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# The nutrition transition in Mexico 1988–2016: the role of wealth in the social patterning of obesity by education

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## Abstract
*Objective:* The present study investigates whether the reversal of the social gradient in obesity, defined as a cross-over to higher obesity prevalence among groups with lower education level, has occurred among men and women in urban and rural areas of Mexico.
*Design:* Cross-sectional series of nationally representative surveys (1988, 1999, 2006, 2012 and 2016). The association between education and obesity was investigated over the period 1988–2016. Effect modification of the education–obesity association by household wealth was tested.
*Setting:* Mexico.
*Subjects:* Women (*n* 54 816) and men (*n* 20 589) aged 20–49 years.
*Results:* In both urban and rural areas, the association between education and obesity in women varied by level of household wealth in the earlier surveys (1988, 1999 and 2006; interaction $P<0{\cdot}001$). In urban areas in 1988, one level lower education was associated (prevalence ratio; 95 % CI) with 45 % higher obesity prevalence among the richest women (1·45; 1·24, 1·69), whereas among the poorest the same education difference was protective (0·84; 0·72, 0·99). In the latest surveys (2012, 2016), higher education was protective across all wealth groups. Among men, education level was not associated with obesity in urban areas; there was a direct association in rural areas. Wealth did not modify the association between education and obesity.
*Conclusion:* The reversal of the educational gradient in obesity among women occurred once a threshold level of household wealth was reached. Among men, there was no evidence of a reversal of the gradient. Policies must not lose sight of the populations most vulnerable to the obesogenic environment.

**Keywords**
Obesity
Nutrition transition
Health inequalities
Education
Wealth
Mexico

The social distribution of obesity is dynamic and changes as a function of country economic development and the nutrition transition[1–3]. In less developed countries obesity tends to be more prevalent among socially advantaged groups. As countries develop economically there tends to be a cross-over to higher rates of obesity among socially disadvantaged groups. This pattern of obesity prevalence, or reversal of the social gradient, may be explained by the process of the nutrition transition. In the early stages of the transition, food is scarce and not varied[4]. Socially disadvantaged populations are disproportionately affected and suffer from undernutrition. They are 'protected' from obesity by a lack of material resources and access to energy. As countries develop and economies become largely based on service industries, most can afford high-energy foods and avoid physical labour. As living conditions improve and food availability, accessibility and diversity increase, disadvantaged populations become at risk of obesity[5]. At the same time, more advantaged groups may become more health conscious and Western ideas of attractiveness associated with thinness may set in, which protects them from obesity.

The obesity prevalence among adults has more than trebled over a period of 25 years in Mexico[6]. It is unclear whether the social patterning of obesity over time in Mexico is consistent with the nutrition transition literature[2,7]. While there is evidence of an inverse association between education and obesity (lower education–higher obesity) among urban women since the late 1980s, there appears to be no association between education and obesity in rural areas and no evidence of a reversal of the social gradient[8].

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Among men using data from 2000, no association between education and obesity was found[9].

The aim of the present study was to investigate whether the reversal of the social (education) gradient in obesity has occurred or is due to occur among men and women in urban and rural areas of Mexico. At country level, gross national income is an effect modifier in the association between socio-economic position (SEP) and obesity[2,7]. Therefore, we hypothesize that within countries, household wealth will be an effect modifier in the association between education and obesity. Education will be protective of obesity over a certain level of household wealth and will not be protective within very poor households[5]. We use five waves of Mexican nationally representative data covering a period of 28 years over which there was sustained economic development and important changes in the food environment in the country[10].

