Socioeconomic inequalities in obesity among Mexican adults 1988-2012

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I, Carolina Pérez Ferrer, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

Background: Obesity prevalence in Mexico has risen substantially over the last 25 years. Its social patterning has not been systematically studied.

Aim: To test the nutrition transition proposition of a crossover from lower to higher rates of obesity among the more disadvantaged groups, leading to emerging and increasing obesity inequalities as Mexico develops economically.

Methods: Data came from four nationally representative surveys (1988, 1999, 2006, 2012); N=51,387 non-pregnant 20-49 year old women and N=18,988 20-49 year old men. Level of education and a household wealth index were used to calculate the relative and slope indexes of inequality (RII and SII respectively). Trends in RII and SII were examined in the period 1988-2012 for women. Change from 2006 to 2012 was examined for men. The contribution of mediating factors to obesity inequality was investigated.

Results: There was support for the nutrition transition proposition among Mexican women. As the country developed economically, obesity became more prevalent among more disadvantaged women. Among men, there was no evidence of a reversal of the social gradient. Higher education and wealth were associated with higher obesity prevalence. Unexpectedly, educational inequalities in obesity among urban women declined over the study period. This was due to faster increases in obesity prevalence among women with more years in education compared to those with less. Psychosocial factors (food insecurity and aspired body size) explained a proportion of educational inequalities in obesity among women. Gender differences in educational inequalities in obesity were partially explained by differences in aspired body size.

Conclusion: This detailed analysis of obesity inequalities in Mexico, and their recent trends, significantly develops existing literature. By using both education and household wealth as markers of SEP, the nutrition transition proposition was investigated in depth. The nutrition transition proposition fits the educational inequality pattern among Mexican women but not men.

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Abbreviations

BMI	Body Mass Index
CESD	Centre for Epidemiologic Depression Studies
CI	Concentration index
CVD	Cardiovascular disease
DHS	Demographic and Health Surveys
FAO	Food and Agriculture Organisation
FFQ	Food Frequency Questionnaire
FSSLC	Food Security Scale for Latin America and the Caribbean
GLM	Generalised linear model
GNI	Gross National Income
HDI	Human Development Index
HIC	High income country
ICESRC	International Covenant on Economic, Social and Cultural Rights
IPAQ	International Physical Activity Questionnaire
LMIC	Low and middle income country
MAR	Missing at random
MCAR	Missing completely at random
MI	Multiple Imputation
MNAR	Missing not at random
NAFTA	North American Free Trade Agreement
OECD	Organisation for Economic Cooperation and Development
PCA	Principal Components Analysis
PSU	Primary sampling unit
RII	Relative index of inequality
SEP	Socioeconomic position
SII	Slope index of inequality
SSB	Sugar sweetened beverages
SSU	Secondary sampling unit
WHO	World Health Organisation

Chapter 1 Introduction, background and literature review

1.1 Introduction

This thesis investigates socioeconomic inequalities in obesity among Mexican adults against a backdrop of important economic and social transitions. Mexico saw significant economic growth, the unfolding of a neoliberal political agenda, education policies, migration from rural to urban areas and radical changes in the food and built environment over the period of study; 1988 to 2012. Obesity arose as one of the key public health problems along with nutrition related chronic diseases which became the most important causes of death.

The nutrition transition literature proposes that the social patterning of obesity is dynamic and closely linked to country economic development. In developed countries obesity tends to be more prevalent amongst those in disadvantaged socioeconomic positions (SEP), while in developing countries there is a direct association between SEP and obesity- increasing prevalence of obesity with increasing socioeconomic advantage (1). There appears to be a crossover to higher obesity prevalence among the most disadvantaged groups as countries develop economically. This thesis will test the nutrition transition proposition among women using four Mexican nationally representative cross-sectional surveys spanning 25 years, from 1988 to 2012 and men using two waves of cross-sectional data spanning six years, from 2006 to 2012.

This study expands current knowledge on the social patterning of obesity in Mexico. Previous studies which have investigated socioeconomic inequalities in obesity in Mexico have used one wave of cross-sectional data. Therefore, they have not been able to trace the nutrition transition. Here, a clear distinction is made between education and household wealth, allowing for a deeper understanding of the nutrition transition process. Further, this thesis distinguishes between people living in urban and rural areas. The level of urbanisation is a moderator in the association between SEP and obesity given the stark differences in economic development between urban and rural areas. Moreover, potential mediators in the association between education and obesity are explored in both men and women. The aim is to better understand the mechanisms causing educational inequalities in obesity. Previous studies of obesity prevalence using Mexican nationally representative data have not investigated this.

In Chapter 1, the Mexican demographic, economic, health and nutrition context is summarised. This section is followed by the rationale for studying obesity inequalities and a conceptual framework for understanding the social determinants of obesity in Mexico. The literature review on the nutrition transition proposition follows, and the chapter ends with a summary of findings and gaps in the research literature. Chapter 2 sets out the objectives and hypothesis for the thesis. Chapter 3 describes the methodology including the data, variables and statistical analyses. This is followed by Chapters 4 through 7 which present the results of original research aimed at confirming or rejecting the hypotheses proposed. The last chapter discusses the findings with reference to the nutrition transition literature and in the light of the economic, cultural and political context in Mexico over the period of study.

1.2 Study context: Mexico

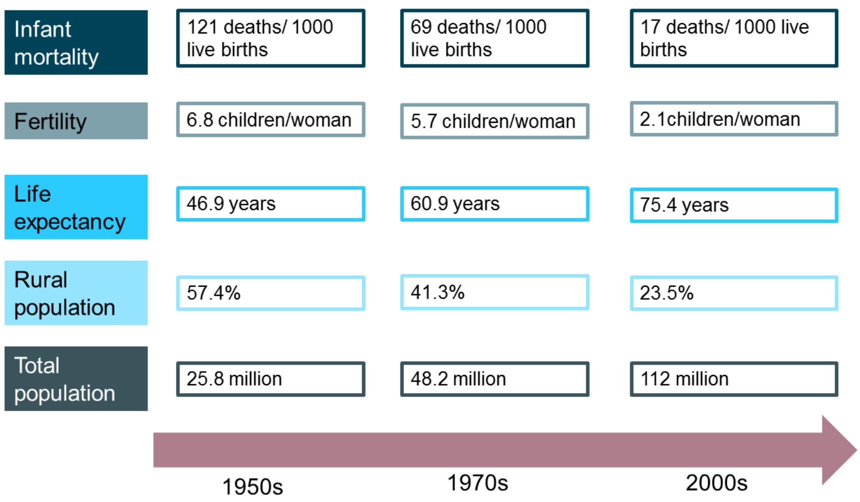
1.2.1 Population and the demographic transition

Mexico is the 11th largest country in the world with a population of 112,322,757 in 2010 (2). The country has experienced a fast paced demographic transition, the shift from high to low mortality and fertility (3, 4). In developed countries the demographic transition began as early as the late 1700s and was characterised by a gradual decline in mortality and fertility over a long period of time (100 to 150 years). In developing countries the demographic transition did not start until the mid-20th century but occurred over a relatively short period of time (4). For example, the death rate in Mexico fell three times as fast as it did during Sweden's demographic transition (4).

Figure 1.1 shows the changes in infant mortality, fertility, life expectancy and total population that occurred in Mexico over a period of 60 years from 1950 to 2012. Mortality declined faster than fertility, leading to more than a tripling in the size of the population. In 2009 fertility had declined to 2.1 children per woman (5), considered replacement level fertility, suggesting the end of the demographic transition and the start of a period of low population growth. Life expectancy had reached 73.1 years for men and 78.8 for women in 2010 (2). Combined life expectancy in Mexico was 2 years longer than in Brazil and 4 years shorter than in the UK in 2012. The demographic transition was fuelled by economic development and by the rapid spread of public health knowledge and practices that became widely available over the transition period. Fertility declines were facilitated by successful reproductive health programmes that increased access to methods of contraception (5, 6).

Urbanisation is common in countries undergoing rapid economic development like Mexico. The rural population has more than halved since the 1950s and accounted for 23.5% in 2005 (defined as the population living in communities with less than 2,500 inhabitants) (Figure 1.1) (2). This has been driven mainly by migration from rural to urban areas. However, Mexico still has the largest rural population of any OECD country (24,276,536 people in 2005). Rural areas encompass more than 80% of the Mexican territory. Despite their importance in terms of geographical area and population size, it is estimated that rural areas contribute a very small fraction of the gross national income (GNI).

Figure 1.1 Demographic transition in Mexico



Data from the Mexican Institute for Geography and Statistics (2)

1.2.2 Economic development and inequality

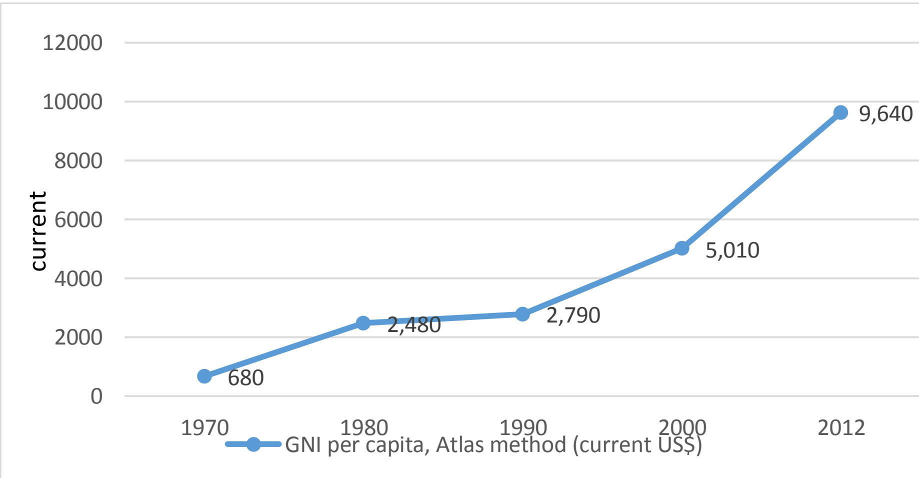
The World Bank classifies Mexico as an upper middle income economy. In 2012 it was ranked the 14th largest economy of the world (7) . Over the past three decades there has been rapid economic growth. The country's GNI per capita increased from 2,480 US dollars in 1980 to 9,640 dollars in 2012 (Figure 1.2) (8).

There is income inequality within the country. Forty two per cent of the population was classified poor in 2006, according to an official definition (9). The Gini coefficient in Mexico was 0.47 in 2012 according to the Wold Bank compared to 0.34 for the UK, 0.42 for China and 0.54 for Brazil (

Table **1.1**). In 2008, the income share held by the most advantaged 10% of the population was 41.4% compared to 1.5% held by the most disadvantaged 10% (10).

Income inequality increased in the period between 1989 to 1994 and declined from 1994 to 2010 (11). The increase in income inequality may have been due in part to labour market policies that disfavoured the low-skilled, for example, a reduction in real minimum wages (11). The decline may have been due to a reduction in wage inequality caused by increases to average wages for low-skilled workers and decreases to average wages for high-skilled workers (11). The gap between the wages of workers with tertiary education and workers with no schooling or incomplete primary school, fell systematically since the early 1990s (12). As a larger proportion of the population achieved higher levels in education as a result of education policies in the early 1990s, there was a larger supply of highly skilled individuals. Demand for highly skilled individuals did not increase as quickly and thus drove down wages. In terms of low skilled workers, demand for them continued to increase as a result of the North American Free Trade Agreement (NAFTA) and the expansion of assembly line activities (*maquiladoras*) in Mexico's manufacturing sector (11). The decline in income inequality may also have been due to a change in social policy from general subsidies to targeted cash transfers (11).

Figure 1.2 GNI per capita in Mexico 1970 -2012



Source: The World Bank (13)

Table 1.1 GNI per capita and Gini coefficient in selected high income and upper middle income countries

Country	GNI per capita** (2012)	Gini coefficient (year)***
United States	52,340	0.45 (2007)
United Kingdom	38,670	0.34 (2005)
Spain	29,620	0.35 (2000)
Chile	14,310	0.52 (2009)
Brazil	11,630	0.54 (2009)
Mexico	**9,640**	**0.47 (2010)**
South Africa	7,610	0.63 (2009)
China	5,720	0.42 (2009)
Morocco	2,960	0.41 (2007)

Source: The World Bank (7, 13)
** US dollars, Atlas method (current US$)
*** Gini coefficient: a value of 0 expresses total equality and a value of 1 maximal inequality (10)

1.2.3 Education policy

Education in Mexico by law is free, non-religious and publicly provided. The public school system enrols 87% of all students in the country (14). It is organised into five levels: 1) preschool, 2) primary education, 3) secondary education, 4) high school (upper secondary education) and 5) higher education. Preschool, primary education and lower secondary education are compulsory.

Up to 1993 only 6 years of primary education were compulsory. In 1993, 3 additional years of lower secondary school became compulsory and in 2005 three more years of preschool were added to basic education. Currently, children in Mexico should study 12 years, from age 3 to age 15 however coverage of preschool is especially poor. The quality of education is very variable and overall poor compared to other countries. In 2012 Mexico was ranked last of all OECD countries on the PISA test score which assesses competencies of 15 year olds in maths, reading and science (15).

A recent nationally representative study on social mobility in Mexico showed that social mobility is poor compared to other countries (16). The correlation between one generation's education level and the next generation's education level is 0.47 compared to 0.31 in the UK. In the extremes of the income distribution there is especially little mobility. Forty eight per cent of adults who were born to parents in the poorest quintile of the wealth distribution remained there. Only 15% of those born in the poorest quintile reached the richer two quintiles. On the other hand, 52% of adults born in the richest quintile of wealth remained there while only 9% moved to the poorest two quintiles.

1.2.4 Health profile

The epidemiologic transition was first described by Omran in 1971 (3) and is characterised by a shift from high mortality, low life expectancy and infectious disease and malnutrition as the main causes of mortality to a period of degenerative and man-made diseases being the most likely causes of death. Mexico is in the age of chronic degenerative diseases however, diseases of poverty and malnutrition still exist in some pockets of the country (17, 18).

Nutrition related chronic diseases predominate as main causes of death (Table 1.2). A third of all deaths are attributable to cardiovascular diseases (CVD) or diabetes. Deaths from diabetes are especially high compared to similarly developed and more developed countries. The age standardised mortality rate for diabetes in Mexico was 83.8 per 100,000 persons in 2008 compared to 5.0 in the UK, 15.2 in the USA and 37.7 in Brazil (19). The CVD mortality rate was 164.8 per 100,000 persons in Mexico higher than 141.7 in the UK, 155.7 in the USA and lower than the mortality rate from CVD in Brazil (237.2 per 100,000 people) (19).

Table 1.2 Main causes of death for women and men, Mexico 2008

	Disease and ICD-10 code	% of total deaths
Women		
1	Diabetes mellitus E10-E14	16.8
2	Ischaemic heart disease I20- I25	10.9
3	Vascular disease (Strokes) I60-I69	6.7
4	Chronic pulmonary obstructive disease J44	3.8
5	Cirrhosis and other chronic diseases of the liver K70, K73, K74, K76	2.9
Men		
1	Diabetes mellitus E10-E14	11.1
2	Ischaemic heart disease I20- I25	10.4
3	Cirrhosis and other chronic diseases of the liver K70, K73, K74, K76	7.0
4	Vascular disease (Strokes) I60-I69	4.6
5	Chronic pulmonary obstructive disease J44	2.9

Ministry of Health, National System for Health Information (20)

1.2.5 The food and built environment

The nutrition transition

The nutrition transition is characterised by a shift from the traditional, low fat, high fibre and high starch diet, to a diet that is high in saturated fat, refined carbohydrates and low in fibre. As part of this transition, physical activity declines as it coincides with industrialization and urbanisation. There is a shift too from a high prevalence of undernutrition and micronutrient deficiencies to a high prevalence of obesity (21).

The nutrition transition literature proposes that in the early stages of the transition, obesity is more prevalent among the more advantaged groups. As the transition advances and countries develop economically, there is a crossover to higher rates of obesity among the more disadvantaged groups and inequalities emerge and widen. This change in the social patterning of obesity linked to economic development will be called the 'nutrition transition proposition' throughout this thesis. The literature review in section 1.5 page 30 summarizes the current literature around this proposition and identifies the gaps.

Mexico is undergoing a nutrition transition alongside its epidemiological transition. While undernutrition has declined to a very low prevalence (2% in adult women), obesity prevalence has trebled in the period between 1988 and 2012. In 2006 Mexico had the second largest prevalence of obesity after the USA among OECD countries at 32% among adults (22).

Changes to the food and built environment fuelled by economic growth, technological change, globalisation and macro level policies underlie the nutrition transition (23, 24). The environment is defined as macro and community level factors, including physical, cultural, economic and policy factors that influence household and individual decisions (24). This section will describe changes to the food and built environment in Mexico over the last 25 years and related changes to the diet and physical activity patterns.

Economic policy and trade agreements

In the 1980s, a neoliberal political ideology was adopted by Mexico's government which continues to this day (25). In 1994 the North American Free Trade Agreement (NAFTA) was signed between Canada, USA and Mexico. Among other things, NAFTA led to radical changes in food policy especially around availability and price of food. Food subsidies to low income sectors were diminished, foreign investment in the Mexican food processing industry was incentivised, as well as growth of multi-national retailers (26).

