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Is there a link between availability of food and beverage establishments and BMI in Mexican adults?

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Abstract

Objective: To study the association between density of stores (food and beverage stores, stores selling only fruits and vegetables, and supermarkets) and the BMI of adults aged ≥20 years in Mexico.

Design: A cross-sectional study was performed. Individual data came from the 2012 National Health and Nutrition Survey, while information on stores was taken from the National Institute of Geography and Statistics' National Statistics Directory of Economic Units. A weighted least-squares model was estimated to test the association between density of stores and BMI of adults adjusting for sex, age, education, presence of hypertension, diabetes or both, household assets index and marginality index at the municipality level.

Setting: Mexico.

Results: An additional 1 SD in the density of fruit and vegetable stores was associated with a reduction of 0·24 (95 % CI −0·37, −0·12) kg/m^2 in BMI when the densities of the other stores were at their mean values. For food and beverage store density, a difference of 1 SD was associated with an increase of 0·50 (95 % CI 0·33, 0·67) kg/m^2 in BMI, while for supermarkets the corresponding association was a reduction of 0·48 (95 % CI −1·52, 0·56) kg/m^2 in BMI.

Conclusions: In places with a higher density of stores that offer unhealthy foods, the BMI of adults tends to be higher.

Keywords
BMI
Density of food stores
Density of supermarkets

BMI is determined by individual dietary decisions and physical activity, family characteristics and eating habits, characteristics of one's surroundings and culture, and, to a lesser degree, by genetic and metabolic factors[1,2]. These factors can be considered either endogenous – that is, they depend on a person's decisions – or external – those that an individual cannot change.

In the last 30 years, the world has seen a significant increase in the consumption of fat, sugar and carbohydrates, as part of a nutritional transition, as well as a parallel decrease in physical activity[3,4]. This phenomenon has resulted from a combination of environmental and social changes associated with economic development, the scarcity of recreational areas (parks, gardens and gyms), a broader access to transport, as well as changes in the processing, distribution and marketing of high-energy foods (high in sugar, fat and salt) that have increased their availability and reduced their prices[5,6]. These changes in the environment have generated an imbalance in the consumption and expenditure of energy, which has been translated into an increase in the prevalence of obesity in the global population. In this sense, Popkin and Salois highlight the importance of studying the link between body mass and the social and dietary environment to which individuals are exposed[4,7].

A specific factor in the environment that can influence an individual's consumption decisions is the availability of stores, restaurants and other types of establishment that offer foods and beverages[8,9]. According to Lucan and Mitra, if people perceive that access to establishments which sell fruits and vegetables is low (e.g. they have to travel further to buy fruits and vegetables), they tend to consume foods that are high in energy[10]. These results are similar to those shown by Franco *et al.* in a study conducted in Baltimore, USA, where scarcity of fruit and vegetable stores was linked to a low-quality diet[11]. In another US study, Rose and Richards showed that access to supermarkets was linked to higher consumption of

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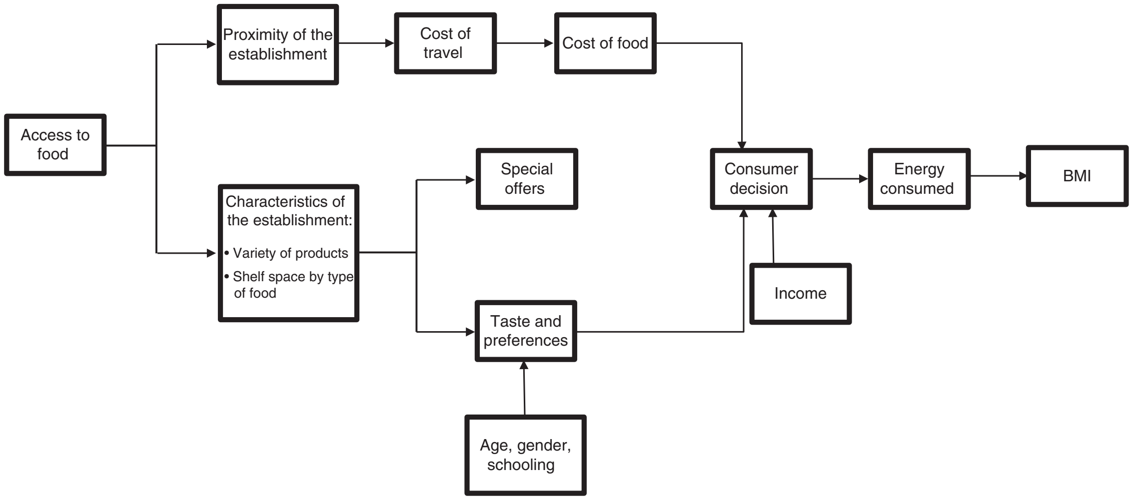