## Methodology

### *Data sources*

Data were extracted from five nationally representative cross-sectional surveys, in Spanish Encuesta Nacional de Nutrición (ENN) and Encuesta Nacional de Salud y Nutrición (ENSANUT), conducted in 1988, 1999, 2006, 2012 and 2016[11–15]. These surveys were designed to collect information on nutrition and the latter three on health and health-related services and interventions. The first two surveys focused on women aged 12–49 years and children. The last three included men and women aged 20 years or above, children and adolescents. ENSANUT 2016 aimed to update key health and nutrition outcomes with a smaller sample compared with previous surveys. We selected women and men aged 20–49 years as our study population. Five data points were available for women (1988, 1999, 2006, 2012 and 2016) and three for men (2006, 2012 and 2016). The design of the sample was similar in all surveys and included stratification and probabilistic selection of clusters in different stages. Individuals in the data sets carry a weight which represents the inverse probability of being sampled adjusted for survey non-response.

Response rates at household level ranged from 80 to 97 %. The achieved sample of households was in the range of 9479 in 2016 to 50 528 in 2012. The total number of women aged 20–49 years with demographic information across the five surveys was 67 071. There were 30 102 men aged 20–49 years with demographic information in the 2006, 2012 and 2016 surveys. Missing values for BMI were on average 17 % across all surveys. Two of the data sets (1999 and 2006) did not distinguish between individuals who refused to be measured and those not selected to be measured. Therefore, missingness due to refusal to be measured is understood to be lower than the overall missingness level. Missing values for education and other covariates were all <5 %. Cases with missing values were excluded after careful examination of missing data patterns suggested that selection bias in the main findings was minimal[16]. After exclusion of missing data and extreme implausible values for BMI (BMI < 10 kg/m$^2$, BMI > 75 kg/m$^2$; less than 0·5 % of the total sample), our analytical sample consisted of 54 816 non-pregnant women and 20 589 men aged 20–49 years.

### *Outcome, exposure and covariates*

BMI was calculated as weight (in kilograms) divided by the square of height (in metres). Obesity was defined as a BMI ≥ 30 kg/m$^2$. Height and weight were measured using standard procedures by trained health teams during home visits[11–13,17]. The main exposure variable was achieved level of education and was categorized as high school or more, secondary, primary and incomplete primary. These categories refer to well-known milestones in the Mexican education system. Education is understood as a measure of adult SEP and likely associated with health by making people more receptive to health education messages and more prone to healthier behaviours.

A wealth index was constructed as a measure of material resources[18]. The index was constructed in each survey using relevant household quality and asset variables (see online supplementary material 1, Tables S1–S3, for more details). Asset ownership and household quality characteristics are likely based at least partially on economic wealth and unlikely to change in response to short-term economic shocks. Relevant variables were those that had the potential to discriminate between wealth groups. If mean ownership of the asset was high (above 85 %), the variable was not selected. Principal component analysis was used to replace the set of correlated assets and household quality variables with a set of uncorrelated principal components which represent unobserved characteristics of the population[19]. The first principal component was kept as it captured the most covariance (40 % on average across surveys). The weights for each variable from the first component were used to generate a household score. The relative rank of households using this score was used as a measure of relative wealth[18,19]. Tertiles of the score were created for each survey individually. The wealth index had internal coherence, such that there were large differences in ownership of assets between wealth groups (see supplementary material 1).

A linear term and a quadratic term of age were included as adjustment covariates in all models because there was a statistically significant curvilinear association between age and obesity prevalence in all survey years. Area of residence has been identified as an effect modifier of the association between education and obesity in previous studies[20], thus analyses were stratified by this variable. Urban areas were defined in the surveys as communities with more than 2500 inhabitants and rural areas as those with fewer than 2500 inhabitants.

### *Statistical analysis*

All analyses accounted for the complex survey design and were weighted. Weights in these surveys represent the inverse probability of being sampled adjusted for survey non-response. Age-standardized obesity prevalence by education group was computed using the Mexican 2000 census population as the standard population. The association between education and obesity was assessed in a regression model where the outcome was obesity and the exposure was education as a continuous variable, adjusted for age and age-squared[21,22]. Generalized linear models (log binomial regression) were used instead of logistic regression as has been recommended when modelling frequent outcomes[21,22]. Generalized linear models estimate the prevalence ratio.