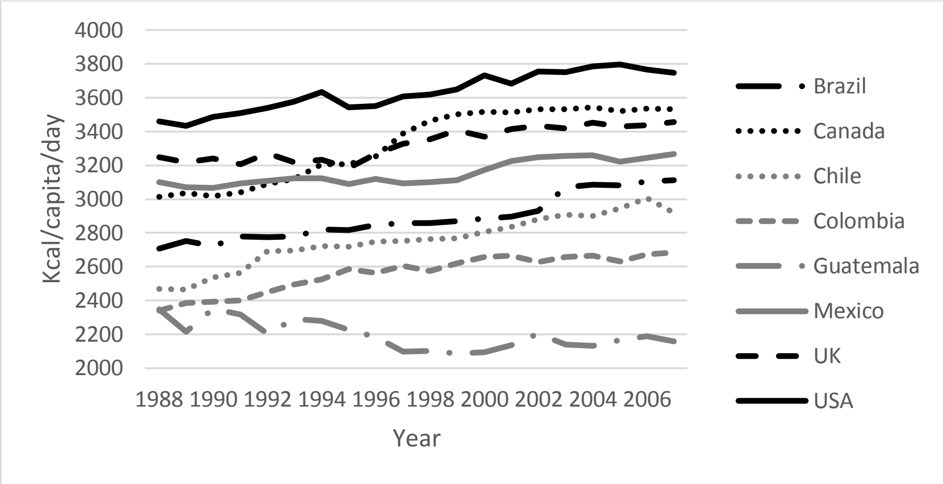
Foreign direct investment in the food industry was 25 times larger in 1999 than it had been in 1989. Sales of processed foods expanded between five and ten percent per year between 1995 and 2003. Baked goods, snacks and dairy products saw particularly large rises in sales (26). The increase in food retailing helped the growth and spread of the processed food market making it available to even the most remote communities (26). The number of chain supermarkets and convenience stores increased from less than 700 in 1997 to 5,729 in 2004 (26). NAFTA and the liberalisation of the Mexican economy in the 1980s may partly explain the increase in calorie availability and the diversification of the food supply observed over the last three decades.

Trends in energy availability in middle and high income countries generally show an increase which appears to parallel the rising prevalence of obesity (27). Energy availability in Mexico increased by approximately 164 kcal per capita per day from 1988 to 2007, a period when obesity prevalence increased significantly (28, 29). Figure 1.3 shows how Mexico's food supply was higher than that in other Latin American countries but lower than that in the USA, Canada and UK (28).

The increase in total energy availability (kcal per capita) over the period 1988 to 2012 (Figure 1.3) may not appear so large however the types of food providing the calories changed significantly. The supply of vegetable oils, sugars and sweeteners, and meat, especially chicken increased while the supply of staple foods such as maize and beans was constant or decreased in the same time period (28). The country's fat supply increased from 85 grams per person per day in 1988 to 96 grams per person in 2007 a 13% increase (Figure 1.4).

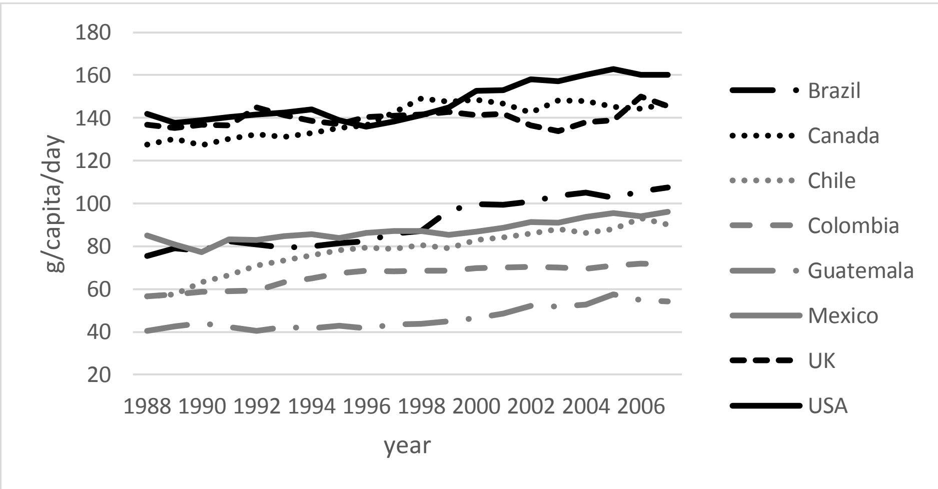
Changes in the Mexican diet were consistent with trends in the food supply. The percentage of total energy from fat in the diet increased from 23.5% to 30.3% from 1988 to 1999 (30). During the same period, the percentage of total energy from carbohydrates decreased. Adults obtained 22.3% of their energy intake from energy containing beverages in 2006 (31).

Figure 1.3 Food supply in selected countries (kcal/capita/day)



Source: FAO, food balance sheets (28)

Figure 1.4 Fat supply in selected countries (g/capita/day)



Source: FAO, food balance sheets (28)

Food prices

Drewnowski argues that food purchases and consumption are strongly influenced by food prices and people's incomes and that this explains a large proportion of the inequalities in obesity (32). In the USA and other developed countries, energy-dense foods composed of refined grains, added sugars, or fats may represent the lowest-cost option to consumers. An important difference between high income countries (HIC) and low and middle income countries (LMIC) is that the traditional diet continues to exist as a cheap alternative to energy dense processed foods.

The evidence for Mexico suggests that similar to developed countries some healthier foods may be more expensive than unhealthier ones (33-35). For example, in 2004, 100 kcal of vegetable oil cost Mex$0.98 compared to Mex$1.99 for 100kcal of fresh oranges (36). However, the traditional diet, which is low in fat, high in fibre, albeit not varied, continues to be a healthier, cheaper alternative to industrialised processed foods. One hundred kcal of tortilla cost Mex$0.58, 100kcal of beans cost Mex$0.40 (2014 prices for beans and tortillas).

According to Drewnowski, it would be expected that at the lower end of the socioeconomic distribution, the traditional cheapest diet would continue to be preferred over more expensive alternatives. This does not appear to be the case. A study that investigated the effect of the 1994 economic crisis on food purchasing behaviours in the Mexican population found that despite economic hardship, families increased their purchases of relatively expensive foods such as soft drinks and industrialised meat and decreased their consumption of cereals and other cheaper foods (25). Further, food price trends suggest that fruits and vegetables became cheaper over the period 1990-2004 while cost of fats and sugars including soft drinks increased (36). Consumption data suggests that the purchase of fruits and vegetables decreased while the purchase of sugary sweetened beverages increased by 37.2% in the period between 1984 and 1998 (30).

At the higher end of the socioeconomic distribution, it would be expected that individuals would opt for more expensive healthier diets. There is little evidence that this occurs in Mexico. In an anthropological study, more advantaged families from Mexico City identified a healthy diet as one that included fresh and natural foods and was 'not fattening'. However, their food diaries over three days did not reflect this health concept (37). The diets of the more advantaged families were as high or higher in fats and sugars than those of the more disadvantaged who did not have the same concept of a healthy diet. Further, convenience stores targeting the upper middle income urban population and selling primarily energy dense foods and beverages, grew at a rate close to 1000 new stores per year during the 1990s and 2000s (26).

Cultural factors with respect to food

Cultural factors with respect to food are likely to play an important role in food decisions which go over and above affordability. Anthropological studies, carried out in Mexico, suggest that there is status attached to some energy-dense foods and beverages. For example, indigenous groups (often very poor) tended to change cheap traditional foods for processed more expensive foods in order to feel more integrated to the wider society (37). Soft drinks were perceived 'bad for health' but were widely consumed because they were a symbol of hospitality, being generous and prestige in a small community in the state of Mexico. Residents of this community had access to free clean water (from a local natural spring) but preferred buying and drinking coke (38).

These findings resonate with those of Blaxter, in which the reasons why English non-manual workers had a healthier diet than manual workers were not explained by differences in beliefs about what a healthy diet was or how important it was (39). Social differences in the adoption of a healthy lifestyle may not be a result of beliefs about health itself; they may be part of what is viewed as appropriate behaviour for 'people like us'. In other words, behaviours that are adopted as part of a process of social distinction (40).

Marketing and advertising

Food decisions are influenced by aggressive marketing and advertising strategies of the food industry. Food advertising during TV viewing has been shown to contribute to obesity by triggering automatic snacking of available food (41). Marketing and advertising of energy dense foods have not been formally regulated in Mexico. A study found that food advertisements made up one fourth of all advertisements seen by children in Mexico. This study monitored the programming of 11 broadcast channels over a period of four months in 2007 (42). Foods more commonly advertised were sweetened beverages, sweets and cereals. Food items were usually linked with positive emotions (42).

Mexican adults reported watching TV as their most frequent leisure time activity (43). This was the case for all education groups with the exception of people educated at university level. It is likely that most of the population is being exposed to thousands of food adverts per year. Food choices are probably highly influenced by marketing and advertising and therefore by the food industry's agenda which is about selling more food.

Environmental factors affecting physical activity

The decline in work related physical activity due to technological change may explain part of the increasing trends in obesity prevalence as countries develop (23, 44). Economic development leads to changes in the strenuousness of work, both at home and in the work place (23). In Mexico in 2012 only 13.5% of the population was employed in the primary sector, doing manual jobs such as agriculture, fishing and mining, compared to 61.8% employed in the service sector consisting mainly of sedentary occupations (43). Further, increasing levels of car ownership (as are shown in Appendix 3), increasing time spent watching television and using computers have likely contributed to declines in physical activity.

Mexican cities are characterised by city centres where economic activity takes place but people do not live. As cities grow, people move out of the centres towards the suburbs. Commuting distances are usually long and people must rely on public or private transport rather than walking or cycling.

Nutrition specific policy

Policy targeted at unhealthy eating is very recent. Up to 2009, there had only been health and nutrition education programmes, for example, through the conditional cash transfer programme *Oportunidades* which targeted mainly the low income rural population. In 2009 the federal government's strategy to tackle overweight and obesity was drawn up (45). It listed ten objectives which target physical activity and different aspects of diet and sets out responsibilities for stakeholders including the food industry, the local governments and civil society. It calls on tackling obesity from a food availability, access, nutrition knowledge and *personal options* perspective. As such, it proposed actions such as increasing the availability of water in schools, working with industry to reformulate foods, consumer friendly food labelling and promoting exclusive breastfeeding for 6 months. Inequalities in obesity are not explicitly mentioned in the document. In addition several of the policy objectives focus on personal choice and health behaviours which may lead to increasing inequalities given that higher SEP groups might adopt recommendations sooner. Since 2009, there have been several policies implemented with the aim of preventing obesity; for example the regulation of foods sold in schools in 2010, taxing sugary sweetened beverages in 2014 and making it compulsory for schools to have drinking fountains.

1.3 Education and wealth as indicators of socioeconomic position

Socioeconomic position (SEP) refers to "the social and economic factors that influence what positions individuals or groups hold within the structure of a society" (46). Three indicators of SEP have been used most often in epidemiological research: occupation, education and a measure of material standard of living for example income or wealth. These measures tap into underlying constructs that may influence health differently (39). This section will focus on education and wealth given that these are the SEP indicators most often used in LMIC and which will be used in this thesis.

Education is a resource which confers knowledge and skills to the individual. 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 (46). Previous research has shown that differences in health knowledge, explain part of the relationship between schooling and behaviours such as smoking and taking up exercise (47, 48).

Further, the amount of education and knowledge a person gains will influence their social networks and status in society. Status determines patterns of consumption, lifestyles and habits of taste which may in turn affect body weight (49). This is in line with Pierre Bourdieu's concept of 'habitus' which refers to the embodiment of social structures (1, 40). Habitus shapes and produces behaviours. This is relevant in the context of the social determinants of obesity because cultural norms about thinness and attractiveness vary by status group (1, 50). Status groups will therefore adopt different behaviours and lifestyles according to their cultural norms to ensure they set themselves apart from other groups. The body, inclusive of appearance, style and behaviours, can be thought of as a social metaphor for a person's status (1).

Education may also be associated with health indirectly by affecting employment prospects, types of occupation and shaping life chances (49). More educated people are more likely to be employed in full time jobs, to be more fulfilled at work and to have more job security than less educated people (51). Employment has been associated with well-being and lower BMI while unemployment has been associated with ill health and higher BMI (52). Work stress and job insecurity have also been negatively associated with health (53, 54). A second indirect pathway by which education affects health is by impacting on income and protecting from economic hardship. In rich countries, empirical evidence suggests that an additional year of education increases earnings by on average 8% (55). Economic hardship might make people feel depressed and hopeless which in turn may affect health behaviours such as physical activity and healthy eating (56, 57). Income has been associated with health and obesity through its conversion into health enhancing commodities through expenditure (46). For example, in developed countries, higher income is associated with consumption of healthier more expensive foods (32). Education has therefore the potential to affect health 'twice over'; directly and independently of income and indirectly through employment and income (55).

The strengths of education as a measure of SEP include that it is commonly collected in health surveys and therefore commonly used in epidemiological studies. Its use allows comparability with other studies. It is also less prone to recall bias and more reliable over time than other SEP measures such as income. For example, there was 89% agreement across three data collection points for education and a 27% agreement in the same study for income (58).

The limitations of using education as a measure of SEP include that it is strongly determined by parental SEP. As such education captures both early life SEP – material, intellectual and other resources of family origin, and own SEP potential (46, 51). The association between education and health may be confounded by the household of origin's socioeconomic position. Further, because education is completed at an early age, it has shortcomings as a measure of adult SEP because it is not sensitive to subsequent changes in SEP (59).

Another limitation of education as an indicator of SEP is that its meaning may vary for different birth cohorts. Older cohorts will be over represented among those classified as less educated because educational attainment has improved over the years (46). Further, quality of education or the curriculum may have changed throughout the years. Knowledge and skills learned in education may differ for older and younger generations.

The material aspect of SEP may be measured with different indicators for example income, consumption expenditure and/or an asset based index. Income is difficult to measure accurately because it tends to fluctuate from season to season; especially in developing countries where self-employment, and agriculture are common (60). Consumption expenditure is time consuming to collect, is prone to recall bias and is not commonly used in epidemiologic studies. For these reasons, an index constructed by combining household assets and household characteristics has been widely used as a proxy for consumption expenditure in low and middle income countries (61, 62). Asset ownership is likely to be based at least partially on economic wealth and unlikely to change in response to short term economic shocks (63). Measures of household quality and ownership of assets are commonly collected in health surveys and are minimally prone to recall bias.

The asset index is commonly referred to as a 'household wealth index' in epidemiological studies. Because it is used as a proxy for consumption expenditure, household wealth is thought to be associated with health through consumption of health enhancing commodities and services (46). A higher household wealth may signify that economic resources have been available to the household to be spent on healthy food for example.

Education and wealth are usually highly correlated however the assumption that education leads to higher wealth and higher occupational standing does not always hold. Firstly, the returns to education may have declined over time as the number of highly skilled jobs have not increased as fast as the supply of highly skilled individuals as occurred in Mexico (11). Secondly, in LMIC, a large proportion of the population works in the informal economy. Formal qualifications are less likely to be necessary for economic success in these settings. Thirdly, monetary rewards for the same level of education differ considerably by sex. Women with the same educational qualifications than men tend to earn less. The correlation between wealth and education appears to be less strong in LMIC than in HIC (64).

1.4 Socioeconomic inequalities in obesity

1.4.1 Why study inequalities in obesity?

The World Health Organisation constitution states that “the enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being without distinction of race, religion, political belief, economic or social condition”(65). This statement is made legally binding by Article 12 of the UN International Covenant on Economic, Social and Cultural Rights (ICESCR), a multilateral treaty which came into force in 1976, which reads “the states parties to the present covenant recognise the right of everyone to the enjoyment of the highest attainable standard of physical and mental health…”(66). This is what is normally referred to as the *right to health*. Governments are therefore responsible for the health of their population and that extends beyond the provision of essential health services to tackling the social determinants of health such as adequate education, housing and food (66). The Commission on Social Determinants of Health emphasised that where inequalities related to health were avoidable, yet not avoided, taking action becomes a matter of social justice (67).

Obesity is associated with cardiovascular disease (68, 69), diabetes (70), some cancers such as oesophagus, pancreatic, colorectal and postmenopausal breast cancer, (71) and mortality (72). The public health implications of increasing obesity prevalence globally are therefore staggering. In five out of the six world regions recognised by the World Health

Organisation, deaths caused by chronic diseases dominate the mortality statistics (73). It has been projected that by 2020, chronic diseases will account for almost three quarters of all deaths worldwide with the majority of deaths occurring in developing regions (73).

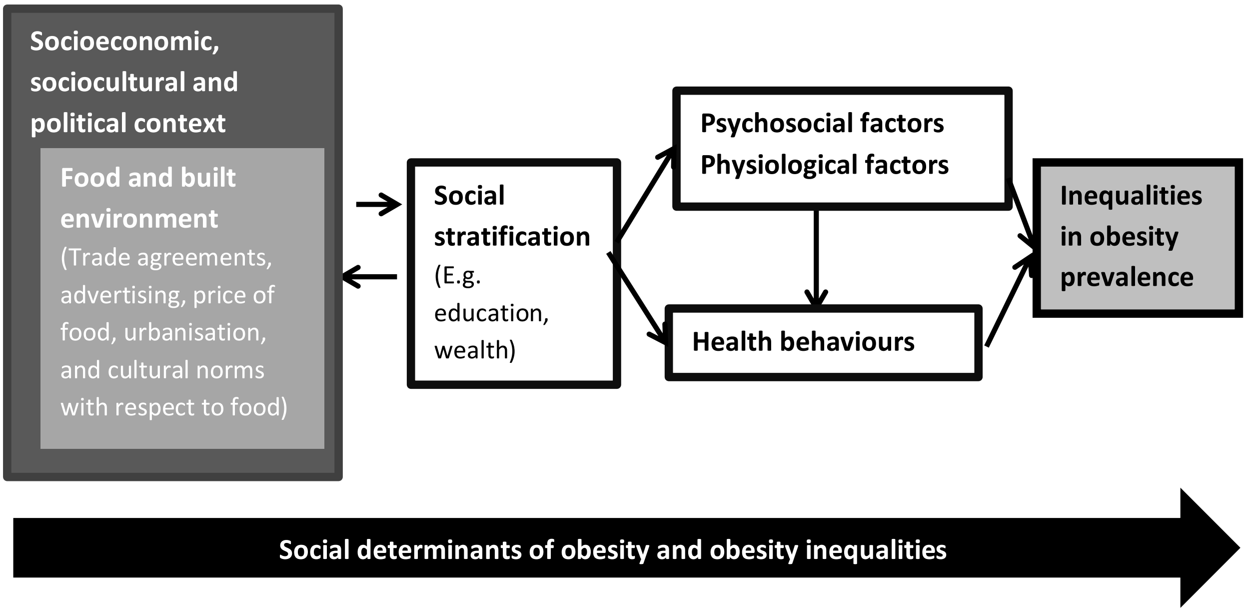
Mexico has signed and ratified the ICESCR and thus has committed to improve the health of its population in an equitable way. As described in the context section of this thesis, page 17, obesity and its related comorbidities are probably the most pressing public health problem in Mexico currently. Therefore, measuring social inequalities in obesity is key to understand which groups must be prioritized in order to prevent obesity and its comorbidities equitably. Likewise, a better understanding of the mechanisms generating inequalities in obesity is crucial to develop effective preventive strategies.

