This is a repository copy of *Proximity and High Density of Convenience Stores Was Associated With Obesity in Children of a Rural Community of Mexico: Using a Geographic Information System Approach*.

1 **Proximity and high density of convenience stores was associated with**

2 **obesity in children of a rural community of Mexico; using a**

3 **Geographic Information System (GIS) approach**

4 Zavala, Gerardo Antonio[1,2,3†]; Tenorio-Palos, Yessica[1†]; Campos-Ponce, Maiza[2]; Elton-

5 Puente Juana Elizabeth[2]; López-González Carlos Alberto[2], Doak Colleen M[4]; Rosado

6 Jorge L[1]; García Olga P[1*]

7 [1]Facultad de Ciencias Naturales, Universidad Autónoma de Querétaro, Querétaro,

8 Mexico

9 [2]Faculty of Earth and Life Sciences, VU Amsterdam University, Amsterdam, Netherlands

10 [3]Faculty of Health Sciences, University of York, York, United Kingdom

11 [4]Public Health, St Ambrose University, Iowa, U.S.A.

12

13 [†]These authors contributed equally in the manuscript

14

15 ***Corresponding Author:** Olga P. García

16 Mailing Address: School of Natural Sciences, Universidad Autónoma de Querétaro, Av

17 Ciencias SN Juriquilla, Querétaro, México 76230

18 Telephone: +52-442-192-1200 ext 5323; 5351

19 Email: olga.garcia@uaq.mx

Abstract

Background: Food environment (FE) has been linked to obesity in urban areas, but there is limited information in rural areas, particularly in developing countries, where prevalence of obesity is high. **Objective:** To determine the association between FE and childhood obesity using Geographic Information Systems (GIS). **Methods:** A total of 218 children (8 10 y) participated in a cross-sectional study. Weight, height and body fat were measured. Geolocation of convenience stores (CS) and participants' households was collected and the amount of processed food (PF) in the stores was measured. The proximity to the nearest CS and the number of CS within a 250m buffer from each participant's household was calculated using GIS. Linear regression models between obesity measurements and food environment were performed. **Results:** The combined prevalence of overweight and obesity was 32%. A total of 91% of the children had access to a CS within 250 m. On average, 48% of the shelf space of the CS were occupied with PF. A positive association between the density of CS with body fat % (β=0.145; 95CI: 0.048, 0.241, p=0.004), abdominal fat % (β=0.206; 95%CI: 0.048, 0.241, p=0.003) and BMI-for-age z-score (β=0.028; 95%CI: 0.005, 0.062, p=0.005) was found. Living closer to CS was associated with increases in body fat% (β=-0.009; 95CI: -0.017, -0.001, p=0.025), abdominal fat % (β=-0.012; 95%CI: -0.023, -0.001, p=0.033) and BMI-for-age z-score (β= -0.002, 95%CI: -0.004, -0.001, p=0.003). **Conclusion:** In a rural community in Mexico, a high density and low proximity to CS is associated with obesity in school-aged children.

Key Words: Childhood obesity, food environment, GIS, rural areas

Introduction

Almost thirty percent of Mexican children are either obese or overweight. According to nutrition and health surveys, prevalence of childhood obesity has stabilized in urban areas while it still rising in rural areas of Mexico [1,2]. Overweight and obese children have an increased risk of oxidative stress, inflammation and insulin resistance and they are more likely to remain obese throughout their life [3]. Obesity is the result of the balance between energy intake and expenditure and a complex interaction with socioeconomic, physiological and genetic factors[4]. In addition, new insight has proved that food environment, which has been defined as the entire environment that influence food selection and food intake[5], plays a key role in the etiology of obesity[6,7]. The food environment includes food stores and food service establishments, such as convenience stores (CS), supermarkets, local markets, restaurants, fast food stands, among others [8,9]. In the developing world, it is also possible to find small CS or neighborhood CS, and these stores represent an important economic model for the retailing business[10]. In Mexico and some parts of Central America, these small CS are called "tienditas" or "misceláneas", are usually family-owned, and are mainly run by the women in the households[11]. By definition, "tienditas" are convenience stores that provide rapid access to essential products such as food staples (tortillas, rice, beans, eggs, bread, sugar, vegetables, canned foods), toiletries (soap, detergents, toothpaste, toilet paper), processed foods (candy, chips, cookies), and some sell other items such as school supplies[11].