To test whether wealth modifies the association between education and obesity, the regression of obesity *v.* the continuous education variable was performed within each wealth tertile. An interaction term between education and wealth was fitted in a separate model. The interaction term was examined for statistical significance using a Wald test. This methodology was repeated for each survey year for urban and rural areas, men and women. The two more recent surveys (2012 and 2016) were pooled since the 2016 sample was small and when divided into several strata the number for each cell was too small for analyses. For the same reason, 1988 and 1999 were pooled for women in rural areas.

## Results

The correlation of education and wealth was low to moderate, ranging from 0·38 to 0·48 in urban areas and from 0·21 to 0·48 in rural areas for women and from 0·37 to 0·43 and 0·24 to 0·31 in urban and rural areas, respectively, for men. The rural population made up on average 21 % of the total population throughout the period. Table 1 shows the characteristics of the study population. There were improvements in education over the 28-year period for women and over the 10-year period for men. The proportion of women with complete high school more than doubled from 1988 to 2016 (from 15·3 to 38·7 %) in urban areas and quadrupled in rural areas (from 5·0 to 20·5 %), while the proportion with incomplete primary education declined from 33·9 to 6·6 % in urban areas and from 61·7 to 18·7 % in rural areas. Men achieved a higher level of education than women in urban areas but not in rural areas. In terms of wealth, the largest proportion of urban households were classified in the richest tertile, while the largest proportion of households in rural areas belonged to the poorest tertile.

Obesity prevalence continued to increase, especially among women, reaching 37·1 % in urban areas and 35·7 % in rural areas in 2016 (Table 1). Among men, obesity prevalence was higher in urban areas compared with rural areas throughout the study period. Table 2 shows obesity prevalence stratified by education level for men and women in urban and rural areas. Education was inversely associated with obesity prevalence (lower education level–higher obesity prevalence) among urban women throughout the study period. Obesity prevalence reached 49·9 % among women with incomplete primary education in 2016 compared with 31·5 % among women with high school or more. In rural areas, education was not associated with obesity prevalence (Table 2). Among men there was a direct association (lower education level–lower obesity prevalence) between education and obesity prevalence in rural areas and no association in urban areas.

Table 3 shows the association between education and obesity prevalence stratified by wealth tertiles. In 1988 among the richest tertile of urban women, one level lower education was associated with 45 % higher obesity prevalence (prevalence ratio = 1·45; 95 % CI 1·24, 1·69), while among the poorest tertile one level lower education was protective of obesity (prevalence ratio = 0·84; 95 % CI 0·72, 0·99). The association between education and obesity prevalence varied by level of wealth (interaction $P < 0·001$). The same pattern was seen among urban women in 1999 and among rural women in 1988/1999 and 2006. As of 2006, the association between education and obesity prevalence did not vary by level of wealth. In online supplementary material 2, Figs S1–S11 illustrate the interaction in the different survey years. Among men, the association between education and obesity did not vary by level of wealth.

## Discussion

In the present study we examined the social distribution of obesity in Mexico in greater detail than previous studies by using data from five nationally representative surveys covering a period of 28 years, including men and women, and using two dimensions of SEP: education and wealth. Our study found that obesity prevalence continued to increase among all education groups in men and women, urban and rural areas of Mexico from 2012 to 2016. The association between education and obesity was modified by wealth among women in the earlier surveys in 1988, 1999 and 2006; while among the richer tertiles, education was protective of obesity prevalence, among the poorest tertile, education was not associated with obesity prevalence or appeared to be a risk factor. This interaction was no longer significant in the more recent surveys, suggesting a reversal of the educational gradient among the poorest women. Among men, the association between education and obesity was not modified by wealth. In urban areas, education was not associated with obesity regardless of wealth and in rural areas, there was a direct association between education and obesity. Our results contribute to the evidence supporting the nutrition transition proposition of a reversal of the social gradient in