1.4.2 Conceptual model for obesity inequalities

Figure 1.5 shows the model for the social determinants of inequalities in obesity that was used to underpin the analyses in this thesis. It is based on the framework proposed by the Commission on Social Determinants of Health (67) and Friel, *et al* (74). The structural determinants (dark grey box) of obesity inequalities are the socioeconomic, socio-political and sociocultural factors which predominate in a country or society. These factors will define both the equitable or inequitable distribution of power, money and resources which drive conditions of daily living and will shape the food and built environment. These factors cannot be measured at the individual level but are crucial for understanding how and why a society is socially stratified. Structural factors will also help explain why disease patterns have changed and why people behave the way they do.

Structural drivers for obesity inequalities in Mexico were discussed earlier in this chapter. They include economic growth, income and social inequality, a neoliberal political agenda, influential trade agreements and urbanisation which have led to changes in the food and built environment and the nutrition transition.

Figure 1.5 Adapted social determinants of health model (67, 74, 75)



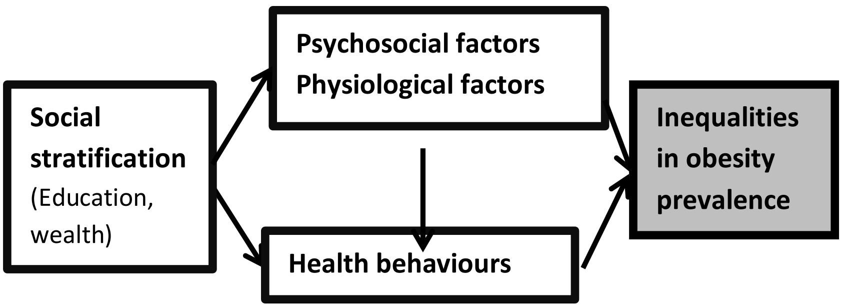
The next three boxes in the model with a white background refer to individual level factors. Social stratification will act as a moderator of the effect of structural determinants on body weight. In other words, people will have differential exposures to risk factors because their social position will affect where they grow, live, work and age (67). The intermediate determinants refer to the pathways by which socioeconomic position affects health. These are grouped into psychosocial factors and biological factors which may affect body weight directly or by influencing health behaviours such as diet and physical activity.

Behavioural factors are commonly placed alongside psychosocial and physiological factors (75). This approach ignores the reasons why health behaviours may vary systematically between socioeconomic groups and alludes to what Bartley has called the *direct behavioural explanation* (39). This explanation assumes that disadvantaged individuals are less endowed with some type of personal characteristic, such as intelligence or coping skills; therefore, they are less able to grasp health education messages or to exert self-control leading to unhealthier behaviours. Although this thesis will not be able to test the pathways as illustrated in Figure 1.5 (because it uses cross-sectional data), it conceptually acknowledges that health behaviours such as diet and physical activity are not socially patterned because of personal characteristics but rather because of other factors i.e. psychosocial including cultural norms and physiological factors (48, 76).

Health behaviours such as diet and sitting time have been found to explain a small proportion of the social inequalities in BMI in developed countries (77-79). In the Whitehall cohort, change in BMI was socially patterned by occupational grade. Behavioural factors such as diet, physical activity, smoking and alcohol consumption explained around 20% of the gradient (80). Ward *et al* concluded that fruit and vegetable intake contributed marginally to the inverse association between education and high risk adiposity among Canadians (79). This suggests that there may be additional mediators in the association between SEP and obesity which are independent of health behaviours. The conceptual framework in Figure 1.5 reflects this. For example it is suggested that psychosocial factors may influence body weight independently of health behaviours perhaps by influencing neuro-endocrine mechanisms.

This thesis will investigate the causal pathways illustrated in Figure 1.6. Given the cross-sectional nature of the data available, this study is limited to investigating association rather than causation. The thesis examines the social patterning of obesity by education and wealth over the period 1988 to 2012. Further it investigates the social patterning of obesity risk factors in the Mexican population. Results of individual level associations will be interpreted in the context of the nutrition transition literature and in light of the Mexican political, cultural and economic context at different points in time.

Figure 1.6 Causal pathways explored in this thesis



Men and women aged 20 to 49

The thesis focuses on men and women aged 20 to 49. Traditionally health and demographic surveys focused on *women of reproductive age* and children, such is the case of the demographic and health surveys carried out in many LMIC and of the 1988 and 1999 Mexican surveys used in this study.

The health and nutrition status of women in this age group has been of interest because of its impact on the nutrition and health outcomes of future generations. When nutrition surveys began, the main concerns were the effects of under-nutrition and micronutrient deficiencies among mothers and children. While micronutrient deficiencies persist in some pockets of the population in middle income countries, under-nutrition among adult women is no longer a public health problem. However, the study of women of reproductive age continues to be important because overweight and obesity also have an impact on the nutrition and health status of future generations. Overweight and obese mothers are at higher risk of having high birth weight babies. High birth weight increases the risk of obesity in children and of diseases such as diabetes in adulthood (81). Maternal overweight has been associated with childhood overweight and obesity (82). Further, as has been described already, the study of obesity among adults is important because obesity is a risk factor for multiple chronic diseases which cause disability and cut short life expectancy. Obesity is therefore a huge burden for health systems and a priority public health problem. Men aged 20 to 49 from the 2006 and 2012 surveys were selected in order to allow comparisons with women. Men were only measured in these two last surveys.

1.5 Literature review on the nutrition transition proposition

This section reviews the literature on the nutrition transition proposition of a crossover to higher rates of obesity among the most disadvantaged groups as countries develop economically. The review focuses on the association between SEP and obesity in adults globally, in the Americas and in Mexico. It specifically highlights studies where education or wealth were used as measures of SEP. The literature review search methodology and table of relevant papers can be found in appendix 1.

1.5.1 Reviews and multi-country studies

Sobal and Stunkard published a landmark review paper in 1989 which presented findings of 144 studies and concluded that in developed countries, obesity was associated with low socioeconomic position (SEP); whereas, in developing countries, the opposite occurred, a direct association between SEP and obesity was found (83). These findings were particularly clear for women but not for men where half of the studies from developed countries found either no association or a direct association between SEP and obesity. This review did not distinguish between SEP indicators used in the original studies (83). Other more recent reviews have updated and supported Sobal and Stunkard's findings and have provided more insight into the meaning of different SEP indicators at different levels of economic development (1, 84-86).

After Sobal and Stunkard's review, McLaren provided the next most comprehensive review of the literature in 2007 including papers from 1988 to 2004. She classified countries by the human development index (HDI) instead of gross national income (GNI) per capita. Her findings mirrored those of Sobal and Stunkard; as one goes from countries with high to medium to low HDI, the proportion of direct associations between SEP and obesity in adult women increased. This pattern was more consistent for education than for any other indicator of SEP. For example, among women from countries with a high HDI, 1% of all associations between education and obesity studied (n=305) were direct. Among women from countries with a low HDI, 100% of associations between education and obesity (n=31) were direct. The association between income and obesity was less consistent even in high HDI countries. Forty five per cent of all associations between income and obesity in high HDI countries were non-significant or curvilinear. In low HDI countries, 50% were non-significant or curvilinear. Among men, there appeared to be a similar pattern of declining direct associations as HDI increased however there was a much larger proportion of non-significant or curvilinear associations both with education and wealth at all levels of HDI (1).

There have been several multi-country studies investigating the association between SEP and obesity. Most of these use demographic and health surveys (DHS) and are thus limited to women from low and lower middle income countries. As such they are unable to explore the association between SEP and obesity along the entire continuum of economic development or among men. In general these studies support the reviews' findings especially when education is used as the SEP measure. The strength and direction of the association between obesity and education tends to be related to country GNI per capita. In very poor countries, such as those in Sub-Saharan Africa, obesity levels tend to be low and to have a direct association with education while in more developed countries, such as some in Latin America and Central Eastern Europe, obesity levels tend to be high and to have an inverse association with education (87, 88). A further study of this type from Subramanian *et al* which included 54 low and lower middle income countries investigated the association between household wealth and BMI (89). It concluded that obesity was still concentrated among the wealthy in LMIC perhaps because food was still relatively expensive and or because of cultural factors favouring larger body sizes. The discrepancies in findings between studies using different indicators of SEP are likely due to the different meaning of each indicator.

Marmot *et al* described the reversal of the social gradient in heart disease in England in a paper published in 1978 (90). They documented how heart disease mortality went from being higher among men from higher social classes to being higher among those from lower social classes. The reversal of the social gradient has since been described for many diseases in diverse geographic regions. Economic development plays a role in the timing of the reversal as has been suggested by the reviews on the association between SEP and obesity described above. As country GNI increases, the burden of obesity tends to shift towards the more disadvantaged groups (84).

The crossover to higher rates of obesity among women of low SEP has been said to occur at a GNI per capita (Atlas method) of about US$2,500 (84, 88). This figure has been widely cited in more recent research; however, it was derived using only 14 studies from LMIC, eight of which were not nationally representative. In addition, it does not distinguish between measures of SEP; therefore, it is likely that this economic threshold may be different depending on the SEP indicator used. The US$2,500 figure has been disputed by a review of more recent studies which identified a lower level of GNI per capita at which the shift occurs (approximately US$1000) (86).

It has been proposed that the reversal of the social gradient for men occurs at higher levels of development than for women (84, 91). However, the evidence to support this claim is not strong. Figure 1.7 from Monteiro's review of LMIC studies illustrates how as countries develop economically, the relative risk (RR) of obesity of more disadvantaged groups increases compared to those from more advantaged groups (84). Although, the figure illustrates a similar trend in the RR for men than women, the regression line for men is heavily influenced by outliers. Further, if confidence intervals had been included for the different points in the figure they would have revealed that estimates above the null (RR=1) for men were not statistically significant. Out of the 14 studies included in this review from LMIC, none found an inverse association between SEP and obesity among men (84).

Figure 1.7 Relative risk (RR) of obesity among men and women of lower socioeconomic status (SES) regressed on the gross national product (GNP) per capita in developing societies (1982-2002)

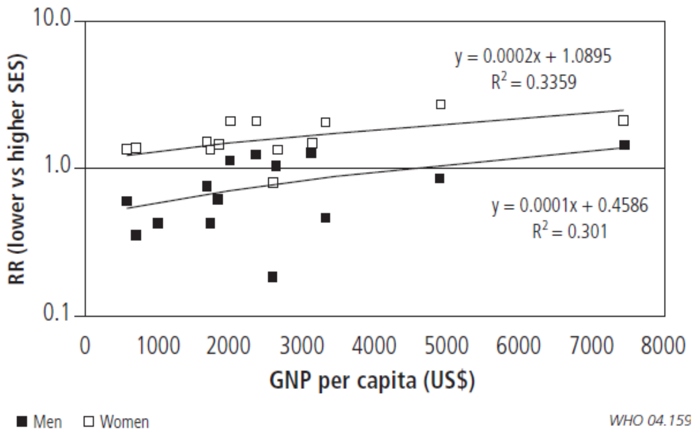


Figure from Monteiro CA, Moura EC, Conde WL & Popkin B (2004) Bulletin of the World Health Organisation (84)

The process leading to the reversal of the social gradient among women has been partially explained by two multi-country studies which included at least two repeated cross-sectional surveys for 39 countries. Country level GNI was directly correlated with faster prevalence growth of overweight for the lowest (vs highest) wealth quintile but not for the lowest (vs highest) education group (92, 93). These findings may explain the reversal of the wealth gradient. By using two repeated cross-sectional surveys for each country, authors were able to suggest that the findings by Subramanian that suggested that obesity was still a condition of the elite in LMIC were dynamic (89). However they did not explain the reversal of the education gradient. These studies are limited by the selection of countries that cluster in the poorer end of the GNI distribution. This may be the reason, for a pattern not being observed using education as SEP measure.

There are several explanations for the reversal of the social gradient in obesity. Most are rooted in the process of the nutrition transition whereby food was scarce and not varied in the earlier stages of the transition affecting disadvantaged populations disproportionately and therefore 'protecting' them from obesity. As countries develop and economies become largely based on service industries, most can afford high-calorie foods and avoid physical labour. Living conditions improve and food availability, accessibility and diversity increases therefore disadvantaged populations become at risk. At the same time, more advantaged groups may become more health conscious and western ideas of attractiveness associated with thinness may set in. This may protect advantaged groups from obesity.

The nutrition transition proposition of a reversal of the social gradient has been recently questioned. Early studies of the association between SEP and obesity appeared to find more marked patterns by level of country development than more recent ones. For example, Sobal and Stunkard found 85 per cent inverse associations between SEP and obesity among women from developed countries. In the more recent review by McLaren the proportion of inverse associations among women from high HDI countries was 59 per cent (1, 83). This may be attributed to the widespread and relatively non-discerning nature of the current obesity epidemic where all SEP groups are affected to some extent (1). The global environment of food production and consumption is likely to have population wide impacts that distinguish less between SEP groups.

The assumption that inequalities widen after the reversal of the social gradient has also been questioned. For example, in the United States and Canada the inverse association between SEP and obesity attenuated over the 1980s and 1990s especially among women (94, 95). This was due to greater increases in the prevalence of obesity in more advantaged compared to less advantaged groups (94-97). In the USA, the timing of the decline in obesity inequalities coincided with large increases in the prevalence of obesity. It has been suggested that social-environmental factors affecting the entire population distribution downplay the effect of individual characteristics such as SEP (94).

The great majority of studies which have investigated the association between SEP and obesity have done so using cross-sectional data especially in LMIC. Reverse causality, for example, that findings are due to obesity leading to poorer economic outcomes cannot be ruled out. One review in particular, focused on longitudinal studies exploring the association between SEP and weight gain in adulthood (85). All studies included came from developed countries. Education was inversely associated with weight gain especially among women but there was also some evidence of this among men (50% of associations inverse 50% no association). Income was not associated with weight gain (85). Observed cross-sectional associations may be attributable to greater weight gain throughout adult life among those of lower education.

1.5.2 Studies from Latin American countries

To contextualize Mexican findings in the Latin American region, studies on obesity trends and the association between obesity and SEP were retrieved for South and Central American countries. Except for Brazil that has a rich literature on socioeconomic inequalities in nutrition outcomes from 1975 to date, there is limited information for other countries. There is a lack of nationally representative surveys or a lack of consecutive comparable surveys to study trends.

Repeated cross-sectional surveys in Brazil showed that from 1975 to 2003 there was a general increase in obesity prevalence in women from 7.4% to 13.0% and underweight prevalence was nearly halved (98-100). The middle income groups had the highest rates of obesity especially between 1975 and 1989 (99). Obesity tended to increase more among lower income women than higher income women during the late 70s and early 80s. In more recent years increases in obesity prevalence rates were restricted to women from the two lower income quintiles (99, 101).

Brazil's findings were consistent with the hypothesis of a threshold at which a crossover to higher rates of obesity among women of low SEP is said to happen (GNI per capita of US$2,500). Brazil's GNI per capita was less than $2,500 in 1975 when a direct association was observed between SEP and obesity. In the period between 1989 and 2003, obesity shifted to the poor and the association between SEP and obesity became inverse (88). GNI per capita was $2,870 in 1991 and $3,290 in 2001.

Other Latin American countries studied include Chile where an inverse association between a composite SEP index and obesity was reported in the city of Santiago in 1987 (at a GNI per capita of just over $2,500) (102) and similarly in the city of Valparaiso in 1997 (84) (at a GNI per capita of $4,970). In 6 cities in Peru in 1998 an inverse association with education was also observed at a GNI per capita level of $2,090 (103). Unfortunately there is no information about trends for these or other countries in Latin America to be able to trace the transition. Further these studies were not nationally representative and did not examine the social patterning of obesity in poorer rural areas. GNI per capita in the urban areas studied was likely to be higher than national GNI per capita.

In less developed countries such as Bolivia, Guatemala and Nicaragua a very clear direct association was seen between obesity and a wealth index (92). The burden of obesity appeared to be switching to the poor in Bolivia (change from 1994 to 2003) but not in the other countries (92). It is important to note that these studies have used a composite wealth index which differs from the SEP measures used in Brazil (income) and other countries where education was used. It is possible that an inverse association with education exists while there still is a direct association with wealth (104).

1.5.3 Studies from Mexico

Five studies were identified in which Mexican nationally representative data were used to investigate the association between SEP and obesity among adults. Only two of these included men. Each of these five studies used one wave of cross-sectional data, the most recent being a 2001 survey. Studies that were not nationally representative, but investigated the association between SEP and obesity in rural areas or lower income populations in Mexico were retrieved to complement the literature review.

Studies from nationally representative samples

The first nationally representative health surveys in Mexico were carried out in the late 1980s. Studies investigating the association between SEP and obesity in these first surveys suggested that the reversal of the social gradient in obesity had already occurred among Mexican women. Studies also showed a clear inverse association between education and obesity but not between wealth and obesity. Martorell used the 1987 Mexican DHS for women of reproductive age and found that women with secondary or higher education had an odds ratio of being obese of 0.58 ($p<0.001$) compared to women with none or primary education after adjusting for age, area of residence and a wealth index (87). Obesity was almost equally distributed across tertiles of a wealth index (87, 105). Monteiro produced similar findings using data of women aged 20 to 49 from the 1999 Mexican Nutrition Survey (88). Women in the highest education quartile had a prevalence ratio of 0.82 (95% CI 0.77, 0.88) of being obese compared to the lowest education quartile (88). These two studies did not stratify by urban or rural area and were limited to women of reproductive age.

A study using nationally representative data from 2000 improved the design of previous studies by investigating the social patterning of obesity separately in urban and rural areas and for men. It found that higher educational attainment was associated with lower odds of obesity in urban women. There was a non-linear association for rural women. Higher wealth increased the odds of obesity for rural women but not for urban women. For men, results suggested education was not associated with odds of obesity. However, for both urban and rural men, higher wealth was associated with higher obesity (106).