Studies addressing the association between food environment and obesity have shown contrasting results among ethnicities, age groups, areas (urban vs rural) and countries [12-18]. For instance, proximity to supermarkets in Indiana, USA, has been

65 associated with a healthier diet and negatively associated with overweight and obesity in

66 children in adolescents (3 – 18 y) [14-16]. In contrast, availability of CS within a 0.25 mile

67 (400m) buffer was associated with a greater risk of overweight and obesity in 6-7 year old

68 girls living in Northern California [17]. In addition, it has been observed that income and

69 ethnicity are not only associated with the location, size and number of stores present in

70 the food environment, but also with the selection of available food[18]. It is important to

71 consider that most of the studies on this topic have come from developed countries, in

72 urban settings, and have been done in adult populations. Interestingly, even though

73 Mexico has one of the highest rates of obesity worldwide, there is limited information

74 concerning the association between food environment and obesity, and the available

75 information is from urban areas. For instance, one study in two urban settings found that

76 the number of mobile food vendors around schools was positively related with children's

77 BMI[19] . In rural settings from developing countries, most families get their food from CS

78 and it is common for children to play a role in household food purchasing [11].

79   Using Geographic Information Systems (GIS) provides a reliable and objective

80 measurement on food environment [20]. A large list of proxies have been used to evaluate

81 food environment, such as the stores within a given radius, the proximity to the nearest

82 food store and the shelf-length of highly processed food and non-processed foods [21]. A

83 major challenge is to identify proxies that better represent food environment and that

84 consider social, racial, physical and age-related factors in a community or an individual.

85 [20,22].

86   Given the high rates of overweight and obesity in Mexico and the large proportion

87 of the population living in rural communities, the main objective of this cross-sectional

88 study is to assess the association between obesity and food environment in children of

89 rural Mexico.

Methods

Population and study design

92   A cross sectional study was conducted among 218 children (8 -10 years) from a

93 rural community named Santa Cruz in the municipality of El Marques within the state of

94 Queretaro, Mexico. The community has a population of 3902, the ethnicity is

95 predominantly mestizo (mixed-race individual), and agriculture is the main economic

96 activity. The nearest supermarket is in the city of Queretaro (nearest metropolitan center),

97 35 km away from El Marques, so people from the community usually buy their food from

98 small CS ("tienditas" or "misceláneas"). Children's information was collected from August

99 2016 until May 2017.

100   Children were recruited from the elementary school in the community. Parents were

101 asked to attend a meeting where the study procedures were explained. Those that agreed

102 to participate, signed consent forms and were included in the study. Also, children

103 provided their assent to participate. Children who were under a prescribed physical

104 activity or diet regimen were excluded from the study. This study was conducted according

105 to the guidelines of the Declaration of Helsinki and all procedures involving human

106 subjects were approved by the Bioethics Committee of the Universidad Autónoma de

107 Querétaro (UAQ).

Demographic questionnaire

109   A demographic questionnaire was answered by the caretaker. The questionnaire

110   included information related to their living conditions (number of rooms in the house, inside

111   running water, home appliances, among others), main mode of transportation, family

112   income and caregiver's level of education. The information in the questionnaire was used

113   to determine the socioeconomic level of the participants' households.

114   ***Physical activity***

115   Physical activity was estimated using a validated questionnaire specifically for

116   Mexican populations[23]. According to the compendium of physical activities of Ainsworth[24],

117   the intensities of the physical activities were categorized in three according to the number

118   of the metabolic equivalent of task (METS): light (<3 METS), moderate (3–6 Mets) and

119   vigorous activity (>6 Mets). The resulting hours of each type were divided into days of the

120   week to obtain daily hours practiced of each type of activity.

121   **Anthropometry and body composition**

122   Children were transported with their mothers from the community to the Nutrition

123   Clinic at the UAQ. Weight, height and waist circumference were measured twice with a

124   precision of 0.1 g or 0.1 cm respectively, in all children by trained personnel following the

125   World Health Organization (WHO) procedures [25]. Children were weighed barefoot and

126   wearing light clothes, using a calibrated digital scale (SECA, mod 813 Hamburg,

127   Germany). Height was measured using a stadiometer (SECA, mod 206 Hamburg,

128   Germany). Nutritional status was calculated based on the WHO criteria of BMI-for-age for

129   children aged 5-19 years using the Anthroplus software (Geneva: WHO, 2009).

130   Underweight was defined as two z-scores below the WHO reference median, overweight

131 as one standard deviation above the WHO reference median and obese as two standard

132 deviations above the reference median of the BMI-for-age z-score (BMIz) [26]. Whole body

133 composition was also measured by a certified technician using Dual-energy X-ray

134 absorptiometry (DXA) (Hologic Mod Explorer, 4500 C/W QDR, INC 35 Crosby Drive,

135 Bedford, MA 01730, USA). Body fat percent and body fat content (Kg) were recorded from

136 the values provided by the DXA. Abdominal fat percent and abdominal fat content (Kg)

137 were estimated following procedures described by Hill *et al* [27]. High body fat for girls was

138 considered above 30% and above 25% for boys[28,29].