Fig. 1 Link between the availability of foods and beverages and consumption

fruits and vegetables at home[12]. The assumption behind these studies is that the type of foods offered in commercial establishments, the way in which these products are presented (shelves) and the distance to obtain them will influence a consumer's consumption decisions[9,13,14] (see Fig. 1).

Several studies have focused on the link between availability of food and beverage establishments and population BMI. For example, Jilcott *et al.* studied how the presence of agricultural markets, fast-food restaurants and convenience stores influenced teenagers' consumption, and found that the greater the number of restaurants, the higher the weight of the individuals[15]. Through a longitudinal analysis, Gibson found that a higher density of small grocery stores was linked to an increase in a person's weight, but showed no relationship with the density of supermarkets. The author suggested that the lack of association happens because most families must travel to go to a supermarket, which might point to the fact that having one nearby might not change the probability of buying food in a supermarket[14]. Authors like Morland, Rundle, Hutchinson, Bodor and co-authors showed a negative association between proximity of supermarkets and BMI in the USA. They argued that this is a result of a higher availability of healthy foods inside those establishments[16–19].

Mexico has the second highest obesity rate within the OECD (Organisation for Economic Co-operation and Development) countries[20]. In 2000, the prevalence of overweight and obesity (defined as the proportion of people with BMI $\geq 25\,kg/m^2$) was 62 %[21], a figure which went up to 70 % in 2006[22] and to 71 % in 2012[23]. Even so, there is only one study that has analysed the link between food availability and BMI in children who live on the Mexico–US border. The study found that a high availability of high-energy foods was related to obesity[24]. There are no additional studies that analyse the association of availability of stores and supermarkets with BMI among adults.

An important element is that high-energy foods have become more available and attractive worldwide: their relative prices have gone down (compared with healthier and doctor-recommended products), they are highly palatable[25] and there is high exposure to their advertising[26]. In Latin America, the annual per capita sales of ultra-processed products have grown by 26·7 % from 2000 to 2013; Mexico's per capita sales of these products ranks fourth[27]. Therefore, in the context of an increase in the availability, palatability and persuasion of these products, a greater access to establishments that offer them may increase their demand and, eventually, affect the population's BMI. Additionally, based on previous evidence, it might be that the availability of establishments that sell only fruits and vegetables, as well as supermarkets that sell a wide variety of foods and beverages, is not associated with BMI.

The present paper aims to study the link between the BMI of Mexicans aged ≥20 years and the density of food and beverage establishments in 2012, using information from the National Health and Nutrition Survey (Spanish acronym: ENSANUT)[23] and the National Statistics Directory of Economic Units[28]. The available information allows the analysis between BMI and the density of establishments (measured as the number per square kilometre) in a particular municipality, distinguishing between three different types of businesses: (i) food and beverage stores; (ii) stores that sell fruits and vegetables only; and (iii) supermarkets.

Methods

Study design and data source

We used a cross-sectional analysis of data from the 2012 Mexican National Health and Nutrition Survey, a population-based household survey (based on a national population of 115 170 278), with sampling representative at the state level (Mexico has thirty-two states) and by rural/urban strata. The survey was designed to estimate the prevalence of health and nutrition conditions, access to services and health determinants. The ENSANUT also includes anthropometric measurements (weight and size), as well as sociodemographic variables[29].