Further, among adults aged over 50 (data from 2001), Smith and Goldman found patterns similar to developed countries in urban areas. Higher level of schooling was significantly associated with a lower prevalence of obesity. The opposite was found in less urban areas

(107). With respect to income, a direct association with obesity was found both in urban and rural areas.

Studies from low income population samples

Studies that focused on the rural Mexican population or other low income samples suggested that the association between SEP and obesity was similar to the one observed in developing countries. For example, Fernald *et al* found a direct association between educational attainment and obesity in a survey of adults representative of the poorest communities in 7 states of Mexico. The same direct association was seen with other measures of SEP such as occupation, quality of housing, household assets and subjective social status. In these communities SEP was directly associated with consumption of carbonated beverages and alcohol suggesting that high calorie foods and beverages were culturally desirable and that higher economic means allowed for higher consumption (108).

However, obesity prevalence appeared to be increasing rapidly among the most disadvantaged women in rural areas perhaps suggesting a proximal reversal of the social gradient in rural areas. Neufeld *et a*l documented a very large increase (from 39% to 73%) in the overweight prevalence and a tripling of the obesity prevalence (from 10% to 30%) over a 6 year period in women living in poverty in a rural community in the state of Morelos, Mexico (109). Less educated women were found to have higher annual rates of change in BMI than more educated women (OR =1.44 95% CI 1.04-2.05 comparing incomplete high school to complete high school or more) after adjusting for age and parity.

In summary, in Mexico, education was inversely associated with obesity among women especially in urban areas (87, 88, 105-107, 109). Among men, no association was found between education and obesity. The association between wealth and obesity was not significant among urban women and tended to be direct among rural women (106-108). Among men, wealth was directly associated with obesity in both urban and rural areas. Among low income women, education appeared to be directly associated with obesity (107, 108).

Mexican studies currently span the period between 1988 and 2001. The developments in the nutrition transition in the last 10 years are yet unknown. Mexican findings are consistent with those of other studies from LMIC which show a different association between education and obesity and wealth and obesity. Further, studies suggest that poorer rural areas are lagging behind in the nutrition transition and that there is a gender difference in the association between SEP and obesity.

1.5.4 Insights into gender differences in the association between SEP and obesity

From the review of the literature for this thesis thus far, it can be concluded that among women there is a well described pattern of inequality where obesity is associated with higher SEP in low income countries and there is a reversal of the social gradient at a given level of economic development. For men, the strength of the association between SEP and obesity appears to be weaker and it is unclear whether the reversal of the gradient occurs at higher levels of economic development than for women.

There are two commonly cited explanations for the observed gender differences in inequalities in obesity. The first relates to gender differences in the social patterning of attitudes towards body shape. Societal attitudes to obesity and body shape aspirations appear to be different among men and women (1, 83, 110, 111). In developed countries, obesity is severely stigmatized among women while there is relative affective neutrality among men (83). For men, larger body size may be valued as a sign of physical dominance while women value being thin. The internalization of social norms about thinness and attractiveness has been found to be socially patterned. Socially advantaged women appear to prefer thinner bodies than socially disadvantaged women (50). Body size aspirations may shape behaviours such as dietary restraint and exercise which are more immediate determinants of obesity.

In some developing countries larger body size remains a sign of prosperity and health. Within countries certain communities may have these values too. For example, in a semi-urban disadvantaged community in Mexico, thin women were thought of as 'anaemic' and men preferred larger women for marriage because they associated larger body sizes with strength and fertility (38). It is likely that as countries develop and are exposed to globalisation, western ideals of beauty permeate through society beginning with more advantaged groups. This may help to explain why the reversal of the social gradient is seen among urban women but not rural women in Mexico. It may also explain why there are less consistent associations between SEP and obesity in both developed and developing countries among men, for whom there appears to be little stigma around obesity.

The second explanation for differences in obesity inequalities between men and women suggests that men's manual occupations may be more physically demanding than women's hence they protect disadvantaged men from obesity and counteract an inverse social gradient in obesity among men (111-115). In England, men's physical activity rates showed steep occupational gradients while women's rates showed much flatter gradients (116).

Differences in obesity inequalities may also be due to gender differences in some other explanatory pathway between SEP and obesity. There may be gender differences in the impact of SEP related factors due to different susceptibilities either through cultural or biological differences (113). For example parity may explain a proportion of the obesity inequalities among women. More disadvantaged women tend to have more children and higher parity is associated with obesity. Men do not have this biologic or social role which may contribute to inequalities.

1.5.5 The interplay between education and wealth in their association with obesity

Education and wealth are common measures of socioeconomic position especially in LMIC and among women where occupation is less applicable. Some studies have used these markers interchangeably, under the umbrella of *socioeconomic position*, without giving thought to their different meanings. Such has been the case of the seminal literature review by Sobal and Stunkard (83) and of Monteiro's highly cited multicounty study (88). A better approach is to make a clear distinction between indicators. Only by understanding what each indicator measures can we begin to explain how they are related to health.

Studies which have made the distinction between education and wealth (or income if available) and studied their association with obesity often have inconsistent findings. Such was the case of McLaren's review in which there was a clear pattern of inequality between education and obesity especially among women but less so using income or wealth (1). Dinsa *et al* found that in 20-30% of studies (out of 10 for men and 16 for women) the association between education and obesity and wealth and obesity differed (86).

In developed countries, the associations between different indicators of SEP and health are more likely to be consistent than in less developed countries. For example, in the USA where income is commonly used as a marker of SEP, higher income and higher education are both protective of obesity (94, 97). In Mexico there was a clear inverse association between education and obesity and no association between wealth and obesity among urban women. Wealth was a risk factor for obesity among rural Mexican women. Among men, wealth appeared to be a risk factor for obesity in both urban and rural areas while education was not associated with obesity (106). The same inconsistent findings in the association between education and wealth with obesity have been reported in Brazil, Peru and Egypt (64, 104). This suggests that in transition societies, income or wealth may be a risk factor for obesity while education is a protective factor.

Recent studies have explored the interplay between these two indicators in transition societies (64, 117). Their main finding was that education may protect against the obesogenic effects of increased household wealth as countries develop. For example in Egypt, moving up one wealth quintile was associated with an increased odds of obesity of 1.78 (95% CI 1.65-1.91) among women with none or primary education. Among women with higher education, higher wealth was not associated with obesity (117). These studies highlight education's protective role possibly through improving knowledge and skills that are used to make better health decisions in an obesogenic environment.

These studies have some limitations. They are unable to explore trends in the interplay between wealth and education because they are limited to data from one or two points in time. As such they are limited in their conclusions about the stage of the nutrition transition at which an interaction between education and wealth is observed and whether the interaction disappears as countries develop. In other words whether there is a reversal of the social gradient observed with both indicators as the country develops further. In addition because of how the question is framed, these studies are not able to explore why education appears not protective in some subgroups within the same country as described in the previous section.

A further hypothesis has not been tested in the literature; whether household wealth moderates the association between education and obesity. Multi-country and review studies suggest that wealth of a country is an effect modifier in the association between SEP and obesity. There is a country wealth threshold at which the majority of the population becomes at risk of obesity with the most disadvantaged having the greatest increased risk. It may be possible to test this hypothesis at a household level and provide more evidence for the reversal of the social gradient. In the absence of at least a minimum level of household wealth that allows for choice of foods and other lifestyle factors, individuals may not be at risk of obesity and education may not appear protective of obesity.

1.5.6 Obesity risk factors that may explain educational inequalities in the Mexican context

The following section summarises the literature on selected obesity risk factors that may explain educational inequalities in the Mexican context. Risk factors will be referred to as *potential mediators* in the association between education and obesity. Potential mediators selected are psychosocial, behavioural and physiological. This section focuses on published literature reviews on the association between each potential mediator and obesity. Further, the social patterning of the potential mediator is described in higher income contexts and when possible specific for Mexico or similarly developed countries.

Psychosocial factors

Food insecurity

In the World Food Summit convened by FAO in 1996 food security was defined as existing when "all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life".

Food insecurity and obesity coexist in populations and households (118, 119). Potential causal links between the two factors have been the subject of studies in recent years. A consistent association between moderate food insecurity and an increased risk of obesity has been found for women (120-122). Among men, food insecurity appears to be 'protective' of obesity (119, 122).

Most of the evidence for the association between food insecurity and obesity comes from cross-sectional studies. Therefore the possibility of reverse causality cannot be rejected. In addition, cross-sectional studies are not able to gauge whether obese women perceive their household food insecurity differently to normal weight women. However, there are a few longitudinal studies which support a causal association between food insecurity and obesity (119). For example, a study using North American longitudinal data found that household food insecurity was associated with increased risk of obesity and weight gain among women especially those with children (123).

The association between food insecurity and obesity appears paradoxical. Food insecurity may be understood as an absolute lack of food which would presumably lead to undernourishment. However, although extreme food insecurity may meet that description, it is the milder forms of food insecurity which are more frequently associated with obesity. Mild or moderate food insecurity may occur when occasionally, the family spends the week's wages too soon and is unable to buy sufficient food until the next pay day. Or when food is available in the household but the individual is concerned about whether it is enough for the near future. The psychological component (stress) of food insecurity is thought to be the key link with obesity.

A number of theories have been developed to explain the effect of cycles of food insecurity and of stress emerging from a food insecurity situation on body weight. An adaptive physiological response leading to binge eating when food is plentiful has been described. Cyclical food restriction has been linked to increased body fat, decreased lean muscle mass and quicker weight gain. Other dietary patterns associated with obesity and also linked to food insecurity are consumption of high-calorie nutrient poor foods to avoid hunger, eating irregular meals or skipping breakfast and consuming less milk, fruits and vegetables (123).

The underlying mechanism for behaviours such as consumption of high-calorie foods in food insecurity situations may be explained by individual's physiological stress response. Stress arising from food insecurity may be associated with obesity by activating neuroendocrine mechanisms in the brain. Stress activates the hypothalamus pituitary adrenal axis where the corticotrophin releasing hormone neurones stimulate cortisol secretion. Chronic stress leads to increased cortisol exposure. Cortisol stimulates hunger and is associated with a preference for palatable foods. Cortisol and eating can both stimulate insulin so it is hypothesised that stress eating may have an effect on visceral fat accumulation (124). This hypothesis has been tested in monkeys (125, 126) but not in humans.

Studies investigating the association between food insecurity and obesity in Mexico have not been published or carried out. This is likely due to health and nutrition surveys not including a food insecurity component (until 2012) and conversely to food insecurity surveys not having a health component. It is unclear whether there is an association and whether there are gender differences in this association.

In this thesis, food insecurity is proposed as a potential psychosocial mediator in the association between education and obesity. Food insecurity is correlated with poverty, however the mechanisms by which it is associated with weight gain appear to be related to coping mechanisms arising from stress and worry of running out of food, especially among women. Food insecurity has been empirically tested as a mediator in the association between SEP and obesity using cross-sectional data from NHANES (57). Food insecurity mediated the association between SEP (education and poverty ratio) with obesity indirectly through depression and physical activity among women. Although said study has limitations because of the nature of the data, it is considered hypothesis generating.

Depressive symptoms

A bi-directional association between depression and obesity has been described in the literature (127-130). A review of longitudinal studies reported that depressed adolescents especially females were more likely to developed obesity in adult life but, conversely, obese adolescent women were more likely to develop depressive symptoms in later life (127). Mechanisms by which depression may cause obesity and vice versa may be independent. Depression may cause obesity by inducing a long term activation of the hypothalamus pituitary adrenal axis. Excess glucocorticoids, specifically cortisol, appear to stimulate hunger and feeding by affecting the reward system in the brain. Therefore unhealthy behaviours such as overeating and smoking may represent forms of pleasure or ways to cope which are driven by the deregulation of the stress system (76). Furthermore, antidepressants have also been linked to an increase in the risk of obesity (129).

Obesity may cause depression through inflammation processes originated in visceral fat (128). This hypothesis suggests that lipid accumulation causes adipocytes to directly secrete the cytokines interleukin (IL) 6 and tumour necrosis factor α (TNFα) inducing a state of chronic inflammation. Inflammation has been linked with risk for depression for example people with inflammatory diseases such as multiple sclerosis have elevated rates of depression and some people administered inflammatory cytokines such as interferon α develop depression (128).

Exposure to chronic stressors and negative life events have been linked with psychosocial distress including depression (131, 132). Depression is more common among disadvantaged populations and this appears to be the case in Latin American cities as well (133). In Mexico, among poor rural women, perceived stress, lack of personal control or social support, and a disadvantaged social position where the strongest correlates of depression symptoms in a large cross-sectional study (132). Depression was found to mediate the association between SEP and physical activity, diet quality and central adiposity in some subpopulations of the USA (56, 57). These two studies used cross-sectional data so are prone to reverse causality but are hypothesis generating.

Aspired body size

In this thesis, aspired body size is understood as a reflection of social norms about thinness and attractiveness. Cultural pressures especially for women's thinness appear to coincide with westernisation and country level economic development (134). Women living in more westernised countries tend to report greater body dissatisfaction, defined as the miss-match between actual body size and aspired body size, than those living in non-westernised countries. Cultural norms about thinness therefore appear to be dynamic and influenced by country wealth and exposure to globalisation especially among women.

Social norms about thinness and attractiveness for men appear to be different than those for women (1, 83, 110, 111). There appears to be relative affective neutrality towards obesity among men (83). For men, larger body size may be valued as a sign of physical dominance.

Aspired body size and its related concept, body dissatisfaction, have been shown to be correlated with weight related behaviours and with actual body weight. For example, obesity prevalence among African American women was higher than among white American women and consistently African American women appeared to prefer larger body sizes than white American women (135). Body image dissatisfaction, has been associated with obesity related behaviours such as dieting and binge eating (136, 137). It is therefore suggested that an individual will modify his or her obesity related behaviours in an attempt to conform to a specific social norm.

Social norms about thinness and attractiveness are socially patterned (50). In more developed countries, socio-economically advantaged women tend to be more dissatisfied with their bodies than socio-economically disadvantaged women (50, 137). In Colombia, a middle income country, an inverse association was found between women's education and aspired body size (138). More educated women preferred slightly thinner bodies than less educated women.

In the Colombian study, obesity was directly associated with education, therefore there was a contrasting association between aspired and real BMI with education. Aspired body size was not associated with current BMI (138). These findings may reflect the stage of the nutrition transition in Colombia where more advantaged groups begin to adopt westernised ideals of attractiveness and health. Speculatively this could be followed by behaviours that match these ideals.

In Mexico, body dissatisfaction and or aspired body size and their association with obesity and SEP have not been studied at a population level. Surveys up to 2012, had not explored the concept of aspired body shape. In 2012, an item was included to measure this. This thesis hypothesises that aspired body size is a potential mediator in the association between education and obesity especially for women.

Given Mexico's level of economic development, it is expected that more advantaged women will report preferring thinner body ideals especially in richer urban areas. This is based on the Colombian findings and on the stage of the nutrition transition in Mexico. Among men, a flatter social gradient in aspired body size is expected in urban areas because of neutrality towards obesity. In rural areas, a direct association between education and aspired body size is expected. Being larger in rural areas may signify less involvement in manual work and higher status. It is assumed that women and men will behave in such a way as to achieve their aspired body size. For example more advantaged women who will prefer a thinner body size will diet and exercise and this will be reflected on their BMI.

Marital status

A review of 20 longitudinal studies exploring the association between marital transitions and obesity or weight gain concluded that transitions into marriage appear to be associated with weight gain while transitions out of marriage were associated with weight loss in both men and women (139). The strength of this review is that it included only longitudinal studies therefore the temporality of events is certain. Selection of more obese people into marriage seems unlikely and is not supported by these findings which tracked weight gain after marriage. However, comparison groups were very variable among the different studies included, as were adjustments for potential confounding variables. The role of parity or children in the family as a confounding factor in the association between marriage and obesity was not described.

Very frequently, marital transitions are not measured in epidemiological studies but marital status is. Marital status has also been associated with obesity in numerous studies. Marital status reflects the end-point of a marital transition therefore its association with obesity is similar to the one described above. Married individuals tend to be more obese than single individuals. Sobal and Hanson reported that marital transitions (measured retrospectively in a cross-sectional study) did not provide additional insights into the marriage- body weight association compared to marital status (140).

Marriage may increase weight by increasing the opportunities for eating due to shared, regular meals and larger portion sizes. Also by decreasing physical activity and decreasing weight maintenance for the purpose of attracting a partner (139).

In the United States, increases in earnings and education increased the likelihood of marriage for both men and women (141, 142). In several developed populations, there was an inverse association between socioeconomic position (employment and education) and marital disruption (143). Studies investigating the association between marital status and obesity and between marital status and SEP in Mexico were searched for but no relevant studies were found.

Marital status will be investigated as a potential mediator in the association between education and obesity in Mexico. It is hypothesised that being married or cohabiting as opposed to single or divorced will increase the prevalence of obesity among both men and women and that being married will be associated with higher education as has been observed in the USA. Marriage could therefore mediate a direct association between education and obesity among men.

Behavioural factors

Diet

The 2003 Joint WHO/FAO expert consultation on diet, nutrition and the prevention of chronic diseases concluded that there was convincing evidence that high intake of dietary fibre decreases the risk of obesity (73). Dietary fibre is mostly found in fruits, vegetables and cereals. The report also concluded that there was convincing evidence about the causal association between high intake of energy-dense micronutrient poor foods and obesity and moderately strong evidence on the causal association between high intake of sugar-sweetened soft drinks and fruit juices and obesity (73).

Dietary habits are social patterned. In more developed countries, more disadvantaged adults tend to consume less fruits and vegetables and more fat and sugar (33, 144). In less developed countries, the social patterning of dietary habits may be dynamic. As with obesity, it is likely that there is a reversal of the social gradient in terms of dietary behaviours. In the early stages of the nutrition transition, advantaged groups will consume diets that are higher in fats and sugar (more westernised) than those of less advantaged groups. As the transition progresses, all socioeconomic groups become exposed to a high fat high sugar diet. More advantaged groups begin to adopt healthier diets while less advantaged groups shift from the traditional diet to a more westernised diet.