Geographical data

140 The geolocation of each participant's household, of all the CS available in the

141 community, and of the school in the community were obtained using ¨Open Data Kit tool¨

142 that was preinstalled in android OS devices equipped with a Global Positioning System

143 (GPS) chip. We identified through a community audit, two types of stores in the

144 community. The first stores that were identified were the "tienditas" or "misceláneas",

145 typical family owned found in Mexico. The second type of food stores found were "food

146 venues", which are local or ambulant small stalls that usually sell 1 or 2 products, such as

147 "aguas frescas" (sugar sweetened fruit drinks), homemade fried chips, candies, among

148 others. For the purpose of this study, we analyzed only CS, since this is where the

149 inhabitants acquire most of their food [30]. The community audit was done by foot and data

150 collection was obtained from August 2016 until May 2017.

In Store Availability

152 Using a measuring tape, a two person team measured the shelf-length (m) of

153 Processed Foods (PF) and Non or Minimally Processed Foods (NMPF) to the nearest cm

154   [31]. The PF were defined as those foods processed to help preserve and enhance nutrients

155   and freshness, foods that combined ingredients (such as flavor, sweeteners, spices and

156   preservatives) for safety and taste, and ready-to-eat foods with minimal or no needed

157   preparation[32]. These PF included foods such as sugar sweetened beverages, salty

158   snacks (chips, popcorn), cookies, pastries, candies (chocolates, hard candy and gum),

159   ice cream, dairy products (except milk), instant soup, doughnuts, box bread, ready-to-eat

160   cereals, ham, sausages, and canned products. The NMPF included fresh fruits and

161   vegetables, unprocessed chicken, beef or pork, eggs, milk, maize tortillas, beans, rice,

162   and water, among others.

163   **Food Store Access**

164   A GIS database was constructed geocoding all the CS and the participants'

165   households using ArcMap 10 (Redlands, CA) (Figure 1). To determine the best density

166   (number of stores/area) proxy for the food environment, four circular buffers of 150 m, 200

167   m, 250 m and 300 m radius were defined around each household. The WGS1984

168   coordinate system with a fuller projection was used to geocode addresses and calculate

169   distances and buffers. The number of stores and the shelf length of each type of food (PF

170   and NMPF) within each buffer was quantified. The length of the buffers was determined

171   based on key GIS data collection information and the characteristics of the community,

172   such as the extension, population and number of stores[33]. The proximity was assess using

173   the Euclidean distance (straight-line distance), to evaluate distance between each

174   participant's household and the nearest convenience store.

175   **Statistical analysis**

176   A descriptive analysis of the demographic variables was performed. As a first step,

177   we assessed which density measure best correlated with obesity. For this purpose, a set

178   of linear regression models between the different measurements of obesity (i.e. BMIz,

179   abdominal and total body fat percent) with the number of stores in 150 m, 200 m, 250 m

180   and 300 m buffers were performed. The 250 m buffer was selected to calculate the density

181   of CS because it had the highest coefficient with body fat (b=0.16), abdominal fat (b=0.22)

182   and BMI (b=0.03).

183   Normality of the independent variables was confirmed by visual inspection and the

184   Shapiro-Wilk test. Linearity of the association was confirmed visually inspecting the data

185   with a LOWESS graph and by plotting the regression residuals. Also, data analysis of all

186   variables where checked for outliers.

187   We evaluated the relationship between in-store food availability (i.e. total shelf

188   length of PF and NPF) and the different measurements of obesity. We performed a linear

189   model assessing the association between obesity and food environment (i.e. density and

190   proximity of CS), while controlling for the different components of food environment and

191   possible confounders (i.e. sex, age, caregiver's educational level, physical activity and

192   proximity to school). All statistical analyses were performed by SPSS v23.0 (SPSS

193   Chicago, IL, USA).

194   To evaluate if "other food venues" have an influence on the measurements of

195   obesity, we carried out sensitivity analysis. We calculated the density and proximity, this

196   time including "other food venues" together with the CS in the linear models (i.e. any food

197   venue or convenience store in a 250m buffer or the shortest distance to any "other food

198   venues" or CS).

Results

The general characteristics of the children who participated in the study are shown in Table 1. Of the total population, 55% percent of the studied children were girls, and 52% of the children had an elevated percentage of body fat. The main mode of transportation inside the community in all participants was walking. More than 90% of the households had low SES, more than 29% of the caregivers did not complete elementary school and 91% of the households had access to at least 1 CS within 250 m for their households.

A total of 58 food venues were found in the whole community: 40 CS and 18 other food venues such as two "tortillerías" (stores that only sell tortillas), one pastry shop, two butcheries and one poultry shop, one fast food restaurant and 11 street vendors that sold different kinds of food such as "tamales", corncob, peanuts, and salty deep-fried "churros". Sixty-two percent (± 16 SD) of the shelf-space in the CS contains PF, which represents an average of 16.73 m (± 9.3 SD) of the shelf-space (Table 2).