We used data from the survey's anthropometric, socio-economic and demographic modules, which had been applied to a sample of 38 208 (representative of 69 245 519 Mexicans) adults aged ≥20 years. From these, we excluded those who had incomplete information on the variables included in the model. A comparison of the sociodemographic and health-related characteristics of people who were included or not included in the analytical sample was performed.

The outcome variable is BMI, which is a measurement of body fat based on weight in relation to height, which makes it easier to compare the weights of individuals of different sizes[30]. Weight and height were measured by qualified personnel during the interview. The measurement was taken under standard procedures, twice under sunlight, with the individual wearing light clothes, without shoes and standing up. Each weight had a precision of ±200 g[31]. At least one member of each gender and age group (20–49, 50–65 and ≥66 years) from each home was measured.

The exposure variable was the density of establishments within a geographic area. Following McKinnon *et al.*[32], we calculated density as the number of establishments per square kilometre in the given municipality, which ranged in area from 100 to 3140 km^2 with a population size from 800 to 1 000 000[33]. The information about the urban supply of food and beverage stores, fruit and vegetable stores and supermarkets for 2012 was obtained from the National Statistics Directory of Economic Units, which contains information on the principal activity and location of 5 million non-itinerant economic units that carry out activities related to manufacturing (11 %), commerce (47 %) and services (39 %). The information from the National Statistics Directory of Economic Units was collected by the National Institute of Geography and Statistics, based on the Economic Census[28]; while territorial extension (km^2) was obtained from the State and Municipal Data Base System[33]. We distinguished three types of establishments, based on the North American industrial classification[34]: (i) food and beverage stores (codes 46111, 461213 and 462112); (ii) stores that only sell fruits and vegetables (code 461130); and (iii) supermarkets (code 462111). We constructed an interaction between the different densities to observe if the association was modified.

The ENSANUT does not have information on the address or geographical coordinates of households (for ethical reasons); therefore, we were not able to examine areas close to the participant's home, only the municipality where they live.

Covariates

We adjusted the model for the following variables that may be linked to both BMI and availability of establishments. At the individual level, we included gender (either male or female), age as count of years (linear and quadratic), level of education (four categories: no education or elementary, middle school, high school, bachelor degree or more) and a variable that indicates if the adult reported to have diabetes, hypertension or both[35,36]. At the household level, a variable of home assets was created[4,37,38] as a proxy for socio-economic status by an analysis of principal polychoric components to create an index of assets that included: television, own car, refrigerator, Internet, water tank, blender, microwave, cable television, stove, washer and dryer. Based on the index of assets created, the sample was divided into three to explore the non-linear connections with BMI.

The models also were fitted with the marginality index calculated by the National Population Council with information from the 2010 Population and Living Census (collected by the National Institute of Geography and Statistics) for each municipality[39]. The marginality index is created with variables added on a municipality-wide scale that indicate the level of access to public services (homes without potable water, electricity and/or a drainage system), level of schooling (adults and people ≥12 years old without an elementary education), and economic and employment conditions (overcrowded houses, without a refrigerator, or that subsist on less than two minimum wages). We stratified the index in five levels, from the less marginal municipals to the most[40]. We did not adjust by type of municipality (urban or rural) because the correlation with the marginality index is high and significant (0·758).