In Mexico, richer, defined using an asset based wealth index, men and women appeared to have a higher intake of total and saturated fat and a lower intake of fibre compared to poorer men and women in 2006 (145). Using the same data (Health and Nutrition Survey from 2006) but analysing dietary patterns yielded consistent findings. Rural and indigenous population were more likely to have a diet based on fewer foods and higher proportion of total energy derived from maize foods. This dietary pattern was more akin to the traditional pre-transition Mexican diet. The advantaged urban population tended to have dietary patterns characterised by more diversity of foods, higher fat and sugar and refined breads. The latter dietary patterns were found to increase the risk of obesity compared to the traditional pattern (146).

Mexican studies have not analysed dietary patterns by education level. This association is likely to be different to that of wealth and diet (higher education associated with healthier diet) given the different meaning of these two indicators. Education may specifically increase knowledge and skills and exposure to social norms regarding health and body image which can make a person more receptive to health education messages and prone to healthier behaviours (46, 147). Further, findings of the social patterning of obesity by wealth and education in LMIC described in page 39 support a different effect of wealth and education on diet given that diet is an immediate risk factor for obesity.

To summarize, there is convincing evidence of a causal association between some aspects of the diet such as dietary fibre and energy dense micronutrient poor foods, and obesity. Dietary behaviours are socially patterned. In the developed world there is a consistent inverse association between SEP and unhealthy dietary behaviours while this association depends on the stage of the nutrition transition in developing countries. Dietary behaviours have therefore been found to explain a proportion of the inverse social gradient in obesity in developed countries (79). Given the stage of the nutrition transition in Mexico, it is hypothesised that healthy dietary behaviours such as consumption of fruits and vegetables will be inversely associated with education especially among women and may explain a proportion of the educational gradient in obesity.

Physical activity

The joint WHO/FAO expert consultation on diet, nutrition and the prevention of chronic diseases concluded in their report that there was convincing evidence that regular physical activity was protective of obesity (73). Public health guidelines promote at least 150 min/week of moderate-vigorous leisure-time physical activity (148). Conversely, a sedentary lifestyle is causative of obesity and this was not explained by exercise deficiency (73, 148). Sitting time has been found to predict cardiovascular disease, obesity, mortality and metabolic syndrome independent of exercise (148).

In a recent Lancet reviews of determinants and correlates of physical activity, education was not a consistent correlate of physical activity; however, income and wealth were directly associated with physical activity in high income countries (149). Men have been consistently found to exercise more than women. Studies focused mostly on leisure time or recreational physical activity.

Studies identified for the same review on the correlates of physical activity in low and middle income countries were mainly cross-sectional and two thirds of them came from China and Brazil. A consistent direct association between socioeconomic position and physical activity was reported (149). However, it is not clear whether studies from low and middle income countries focused mainly on leisure time physical activity as they did in higher income countries. Leisure time physical activity makes only a small proportion of overall physical activity in LMIC (150). Total physical activity may, therefore, have different socioeconomic correlates.

In LMIC, occupation related activities and human-powered transportation make up a large proportion of the overall physical activity. Higher levels of physical activity may be more common among more disadvantaged groups. Manual jobs, for example subsistence agriculture in rural areas, require high levels of physical activity. As countries develop, urbanise and economies become more service orientated, overall physical activity in the population declines. People in urban areas rely on motorised transport and may have sedentary occupations. At the same time, recreational physical activity may become more important for certain health conscious groups. Therefore, in countries in transition, the social gradient in physical activity is expected to be dynamic. A similar reversal of the social gradient as described for diet and obesity may be observed, where physical activity is first inversely associated with socioeconomic position but as disadvantaged groups become more sedentary (as a result of urbanisation and a service economy) and advantaged ones more health conscious the association becomes direct.

This distinction between sport and overall physical activity is important in Mexico. According to the 1999 Mexican Nutrition Survey, leisure time physical activity was uncommon among Mexican women with only 16% of women reporting that they regularly had some. Women with more education were more likely to engage in leisure time physical activity than women with less education (151). On the other hand, overall physical activity i.e. a measure that incorporates leisure time physical activity, domestic and gardening activities, work related physical activity and transport-related physical activity, was socially patterned in the opposite way among women. More advantaged women were less active than more disadvantaged women (SEP measured using household income) (152). Among men there was no social patterning of physical activity by SEP (household income) (152). A possible explanation is that recreational physical activity among more advantaged men may have matched occupational physical activity among disadvantaged men therefore no gradient was observed. Urban or rural dwelling was found to be an effect modifier in the association between gender and overall physical activity. Women were less active than men in rural areas, in urban areas women were more active than men (152).

Physical activity will be tested as a potential mediator in the association between education and obesity in this thesis. Among urban women it is hypothesised that more women, especially those who are more advantaged, will take part in leisure time physical activity compared to 1999 due to increased health awareness and widespread western ideals of thinness. This may have shifted the overall physical activity gradient to coincide with the leisure time physical activity gradient i.e. higher education, higher physical activity. Physical activity, is therefore, expected to mediate the inverse education obesity association. Among rural women, a flatter gradient in physical activity is expected as leisure time physical activity is unlikely and household and occupation activities are similar across education groups. Physical activity is not expected to play a role in the education obesity association among rural women. Among men of both urban and rural areas, it is hypothesised that more disadvantaged ones will have a higher overall physical activity. This will be due to men with fewer years in education doing manual jobs which require physical exertion, for example agriculture in rural areas. It may also be due to disadvantaged men having to walk more in order to get to work than more advantaged men in urban areas. Previous Mexican studies examining the correlates of physical activity among men, have not assessed whether physical activity is socially patterned by education (152).

Sitting time is expected to be socially patterned in the opposite direction to physical activity in both men and women of urban and rural areas.

Physiologic factors

Parity

Parity was associated with overweight in middle and high income countries but not in low income countries according to a study which included 50 Demographic and Reproductive Health Surveys (153). Longitudinal analyses have found that weight retention one year after delivery is a predictor of future overweight up to 15 years later (154). Excessive gestational weight gain and the inability to lose this weight after giving birth are thought to be two of the main mechanisms by which parity is associated with overweight (155). A change in lifestyle factors such as eating behaviour and physical activity may be another potential mechanism (155).

According to comparative studies, Latin America stands out as the region where the high education-low fertility relationship is strongest (156). There were wide differences in parity by education group in several Latin-American countries including Mexico in the late 1980s (157). In Mexico, women with no education had 6.4 live births compared to 2.4 among women with more than 10 years of education (157). Much of the inequality was attributed to differential access to methods of contraception given that the reported desired family size among the same women was similar across education groups (157).

Parity is expected to be a mediator in the association between education and obesity among urban women in Mexico. Among rural women, parity may not be associated with obesity as has been found in low income countries.

1.6 Summary of the evidence reviewed and implications for this thesis

Obesity prevalence has more than trebled in the last 25 years in Mexico. Inequalities in obesity will translate into inequalities in morbidity and mortality. By endorsing the UN International Covenant on Economic, Social and Cultural Rights, Mexico has committed to improve the health of its population in an equitable way. There are gaps in the obesity literature for Mexico, which must be addressed in order to correctly inform health policy which can lead to equitable improvements in health.

This thesis is underpinned by the social determinants of health framework which acknowledges several levels in the production of health inequalities. The structural drivers of obesity and obesity inequalities refer to the socioeconomic, sociocultural and political context in Mexico. Specifically, structural drivers have led to changes in the food and built environment which underlie the nutrition transition. Socioeconomic position is understood to moderate the effect of the macro-level context on individual level body weight. Socioeconomic position is associated with health through material, psychosocial, physiological and behavioural pathways. This thesis explores obesity inequalities in the context of the nutrition transition literature.

The changing Mexican context 1980s-2012

The Mexican context in the period from 1980s to 2000s was one of economic growth with an unequal distribution of income. A large proportion of the population lived in poverty especially in rural areas. There were improvements in attendance to education as a result of education policies in the early 1990s. Mexico saw advancement in its health and nutrition indicators, for example an increase in life expectancy and a decrease in undernourished population, however new challenges arose.

Nutrition related chronic diseases became the main causes of death and obesity prevalence trebled in less than 30 years. Structural determinants of the rising obesity trends in Mexico include urbanisation, liberalisation of the food market leading to increased availability of high sugar and high fat foods and aggressive marketing by the food industry. The changes have been characteristic of the nutrition transition. The diet of Mexicans has shifted away from the traditional, low fat, low sugar, high fibre diet to one that is high in fat, high in sugar and low in fibre. The changing context is likely to have had a differential impact on individuals depending on their more immediate socioeconomic environment.

Literature review on the nutrition transition proposition

The literature review included reviews, multi-country studies and individual country studies from the Americas and Mexico on the association between SEP and obesity. There tended to be agreement on the proposition that country economic development is associated with obesity and obesity inequalities. A reversal of the social gradient has been described in which, at a specific level of economic development, there is a crossover to higher rates of obesity among the more disadvantaged groups. Some studies have questioned the level at which the transition occurs and the generalizability of these observations to individual countries.

The reviews of the literature and multi-country studies tested ecologic hypotheses and showed, for example, that country GNI moderates the association between SEP and obesity. However, they provided very little information on the nuances of the obesity epidemic in individual countries. This is a limitation of these studies because they mask important differences between countries which may lead to the wrong conclusions for policy makers. For example in Jones-Smith *et al* study, it was concluded that "some countries show a faster growth rate in overweight in the lowest (vs highest) education groups, which is indicative of an increasing burden of overweight among lower education groups in lower income countries" (93). This conclusion, although generally supported by their findings, masks that in 46% of the countries studied, the groups with higher education had higher increases in overweight prevalence. In addition these multi-country studies generally leave out countries in which DHS or other standardised surveys have not been carried out.

In Latin America, there was limited evidence on the social patterning of obesity. In the few studies identified, a transition to higher rates of obesity among the most disadvantaged groups was described. Consistent with the nutrition transition proposition, the transition appeared to occur at a GNI of $2,500 USD per capita. These studies had limitations, most used data which was not nationally representative and all except for the Brazilian ones, used one or two cross-sectional surveys to draw conclusions about the transition.

In Mexico, studies on the association between SEP and nutrition outcomes were also limited, especially those that were nationally representative. Trends in obesity inequalities have not been systematically studied. Studies retrieved were based exclusively on cross-sectional data from one point in time. They reported an inverse association between education and obesity in urban areas among women and no or direct association in rural and or poor areas. The surveys found, for the period 1988 to 2000, that the association with wealth was not significant among urban women and direct among men and rural women.

The focus of most studies from LMIC has been to identify the level of economic development at which inequalities in obesity emerge. Few studies have monitored inequalities in obesity after the reversal of the social gradient especially in LMIC. It is generally assumed that inequalities in obesity will widen because the most disadvantaged groups will continue to have the largest increase in obesity prevalence. There are some examples of declining obesity inequalities from developed countries. In the USA and Canada the most advantaged women appear to have become obese faster than the most disadvantaged women in the 1980s and 1990s.

A further gap in the literature is the inconsistency in differentiating between SEP indicators and how their effects compare in different contexts. For example, Monteiro's multi-country study which described a $2,500USD GNI per capita threshold for the reversal of the social gradient did not distinguish between studies using education and wealth as measures of SEP (84). Education and wealth measure different dimensions of SEP and are only moderately correlated in developing countries. Their association with obesity is likely to be different. Therefore the conclusions reached by some studies which use these markers interchangeably may be flawed. Further, measures of wealth used in multi-country and individual country studies measure country specific relative wealth. Therefore multi-country studies compare very different levels of absolute wealth. Education is perhaps more comparable across countries.

There were significantly fewer studies examining obesity inequalities among men than women, especially in LMIC. This is probably due to the fact that research on this topic for LMIC used demographic and health survey data which included women only. Given that obesity prevalence among men is almost as high as it is among women, investigating the social patterning of obesity among them is as relevant to public health. Moreover, empirical testing of the reasons why there appears to be a different (weaker or contrasting) association between SEP and obesity among men compared to women has seldomly been done.

In HIC psychosocial, material, physiological and behavioural factors explain a large proportion of obesity inequalities. Studies have used longitudinal data to test hypothesised pathways and have been able to control for potential confounders such as parental social class. In LMIC including Mexico, the mechanisms that explain the social patterning of obesity have not been studied systematically. This may be due to the lack of longitudinal data which limits the validity of studies and also to the dynamic nature of the social patterning of obesity in less developed countries.

The review for this thesis identified known psychosocial, behavioural and physiological obesity risk factors which could explain obesity inequalities in the Mexican context. These were: food insecurity, depression, aspired body size, marital status, parity, diet and physical activity. The literature review highlighted the current evidence about their association with obesity and with SEP in different contexts. Diet and physical activity are well established causal risk factors of obesity. However, more evidence is required on the association between food insecurity, depression and aspired body size with obesity. Plausible causal mechanisms have been described but research has been limited to cross-sectional studies. Reverse causality for example, that obesity causes depression, cannot be ruled out. This gap in the literature is outside the scope of this thesis and is therefore a limitation of the analyses in Chapter 7.

This thesis will address several of the gaps in the literature identified. Trends in socioeconomic inequalities in obesity among women using four nationally representative surveys covering 25 years will be studied for the first time. This will answer the question of whether the Mexican inequality trends fit the nutrition transition proposition pattern described in multi-country and review studies. Increases in obesity prevalence by SEP group over time will be studied in order to identify the SEP groups that have been most affected by the changing food and built environment.

Further, a clear distinction between education and wealth will be made consistent with the understanding that these indicators measure different dimensions of SEP and are associated with obesity through different pathways. The separate and combined effects of both indicators on obesity will be investigated with the aim of gaining further insight into the nutrition transition proposition for Mexico and other LMIC. Previous studies which have used both indicators have not explored a potential interaction between the two of them with one exception (117).

As mentioned above, few studies from LMIC investigate the social patterning of obesity for men. This thesis will address this gap using two recent surveys. Further, potential mediator variables in the association between education and obesity will be investigated for men and women. This analysis is mainly hypothesis generating as it is based on cross-sectional data. However, it is one of very few attempts to try to explain how education is associated with obesity in LMIC. It gives an insight into the social patterning of obesity risk factors in the Mexican population which may extend our understanding of the epidemiology of obesity.

Chapter 2 Aim, objectives and hypotheses

2.1 Aim

The overall aim of this thesis is to investigate inequalities in obesity among Mexican women and men. The hypotheses revolve around the nutrition transition proposition of a crossover to higher rates of obesity among the most disadvantaged groups which leads to emerging and increasing inequalities as countries develop economically. Using four waves of nationally representative cross-sectional surveys, inequality time trends among women are investigated. The surveys span a period of 25 years, from 1988 to 2012, over which there was sustained economic development, improvements in education and changes in the food and built environment in Mexico. The two more recent surveys are then used to explore inequalities in obesity among men compared to women and potential mediators in the association between education and obesity in the Mexican context. Investigations are carried out separately for urban and rural areas because of large differences in economic development within the country which may have an impact on the social patterning of obesity.

2.2 Objectives

Objective 1

Examine time trends in educational inequalities in obesity over the period 1988 to 2012 for women.

Objective 2

a) Examine time trends in inequalities in obesity by wealth over the period 1988 to 2012 for women.
b) Investigate the role of wealth as an effect modifier in the association between education and obesity over the period 1988 to 2012 among women.

Objective 3

Investigate inequalities in obesity by wealth and education among men over the period 2006 to 2012 and compare them to women's inequalities in obesity.

Objective 4

a) Explore the educational gradient of obesity risk factors in Mexican men and women.

b) Investigate potential mediating factors in the association between education and obesity.

2.3 Hypotheses

Hypothesis for objective 1

An inverse educational gradient will be observed among women in urban areas and inequalities will increase in the study period. This hypothesis is based on the GNI per capita level in Mexico over the period 1988 to 2012 (over US$2,500) (13), previous Mexican studies which reported an inverse association between education and obesity since 1987 (87), and the literature that reports that obesity prevalence increases faster among more disadvantaged groups as countries develop economically (93, 101).

In rural areas, a direct association between education and obesity is expected among women and there will be faster increases in obesity prevalence among the lower education groups suggesting a reversal of the social gradient in the future is likely. Rural areas in Mexico have a significantly lower level of economic development than urban areas (158). Therefore, it is expected that the social patterning of obesity will be similar to developing countries in the earlier survey years but shifting as the country develops economically (1, 93).

Hypothesis for objective 2-a

Poorer women in both urban and rural areas will exhibit larger increases in obesity prevalence over the period 1988 to 2012 compared to more advantaged women. This will lead to a reversal of the wealth gradient in urban areas and a shift from a direct association between wealth and obesity to an inverted U shape association in rural areas. The reversal of the wealth gradient will be observed at a higher level of country GNI per capita compared to education.

This hypothesis is based on a study using Mexican data from 2000 that reported no association between wealth and obesity among urban women and an inverse association between education and obesity (106). Among rural women, a direct association between wealth and obesity was described (106). Further, it is based on the literature of the nutrition transition proposition which reports a crossover to higher rates of obesity among the poorest population groups as countries develop economically (101). The reversal of the wealth gradient in obesity may be more sensitive to country income inequality. When income inequality is large, as in Mexico, a proportion of the population may live in absolute poverty even at apparent high levels of country GNI per capita. Absolute poverty will 'protect' from obesity. This may be why the reversal of the wealth gradient may be observed at a higher level of GNI per capita (reflecting a lower level of absolute poverty) compared to education.

Hypothesis for objective 2-b

Education and wealth will be less correlated in Mexico than in HIC as was explained in section 1.3. It is hypothesised that the education gradient will vary by levels of wealth. Education will be protective of obesity at higher levels of wealth but not at lower where absolute poverty will preclude women from becoming obese. A reversal of the education gradient will be observed among poorer women in the period of study (1988-2012) due to widespread improvements in the standard of living.

Hypothesis for objective 3

Multi-country and reviews studies on the social patterning of obesity suggest that there is a transition to higher rates of obesity among the most disadvantaged men at a higher level of country economic development compared to women (1, 84). Therefore, this thesis hypothesises that among Mexican men, a reversal of the wealth/education gradient in obesity will be observed over the period of study 2006 to 2012 in urban areas. In poorer rural areas the direct association between wealth/education and obesity described in previous studies will persist (106).