As summarized in Table 3, children with high body fat percent had access to more CS compared to children with normal body fat percent. No differences were observed in proximity to CS in children depending on their body fat percent.

As observed in Table 4, when adjusting for confounding (sex, age, caregiver's educational level, physical activity and proximity to school), the density of CS was positively associated with all the measurements of obesity (body fat %, abdominal fat % and BMIz). The proximity to CS was negatively associated with all the measurements of obesity, an increase of 100 meters in the proximity to the nearest convenience store was

10

221   associated with lower body fat -0.9% (95%CI -1.7% and -0.1%) abdominal fat -1.12%

222   (95%CI -2.3% and -0.1%) and BMI-for-age-z-score -0.2 (95%CI -0.4% and -0.1%). Also,

223   the shelf-meters of both PF and NMPF were positively associated with higher BMIz.

224   However, no differences were observed between groups when analyzing the PF/NMPF

225   ratio.

226   The sensitivity analysis showed no variations in the coefficient or the direction of

227   the associations between density and proximity with the measurements of obesity after

228   including "other food venues".

Discussion

230   In the present study, the food environment of a rural community of Mexico was

231   evaluated. To the best of our knowledge, the results show for the first time the relationship

232   between obesity and measures of food environment in a rural setting in Mexico, where no

233   supermarkets are available, and where its habitants are compelled to buy their food in

234   small CS. In this community, a high density and low proximity to CS was associated with

235   obesity in children, and they were exposed on average to 11.5 CS within 250 m from their

236   household.

237   The food environment of this community differs importantly from other studies in

238   different countries. The main reason of these differences is that most of the studies that

239   have evaluated food environment and its relationship with obesity, have been done in high

240   income countries, in both urban and rural communities. There is limited research of this

241   type in rural communities from lower-medium income countries, such as Mexico. This has

242   to be taken into consideration when comparing the results from a rural community in

243 Mexico to those from other settings in high income countries with different contexts. For

244 instance, in a community in Texas, near the border between Mexico and the United states,

245 three CS could be found within a 1600 m buffer of the participants' households[7]. In

246 Denmark, in metropolitan areas only 54% of the population had one or more CS within a

247 250 m buffer and in non-metropolitan areas only 22% of the population had one or more

248 CS within a 250 m buffer [34]. In the city of New Orleans in the US, 38% of the studied

249 households had one store within 1600 m buffer and 62% had the nearest store farther

250 than 1600 m buffer[35]. In contrast, in the present study, 91% of the children living in the

251 studied community had access to at least 1 CS in a 250 m buffer. Thus, when comparing

252 with other populations and areas in developed countries, the children of this rural

253 community had access to a higher number of CS in their environment.

254 Higher density and proximity of food stores was associated with a higher BMI, and

255 with higher body and abdominal fat in 8-10 year children living in a rural setting. Most of

256 the studies that have evaluated the association of food environment and obesity have

257 been done in adults and in urban areas, and only a few studies have been done in rural

258 settings and in children[7,19,36-39]. Results of studies in adults in both urban and rural area

259 are similar to the results of the present study. For instance, in urban settings in the US,

260 proximity, and frequent use of CS, are associated with higher BMI in adults and

261 households[37,40,41]. Food swamps with a higher density of establishments selling high

262 calorie food and lower density of establishments selling healthier food are predictors of

263 adult obesity, particularly in counties with income inequality and low mobility[42].

264 Similarly, studies in rural communities have found that limited access to healthy

265 foods is one of the main contributors to a poor diet and obesity[43]. Studies that have

266 evaluated the role that the food environment has on childhood obesity have produced

267 inconsistent result [44,45]. In Canada, 58% of children had access to one CS within 800 m

268 walking, and proximity and density was not associated with obesity[46], while children living

269 near a CS in Guam were most likely to have higher BMI z-score compared to those that

270 lived farther away[47]. Similarly, the presence of one or more CS around participants

271 households (a block around or in a 1600 m buffer) in different cities in the US was

272 positively associated with obesity in both children and adolescents[6,7]. In addition, the

273 presence of CS near schools has also been associated with obesity in different countries

274 [19,38,48]. In Mexico, for instance, the number of mobile food venues around both, public and

275 private schools, was positively associated with obesity[19]). Thus, the evidence suggests

276 that the density of CS near children's households and schools is strongly associated with

277 higher BMI.

278 The association between the density of food venues and obesity in the population

279 studied may be explained by different social and psychological factors. It is more likely

280 that children living close to a higher density of stores can find a store in their way to their

281 destination (i.e. school, family member house, while playing in the street) and therefore

282 have increased access to CS and food products compared with children living far away

283 from CS [49,50]. Also, children sharing a higher density of stores are exposed to visual cues

284 more often, both outside and inside the stores, where advertisement as promotions, free

285 toys, and colorful labels of their food products may be found [51,52].