**Table 1** Descriptive characteristics of Mexican men (*n* 20 589) and women (*n* 54 816) aged 20–49 years in urban and rural areas; data from five nationally representative cross-sectional surveys, Encuesta Nacional de Nutrición (ENN) and Encuesta Nacional de Salud y Nutrición (ENSANUT), conducted in 1988, 1999, 2006, 2012 and 2016

| | Women | | | | | | | | | | Men | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1999 | | 2006 | | 2012 | | 2016 | | 2006 | | 2012 | | 2016 | |
| | Mean or % | SE | Mean or % | SE | Mean or % | SE | Mean or % | SE | Mean or % | SE | Mean or % | SE | Mean or % | SE | Mean or % | SE |
| Urban | | | | | | | | | | | | | | | | |
| *n* | 8995 | | 8228 | | 9906 | | 9588 | | 1724 | | 6513 | | 6734 | | 748 | |
| Mean age (years) | 32·4 | 0·1 | 32·8 | 0·1 | 34·0 | 0·1 | 33·8 | 0·1 | 33·6 | 0·3 | 33·3 | 0·2 | 33·2 | 0·2 | 32·8 | 0·4 |
| Obesity prevalence* | 9·5 | 0·4 | 25·8 | 0·5 | 30·9 | 0·7 | 34·5 | 0·8 | 37·1 | 2·0 | 23·9 | 0·8 | 29·5 | 0·8 | 30·7 | 2·6 |
| Education | | | | | | | | | | | | | | | | |
| ≥High school | 15·3 | 0·8 | 34·3 | 0·8 | 26·5 | 0·9 | 38·0 | 0·9 | 38·7 | 3·2 | 35·3 | 0·9 | 40·6 | 0·9 | 44·3 | 3·1 |
| Secondary | 22·0 | 0·7 | 21·7 | 0·5 | 32·2 | 0·8 | 32·8 | 0·8 | 38·6 | 2·3 | 32·6 | 0·9 | 33·3 | 0·9 | 34·7 | 2·9 |
| Primary | 28·8 | 0·7 | 24·5 | 0·5 | 24·2 | 0·7 | 18·6 | 0·6 | 16·1 | 1·6 | 20·8 | 0·7 | 17·8 | 0·7 | 14·9 | 1·8 |
| <Primary | 33·9 | 1·3 | 19·5 | 0·7 | 17·0 | 0·7 | 10·6 | 0·5 | 6·6 | 0·8 | 11·3 | 0·5 | 8·3 | 0·4 | 6·1 | 1·1 |
| Wealth | | | | | | | | | | | | | | | | |
| Richest | 36·4 | 1·5 | 50·8 | 0·9 | 45·7 | 1·0 | 47·7 | 1·1 | 58·4 | 2·8 | 47·9 | 0·9 | 49·7 | 0·9 | 60·4 | 2·9 |
| Middle | 29·1 | 1·0 | 35·0 | 0·7 | 34·7 | 0·8 | 33·7 | 0·8 | 25·8 | 2·1 | 34·6 | 0·9 | 33·8 | 0·9 | 25·9 | 2·7 |
| Poorest | 34·5 | 1·7 | 14·2 | 0·6 | 19·6 | 0·8 | 18·6 | 0·8 | 15·8 | 1·7 | 17·5 | 0·6 | 16·6 | 0·6 | 13·7 | 1·6 |
| Rural | | | | | | | | | | | | | | | | |
| *n* | 1323 | | 4312 | | 4068 | | 4943 | | 1729 | | 2342 | | 3399 | | 853 | |
| Mean age (years) | 32·2 | 0·3 | 32·6 | 0·1 | 33·7 | 0·2 | 33·4 | 0·2 | 33·2 | 0·4 | 34·9 | 0·2 | 33·3 | 0·2 | 33·2 | 0·5 |
| Obesity prevalence* | 8·1 | 1·2 | 21·5 | 0·8 | 27·9 | 1·2 | 30·7 | 1·0 | 35·7 | 2·0 | 17·5 | 1·1 | 20·3 | 1·0 | 22·6 | 1·9 |
| Education | | | | | | | | | | | | | | | | |
| ≥High school | 5·0 | 1·0 | 7·1 | 0·7 | 5·6 | 0·6 | 16·0 | 1·0 | 20·5 | 1·8 | 7·9 | 0·8 | 17·9 | 1·0 | 15·9 | 1·8 |
| Secondary | 11·2 | 1·7 | 12·1 | 0·7 | 21·0 | 1·1 | 30·8 | 1·3 | 37·3 | 2·4 | 22·5 | 1·2 | 30·1 | 1·1 | 38·8 | 3·0 |
| Primary | 22·1 | 2·3 | 28·1 | 0·9 | 29·5 | 1··0 | 28·0 | 1·0 | 23·5 | 1·5 | 32·5 | 1·3 | 28·6 | 1·1 | 26·4 | 2·8 |
| <Primary | 61·7 | 4·1 | 52·7 | 1·4 | 43·9 | 1·6 | 25·2 | 1·2 | 18·7 | 2·5 | 37·1 | 1·4 | 23·5 | 1·0 | 18·9 | 2·3 |
| Wealth | | | | | | | | | | | | | | | | |
| Richest | 10·6 | 2·1 | 8·3 | 0·7 | 8·0 | 0·9 | 15·3 | 1·0 | 23·2 | 2·7 | 9·7 | 1·0 | 15·8 | 0·9 | 19·2 | 2·3 |
| Middle | 19·5 | 2·7 | 29·1 | 1·3 | 26·3 | 1·4 | 33·6 | 1·2 | 35·7 | 2·0 | 27·8 | 1·3 | 32·6 | 1·1 | 35·9 | 3·0 |
| Poorest | 69·9 | 4·4 | 62·6 | 1·7 | 65·6 | 1·8 | 51·1 | 1·6 | 41·1 | 3·4 | 62·5 | 1·4 | 51·6 | 1·1 | 44·9 | 3·0 |