Hypotheses for objective 4-a

Among women, obesity risk factors will be inversely associated with education consistent with an inverse association between education and obesity. Among men, those living in rural areas and in more disadvantaged education groups are expected to have higher physical activity levels than more educated urban men and women. Further, a flatter social gradient in aspired body size is expected among urban men compared to women and a direct association between education and aspired body size is expected among rural men. The rationale of this hypothesis is described in section 1.5.6.

Hypotheses for objective 4-b

Potential mediating factors in the inverse association between education and obesity among women will be similar to those identified in developed countries and can be grouped in psychosocial, behavioural and physiological. Potential mediating factors in the direct association between education and obesity among men will be physical activity and aspired body size. The rationale for this hypothesis is described in section 1.5.6.

Chapter 3 Methodology

This chapter describes the methodology of the thesis. It first describes the datasets including some of their limitations and strengths. Variables used throughout the thesis are listed next. This is followed by an account of the statistical analyses carried out. Only statistical methods used throughout the thesis are described in this section. Chapter specific statistical procedures will be explained at the beginning of each results chapter. A brief description of the sample sizes used in each chapter is presented last.

3.1 Data

Data used in this thesis were extracted from four nationally representative cross-sectional surveys conducted in Mexico in 1988, 1999, 2006 and 2012 (159-162). These were the *Encuesta Nacional de Nutrición* (National Nutrition Survey) of 1988 and 1999 and the *Encuesta Nacional de Salud y Nutrición* (National Health and Nutrition Survey) of 2006 and 2012. These surveys were designed for population surveillance of nutrition and health outcomes and health related services and interventions. The first two surveys focused on women aged 12 to 49 and children. The last two focused on men and women aged 20 years and older, children and adolescents. Previous to 1988, there was one Demographic and Health Survey (DHS) carried out in Mexico in 1987. Previous to that, only small nutrition surveys targeting rural areas were carried out.

The Mexican Institute for Geography and Statistics was in charge of the sample calculations and design of the surveys. The operational aspects and data management were the responsibility of the Ministry of Health for the first 1988 survey and of the National Institute of Public Health for all subsequent ones. All surveys, including questionnaires, datasets and documentation, are available to the public and can be accessed online (163, 164).

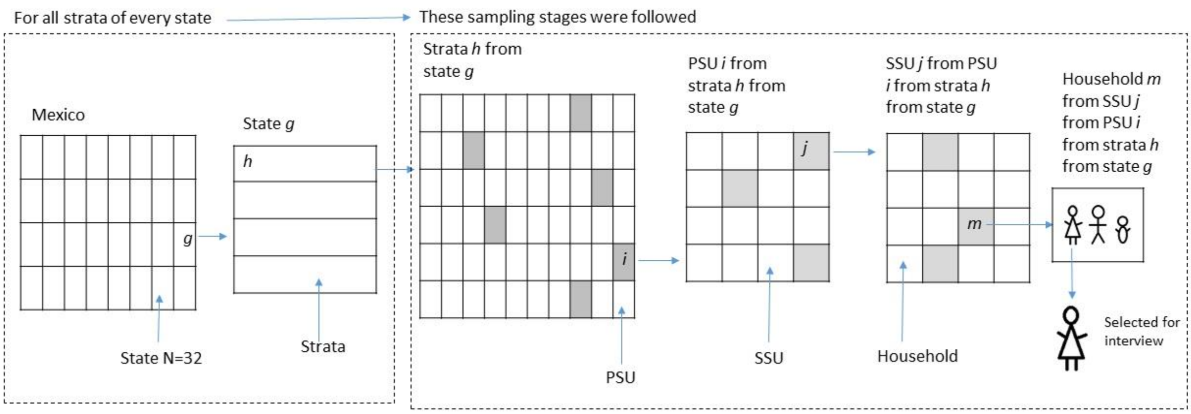
Sampling design

The surveys had a multistage, stratified, cluster sampling with unequal probabilities of selection for elements. This type of design is usually termed *complex sample design* (as opposed to simple random sampling), and is commonly used in population based surveys. The sample design was similar for the four surveys. The general characteristics and sampling stages are illustrated in Figure 3.1 and explained below.

Strata are non-overlapping, homogeneous groupings of population elements or clusters of elements that are formed by the sample designer prior to the selection of the sample (165). Stratification variables in Mexican surveys included degree of urbanisation (except for 1988) and socioeconomic factors. Appendix 2 describes the specific stratification variables and number of possible strata used in each of the surveys. The number and definition of strata are the main differences in the sampling design of the surveys.

Primary sampling units (PSU; municipal subdivisions) were defined across the entire country. A sample of PSUs was selected in each stratum at state level, with probability proportional to stratum size (proportionate allocation). Secondary sampling units (SSU), smaller geographic units within each sampled PSU, were defined and a sample of these was selected following the same procedures. Within sampled SSUs a given number of households were selected. Within each sampled household all women were interviewed and measured in the 1988 and 1999 survey or one adult was randomly selected to be interviewed and measured in the 2006 and 2012 surveys.

Figure 3.1 Schematic representation of survey sampling procedure



State: Mexico is composed of 32 federal entities; 31 states and 1 *federal district* (Mexico City)
Strata: based on size of communities and socioeconomic position. Number of strata varies by state and by survey.
PSU: Primary Sampling Unit- municipal subdivisions comprising of 100 to 640 households depending on level of urbanisation
SSU: Secondary Sampling Unit- Blocks of households

Household sample size

The sample size was calculated to be large enough to detect an uncommon outcome (e.g. the proportion of moderately undernourished children in 1988) with 95% confidence. A weighting was used in the sample size calculation to adjust for the design effect. This common practice adjusts for the precision loss expected from the complex sample design (165). An expected non-response rate of 20% was also taken into account and the sample size was increased accordingly.

Table 3.1 lists the calculated household sample sizes. They ranged from 16,520 in 1988 to 59,035 households in 2012. Response rate at household level ranged from 80% to 97% across the four surveys. Achieved household sample size ranged from 13,263 in 1988 to 50,528 in 2012. The individual sample sizes analysed for this thesis will be given in a later section as well as at the beginning of each results chapter.

All surveys oversampled rural population, this was done to increase sample size and precision of estimates in rural areas. Survey weights adjust the samples to the real population proportions as can be seen in Table 3.2. Survey weights will be described below.

Table 3.1 Survey household sample sizes and response rate

Year	Number of Households				
	Calculated sample size	Response rate	Achieved sample size	Urban n (%)	Rural n (%)
1988	16,520	80.3%	13,263	11,342 (85.5)	1,921 (14.5)
1999	21,000	85.4%	17,944	11,516 (64.2)	6,428 (35.8)
2006	48,600	97.0%	47,152	34,805 (73.8)	12,347 (26.2)
2012	59,035	85.6%	50,528	34,461 (68.2)	16,067 (31.8)

Table 3.2 Sample distribution and representativeness using weights

Year	Population size	Urban % (95% CI)	Rural % (95% CI)
1988	15,053,815	81.5 (80.6,82.4)	18.5 (17.6,19.4)
1999	21,722,832	75.8 (72.5,79.1)	24.2 (20.9,27.5)
2006	23,759,124	77.7 (77.7,77.8)	22.3 (22.2,22.3)
2012	29,429,252	78.5 (77.0,80.0)	21.5 (20.0,23.0)

Questionnaires

The Mexican surveys included a household questionnaire, an adult questionnaire and in more recent surveys, additional questionnaire modules. The household questionnaire collected information such as sex, age and education for every member of the household. It also collected information about household characteristics, for example source of water, and ownership of assets. The adult questionnaire was administered to the sampled adult in the household. This questionnaire collected information on morbidity, use of health services, receipt of government benefits and of relevance to this thesis, measured weight and height, depression and perceived body size (in the 2006 and 2012 surveys). Additional questionnaire modules were for example a food frequency questionnaire, a physical activity questionnaire (in 2006 and 2012) and a food insecurity questionnaire (in 2012). These were administered to a subsample of individuals.

Ethics statement

Written consent was obtained from adults participating in the surveys, including the parents or tutors of children. Verbal consent was obtained from children. The survey protocols, data collection instruments and consent forms and procedures were approved by the ethics committee of the National Institute of Public Health in Mexico.The present thesis was based on anonymous, public-use data sets with no identifiable information on the study participants.

Limitations of the surveys used

Several limitations of these data should be noted. Non-response at household level was low however, it may still have introduced selection bias if households that did not respond were systematically different to those that did. Personal communication from the National Institute of Public Health suggested that non-response at household level was usually due to 'households' selected not being inhabited for example, selection of an office building into the sample. Non-response at household level was adjusted for in the survey weights and will be discussed in detail below (page 78). Item non-response, for example missingness in the body weight data, may also introduce selection bias. Missingness and how it is managed in this thesis is described at the beginning of each chapter together with implications of different missing data patterns in the findings.

The proportion of urban/rural dwellers from the 1988 sample was significantly different to the 1980 census estimate (66.3% urban; 33.7% rural), in part because the 1988 survey did not stratify by degree of urbanisation in the sampling design. The representativeness of findings especially for rural areas in this survey is a limitation of this study.

A further limitation is that the earlier surveys were more basic in their enquiry. With each subsequent survey, more topics have been added and questions have been improved. This resulted in better quality surveys however; some variables of interest were only measured in the last surveys (for example food insecurity). Changes to some items render variables not comparable throughout the years. Mexican surveys were cross-sectional and therefore have all the limitations of cross-sectional data. Exposure, outcome and mediation variables were all measured in the same point in time. It is not possible to establish temporality therefore this study will report on associations which may or may not be causal.

Strengths of the surveys

The surveys were nationally representative and have large sample sizes which allow for the detection of small associations. Further, height and weight were measured by trained staff. The surveys span a period of 25 years in which there were important changes in the food and built environment as well as sustained economic growth in Mexico. Therefore these data are well suited to study trends in health outcomes and to trace the epidemiological and nutrition transition in the country.

3.2 Variables

Table 3.3 presents an overview of the variables used in this thesis. It describes the type of variable and coding as well as the chapter or chapters in which each variable was used. As can be seen from the table, potential mediator variables were only used in Chapter 7 using data from 2012. Although it would have been interesting to explore whether potential mediator variables had a role in explaining the trends in inequality in the period 1988 to 2012, this was not possible because most of the potential mediator variables were only available in the 2012 survey.

Table 3.3 Variables used in this thesis

Variable	Type or coding	Chapter 4 (trends educational inequalities)	Chapter 5 (effect modification by wealth)	Chapter 6 (inequalities among men)	Chapter 7 (mediation)
Outcome					
Obesity (BMI ≥ 30)	Binary, 1= yes; 0=no	✓	✓	✓	✓
Obesity class II & III (BMI ≥ 35)	Binary, 1=yes; 0=no	✓			
Main exposure					
Education	Categorical, 1=higher education; 2= high school; 3=secondary school; 4= primary or less	✓	✓	✓	✓
Wealth	Categorical (tertiles), 1=richest; 2=middle; 3=poorest		✓	✓	
Confounders/effect modifier					
Age group	Categorical, 1=20-24.9; 2=25-29.9;3=30-34.9, 4=35-39.9; 5=40-44.9; 6=45-49.9	✓	✓	✓	✓
Level of urbanisation	1= urban; 2=rural	✓	✓	✓	✓
Sex	1=male; 2=female			✓	✓
Other variables					
Year of birth	Continuous	✓	✓		

Variable	Type or coding	Chapter 4 (trends educational inequalities)	Chapter 5 (effect modification by wealth)	Chapter 6 (inequalities among men)	Chapter 7 (mediation)
(survey year- age)					
Pseudo-cohort	1= women born 1940s; 2= women born 1950s; 3=women born 1960s; 4=women born 1970s	✓			
Survey identifier	1= 1988; 2=1999; 3=2006; 4=2012	✓	✓	✓	
Years since baseline	Continuous, 1= 1988 to 25=2012	✓	✓		
Perceived body weight status *	Categorical, 1=underweight; 2=normal weight; 3=overweight; 4=obese	✓		✓	
Potential mediators					
Food insecurity	1= food secure; 2=mild food insecurity; 3=moderate food insecurity; 4=severe food insecurity				✓
Depression symptoms	Binary, 1= clinically significant depression symptoms; 0= no significant depression symptoms				✓
Aspired body size	Ordinal, 1 to 9				✓
Marital status	Categorical, 1=married or cohabiting; 2= separated, divorced or widowed, 3=single				✓
Fruit and vegetable consumption	Categorical, 1=lower consumption 2= higher consumption				✓
Soda	Categorical, 1=lower consumption 2= higher consumption				✓
Cakes and snacks	Categorical, 1=lower				✓

Variable	Type or coding	Chapter 4 (trends educational inequalities)	Chapter 5 (effect modification by wealth)	Chapter 6 (inequalities among men)	Chapter 7 (mediation)
	consumption 2= higher consumption				
Physical activity	Categorical, 1= high physical activity; 2=moderate physical activity; 3= low physical activity				✓
Sitting time (tertiles of sitting minutes per day)	Categorical, 1= high; 2= moderate; 3=low				✓
Parity	Continuous and Categorical, 1= nulliparous; 2=1 to 2 live births; 3=3 to 4 live births; 4= 5 or more				✓

* Perceived body weight status was used in the analysis of missing BMI values in the 2006 survey (see chapter 4 and chapter 6) but not in the main analysis

3.2.1 Outcome

Obesity

BMI is the most commonly used measure of adiposity in population studies for several reasons. It has been shown to be highly correlated with other more precise measures of body fat, for example dual energy X-ray absorptiometry (166). The magnitude of the correlation between BMI and disease markers such as blood pressure, plasma lipids and glucose is similar to that of body fat measured using gold standard techniques (166). Lastly it is a simple indicator based on non-invasive and cheap measurements (weight and height). Its use allows comparability with many other studies globally.

There are several limitations of BMI which should be noted. It is an imperfect measure because it does not directly assess body fat. It is sex specific; for an equivalent BMI, women have more body fat than men (167). Further, muscle and bone are heavier than fat so for some people, for example athletes, BMI will not be a good reflection of body fat. An additional limitation is that BMI does not distinguish between different distributions of fat. Accumulation of fat in the abdomen has been shown to increase risk of disease more significantly than fat in the extremities. Measurements such as waist circumference or waist to hip ratio have been recommended as complements to BMI (168).

Despite the widely recognized limitations of BMI, a review of studies on obesity inequalities found no differences in the patterns observed in studies that used BMI versus those using waist circumference or waist to hip ratio (86). This suggests that BMI may still provide a sufficiently reliable picture of the degree of socioeconomic inequalities in overweight/obesity in developing countries. This thesis uses BMI only as waist and hip circumferences were not measured in all surveys.

The risk of developing health problems rises progressively for BMIs over 25 (169). A graded classification of overweight and obesity was created to be able to make meaningful comparisons of weight status within and between populations and to identify individuals and groups at risk of morbidity and mortality, among other things. Cut points of BMI were defined based on increasing risk of chronic diseases. For example, a BMI of 25 to 29.99 is considered to increase risk of chronic diseases compared to a 'normal' BMI of 18.5 to 24.99. The subsequent cut points (i.e. BMI= 30 to 34.99; 35 to 39.99; ≥40) increase risk further in a progressive graded way.

In this study obesity was defined as a body mass index (BMI) greater or equal to 30 kg/m^2, consistent with the World Health Organisation definition (170). Obesity class II and III was defined as a BMI equal or greater to 35 kg/m^2. BMI was calculated as weight in kilograms divided by the square of height in meters. Height and weight were measured by trained staff in the household visits following standard protocols (159-161, 171). Height was measured without shoes or hair/head accessories. The position of the body for correct measurement was detailed in the protocol (172). For weight, portable scales were used with precision +-1 kg in the earlier surveys and precision +-200g in the later surveys. Individuals were weighed without shoes. The measurement protocol included instructions to calibrate the scales.

3.2.2 Exposure variables

Education

Education was defined as self-reported attendance to higher education, high school, secondary, or primary education or less. These categories refer to well-known stages in the Mexican education system.

Wealth

A wealth index was constructed as a proxy for consumption expenditure (173). An index was constructed in each survey using relevant household quality and asset variables (Table 3.4). Relevant variables were those that had the potential to discriminate between wealth groups.

This was assessed by looking at the mean ownership of each asset. If mean ownership was high (above 85%) the variable was not selected.

Principal Component Analysis (PCA) was used to replace the set of correlated asset and household quality variables, with a set of uncorrelated principal components which represent unobserved characteristics of the population (63). From PCA the first principal component was kept as it captured the most covariance (see Table 3.4). 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 (63, 173). Tertiles of the score were created for each survey individually. This produced a measure of wealth for each wave which was independent of improvements in ownership of assets and household characteristics that took place from 1988 to 2012.

Table 3.4 Assets used to construct the wealth index per year, eigenvalue of first principal component and covariance explained

	1988	1999	2006	2012
Assets and household characteristics included in index	Radio TV Refrigerator Telephone Vehicle Floor material Piped water Sewage Toilet	Radio TV Refrigerator Telephone Vehicle Floor material Piped water Sewage Toilet Washing machine Separate kitchen Number of rooms	Refrigerator Telephone Vehicle Floor material Sewage Washing machine Number of rooms Computer	Refrigerator Telephone Vehicle Floor material Sewage Number of rooms Computer Separate kitchen Number of lightbulbs Pay TV Internet connection
Eigenvalue	3.9	4.3	3.6	4.1
Covariance explained	43%	36%	40%	37%

The indexes had internal coherence, such that there were large differences in ownership of assets between wealth groups (Table 3.5 & Table 3.6). For example, in urban areas in 1988, 3.8% of households classified in the poorest wealth tertile owned a vehicle, compared to 10.9% of those in the middle wealth tertile and to 74.5% in the richest wealth tertile. In 2012 in urban areas, 5.4% of the poorest households had pay TV compared to 61.5% of the richest households.