286 In the present study, shelf-space dedicated to PF, which tend to be more energy

287 dense, was higher than NMPF, and the shelf-space of both was associated with obesity

288 in children. However, no association was observed of PF/NMPF with any measure of

13

289   obesity. These results suggest that the density and proximity of CS are better predictors

290   of obesity than the proportion of PF/NMPF. To our knowledge, no studies have evaluated

291   the relationship between shelf-space of specific foods and obesity in Mexico, but there is

292   evidence in developed countries. Studies in both Australia and the United States have

293   shown that shelf-space dedicated to energy dense food and less healthy foods is greater

294   in neighborhoods with low SES[39,53]. Rural stores in Australia had lower shelf space of

295   fruits and vegetables and higher shelf space of soft drinks compared to urban stores, and

296   rural areas in this country have high prevalence of overweight and obesity[54].

297   Some limitations of the study need to be addressed. The cross-sectional design of

298   the study does not allow to draw conclusions about causality. Even though associations

299   between food environment and obesity were observed, these associations were small.

300   Since obesity is a multifactorial disease, other factors, such as genetics, may be more

301   important. In addition, there may be behaviors that were not measured in the study, such

302   as the routes the children take to visit family members that may influence their exposure

303   to the food environment of the community. Another limitation is the small sample size of

304   the participants. Also, no information of how often children actually shop in the CS is

305   available, or what type of food they actually purchase. Despite adjusting for proximity to

306   the school, children shared similar food environments near their houses and their school,

307   and thus, the assumption of independence of residuals might be violated. Physical activity

308   was measured using self-reported data and this may be subject to recall bias.

309   The main strength of the study was the assessment of all the CS available to the

310   community, providing better estimates for the associations found. Another strength of the

311   study was using DXA to measure body composition as an indicator of obesity. Also, the

312   present study is one of the few addressing the relationship between "tienditas" and

313   childhood obesity in rural communities, where supermarkets are not available.

314   Future studies in rural communities should include information regarding how often

315   the children buy food in the CS, what type of food they purchase, and how children move

316   within the community, around their households and their school.

317

318   **Conclusion**

319   Georeferenced locations provide a useful approach to assess the relationship

320   between food environment and obesity by modelling spatial accessibility (density,

321   proximity to CS and exposure to processed foods). The results show that food

322   environment near participants' households is associated with obesity in 8-10 year old

323   children living in a rural community in Mexico. In a country where prevalence of childhood

324   obesity is one of the highest in the world, understanding the food environment will

325   contribute to shape the environment to promote and support healthy eating and thus,

326   prevent childhood obesity.

327   **Author Contributions**

328   OPG, MCP and GAZ conceived and designed the study. YTP and GAZ carried out

329   the field work, YTP, JLR, JEEP, CALG, CMD and GAZ analyzed and interpreted data,

330   and OPG, CALG and JLR gave important intellectual advice. OPGO, GAZ and YTP

331   drafted the manuscript. All authors were involved in revising the paper and had final

332   approval of the submitted and published versions.

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Conflict of interest

338   The Authors declare that there is no conflict of interest.

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References

344 1.   Hernández-Cordero S, Cuevas-Nasu L, Morales-Ruán M, Humarán IM-G, Ávila-Arcos M, Rivera-
345   Dommarco J. Overweight and obesity in Mexican children and adolescents during the last 25
346   years. *Nutrition & diabetes.* 2017;7(3):e247.
347 2.   Shamah-Levy T, Cuevas-Nasu L, Rivera-Dommarco J, Hernández-Ávila M. Encuesta Nacional de
348   Nutrición y Salud de Medio Camino 2016 (ENSANUT MC 2016). *Informe final de resultados*
349   *Recuperado de https://www insp mx/ensanut/medio-camino-16 html/[Links].* 2016.
350 3.   Laura Anca P, Bogdana V, Olivia T, Horia V, Dumitru O, Leon Z. The Relations Between Immunity,
351   Oxidative Stress and Inflammation Markers, in Childhood Obesity. *Free radical biology &*
352   *medicine.* 2014;75 Suppl 1:S44-45.
353 4.   Friedman JM. Obesity: Causes and control of excess body fat. *Nature.* 2009;459(7245):340-342.
354 5.   Timperio A, Crawford D, Leech RM, Lamb KE, Ball K. Patterning of neighbourhood food outlets
355   and longitudinal associations with children's eating behaviours. *Preventive medicine.*
356   2018;111:248-253.
357 6.   Galvez MP, Hong L, Choi E, Liao L, Godbold J, Brenner B. Childhood obesity and neighborhood
358   food-store availability in an inner-city community. *Academic pediatrics.* 2009;9(5):339-343.
359 7.   Laska MN, Hearst MO, Forsyth A, Pasch KE, Lytle L. Neighbourhood food environments: are they
360   associated with adolescent dietary intake, food purchases and weight status? *Public health*
361   *nutrition.* 2010;13(11):1757-1763.
362 8.   Wang MC, Gonzalez AA, Ritchie LD, Winkleby MA. The neighborhood food environment: sources
363   of historical data on retail food stores. *International Journal of Behavioral Nutrition and Physical*
364   *Activity.* 2006;3(1):1.
365 9.   Leung CW, Laraia BA, Kelly M, et al. The Influence of Neighborhood Food Stores on Change in
366   Young Girls' Body Mass Index.