Analysis

A descriptive analysis was undertaken of the variables used in the model, accounting for the complex survey design to permit population-level estimates. Next, a weighted least-squares model was estimated to test the association between density of establishments and the BMI of adults. The standard errors were fitted at the municipality level with the Taylor series linearization method. The general specification model was as follows:

$$\mathbf{y}_{ij}=\mathbf{d}_j'\alpha+\mathbf{I}_i'\beta+\mathbf{M}_j'\gamma+\epsilon_{ij},$$

where $\mathbf{y}_{ij}$ represents the outcome variable (BMI) of individual i living in municipality j; $\mathbf{d}_j'$ is a vector that represents variables for the density of stores by type of establishment in municipality j and their interactions; $\mathbf{I}_i'$ represents a vector of covariables at the individual and household level (gender, age, level of schooling, the presence of chronic disease and socio-economic status); and $\mathbf{M}_j'$ is the level of marginality. α are the parameters of the variables for the density stores, β the parameters for the covariates, γ is the parameter for the marginality variables and ε is the error term. We centred and standardized the variables of density by subtracting the mean from each observation and dividing by the standard deviation, with the idea of a better interpretation of the results. The dependent variable was log transformed. We added three interaction terms to test whether higher densities of different stores in municipalities combined influenced BMI. The interactions were as follows: one between density of food and beverage stores and density of supermarkets; a second between density of stores selling fruits and vegetables and density of supermarkets; and a third between density of stores selling foods and beverages and density of stores selling fruits and vegetables.

Results

For the final analytic sample, only adults with complete weight and height information and all covariables were considered. We found that the adults excluded from the final sample, on average, presented a higher level of schooling and they were mostly male. However, there were no differences in the rest of the variables. The final analytic sample comprised 37 174 adults, representing 68 251 509 Mexican adults. The mean BMI was 28·3 kg/m^2, 53 % of the sample were women, adults had a mean age of 42 years, 22 % of adults had hypertension, diabetes or both, and 7·5 % had no schooling (Table 1). On average, there were 1·2 food and beverage stores, 2·4 fruit and vegetable stores, and 0·2 supermarkets per square kilometre. Of the individuals in the sample, 7 % lived in a municipality with a high or very high level of marginality, while 59 % lived in municipalities with very low marginality.

Table 2 shows results of the weighted least-squares regression model that estimates the association between BMI and the density of establishments. The interaction terms allow us to analyse whether the association with BMI for each density changes for different values of the other two densities. The coefficients of main terms for the density variables show the association for each density separately while keeping the remaining densities at the mean (each density variable was centred at the mean). An additional 1 SD in the density of fruit and vegetable stores was associated with a reduction of 0·24 kg/m^2 in BMI when the densities of the other stores were at their mean values. For food and beverage store density, a difference of 1 SD was associated with an increase of 0·50 kg/m^2 in BMI, while for supermarkets the corresponding association was a reduction of 0·48 kg/m^2 in BMI. Interaction terms showed that as the density of food and beverage stores increased, the negative relationship between density of fruit and vegetable stores and BMI decreased in magnitude (the slope coefficient became less negative). Slope coefficients for each density at selected levels of the other two densities are shown in Table 3.

Table 1 General characteristics of 37 174 Mexican adults aged ≥20 years, 2012 National Health and Nutrition Survey

	Mean or proportion	SD
Environment level		
Density of establishments (number/km^2, average per municipality)		
Food and beverage stores	1·20	1·89
Fruit and vegetable stores (exclusively)	2·38	4·77
Supermarkets	0·22	0·32
Marginality rate (% of individuals per municipality)		
Very low	58·8	0·49
Low	15·0	0·35
Medium	19·5	0·39
High	3·3	0·18
Very high	3·6	0·19
Individual level		
BMI (kg/m^2)	28·26	5·52
BMI category (% of overweight or obese individuals)	71·3	0·45
Gender (% of women)	52·9	0·49
Age (years)	42·16	16·12
Level of education (% of individuals)		
No schooling or elementary	40·0	0·49
Middle school	29·1	0·45
High school	18·9	0·39
Bachelor degree or higher	12·0	0·32
With chronic disease (% of individuals)	22·0	0·42

Sample is representative of 68 251 509 Mexicans. Weighted by the survey's design.