Data are presented as percentages with their standard errors except for *n* and age; age is presented as means with their standard errors.
*Age-standardized obesity prevalence.

**Table 2** Distribution of age-standardized obesity prevalence by education level among Mexican men (*n* 20 589) and women (*n* 54 816) aged 20–49 years in urban and rural areas; data from five nationally representative cross-sectional surveys, Encuesta Nacional de Nutrición (ENN) and Encuesta Nacional de Salud y Nutrición (ENSANUT), conducted in 1988, 1999, 2006, 2012 and 2016

| | Women | | | | | | | | | | Men | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1999 | | 2006 | | 2012 | | 2016 | | 2006 | | 2012 | | 2016 | |
| | % | SE | % | SE | % | SE | % | SE | % | SE | % | SE | % | SE | % | SE |
| Urban | | | | | | | | | | | | | | | | |
| ≥High school | 5·1 | 0·9 | 20·0 | 0·9 | 23·6 | 1·4 | 29·3 | 1·2 | 31·5 | 3·5 | 24·5 | 1·4 | 30·9 | 1·3 | 36·8 | 4·5 |
| Secondary | 7·7 | 0·9 | 24·2 | 1·1 | 30·4 | 1·2 | 36·2 | 1·3 | 38·3 | 3·1 | 23·0 | 1·4 | 29·3 | 1·5 | 20·5 | 2·8 |
| Primary | 11·7 | 0·7 | 27·7 | 1·0 | 35·5 | 1·5 | 38·8 | 1·8 | 39·4 | 4·0 | 25·8 | 1·7 | 30·6 | 2·0 | 32·4 | 5·4 |
| <Primary | 10·2 | 0·7 | 33·6 | 1·4 | 37·8 | 1·9 | 37·0 | 2·5 | 49·9 | 6·8 | 19·5 | 1·8 | 23·5 | 2·2 | 39·1 | 8·0 |
| Linear trend | | | | | | | | | | | | | | | | |
| PR | 1·20 | | 1·18 | | 1·15 | | 1·11 | | 1·16 | | 0·97 | | 0·96 | | 0·91 | |
| 95 % CI | 1·10, 1·32 | | 1·14, 1·23 | | 1·11, 1·19 | | 1·07, 1·15 | | 1·05, 1·28 | | 0·91, 1·03 | | 0·91, 1·01 | | 0·72, 1·13 | |
| Rural | | | | | | | | | | | | | | | | |
| ≥High school | 2·8 | 1·5 | 18·2 | 2·2 | 26·2 | 4·3 | 24·3 | 2·1 | 26·5 | 4·4 | 24·7 | 4·4 | 25·5 | 2·6 | 32·0 | 4·3 |
| Secondary | 8·2 | 2·7 | 28·7 | 2·3 | 29·0 | 2·5 | 32·1 | 1·7 | 39·2 | 3·0 | 20·0 | 2·4 | 21·9 | 1·6 | 26·4 | 3·5 |
| Primary | 10·3 | 2·4 | 26·6 | 1·5 | 30·6 | 1·8 | 31·8 | 2·0 | 42·2 | 4·3 | 17·6 | 1·8 | 20·8 | 1·9 | 20·0 | 3·4 |