367   10.   Liese AD, Weis KE, Pluto D, Smith E, Lawson A. Food store types, availability, and cost of foods in
368   a rural environment. *Journal of the American Dietetic Association.* 2007;107(11):1916-1923.
369   11.   Pisani MJ, Yoskowitz DW. A Sstudy of small neighborhood "tienditas" in Central America. *Latin*
370   *American Research Review.* 2012:116-138.
371   12.   Morland KB, Evenson KR. Obesity prevalence and the local food environment. *Health & place.*
372   2009;15(2):491-495.
373   13.   Zenk SN, Powell LM. US secondary schools and food outlets. *Health & place.* 2008;14(2):336-346.
374   14.   Michimi A, Wimberly MC. Associations of supermarket accessibility with obesity and fruit and
375   vegetable consumption in the conterminous United States. *International Journal of Health*
376   *Geographics.* 2010;9(1):1.
377   15.   Inagami S, Cohen DA, Finch BK, Asch SM. You are where you shop: grocery store locations,
378   weight, and neighborhoods. *American journal of preventive medicine.* 2006;31(1):10-17.
379   16.   Liu GC, Wilson JS, Qi R, Ying J. Green neighborhoods, food retail and childhood overweight:
380   differences by population density. *American Journal of Health Promotion.* 2007;21(4s):317-325.
381   17.   Leung CW, Laraia BA, Kelly M, et al. The influence of neighborhood food stores on change in
382   young girls' body mass index. *American journal of preventive medicine.* 2011;41(1):43-51.
383   18.   Baker EA, Schootman M, Barnidge E, Kelly C. The role of race and poverty in access to foods that
384   enable individuals to adhere to dietary guidelines. *Prev Chronic Dis.* 2006;3(3):A76.
385   19.   Barrera LH, Rothenberg SJ, Barquera S, Cifuentes E. The toxic food environment around
386   elementary schools and childhood obesity in Mexican cities. *American journal of preventive*
387   *medicine.* 2016;51(2):264-270.
388   20.   Charreire H, Casey R, Salze P, et al. Measuring the food environment using geographical
389   information systems: a methodological review. *Public health nutrition.* 2010;13(11):1773-1785.
390   21.   Moore LV, Roux AVD, Brines S. Comparing perception-based and geographic information system
391   (GIS)-based characterizations of the local food environment. *Journal of Urban Health.*
392   2008;85(2):206-216.
393   22.   Moore LV, Diez Roux AV. Associations of neighborhood characteristics with the location and type
394   of food stores. *American journal of public health.* 2006;96(2):325-331.
395   23.   Hernández B, Gortmaker SL, Laird NM, Colditz GA, Parra S, Peterson KE. Validez y
396   reproducibilidad de un cuestionario de actividad e inactividad física para escolares de la ciudad
397   de México. *Salud pública de México.* 2000;42(4).
398   24.   Ainsworth BE, Haskell WL, Whitt MC, et al. Compendium of physical activities: an update of
399   activity codes and MET intensities. *Medicine and science in sports and exercise.* 2000;32(9;
400   SUPP/1):S498-S504.
401   25.   Lohman T, Roche A, Martorell R. *Standarization Reference Manual.* Champaign, IL: Human
402   Kinetics; 1988.
403   26.   de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO
404   growth reference for school-aged children and adolescents. *Bull World Health Organ.*
405   2007;85(9):660-667.
406   27.   Hill AM, LaForgia J, Coates AM, Buckley JD, Howe PR. Estimating abdominal adipose tissue with
407   DXA and anthropometry. *Obesity (Silver Spring, Md).* 2007;15(2):504-510.
408   28.   Ellis KJ, Abrams SA, Wong WW. Body composition of a young, multiethnic female population. *The*
409   *American journal of clinical nutrition.* 1997;65(3):724-731.
410   29.   Ellis KJ. Body composition of a young, multiethnic, male population. *The American journal of*
411   *clinical nutrition.* 1997;66(6):1323-1331.
412   30.   Chaudhari LS, Begay R, Schulz LO. Fifteen years of change in the food environment in a rural
413   Mexican community: the Maycoba project. *Rural Remote Health.* 2013;13(3):2404.

