shop. food establishments
Convenience store	Sale of processed food and non-food products. Usually associated with another activity, with 24-hour opening hours.
Grocery store	Mini-market and warehouses predominantly selling food products, with an area of<300 square meters.
Bakery	Bakery and pastry shop commonly selling locally produced bread, donuts, cakes, pies and other baked items. Overall, sells bakery, dairy, pastry, candy and similar products.
Restaurant	Self-service or pay-by-weight service that sells prepared food, with or without alcohol, to the general public.
Supermarket	Retailer of general sales products for cleaning, personal hygiene, clothing, hardware etc, with predominance of diverse food items. Area between 300 and 5000 square meters.

β Coefficient, with 95% Confidence Interval – 95% CI) or Poisson Regression (excess weight and obesity; data were expressed as prevalence ratio – PR, with 95% CI) (Barros and Hirakata, 2003). As the sampling was obtained by clustering, having as primary sample unit the census tract, and as the analysis unit each individual, we considered in all statistical analyses the sample design to obtain more accurate standard errors.

Two adjusted models were proposed, as follows: a) one model was adjusted for the intervening variables (sex, age, skin color, marital status, asset index, demographic density and dwelling time in the neighborhood); and b) another model was adjusted for the intervening variables plus food establishments. The results of both adjusted analyses were very similar to those of the unadjusted data; hence, they were not disclosed herein. Results with two-tailed *P*-values < 0.05 were considered statistically significant.

3. Results

Among the eligible participants (n = 1,429), 91% (n = 1,300) responded to the questionnaire. Non-respondents ($n = 129$) were mostly due to refusal to participate in the study (77%), followed by sample dropouts (23%). Unresponsiveness was more frequent among males and downtown residents, regardless of age. Those who lived one year or less in the selected household were excluded from the present study (n = 108), resulting in a final sample of 1,139 individuals.

Most of the sample consisted of females (56%), white (84%) and single (45%) individuals, aged from 18 to 96 years, with an average age of 46.5 years (SD 17.1). The sample had a median *per* capita income of USD 250 (IQ 150 to 440); 11 years of schooling (IIQ 6 to 13); 16 years living in the neighborhood (IQ 7 to 30); three residents in the household (IQ 2 to 4); and a population density of 6,037 inhabitants/km^2 (IQ 1,510 to 9,723).

The analysis of food environment variables indicated the presence of 6.1% ($n = 69$) grocery stores, 5.7% ($n = 65$) restaurants, 5.1% ($n = 58$) bakeries, 4.7% ($n = 61$) street fairs, 4.4% ($n = 50$) snack bars, 3.8% (n = 43) supermarkets, 0.7% (n = 8) convenience stores and 0.2% (n = 2) fruit shops within the 100-meter buffer around each household.

Table 2 shows the sample characteristics, mean BMI, and prevalence rates of excess weight and obesity in the presence or absence of each food environment variable within the 100-meter buffer. The mean BMI in the total sample was 27.0 kg/m^2 (SD 4.8), with a minimum of 25.1 kg/m^2 (presence of a fruit shop near household) and a maximum of 28.9 kg/m^2 (presence of a convenience store near household). The overall prevalence of excess weight was 61.6% (95% CI 58.9; 64.3), ranging from 46.2% (restaurant near household) to 87.5% (convenience store near household). In the total sample, the prevalence of obesity was 23.7% (95% CI 21.3; 26.1), ranging from 12.3% (restaurant near household) to 50% (convenience store and fruit shop near household).

Unadjusted and adjusted analyses of the associations between BMI and food environment variables are presented in Table 3. The unadjusted analysis indicated that the presence of a convenience store within the 100-meter buffer was associated with an increase of 1.99 kg/m^2 in BMI mean values (95% CI 0.48; 3.49). On the other hand, the presence of a fruit shop or restaurant near the household reduced BMI values by 1.88 kg/m^2 (95% CI −2.19; −1.56) and 1.77 kg/m^2 (95% CI −2.87; −0.68), respectively. The adjusted analysis showed these same associations and further revealed an association with the street fair variable, which increased the mean BMI by 1.24 kg/m^2 (95% CI 0.02; 2.46).