| <Primary | 7·5 | 1·3 | 19·8 | 1·0 | 27·1 | 2·3 | 31·6 | 2·2 | 37·0 | 5·7 | 14·4 | 1·6 | 15·2 | 2·3 | 16·5 | 3·8 |
| Linear trend | | | | | | | | | | | | | | | | |
| PR | 0·99 | | 0·93 | | 0·94 | | 1·02 | | 1·02 | | 0·88 | | 0·86 | | 0·77 | |
| 95 % CI | 0·79, 1·24 | | 0·87, 0·98 | | 0·87, 1·03 | | 0·97, 1·09 | | 0·91, 1·15 | | 0·78, 1·00 | | 0·78, 0·94 | | 0·64, 0·93 | |

PR, prevalence ratio.

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**Table 3** Association between education and obesity stratified by wealth tertile among Mexican men (*n* 20 589) and women (*n* 54 816) aged 20–49 years in urban and rural areas; data from five nationally representative cross-sectional surveys, Encuesta Nacional de Nutrición (ENN) and Encuesta Nacional de Salud y Nutrición (ENSANUT), conducted in 1988, 1999, 2006, 2012 and 2016

| | Women | | | | | | | | Men | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 (urban) or 1988/1999 (rural)* | | 1999 | | 2006 | | 2012/2016 | | 2006 | | 2012/2016 | |
| | PR | 95 % CI | PR | 95 % CI | PR | 95 % CI | PR | 95 % CI | PR | 95 % CI | PR | 95 % CI |
| Urban | | | | | | | | | | | | |
| Richest | 1·45 | 1·24, 1·69 | 1·25 | 1·18, 1·31 | 1·19 | 1·12, 1·26 | 1·18 | 1·09, 1·29 | 0·99 | 0·89, 1·10 | 1·02 | 0·85, 1·21 |
| Middle | 1·36 | 1·17, 1·59 | 1·18 | 1·10, 1·27 | 1·15 | 1·07, 1·23 | 1·05 | 0·96, 1·15 | 1·03 | 0·93, 1·13 | 1·05 | 0·90, 1·23 |
| Poorest | 0·84 | 0·72, 0·99 | 1·10 | 0·99, 1·23 | 1·15 | 1·05, 1·27 | 1·10 | 1·00, 1·22 | 0·94 | 0·82, 1·08 | 0·84 | 0·70, 1·02 |
| Interaction *P* | <0·001 | | 0·02 | | 0·28 | | 0·22 | | 0·50 | | 0·31 | |
| Rural | | | | | | | | | | | | |
| Richest | 1·21 | 1·06, 1·38 | – | | 1·06 | 0·90, 1·25 | 1·03 | 0·91, 1·16 | 0·85 | 0·68, 1·07 | 0·94 | 0·70, 1·26 |
| Middle | 1·09 | 0·98, 1·22 | – | | 1·01 | 0·88, 1·15 | 1·06 | 0·93, 1·20 | 1·02 | 0·84, 1·24 | 0·78 | 0·66, 0·93 |
| Poorest | 0·83 | 0·72, 0·94 | – | | 0·94 | 0·84, 1·05 | 1·02 | 0·92, 1·14 | 1·03 | 0·87, 1·22 | 0·85 | 0·73, 1·00 |
| Interaction *P* | <0·001 | | – | | 0·02 | | 0·81 | | 0·34 | | 0·70 | |