An alternative methodology to construct the wealth index was considered and tested alongside the one described above (Appendix 3). A wealth index was constructed using the same set of assets and household characteristics throughout the four surveys in order to take into account changes in wealth over time (174). Both indexes were highly correlated and their association with obesity was not different in any of the surveys. However, the survey specific wealth index was considered theoretically more appropriate because ownership of assets and households characteristics improved substantially from 1988 to 2012 (see Table 2 in Appendix 3). Therefore, the same set of assets and household characteristics that correctly discrimated between wealth groups in 1988 may have not longer done so in 2012. By incorporating period relevant information the wealth index used in this thesis may be more robust.

Table 3.5 Mean ownership of of assets and household characteristics by wealth level in urban areas 1988-2012

	1988			1999			2006			2012		
	Poorest~	Middle	Richest	Poorest	Middle	Richest	Poorest	Middle	Richest	Poorest	Middle	Richest
N	3,758	3,232	3,738	2,143	3,979	5,156	7,966	12,152	14,652	7,871	11,718	14,771
	%	%	%	%	%	%	%	%	%	%	%	%
Fridge	15.8	89.4	99.8	16.4	80.0	99.2	47.4	94.2	99.7	60.4	94.8	99.4
Telephone	0.2	7.2	76.8	0.5	11.6	79.0	5.1	49.3	94.3	49.5	87.0	98.9
Vehicle	3.8	10.9	74.5	2.3	13.0	64.0	2.8	17.9	68.1	4.7	24.6	70.4
Floor material*	1.7	2.2	2.6	1.8	2.2	2.7	1.9	2.2	2.6	2.0	2.3	2.7
Sewage type *	2.2	1.1	1	1.8	1.3	1.1	1.6	1.2	1.0	1.4	1.1	1.0
Radio	76.3	97.7	99.8	67.3	90.6	98.1						
TV	54.6	98.7	100	66.8	97.2	99.9						
Water source	71.1	99.8	100	85.8	98.1	99.8						
Toilet	68.5	99.9	100	84.9	99.8	100						
Number of rooms*				1.6	2.4	3.9	1.8	2.7	3.9	2.2	3.5	4.7
Washing machine				5.6	44.8	89.9	8.9	50.4	87.3			
Kitchen				58.8	88.3	98.1				66.1	94.3	97.8
Computer							0.2	2.3	42.7	0.7	6.2	69.4
Number of light bulbs*										3.3	5.6	9.4
Internet connection										0	1.4	57.7
Pay TV										5.4	19.1	61.5

*All assets presented as percentages except for floor material, sewage type, number of rooms and number of light bulbs which are presented as means. Variables coded: 1 household owns the asset 0 does not own it; floor material: 1 dirt, 2 cement 3 other better materials; sewage type: 1 connected to main public sewage, 2 connected to septic tank, 3 not connected; water source 1 tap within or outside household 0 other source of water; number of rooms and number of light bulbs are continuous and range from 0 to 8 and from 0 to 22 respectively.
~ Poor, middle and richest refer to tertiles of the wealth index

Table 3.6 Mean ownership of of assets and household characteristics by wealth level in rural areas 1988-2012

	1988			1999			2006			2012		
	Poorest~	Middle	Richest	Poorest	Middle	Richest	Poorest	Middle	Richest	Poorest	Middle	Richest
N	1,197	345	216	3,680	1,900	606	7,847	3,378	1,018	8,937	5,079	2,029
	%	%	%	%	%	%	%	%	%	%	%	%
Fridge	12.6	88.2	100	14.4	82.7	99.2	39.0	95.3	99.4	50.9	98.5	99.2
Telephone	0	5.5	60.2	0.2	4.7	38.9	7.1	45.3	87.2	27.8	79.3	96.6
Vehicle	5.7	18.3	71.2	5.3	32.0	77.6	6.0	41.9	84.2	8.6	48.1	82.2
Floor material*	1.6	2.2	2.6	1.6	2.1	2.5	1.7	2.1	2.6	1.9	2.2	2.6
Sewage type*	2.6	1.3	1.1	2.4	1.9	1.4	2.5	1.9	1.5	2.1	1.6	1.4
Radio	76.5	97.9	100	66.0	91.6	97.8						
TV	43.9	97.2	100	52.2	96.9	99.0						
Water source	59.2	100	100	55.1	88.8	96.5						
Toilet	51.0	100	100	63.6	96.7	100						
Number of rooms*				1.8	2.7	4.4	1.9	2.8	3.9	2.5	3.7	4.8
Washing machine				4.1	45.1	90.2	8.9	51.1	82.5			
Kitchen				79.6	95.6	99.7				79.7	96.8	99.3
Computer							0.1	1.1	21.1	0.3	5.0	47.3
Number of light bulbs*										3.3	5.6	8.5
Internet connection										0	0.5	20.8
Pay TV										5.3	23.2	58.8

*All assets presented as percentages except for floor material, sewage type, number of rooms and number of light bulbs which are presented as means. Variables coded: 1 owns the asset 0 does not own it; floor material: 1 dirt, 2 cement 3 other better materials; sewage type: 1 connected to main public sewage, 2 connected to septic tank, 3 not connected; water source 1 tap within or outside household 0 other source of water; number of rooms and number of light bulbs are continuous and range from 0 to 8 and from 0 to 22 respectively.
~ Poor, middle and richest refer to tertiles of the wealth index

3.2.3 Covariates

Age

Given the curvilinear association of age with BMI (see Chapter 4), age squared and age group terms were included as adjustment covariates in all models. Age group was a categorical variable divided into 5 year bands.

Level of urbanisation

Urban areas were defined as communities with a population of more than 2,500 and rural areas were those with population ≤2,500. This is the definition that has been used in most population level studies in Mexico. Level of urbanisation has been identified as an effect modifier of the association between education and obesity (175).

Survey year

Records from each survey wave were given an identifier number from one to four (1988=1 and 2012=4) in order to stratify the analyses. For analyses of trend, each survey wave was assigned a calendar year such that 1988=1 and 2012=25.

Height

Height in cm was used as an adjustment covariate in a sensitivity analysis in Chapter 4 (page 104).

3.2.4 Potential mediators

Food insecurity

Food insecurity was measured in the 2012 Mexican health and nutrition survey using the Food Security Scale for Latin America and the Caribbean (FSSLC). This scale measures four dimensions of food insecurity: psychological (anxiety and worry), quantity of food, quality of the diet and hunger (176). FSSLC has been piloted and validated in several countries of Latin America including Mexico and is used widely in population surveys. The validation study in Mexico concluded that FSSLC had high internal reliability (Cronbach's alpha 0.91) and was highly correlated with measures of poverty and of food consumption (176, 177). A higher degree of food insecurity was inversely associated with consumption of fruits and vegetables, meat and dairy products (176).

The scale consists of 15 questions divided into two sections (Appendix 4). The first eight questions refer to situations which lead to food insecurity as experienced by the adults in the household. The second section refers to situations affecting those under 18 years old. Adult only households answered the first 8 questions only. Possible responses to all items are yes, no, don't know. In accordance with the FSSLC guidelines (176), *yes* answers were scored one and *no* answers zero. *Don't know* answers were coded missing. Points were summed to produce a scale score, omitting households with missing values in any single item. Households were classified in four categories depending on their score (see Appendix 4); food secure, mild food insecurity, moderate food insecurity and severe food insecurity. A second variable was tested alongside this one to reflect only the psychological dimension of food insecurity. Households answering yes to the first item of the questionnaire were classified food insecure.

Depressive symptoms

Depressive symptoms were measured in the 2012 Mexican health and nutrition survey using an abbreviated form of the Centre for Epidemiologic Depression Studies scale (CES-D) (178). The CES-D scale is a screening test for depression and depressive disorders. The full version has 20 items which measure symptoms of depression in nine different dimensions as defined by the American Psychiatric Association Diagnostic and Statistical Manual. It is used widely in population based studies. The abbreviated scale used in the Mexican survey was originally developed and validated in the Spanish population and subsequently validated in the Mexican adult population (179, 180). It included 7 items from the original 20 item scale measuring the dimensions of dysphoric mood (sadness), motivation, concentration, loss of pleasure and poor sleep (Appendix 5).

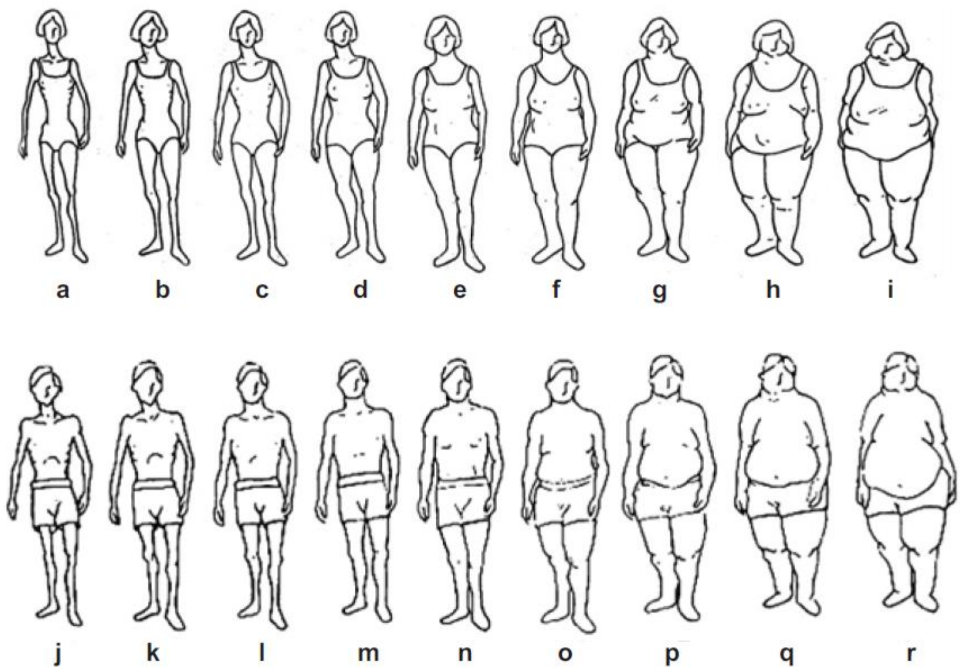
There were 4 possible answers to each item: never or almost never, 1 to 2 days, 3 to 4 days and all the time. To derive the variable for this thesis, answers were re-coded 0-3 according to the scale guidance (3 to 0 for the item worded positively). The points for each individual were added (min 0 max 21). A cut point of 9 or greater was used to classify individuals as having clinically significant depressive symptoms.

The cut point to identify clinically significant depression symptoms was determined in a validation study carried out in Mexico using the following as gold standard measures separately: diagnostic criteria of ICD-10, DSM-IV and Beck's depression inventory. The instrument was deemed to have high sensitivity and specificity (90.2% and 86% against ICD-10 and 80.4% and 89.6% against DSM-IV) (180).

Aspired body size

Aspired body size was measured using a series of 9 drawn female and male figures of increasing body size proposed by Stunkard *et al* (181) and shown in Figure 3.2. Survey respondents were asked to select the silhouette that most closely resembled how they would like to look. This selection was called *aspired body size*. Answers were coded 1 to 9 (a/j=1, i/r=9; Figure 3.2).

Figure 3.2 Figures of Stunkard



Marital status

All survey waves asked whether participants were cohabiting, married, separated, divorced, widowed or single. For this study a variable with three categories was created: married and cohabiting; separated, divorced or widowed; and single. This variable identifies people that have had transitions in or out of marriage and those who have not had them.

Diet

Usual dietary intake in the past week was measured using a food frequency questionnaire (FFQ) in the 2006 and 2012 surveys. The underlying principle of the food frequency approach is that average long term diet is the exposure of interest rather than intake over a few specific days (which results from food diaries and 24 hour recalls). FFQ sacrifice precise intake measurements for more crude information relating to an extended period of time (182).

The food frequency questionnaire in the 2012 National Nutrition survey included 154 food items of which 46 were used in this study. The frequency response section enquired about number of days over the week previous to the survey, number of times each day and number of portions of each food item consumed. An additional question about portion sizes was included i.e. whether the size of the portions consumed was equal to the standard portion defined by the questionnaire (see Appendix 6) smaller or larger. A similar FFQ was used in 2006 (with fewer food items, same frequency section). The Mexican FFQ was based on one developed in the late 1990s by the Mexican Institute of Public Health using the methodology proposed by Willet *et al* to select relevant food items and design a frequency response section (182). It was validated among women living in Mexico City in the late 1990s and has not been validated again, even after substantial changes (Monterubio 2014, pers. comm.).

The dietary variables of interest in this thesis were: fruits and vegetables, cakes and snacks and soda, defined as sugar sweetened carbonated beverages. The category of cakes and snacks included energy-dense micronutrient poor foods such as candy, processed cakes and doughnuts. To derive these variables, portions per day of each food item were calculated. A continuous variable was created first, portions of fruits and vegetables were added (15 fruits and 16 vegetables see Appendix 6). Values over 25 portions per day were coded missing because they were considered unreliable. Portions of processed sweet and savoury snacks were added (14 categories see Appendix 6). Subsequently, binary variables were created using a median split. These variables reflect higher or lower intakes of the specific food group.

Physical activity

Physical activity was measured in 2006 and 2012 using the short form of the International Physical Activity Questionnaire (IPAQ) (183). IPAQ assesses physical activity undertaken across domains including leisure time physical activity, domestic and gardening activities, work related physical activity and transport-related physical activity. In addition it asks about sitting time. Interviewees report how frequently and for how long they participated in walking, moderate and vigorous activities in the 7 days previous to the survey.

The International Physical Activity Questionnaire (IPAQ) (183) was designed as a standardised instrument for population surveillance of physical activity among adults (15-69 year olds). It was validated in 12 countries and deemed acceptable for use more widely because of its high test-retest reliability and acceptable criterion validity (184).

In order to weight the time spent doing different types of activities by their intensity, METs are used. MET is a physiological measure expressing the energy cost of physical activities. The MET is defined as the ratio of the work metabolic rate to a standard resting metabolic rate of 1.0 $kcal \cdot kg^{-1} \cdot h^{-1}$. One MET is considered the energy cost of a person at rest (185). In 1993 a compendium of physical activities was published which provided a comprehensive list of physical activities and their associated MET values (185). The original compendium was updated in 2000 and subsequently in 2011.

To analyse the data from IPAQ, an average MET score was derived for each type of activity (walking, moderate, and vigorous) based on the 2000 compendium (186). This was done by the IPAQ research group. Moderate intensity activities were defined as those with a MET between 3 and 5.9, for example, bicycling for leisure (MET=4), cleaning, sweeping carpets or floors (MET=3.3), rubbish collector, walking and dumping bins into truck (MET=4.0). Vigorous activities were those with a MET ≥6, for example, mountain biking uphill (MET= 14), running stairs up (MET=15), fire fighter including hauling fire hoses, hoisting equipment, wearing full gear (MET=9). METs for all walking categories were averaged, for example, walking on job less than 2.0 mph at very slow speed in office or lab (MET=2) and walking briskly at 3.5mph carrying objects less than 25lb (MET=4.8) (183). The average METs for each type of activity were 3.3 for walking, 4.0 for moderate activity and 8.0 for vigorous activity.

To construct a continuous physical activity variable for this study three steps were followed. First data were cleaned; *don't know* and *no response* responses were coded as missing. Responses in the hours column greater than 12 were recoded 12 (n=6 vigorous activity; n=8 moderate activity; n=14 walking in 2012). Responses in duration provided in hours and minutes were converted into minutes following IPAQ recommendations (183). When duration/ time was reported weekly (instead of daily) it was divided by 7. The second step was creating a variable for MET-minutes/week for each activity (walking, moderate, vigorous). The third step was creating a total physical activity MET-minutes/week variable by adding the three scores from the previous step.

A categorical variable was derived from the continuous MET-minutes/week variable using IPAQ criteria:

- High physical activity: vigorous intensity activity on at least 3 days achieving a minimum total physical activity of at least 1500MET- minutes/week or 7 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum total physical activity of at least 3000 MET-minutes/week.

- Moderate physical activity: 3 or more days of vigorous-intensity activity of at least 20 minutes per day or 5 or more days of moderate-intensity activity and/or walking of at least 30 minutes per day, or 5 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum total physical activity of at least 600 MET-minutes/week.
- Low physical activity: Those individuals who do not meet criteria for high and moderate.

Sitting time

The question on sitting is similar to the ones for activity except that it asks for the number of hours and minutes the individual spent sitting on one specific day of the week previous to the survey. If the individual found it difficult to answer the first question because, for example, the number of hours sitting varied from day to day then he/she was asked about the number of hours and minutes he/she sat on the Wednesday previous to the interview.

To construct the variable for analysis, *no response* and *don't know* responses were coded missing (n=238 in 2012). Hours and minutes a day were transformed to minutes a day. Minutes of the day recalled (i.e. chosen by the individual or Wednesday if they could not answer the first question) were divided into tertiles to derive a categorical variable. IPAQ recommends data on sitting should be reported as median values of minutes a day sitting and interquartile ranges (183).

Parity

Parity was defined as the number of live births. A continuous measure was used for descriptive purposes and a categorical variable was derived and used in all models. Categories for parity were: 0 live births, 1-2 live births, 3-4 live births and 5 or more.

3.2.5 Other variables

Perceived body weight status

A questionnaire item asking individuals whether they perceived themselves underweight, normal weight, overweight or obese was available only in 2006. This variable was used to analyse whether missing values for BMI were associated with perception of being overweight or obese.

3.3 Statistical analysis

Preparation of the datasets

Several steps were followed to prepare the data for analysis. One dataset per questionnaire was available, for example in 2012 there were six datasets corresponding to six questionnaires relevant for the study: household, adult, anthropometry, food insecurity scale, food frequency questionnaire and physical activity.

First, the household datasets were dealt with. Relevant variables for the wealth index were identified and the wealth index was constructed as has been described above. Household datasets were also pooled together to construct a wealth index with common variables across the four surveys which was compared to the one used in this thesis (Appendix 3). Next household datasets with the wealth index variable were separated. These datasets were merged with the individual level datasets of each survey. Depending on the survey and the number of questionnaires, one or more individual level datasets were needed to incorporate the necessary variables for the study.

Once the household and individual datasets were merged, variables of interest were created in an identical way throughout the four surveys. This included identifying and relabeling the survey weight, strata and cluster variables.