Unadjusted and adjusted analyses of the associations of excess weight and obesity with food environment variables is shown in Table 4. The unadjusted analysis showed that the presence of a convenience store within the 100-m buffer was associated with an increased likelihood of being above normal weight (43%, 95% CI 14%; 79%) and obese (115%, 95% CI 48%; 213%). The presence of a restaurant near the household decreased the residents' probability of being above normal weight by 26.0% (95% CI 7%; 41%) and obese by 49.0% (95% CI 5%; 73%). While the presence of a fruit shop decreased the probability of being above normal weight by 19.0% (95% CI 14%; 23%). Of note, there were only two individuals living close to a fruit shop in the study sample (one obese individual with a BMI of 30.1 kg/m2 and one non-obese individual with a BMI of 20.1 kg/m2), resulting in a prevalence of obesity of 50.0% (versus 23.4% for those individuals with no fruit shops near their households). All the associations remained significant in the adjusted analysis.

Table 2
Descriptive analysis of mean BMI and prevalence of excess weight and obesity by type of food establishment among adults aged 18 years or older, residing in the urban area of Rio Grande, Brazil, 2017 (n = 1,139).

Food establishment	n	BMI		Excess Weight		Obesity	
		Mean	(SD)	%	95% CI	%	95% CI
Street fair							
No	1085	26.9	4.8	61.2	58.3; 64.1	23.0	20.5; 25.6
Yes	54	28.0	5.3	66.7	53.7; 79.7	31.5	18.7; 44.3
Fruit shop							
No	1137	27.0	4.9	61.5	58.6; 64.3	23.4	20.9; 25.9
Yes	2	25.1	7.1	50.0*	–	50.0*	–
Snack bar							
No	1089	27.0	4.9	61.4	58.5; 64.3	23.3	20.8; 25.8
Yes	50	26.9	2.7	62.0	48.0; 75.9	26.0	13.4; 38.6
Convenience store							
No	1131	26.9	4.9	61.3	58.4; 64.1	23.3	20.8; 25.7
Yes	8	28.9	4.0	87.5	57.9; 117.1	50.0	5.3; 94.7
Grocery store							
No	1070	26.9	4.8	61.5	58.6; 64.4	23.4	20.8; 25.9
Yes	69	27.3	6.1	60.9	49.1; 72.7	24.6	14.2; 35.1
Bakery							
No	1081	27.0	4.9	61.6	58.7; 64.5	23.5	21.0; 26.0
Yes	58	26.5	3.9	58.6	45.6; 71.7	22.4	11.3; 33.5
Restaurant							
No	1074	27.1	4.9	62.4	59.5; 65.3	24.1	21.6; 26.7
Yes	65	25.3	4.3	46.2	33.7; 58.6	12.3	4.10; 20.5
Supermarket							
No	1096	26.9	4.9	61.2	58.3; 64.1	23.2	20.7; 25.7
Yes	43	27.8	5.3	67.4	52.9; 82.0	30.2	15.9; 44.5
Total	**1139**	**27.0**	**4.8**	**61.6**	**58.9; 64.3**	**23.7**	**21.3; 26.0**

Note: SD, standard deviation; 95% CI, 95% confidence interval; (*) no calculation could be made because the sample size consisted of one individual.

4. Discussion

This study investigated the contribution of food environment to mean BMI, excess weight and obesity status. Although most of food establishments were not associated with the outcomes analyzed, a few

Table 3
Unadjusted and adjusted analysis of the association between **BMI** and food environment variables among adults aged 18 years or older, residing in the urban area of Rio Grande, Brazil, 2017 (n = 1,139).

Food establishments within a 100-m buffer size	Unadjusted analysis		Adjusted analysis*	
	β coefficient	95% CI	β coefficient	95% CI
Street fair	1.15	−0.13; 2.42	**1.24**	**0.02; 2.46**
Fruit shop	**−1.88**	**−2.19; −1.56**	**−1.46**	**−2.01; −0.91**
Snack bar	−0.01	−1.41; 1.40	0.05	−1.37; 1.47
Convenience store	**1.99**	**0.48; 3.49**	**1.65**	**0.23; 3.08**
Grocery store	0.35	−1.24; 1.95	0.30	−1.32; 1.91
Bakery	−0.51	−1.65; 0.62	−0.43	−1.62; 0.76
Restaurant	**−1.77**	**−2.87; −0.68**	**−1.83**	**−2.99; −0.68**
Supermarket	0.83	−0.38; 2.05	1.10	−0.48; 2.67

Note: 95% CI, 95% confidence interval; * the model was adjusted for the variables: sex, age, skin color, marital status, schooling, asset index, dwelling time in the neighborhood, number of residents in the household, and demographic density. Values in **bold** indicate statistically significant associations ($P < 0.05$).