PR, prevalence ratio.
*1988 and 1999 data were pooled for women in rural areas due to small sample sizes in each cell.

obesity as countries develop but only among women. They challenge this proposition for men[2].

Our hypothesis, that household wealth would be an effect modifier in the association between education and obesity, was supported among women. In the earlier surveys, when absolute poverty was more widespread, wealth was an effect modifier of the association between education and obesity. Education was protective among the relatively richer groups but not among the poorest. The poorest groups were poor in absolute terms that may have meant limited access to foods and high physical activity associated with manual occupations, which 'protected' them from obesity. In the more recent surveys as the country has continued to develop economically, the relatively poorest women have crossed the wealth threshold, which we interpret as women becoming vulnerable to the obesogenic environment. In this situation, education becomes protective for the poor as well as for richer women.

These findings are consistent with Mexican studies conducted among low-income populations[23,24]. Fernald *et al.* reported that education was directly associated with obesity among women living in poor communities in 2003. Our study gives context to Fernald *et al.*'s findings which seemed at odds with contemporaneous Mexican studies using nationally representative data that had found an inverse association between education and obesity. Further, our findings may also explain why no association between education and obesity had been reported in rural areas[8,9] even at levels of gross national income per capita above $US 8000 (significantly above the wealth threshold for the reversal of the social gradient in countries[2]). High income inequality has persisted in Mexico, so it is plausible that a large proportion of the rural population was and is still living in extreme poverty; that is, below the wealth threshold at which they would become at risk of obesity.

Education may affect health directly by affecting a person's receptivity to health education messages and making him or her more prone to healthier behaviours[25]. Education may also be associated with health indirectly by affecting employment prospects, types of occupation and income[26]. Income has been associated with obesity through its conversion into health-enhancing commodities through expenditure[25]. In developed countries, higher income is associated with consumption of healthier more expensive foods[27].

Among men our hypothesis was not supported; there was no evidence of a cross-over to higher prevalence of obesity among less educated men. The literature suggests that the strength of the association between SEP and obesity is weaker for men[1,2] and the country wealth threshold at which the reversal of the social gradient occurs is higher compared with women[2,28]. The absence to date of a cross-over to higher rates of obesity among disadvantaged men is not consistent with the social

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determinants of health model, which suggests that, in general, lower SEP is linked with adverse health status[29]. Usually in more developed countries, disadvantage is associated with adverse living conditions, psychosocial risk factors and unhealthy behaviours which lead to an increased risk of diseases. The social distribution of obesity among men in Mexico, and potentially other similarly developed countries, may be to do with higher physical activity being associated with social disadvantage and thus protecting disadvantaged groups from obesity. Manual jobs such as agriculture in rural areas and building and construction in urban areas are associated with lower education and lower obesity prevalence.