We also found a positive association between age and BMI, and a negative association for the age-squared term, which indicates that BMI increases with age but decreases at an older age. On average, women had higher BMI than men. Adults with higher levels of education had on average lower BMI compared with adults without any schooling, and the relationship was stronger for those with a bachelor degree or more. In contrast, adults in households with medium and high socio-economic level had higher BMI on average than adults with low socio-economic level. Low, medium and highest marginalization index showed a positive association with BMI compared with the lowest, but high index compared with the lowest did not show significant difference in the association with adults' BMI. Adults with higher levels of education on average had lower BMI, contrary to adults in households with higher socio-economic level who had higher BMI. Having a chronic disease was positively associated with BMI.

Discussion

The results of the regression model show that higher density of stores selling foods and beverages is associated with higher BMI in Mexican adults. This association can not only be explained by a higher availability of food but also by the fact that these types of establishments offer a greater supply of unhealthy, rather than healthy,

Table 2 Link between the density of establishments and BMI in 37 174 Mexican adults aged ≥20 years, 2012 National Health and Nutrition Survey

	Dependent variable			
	BMI (kg/m²)	95 % CI	Log BMI (%)	95 % CI
Density of establishments (standardized)				
Fruit and vegetable stores (exclusively)	–0·24**	–0·37, –0·12	–0·7^(*)	–1·1, 0·3
Food and beverage stores	0·50**	0·33, 0·67	1·5**	0·5, 2·1
Supermarkets	–0·48	–1·52, 0·56	–0·7**	–4 0, –2·6
Densities' interaction				
Fruit and vegetable stores with supermarkets	0·17^(*)	–0·05, 0·38	0·4	–0·3, 1·1
Fruit and vegetable stores with food and beverage stores	0·02*	0·00, 0·04	0·1**	0·0, 0·1
Food and beverage stores with supermarkets	–0·51**	–0·78, –0·24	–1·6**	–2·5, –0·7
Marginality index (lowest as reference)				
Low	1·33**	0·87, 1·79	4·3**	2·6, 5·9
Medium	1·02**	0·55, 1·47	3·4**	1·8, 5·1
High	– 0·14	– 0·71, 0·43	– 0·06	– 2·6, 1·4
Highest	1·23**	0·78, 1·68	3·5**	2·0, 5·1
Sex (1 = woman)	1·14**	0·95, 1·32	3·9**	2·9, 4·2
Age (years)	0·40**	0·37, 0·43	1·5**	1·4, 1·6
Age-squared (years²)	– 0·004**	– 0·004, –0·004	– 0·01**	– 0·01, 0·01
Chronic diseases (1 = hypertension, diabetes or both)	1·96**	1·71, 2·21	6·4	5·6, 7·3
Education (no education or elementary school as reference)				
Middle school	– 0·16	– 0·39, 0·06	– 0·5	– 1·3, 0·2
High school	– 0·29*	– 0·57, –0·02	– 1·0*	– 1·9, –0·01
Bachelor degree or higher	– 0·79**	– 1·13, –0·46	– 2·8**	– 3·9, –1·6
Household assets index (low as reference)				
Medium	0·77**	0·55, 0·98	2·9**	2·1, 3·6
High	0·92**	0·67, 1·17	3·5**	2·9, 4·2
Observations (*n*)	37 174		37 174	
Expanded sample (*n*)	68 251 509		68 251 509	
R^2	0·092		0·09	

^(*) $P<0·1$, *$P<0·05$, **$P<0·01$. The design of the sample was taken into account.

Table 3 Slopes between each density and BMI at selected levels of the other two densities in 37 174 Mexican adults aged ≥20 years, 2012 National Health and Nutrition Survey

	Level of density while holding the other densities at the mean	
	Mean – 1 SD	Mean + 1 SD
Slope of the relationship between density of fruit and vegetable stores and BMI		
Supermarkets	–0·39**	–0·06
Food and beverage stores	–0·24**	–0·20**
Slope of the relationship between density of supermarkets and BMI		
Fruit and vegetable stores	–0·52	–0·18
Food and beverage stores	0·15	–0·86^(*)
Slope of the relationship between density of food and beverage stores and BMI		
Fruit and vegetable stores	0·46**	0·50**
Supermarkets	1·00**	–0·03