Table 4
Unadjusted and adjusted analysis of the association between **excess weight** and **obesity** and food environment variables among adults aged 18 years or older, residing in the urban area of Rio Grande, Brazil, 2017 (n = 1,139).

Food establishments within a 100-m buffer size	Unadjusted analysis		Adjusted analysis*	
	PR	95% CI	PR	95% CI
	Excess Weight			
Street fair	1.09	0.94; 1.26	1.14	0.97; 1.33
Fruit shop	**0.81**	**0.77; 0.86**	**0.90**	**0.81; 0.99**
Snack bar	1.01	0.80; 1.27	1.03	0.81; 1.31
Convenience store	**1.43**	**1.14; 1.79**	**1.45**	**1.16; 1.82**
Grocery store	0.99	0.78; 1.25	0.99	0.79; 1.23
Bakery	0.95	0.74; 1.23	0.97	0.76; 1.25
Restaurant	**0.74**	**0.59; 0.93**	**0.74**	**0.58; 0.95**
Supermarket	1.10	0.94; 1.29	1.13	0.97; 1.31
	Obesity			
Street fair	1.37	0.90; 2.07	1.34	0.91; 1.99
Fruit shop	**	**	**	**
Snack bar	1.11	0.70; 1,78	1.15	0.71; 1.85
Convenience store	**2.15**	**1.48; 3.13**	**1.85**	**1.12; 3.05**
Grocery store	1.05	0.66; 1.69	0.99	0.62; 1.59
Bakery	0.95	0.57; 1.60	0.97	0.55; 1.69
Restaurant	**0.51**	**0.27; 0.95**	**0.51**	**0.27; 0.95**
Supermarket	1.30	0.76; 2.24	1.37	0.78; 2.42

Note: PR, prevalence ratio; 95% CI, 95% confidence interval; * the model was adjusted for the variables: sex, age, skin color, marital status, schooling, asset index, dwelling time in the neighborhood, number of residents in the household, and demographic density. Values in **bold** indicate statistically significant associations ($P < 0.05$). ** It was omitted due to few number of individuals (two).

associations were observed within a 100-m maximum radius of the households. Individuals living in areas near convenience stores presented higher BMI values and a higher prevalence of excess weight and obesity. However, those who lived near restaurants presented lower BMI values and a lower prevalence of excess weight and obesity. Moreover, living near fruit shops was associated with lower BMI values and a lower prevalence of excess weight. Lastly, our findings indicate that the presence of street fairs was associated with increased BMI values.

The presence of some types of food establishments can dramatically influence the resident's food choices and thereby impact their diet-related health outcomes (Morland and Evenson, 2009). Proximity to establishments that provide unhealthy food has been considered an important risk factor for excess weight status in urban areas (Michimi and Wimberly, 2015). Consistent with this, our study showed that individuals living near convenience stores had a higher probability of being above normal weight and obese, with greater BMI values, which is also in line with studies carried out with adult Canadians (Spence et al., 2009) and Americans (Yan et al., 2015; Morland and Evenson, 2009; Rundle et al., 2009; Bodor et al., 2010). Convenience stores provide easy access to high-energy manufactured products (Rundle et al., 2009). As shown in a study carried out in Los Angeles, USA, easy access to these products negatively influences the individual's weight, particularly among those who can easily reach such stores from a walkable distance (400-meter radius) (Mejia et al., 2015).

In our study, individuals who lived near restaurants and fruit shops had a lower mean BMI and a lower probability of being above normal weight. The presence of restaurants was also associated with a lower risk of being obese. This study further showed that residents who lived near street fairs had higher BMI values. These findings are in line with the literature (Yan et al., 2015; Morland and Evenson, 2009). Restaurants and fruit shops are considered establishments that provide access to healthy food, particularly the latter, which commonly sell fruit and vegetables/fresh produce. While restaurants can also offer unhealthy foods, they frequently give several food choices to the clients, making them an acceptable place to properly eat at. The literature points out that access to healthy food establishments is associated with a lower mean BMI and a lower probability of being above normal weight and/or obese (Rundle et al., 2009; Matozinhos et al., 2015). In Brazil, a study found that the obesity rates among adults decreased as the number of restaurants and healthy food outlets in the neighborhood increased (Matozinhos et al., 2015). In our study, the presence of street fairs was unexpectedly associated with a higher BMI. One possible hypothesis is that these establishments offer not only fresh foods, but also manufactured products (canned food, candy, jams, among others), which may be considered unhealthy options.