There are policy implications from the present study. First, we have documented a further increase in obesity prevalence among both men and women in the most recent years (2012–2016), with dramatic increases in obesity prevalence among women with less than primary education. This shows that the policies and programmes implemented so far in Mexico, particularly the tax on sugar-sweetened beverages and widespread health promotion campaigns, have not been enough to curb the upward trends. Additional policies and programmes are urgently needed which must take account of the social distribution of obesity prevalence. Both population-wide and targeted interventions to the most vulnerable are needed to address increasing health inequalities. Second, although education is protective of obesity as shown in our study, improving education is insufficient to reverse the increase in obesity prevalence. We have shown large improvements in education over the period 1988 to 2016 and large increases in obesity prevalence. Individual protective factors such as education seem to be eclipsed by obesogenic changes in the food environment. More action on regulating the food environment, including food labelling, food prices, product formulation and marketing, is needed.

### Strengths and limitations of the study

Our study strengths include using nationally representative data from comparable health surveys over a period of 28 years for women and 10 years for men. The length of the period and quality of the Mexican surveys, uncommon in low- and middle-income countries, allowed for the current detailed analysis of the social distribution of obesity which significantly develops the literature on the topic. Trained personnel measured height and weight. Two dimensions of SEP were used, education and wealth, with a clear theoretical underpinning. Our study showed that wealth and education measure different aspects of SEP and were only moderately correlated, potentially due to lower monetary rewards for educational investments in markets that are not fully developed like Mexico's[7]. The low correlation allowed for the study's robust analyses.

Education level is minimally prone to recall bias and is frequently used as an indicator of SEP in low- and middle-income countries; its use allows comparability with previous studies. The wealth index was constructed for the present study using a unified methodology across surveys. Assets and household characteristics were carefully selected based on *a priori* criteria. The index was robust in discriminating across wealth groups as shown in supplementary material 1. In Mexico, the wealth index may provide a more stable and reliable measure of material resources than consumption expenditure since consumption expenditure may be volatile and inaccurate due to economic shocks and seasonality in consumption patterns[30].

The surveys were cross-sectional and therefore have the expected limitations. Exposure, effect modifier and outcome variables were measured at the same point in time. Temporality cannot be established and therefore reverse causality in the associations observed cannot be rejected. However, reverse causality in the association between education and obesity is unlikely. Education is completed in the early years of adulthood while obesity prevalence increases with age[16].

The meaning of education may vary for different cohorts with differing distributions of knowledge, skills and opportunities that affect health[25]. We believe this is unlikely to have affected our findings since a previous study using Mexican data suggested that the protective effect of education was not significantly different for women born earlier in the century (less educated) than later (more educated)[8]. A further limitation of education in the present study is that it was not possible to distinguish between good- and poor-quality education with the available data sets. The quality of education is likely to influence knowledge, cognitive skills and analytical abilities in the health domain[25].

The wealth index measured relative wealth in each survey, but absolute levels of wealth were potentially higher with each subsequent survey. A sensitivity analysis using a wealth index constructed from the same assets and household characteristics across surveys showed similar results (data not shown). It was felt that using survey-specific variables made the index more robust[16]. Related to this point, the wealth threshold referred to herein cannot be specified in monetary or income terms because of its relative nature.

## Conclusion

Obesity prevalence in Mexico continued to increase among all socio-economic groups but the highest burden was among the most disadvantaged women, where almost one in two was obese in 2016. The study showed that upon reaching a threshold level of household wealth, the relatively poorest women became vulnerable to the obesogenic environment. A full reversal of the education gradient is expected among women in rural areas. Among men, obesity prevalence increased over the study period but was not socially patterned by education in urban areas and there was no evidence to suggest emerging inequalities in obesity. In rural areas, there was a direct association between education and obesity among men. These findings underscore the importance of current efforts in public policy to curb the obesity epidemic in Mexico[31] and suggest that more effort is needed to reverse the trends. The findings also identify the most vulnerable groups. Policy makers must keep in mind health inequalities as they design and implement future policies and programmes.


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## Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1368980018001167

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