414 31. Monteiro CA, Levy RB, Claro RM, Castro IRRd, Cannon G. A new classification of foods based on
415   the extent and purpose of their processing. *Cadernos de saude publica.* 2010;26:2039-2049.
416 32. Weaver CM, Dwyer J, Fulgoni III VL, et al. Processed foods: contributions to nutrition. *The*
417   *American journal of clinical nutrition.* 2014;99(6):1525-1542.
418 33. Thornton LE, Pearce JR, Kavanagh AM. Using Geographic Information Systems (GIS) to assess the
419   role of the built environment in influencing obesity: a glossary. *International Journal of*
420   *Behavioral Nutrition and Physical Activity.* 2011;8(1):71.
421 34. Lind PL, Jensen PV, Glümer C, Toft U. The association between accessibility of local convenience
422   stores and unhealthy diet. *The European Journal of Public Health.* 2016:ckv242.
423 35. Rose D, Richards R. Food store access and household fruit and vegetable use among participants
424   in the US Food Stamp Program. *Public health nutrition.* 2004;7(08):1081-1088.
425 36. Daly CM, Foote SJ, Wadsworth DD. Physical Activity, Sedentary Behavior, Fruit and Vegetable
426   Consumption and Access: What Influences Obesity in Rural Children? *Journal of community*
427   *health.* 2017;42(5):968-973.
428 37. Larson NI, Story MT, Nelson MC. Neighborhood environments: disparities in access to healthy
429   foods in the US. *American journal of preventive medicine.* 2009;36(1):74-81. e10.
430 38. Tang X, Ohri-Vachaspati P, Abbott JK, et al. Associations between food environment around
431   schools and professionally measured weight status for middle and high school students.
432   *Childhood Obesity.* 2014;10(6):511-517.
433 39. Cameron AJ, Thornton LE, McNaughton SA, Crawford D. Variation in supermarket exposure to
434   energy-dense snack foods by socio-economic position. *Public health nutrition.* 2013;16(7):1178-
435   1185.
436 40. Ghosh-Dastidar B, Cohen D, Hunter G, et al. Distance to store, food prices, and obesity in urban
437   food deserts. *American journal of preventive medicine.* 2014;47(5):587-595.
438 41. Bodor JN, Rice JC, Farley TA, Swalm CM, Rose D. The association between obesity and urban food
439   environments. *Journal of Urban Health.* 2010;87(5):771-781.
440 42. Cooksey-Stowers K, Schwartz M, Brownell K. Food swamps predict obesity rates better than food
441   deserts in the United States. *International journal of environmental research and public health.*
442   2017;14(11):1366.
443 43. Lenardson JD, Hansen AY, Hartley D. Rural and remote food environments and obesity. *Current*
444   *obesity reports.* 2015;4(1):46-53.
445 44. Cobb LK, Appel LJ, Franco M, Jones-Smith JC, Nur A, Anderson CA. The relationship of the local
446   food environment with obesity: a systematic review of methods, study quality, and results.
447   *Obesity.* 2015;23(7):1331-1344.
448 45. Zhou Q, Zhao L, Zhang L, et al. Neighborhood supermarket access and childhood obesity: a
449   systematic review. *Obesity Reviews.* 2019.
450 46. Le H, Engler-Stringer R, Muhajarine N. Walkable home neighbourhood food environment and
451   children's overweight and obesity: Proximity, density or price? *Canadian Journal of Public Health.*
452   2016;107(1):eS42-eS47.
453 47. Matanane L, Fialkowski MK, Silva J, et al. Para I Famagu'on-Ta: Fruit and Vegetable Intake, Food
454   Store Environment, and Childhood Overweight/Obesity in the Children's Healthy Living Program
455   on Guam. *Hawai'i Journal of Medicine & Public Health.* 2017;76(8):225.
456 48. Ellaway A, Macdonald L, Lamb K, Thornton L, Day P, Pearce J. Do obesity-promoting food
457   environments cluster around socially disadvantaged schools in Glasgow, Scotland? *Health &*
458   *place.* 2012;18(6):1335-1340.
459 49. Kestens Y, Daniel M. Social inequalities in food exposure around schools in an urban area.
460   *American journal of preventive medicine.* 2010;39(1):33-40.

461   50.   Rossen LM, Curriero FC, Cooley-Strickland M, Pollack KM. Food availability en route to school
462   and anthropometric change in urban children. *Journal of Urban Health.* 2013;90(4):653-666.
463   51.   Strasburger VC. Children and TV advertising: nowhere to run, nowhere to hide. *Journal of
464   Developmental & Behavioral Pediatrics.* 2001;22(3):185-187.
465   52.   Ashton D. Food advertising and childhood obesity. *Journal of the royal society of medicine.*
466   2004;97(2):51-52.
467   53.   Caspi CE, Lenk K, Pelletier JE, et al. Association between store food environment and customer
468   purchases in small grocery stores, gas-marts, pharmacies and dollar stores. *The international
469   journal of behavioral nutrition and physical activity.* 2017;14(1):76.
470   54.   Cameron AJ. The shelf space and strategic placement of healthy and discretionary foods in
471   urban, urban-fringe and rural/non-metropolitan Australian supermarkets. *Public Health Nutr.*
472   2018;21(3):593-600.