^(*) $P<0·1$, *$P<0·05$, **$P<0·01$.

foods[14], which concurs with previous findings[14–16]. The model also shows that higher exposure to supermarkets is associated with lower BMI in Mexican adults. However, the relationship is not significant and this can be linked to the fact that, in a supermarket, high-energy foods and sweetened beverages are available alongside fruits and vegetables. We also found that density of fruit and vegetable stores was negatively associated with BMI, similar to Ahern *et al.*'s findings[41]. With the standardized coefficients, we can observe that the density of food and beverage stores has a higher association with the BMI of adults than the density of stores that sell fruits and vegetables and the density of supermarkets. Finally, with the interaction of the variables, the model shows that municipalities with higher density of both fruit and vegetable stores and food and beverage stores have on average adults with higher BMI, contrary to those municipalities where the density of food and beverage stores and supermarkets is high, in which the adults on average have lower BMI. This relationship could be explained because those with large numbers of supermarkets and food and beverage stores could be more developed municipalities, with a population with higher income and more opportunities for exercise[42].

Results of the association between socio-economic status (measured by household assets index) and BMI are consistent with some results of studies in developing countries[37,38]. The negative association observed between level of schooling and adults' BMI could be associated with better knowledge and skills to make better decisions related to health and prevention of diseases[43].

The relationship between the highest marginalization index and adults' BMI compared with the lowest could be explained by the elevated level of social inequality and material deprivation in the former municipalities that may restrict individual choices about physical activity and quality of diet[44,45]. These are consistent with the results shown by Do *et al.*[46] for Latin-American communities; however, in-depth research is needed to analyse the relationship between obesity and marginalization in Mexico.

Some limitations should be noted. The first one is the potential endogeneity between the availability of stores and an individual's BMI. It is not possible to know if an individual's decision to move from the place where he/she lives and/or works was based on preferences or lifestyle, or if the environment itself was modified over the time when the individual already lived and/or worked there. That is to say, we cannot know if the individual made the decision to live in an unhealthy environment or if the environment underwent changes through time that may have affected the consumer choices. However, only 3·2 % of families' report mobility in the country, which is why we assume that it is unlikely that the decision to move is based on the availability of food and beverage stores[47].

Second, we are not able to determine whether the adults buy food close to their home or eat at restaurants instead of eating at home; according to the National Institute of Geography and Statistics, 46 % of households report buying prepared foods, but the weekly expenditure on this kind of food represents only 13·7 % of the total expenditure on food. Also, only 18·5 % of adults work in a different municipality from where they live[48]. Third, we have no information to analyse whether individuals move to another municipality to buy foods and beverages but we think that is unlikely; given that municipalities are large areas, in most cases they represent an entire city. Additionally, the informal food market is not taken into consideration because there is no information available about the supply of such establishments; moreover, the source used does not consider establishments in communities with fewer than 2500 inhabitants.

Another limitation is that the study assumes that the link observed between density of food and beverage stores and BMI results from an increase in consumption that we do not show. As consumption would act as a mediator variable (because it is related to both density of stores and BMI), it is correct to exclude it from the analysis. Neither is the physical activity of adults taken into account for the same reason. Although physical activity is reported in the survey, it is self-reported and some studies have documented potential misreporting[49,50]. Additionally, physical activity was answered only by a sub-sample of individuals (11 027 adults) with significant differences in age (younger people) and sex (greater proportion of woman) compared the whole sample[49].

Finally, the association between having a chronic disease and BMI could be endogenous; however, it is not the variable of interest in the model and the results without the variable do not change drastically (results not shown).

The present study suggests that there is wide scope for the elaboration of new research work that can help prove the hypotheses this investigation puts forth, thereby promoting the creation of public policies that compel the establishment of healthy environments and lifestyles, like the creation of consumption barriers for high-energy foods and the implementation of taxes, as well as orientation programmes, that would allow consumers to make well-informed decisions.

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