Intriguingly, no associations between the presence of snack bars, grocery stores, bakeries and supermarkets, and the health-related outcomes, were observed herein. Such associations were expected, especially with the snack bar variable, which includes fast food stores. Studies conducted in other locations have reported strong associations between fast food establishments and BMI, excess weight and obesity (Morland and Evenson, 2009; Bodor et al., 2010; Mejia et al., 2015; Hattori et al., 2013; Kim et al., 2008; Pruchno et al., 2014; Xu et al., 2015; Xu and Wang, 2015; Prince et al., 2011). It is worth noting that when checking for associations, these studies considered greater distances from the household or the presence of food establishments within the neighborhood or census tract. The individuals' access to these establishments was most probably done by motorized transport (Mejia et al., 2015; Hattori et al., 2013); *i.e.*, individuals travel greater distances to purchase such foods, either by car, motorcycle or bus, or even buy them via telephone/internet and have them home delivered.

A study with adults carried out in California, USA (Hattori et al., 2013), examined the association between the number and type of food establishments within varying distances and health-related outcomes, which included BMI, excess weight and obesity. The authors concluded that the presence of food stores within ≤1,600 m from the household

was not strongly associated with the resident's BMI. Significant associations were only found when food stores were located within distances greater than 1,600 m (Hattori et al., 2013). Even though buffers of up to 3,200 m were considered in our study, no significant associations were observed. Another important aspect to consider is that Rio Grande has few fast food stores, most of which are concentrated in four areas, unlike other urban centers where this type of food store is more numerous and evenly distributed.

This study has important limitations to consider, namely: (i) the cross-sectional design does not determine whether associations are causal, which may incur in reverse causality bias; (ii) it remains unclear whether the environment makes individuals healthier or whether those who are healthier choose to live in environments with healthy options; (iii) the weight and height data used to assess the outcomes of interest were self-reported, it is already know (by other studies) that the self-reported BMI underestimate the BMI measured objectively. So, if we obtained higher BMI average and higher obesity prevalence, it would be expected to find more significant results with the food establishments. While there is a tendency of underestimating weight and overestimating height measurements, this form of data collection has been commonly used in epidemiological studies (Gorber et al., 2007) and was previously validated for Brazilian adults (Fonseca et al., 2004); (iv) another relevant aspect to consider is that only the household environment was examined in our study, that is, other environments were not surveyed, and it was not questioned either where else the individuals had access to food products. Several people commonly reach food stores located near their work or study place; (v) although official data were used in this study, information on the food establishments was not audited and could be incomplete or outdated. To prevent potential bias, the data were verified through information available on the internet and on online maps with panoramic views. Only food stores close to the individuals' households (100 m) were found to be associated with the outcomes of interest, but they were present in a low frequency (for example: there were only two fruit shops and eight convenience stores inside that buffer in our sample); (vi) the number of food stores could have been underestimated, since information about them was based on the municipality's permits and, therefore, no informal food outlets were accounted for; (vii) lastly, individual measurements were collected in 2016, whereas information on food environment was collected in 2017. This difference should be considered, even though environmental characteristics typically take long to change (Rundle et al., 2009).

The strengths of this study include the use of a representative sample of a municipality in the interior of Brazil. The few studies conducted in the country (Matozinhos et al., 2015; Velásquez-Meléndez et al., 2013) have addressed only the population residing in state capitals. In addition, various types of food establishments were analyzed herein, unlike most studies in the field which consider few food environment variables. Three outcomes were evaluated simultaneously – BMI (continuous variable), excess weight and obesity, thus allowing to check for different associations. Importantly, objective measures of the environment were also examined.

In this study, we found few significant associations between food environment and BMI, excess weight and obesity in adults. Only the presence of convenience stores and restaurants significantly influenced the three outcomes of interest, with the former being a risk factor and the latter, a protective factor. The lack of more associations can be explained by the residents' purchasing patterns, who seem to purchase food products outside their neighborhoods. The greater availability of motorized means of transportation (Michimi and Wimberly, 2015) – which was not object of this study – has gradually decreased the need for food stores nearby. Future cross-sectional and longitudinal research should determine the influence of the work and/or study environment on the health-related outcomes described herein. Thus far, it remains unclear whether changes in the food environment can mitigate the high prevalence rates of excess weight and obesity.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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