473

474 **Table 1.** Main characteristics of the study participants and according to body fat

475 percentage (normal/high).

Characteristics	Total (n=218) Mean ± SD[1]			Normal body fat (n=105) Mean ± SD			High body fat (n=113) Mean ± SD		
Age (months)	100.6	±	18	97.14	±	18.07	104	±	18.34
Physical activity level									
Moderate physical activity (h/week)	8.57	±	7.53	8.93	±	8.06	8.24	±	7.02
Intense physical activity (h/week)	3.37	±	4.15	3.59	±	5.00	3.15	±	3.14
Anthopometry and body									
Weight (kg)	27.07	±	8	23.36	±	4.94	30.5	±	8.4*
Height (cm)	125.3	±	10	122.94	±	9.28	127	±	9.84*
Waist circumference (cm)	59.07	±	9	54.12	±	5.2	63.7	±	9.25*
Height for age (z-score)	-0.72	±	1	-0.89	±	1.02	-0.56	±	0.88
BMI[2] for age (z-score)	0.33	±	1	-0.34	±	1.06	0.96	±	1.02*
Body fat (%)	28.77	±	7	23.42	±	3.57	33.7	±	4.78*
Abdominal fat (%)	27.82	±	10	20.33	±	4.32	34.8	±	7.62*
	n		%	n		%	n		%
Caregiver's educational level									
No formal education	5		4.4%	14		6.4%	9		8.6%
Incomplete elementary school	28		24.8%	50		22.9%	22		21.0%
Complete elementary school	56		49.6%	114		52.3%	58		55.2%
Middle school or more	24		21.2%	40		18.3%	16		15.2%

476 [1] SD: Standard Deviation; [2] BMI: Body Mass Index

477 *Different with t-test or Chi squared-test with Bonferroni correction for multiple

478 comparisons between normal and high body fat (>30% girls and >25% boys).

479

480

481

482 **Table 2.** Linear meters of non or minimally and process foods from the convenience

483 stores of the community

	Mean	SD[1]	Median	Minimum	Maximum
Non or Minimally Processed Foods	10.2	10.82	8.90	0	15.32
Processed Foods	16.72	9.32	16.78	0	22.57

[1] SD: Standard Deviation

484

485 **Table 3.** Density and proximity to convenience stores of the study participants according to body fat percentage

486 (normal/high).

	Total (n=218)		Normal body fat (n=105)		High body fat (n=113)	
	Mean (SD)[1]	Median (range)	Mean (SD)	Median (range)	Mean (SD)	Median (range)
Density (n CS[2]/250 m buffer)	11.5 (8.5)	11 (0 - 28)	9.6 (7.8)	10 (0-25)	12.8 (8.7) *	13 (0 - 28)
Proximity to closer store (m)	126.5 (107.2)	86.92 (5.5 - 683.8)	142 (106.7)	100.6 (5.8 - 378.5)	115.6 (107.0)	79.4 (5.6 - 682.8)

[1] SD: Standard Deviation; [2] CS: Convenience stores

*Different with t-test with Bonferroni correction for multiple comparisons between normal and high body fat

487

22

Table 4. Association between food environment and measurements of obesity.

	Body fat %			Abdominal fat %			BMIz[3]		
	β[1]	95% CI [2]	*p**	β	95% CI	*p*	β	95% CI	*p*
CS[4] Density (n/250 m buffer)	0.145	(0.048; 0.241)	0.004	0.206	(0.069; 0.343)	0.003	0.028	(0.005; 0.062)	0.005
Proximity (m)	-0.009	(-0.017; -0.001)	0.025	-0.012	(-0.023; -0.001)	0.033	-0.002	(-0.004; -0.001)	0.003
Food Access in CS (250m buffer)									
Shelf-space PF[5] (m)	0.071	(-0.249; 0.392)	0.662	0.047	(-0.409; 0.502)	0.845	0.002	(0.000; 0.003)	0.008
Shelf-space NMPF[6] (m)	0.055	(-0.105; 0.216)	0.497	0.049	(-0.178; 0.277)	0.661	0.072	(0.009; 0.135)	0.025
Ratio PF/NMPF	0.210	(-0.592; 0.479)	0.125	0.266	(-0.121;0.654)	0.174	-0.012	(-0.061; 0.037)	0.662

[1] *β*: beta regression coefficient; [2] BMIz: body mass index z-score; [3]CI: 95% confidence interval; [4]CS: convenience stores;

[5]PF: processed foods; [6]NMPF: non or minimally processed foods

*Adjusted by: sex, age, caretaker's educational level, physical activity and proximity to school