For the analysis of chapters 4 and 5, the datasets of the four surveys were pooled together. This was done to make the analysis more efficient. Individual survey analyses were not affected by this; models were run separately for each year (e.g. four separate models - one for each survey year- with a flag variable to indicate survey year). For the analyses of chapter 6 datasets from 2006 and 2012 were pooled. In chapter 7, only 2012 was used.
Once the data were pooled into one large dataset, pregnant women, those younger than 20 years old and extreme, implausible values for BMI (BMI<10, BMI>75; less than 0.5% of total sample) were dropped. Missing data patterns were then analysed.

Missing data

There are two levels of non-response which can introduce bias. Survey non-response refers to sampled households that refused to be interviewed, or sampled households where no interviews could be carried out for some other reason (for example, because the selected 'household' was a shop). These households do not exist in the datasets. Survey non-response levels have been described earlier in this chapter, page 60. This type of non-response was taken into account and corrected within the survey weights as will be explained in the next section. The second type of non-response is item non-response, for example individuals with information on most questions but missing data on weight. Item non response was further analysed to assess potential bias in the findings.

Descriptive analysis of missing data

An indicator variable flagging cases with missing data was created. Using chi-squared tests, systematic differences between respondents with incomplete and complete data were assessed. Based on this analysis, the missing data mechanism was identified. Missing data mechanisms are classified into three types: missing completely at random (MCAR), missing at random (MAR) or missing not at random (MNAR). MCAR occurs when the missingness does not depend on the values of the data, either missing or observed. MAR occurs when the missingness depends only on the observed data and not on the unobserved data. MNAR occurs when even after accounting for all the available observed information, the reason for observations being missing still depends on the unseen observations themselves. When the missing data mechanism was identified to be MAR, further actions were taken in order to ensure that missing data was not introducing bias to the findings. These included, for example, analysing whether missingness in weight was associated with an individual's perceived overweight status and multiple imputation.

Multiple imputation

The imputed values in multiple imputation (MI) are derived from an iterative process that uses observed data. MI produces several imputed values for each missing value. For example, if an individual is missing data on weight, an MI procedure produces 20 estimates (or as many as are specified) of that missing value. For each set of imputed values there is a separate complete dataset. Complete datasets are analysed separately and parameter estimates are combined to obtain a single best estimate. One of the advantages of MI over single imputation methods is that it produces sounder parameter estimates including their standard errors because it is based on several imputations (187).

MI was done using Stata 11 chained equations command *ice*. All analysis variables (BMI, age, urban/rural, education and wealth index) were included in the imputation model in order to avoid bias as suggested in the literature (188, 189). In addition auxiliary variables, those that predicted BMI or predicted the missingess of BMI but were not part of the analytic model, were included (i.e. employment, region of the country, self-identifying as indigenous, marital status and social security affiliation). Inclusion of auxiliary variables is recommended to improve the imputation model and reduce standard errors (188). The nature of the variables was specified in the model; whether they were continuous, ordered or nominal categorical, and whether they were complete or incomplete. This allowed Stata to run an appropriate regression (logistic, linear, multinomial) to impute each variable. Twenty imputations were created. Recent guidance on multiple imputation suggests that the number of imputations should be at least equal to the percentage of incomplete cases in order to obtain stable estimates (188).

The imputed datasets were analysed and parameter estimates were compared to those of a complete case analysis. Appendix 7 provides further information on the methodology and analysis of imputed datasets.

Adjustment for complex survey design

An adjustment for the complex survey design was necessary in this study because the formulae and approaches used in statistical software packages (without survey adjustments) for variance estimation are based on the assumption of independence of the sample observations. This is only true for simple random samples. The clustering of sample elements and the use of survey weights produce estimates with larger standard errors than simple random samples of equal size (165). Sample or population elements refer to Primary Sampling Units, Secondary Sampling Units or households; depending the stage of sampling. Stratification reduces variance. Therefore, in order to estimate correct and unbiased estimates from survey data it is important to recognise these design elements and account for them in the statistical analysis.

Effect of clustering

The increase in standard errors due to clustered sampling is caused by correlations of observations within sample clusters. Many characteristics measured on sample elements within naturally occurring clusters are correlated, for example households in a specific primary sampling unit in Mexico are likely to share both measured and unmeasured characteristics such as socioeconomic position or environmental factors such as access to food. When these similarities are present, the amount of statistical information contained in a clustered sample is less than in an independently selected simple random sample of equal size (165). Therefore, clustered sampling increases the standard errors of estimates relative to simple random samples.

Effect of stratification

Stratification may reduce standard errors of population estimates. Stratified sampling selects individual samples from each stratum. Population characteristics within strata are more homogeneous than between strata. For example households in stratum *h* in the 2006 survey may all be in the state of Guanajuato, in small cities (2,500-99,999 people) and most of the population affiliated to the conditional cash transfer programme. In the statistical analysis, separate estimates of the statistic of interest are computed for sample cases in each stratum and then weighted and combined to form the total population estimate (165). Sampling variances of sample estimates are computed in the same way, separately for each stratum and then combined. Because households in each stratum are homogeneous, variance within strata is smaller than variance between strata. When strata variances are combined, variance attributable to differences between strata is eliminated from the sampling variance of the total population estimate and therefore standard errors are reduced.

Effect of survey weights

In a complex sample design, each population element does not have equal probability of sample selection. Survey weights are provided by the survey designer in order to adjust the sample back to an unbiased representation of the survey population. Survey weights inflate the standard errors of survey estimates.

In the Mexican surveys, survey weights were estimated at household and individual level, for the main sample and for the diet and physical activity subsamples in the 2006 and 2012 surveys. Survey weights are the product of a sample selection weight and a non-response adjustment factor. The sample selection weight is the inverse probability of being sampled. For example, the survey weight for a household was given by the number of households it represented in the region, state, primary sampling unit and secondary sampling unit. If household *m* was sampled with probability *fm*=1/10, then household *m* represented 10 households in the population (itself and nine others). The non-response adjustment factor was given by the number of households that were successfully interviewed in each primary sampling unit divided by the number of households originally selected for the sample in that same primary sampling unit. The sum of sample weights equals the population size.

Adjustment for complex sample design in STATA

All analyses in this thesis were adjusted for the complex survey design using STATA command *svy*. The first cluster level (PSU) variable, stratum variable and weight variable were identified. *Svy* commands allow for multiple levels of clustering but only the first level must be specified (i.e. PSU) (190). Table 3.7 shows the prevalence and standard error of obesity among 20 to 49 year old women in the four survey waves. The first two columns show the unadjusted proportions and standard errors. The last two columns show the same thing after adjustment for complex survey design. As described in this section, standard errors were increased as a result of clustering and weighting. There was a small variation in the point estimates which was due to the correction of bias using weights.

Table 3.7 Comparison of estimates adjusting and not adjusting for the complex survey design

	Not adjusted for survey design		Adjusted for survey design	
Survey year	**Obesity, %**	**Standard error**	**Obesity, %**	**Standard error**
1988	10.3	0.30	9.4	0.40
1999	26.3	0.39	25.4	0.47
2006	34.4	0.40	32.3	0.60
2012	37.1	0.40	35.4	0.64

Direct age standardisation

Age standardised estimates are presented for obesity. This was necessary because the period of study is 25 years, over which time the population in Mexico aged considerably. Obesity, as many other health outcomes, is associated with age; therefore, in order to compare the prevalence of obesity in surveys with different age distributions, it was necessary to adjust for this variable. Direct age standardisation used the Mexican 2000 census population as the standard population.

Two sample *t*-test

Differences in means for subpopulations, for example between urban and rural areas or between the last and first survey, were assessed using two sample *t*-tests.

Corrected chi-squared test

The prevalence of obesity in relation to exposure, confounding and/or mediation variables was examined using a corrected Pearson chi-squared test. Because of the complex sampling design, the distribution of the uncorrected version is not chi-square. The chi-square statistic is converted to an F statistic. The p-value for the corrected F statistic can be interpreted in the same way as a p-value for the Pearson chi-squared statistic for ordinary data.

Generalised linear models (GLM)

As suggested in the literature (191, 192), generalised linear models (log binomial regression) were used as a better alternative to logistic regression when dealing with frequent outcomes such as obesity. GLMs with binomial distribution and a logarithmic link function estimate prevalence ratios. These were used to estimate the relative index of inequality (described below) and the obesity prevalence ratio between two different points in time (193).

GLMs with an identity link function estimate risk differences. These were used to estimate the slope index of inequality (described below) (193).

Relative index of inequality (RII) and slope index of inequality (SII)

It is recommended that both absolute and relative measures of inequality are used in order to better understand socioeconomic inequalities in health (194-196). Relative measures are more readily understood and are less dependent on the overall prevalence of the disease. Absolute inequalities rely more heavily on the prevalence of the disease and are necessary to estimate the public health burden of inequalities in a country or society.

Ideally, both absolute and relative measures of inequality should have the following three characteristics: 1. they must reflect the health inequalities that originate from the socioeconomic factors; 2. they must reflect the experiences of the entire population (rather than just the two extreme SEP groups); and 3. they must be sensitive to changes in the distribution of the population across SEP groups (197). Indicators that meet these criteria are the Concentration Index (C), the Slope Index of Inequality (SII) and the Relative Index of Inequality (RII) (197). The concentration index and the RII/SII are mathematically similar (194, 197). They both rely on ranking individuals in the population by SEP. The RII is equal to the concentration index divided by twice the variance of the relative rank variable (197). Concentration index values range from -1 (all the population's ill health is concentrated in the hands of the most disadvantaged person) to +1. The RII and SII values range from 0 to ∞. The RII is interpreted as the prevalence ratio between the two ends of the educational hierarchy– obesity prevalence at the bottom divided by obesity prevalence at the top. The SII is the prevalence difference between the same ends.

In epidemiology, rate ratios and rate differences are more commonly used and easier to interpret therefore the RII and SII were selected as summary measures of inequality in this study. Because the RII and SII take into account both the population size and the relative socioeconomic position of groups they are well suited to measure health inequalities over time and across populations (194).

To calculate the RII and SII, education level was transformed into a summary measure with a scale from 0 (highest level of education) to 1 (lowest level of education). This measure was weighed to reflect the share of the population at each educational level by calculating the midpoint of the proportion in the population in each category. This was done separately for urban and rural areas of each survey wave. For example, 22% of the study participants in urban areas in 2012 were in the higher education group and 20% were in the high school group. Participants in the higher education group were assigned a score of 0.11 (0.22/2) meaning 89% of the urban population of 2012 had lower education than the average person in this group. Those in the high school group were assigned a score of 0.32 (0.22+(0.20/2)) and so on for each education level (198). To obtain the RII and SII, obesity was regressed on the new education variable and the model was adjusted for age.

Time trends of the RII and SII

Time trends of the relative index of inequality and slope index of inequality over the period 1988 to 2012 were tested by estimating the p value for an interaction term between education or wealth and calendar years since baseline, i.e. 1988 survey was coded 1, 1999 11 and so on, to account for the different time intervals between surveys. The model was adjusted for age, age squared, calendar year and education or wealth (199, 200). Quadratic calendar year terms were included to test deviations from linearity in the time trends.

Excess obesity cases

Using the slope index of inequality and the total population (weighted expanded sample), excess obesity cases were estimated. Excess obesity cases were the difference between the observed obesity cases among the most obese SEP group minus the expected obesity cases. The expected obesity cases were given by subtracting the SII from the observed obesity prevalence among the most obese SEP group.

Increases in obesity prevalence by SEP

To explore the magnitude and statistical significance of relative and absolute increases in obesity prevalence by education or wealth level over time, obesity was regressed on survey wave, in education or wealth stratified models (99). Models were adjusted for age and age squared. GLMs with a logarithmic link function were used to estimate prevalence ratios (relative increases) and normal linear regression to estimate prevalence differences (absolute increases). Mantel-Haenszel x^2 tests for homogeneity were calculated to assess statistical differences in obesity prevalence ratios across education levels (201).

3.4 Sample size in each chapter

The size of samples varied according to the number of surveys used in the analysis of each chapter, the demographic group studied and the number of variables used in the analysis (because of missing data). All chapters focus on the age group 20 to 49. Chapters 4 and 5 use data from four surveys 1988, 1999, 2006 and 2012 and focus on women (n=51,387). Chapter 6 uses two surveys (2006 and 2012) and focuses on men and women (n=47,522). Chapter 7 uses the 2012 survey because potential mediators of interest were only measured in this survey. Chapter 7 focuses on men and women (n=21,756). Appendix 8 details the process followed to obtain the analytical samples for each chapter.

Chapter 4 Trends in educational inequalities in obesity among women

4.1 Introduction

The objective of this chapter is to investigate time trends in educational inequalities in obesity among Mexican women in the period from 1988 to 2012. Trends are presented separately for urban and rural areas and compared. It is hypothesised that an inverse educational gradient will be observed in urban areas and that inequalities will increase in the study period. In rural areas, a direct association between education and obesity is expected as well as faster increases in obesity prevalence among the lower education groups suggesting a a reversal of the social gradient in the future is likely. The hypotheses are based on evidence which suggests that as a country develops economically, obesity increases faster among the more disadvantaged women compared to the more advantaged ones and inequalities emerge and widen (84, 92, 93, 99, 117, 202). In 1988, Mexico's GNI per capita was above the level at which the reversal of the social gradient has been observed in other countries and the economy continued to grow over the study period. However, rural areas in Mexico were significantly poorer than urban areas. In 2007, GNI per capita was estimated to be 73% lower than national average in rural areas and 41% higher than national average in urban areas (158).

Sensitivity analyses are presented to examine a) whether inequalities in obesity differ between birth cohorts over time, b) whether differential changes in height by education group confound the inequality time trends and c) whether trends in inequality vary if the outcome of interest is overweight (BMI ≥25) or class II and III obesity (BMI ≥35).

4.2 Methods

4.2.1 Analytic sample

The total number of women aged 20 to 49 with demographic information across the four surveys was n=60,331. After exclusion of participants with missing data and extreme, implausible values for BMI (BMI<10, BMI>75; less than 0.5% of total sample) the analytical sample consisted of n=51,387 non-pregnant, 20 to 49 year old women. Analysis of missing values for this sample is presented (section 4.3.1).

The sensitivity analysis investigating inequalities over time by birth cohort was based on a different sample and limited to urban areas because inequality trends were only significant in urban areas. Women born between 1940 and 1979 were selected from the 1988, 1999, 2006 and 2012 surveys inclusive of women 49 years old and older. This span of birth years was of interest because women born within this period were measured in at least 3 time points. After exclusion of missing data and extreme, implausible values for BMI (BMI<10, BMI>75) the analytical sample consisted of n=37,333 non-pregnant women.

4.2.2 Variables

The outcome of interest was a binary variable for obesity (0=BMI<30, 1=BMI≥30) and the main exposure was a categorical variable for attendance to education (1=higher education, 2=high school, 3=secondary education, 4=primary education or less). Age was a confounder of the association between education and obesity; therefore, models were adjusted for age. A quadratic term of age was included in models given the curvilinear association of age with obesity (see page 94). Urban/rural dwelling was an effect modifier of the association between education and obesity in some survey years (see page 95); therefore, all analyses were stratified by level of urbanisation (rural areas ≤2,500 inhabitants). For the first sensitivity analysis, year of birth was calculated by subtracting the age of the woman from the year of the survey. Four *pseudo cohorts* were created, women born in the 1940s, 1950s, 1960s and 1970s. For the second sensitivity analysis, height in cm was used as an adjustment covariate. For the third sensitivity analysis, obesity class II and III defined as a BMI≥35 was used as the outcome variable.

4.2.3 Analysis of missing data

An indicator variable flagging missing data for BMI (and hence the binary obesity variable) was created in the pooled four survey dataset. Using chi-squared tests, systematic differences between respondents with a BMI measurement and without were assessed.

To examine whether missing data was MAR or MNAR, a questionnaire item on perceived body weight status was analysed. This item was only available in 2006. BMI missingness was assessed across categories of perceived overweight status to gauge whether this could have influenced women’s decision to be measured.

It is debatable whether multiple imputation is useful to impute the outcome variable when exposure and covariates are complete as in this study (203). However, multiple imputation was carried out in order to test whether power and precision of the study could be increased. Details of the methodology and results are presented in Appendix 7.

4.2.4 Statistical analysis

Age-standardised prevalence of obesity by education group in each survey wave was estimated. Linearity in the education gradient was assessed by regressing obesity on education as a continuous variable, adjusted for age and age squared (191, 192). Deviation from linearity in the education gradient was tested by adding a quadratic term for education to the model.

As described in the methodology section 3.3, the relative index of inequality and slope index of inequality were estimated in each survey wave. All models were adjusted for age and quadratic age and stratified by urban and rural areas. Using the SII, excess obesity cases were calculated when inequalities were statistically significant. The trends over time of the RII and SII were tested by estimating the p value for an interaction term between education and calendar years since baseline as was described in page 84. Obesity prevalence increases by education level were calculated by regressing obesity on survey wave in models stratified by education. GLM with a logarithmic link function were used to estimate relative increases while conventional linear regression was used to estimate absolute increases.

Cohort effect

As in the main analysis, education level was transformed into a summary measure with a scale from 0 (highest level of education) to 1 (lowest level of education) and weighted to reflect the share of the population at each educational level. For this analysis the summary education variable was constructed for each cohort instead of each survey wave. The relative index of inequality was estimated for each period stratified by cohort. Obesity prevalence and educational inequalities were illustrated over period and age stratified by birth cohort. The trend of the relative index of inequality for each cohort over time was estimated.

4.3 Results

4.3.1 Missing values

Missingness in exposure variables and other covariates was low (≤5.3%). Missing values for weight and height and hence BMI varied from 8.6% in 1988 to 20% in 2006 (Table 4.1). The 1999 and 2006 datasets did not distinguish between women who were selected to be measured and not measured and those not selected to be measured. Missingness among selected individuals is therefore thought to be significantly lower than the overall missingness presented in Table 4.1.

Field reports suggest high acceptance of anthropometric measurements (Monterubio 2012, pers. comm., 19 October). Missingness was more likely due to operational issues such as nurses not visiting some households or the woman not being present in the household when the health teams visited. For example, in 2006, women who were missing a weight and height value were also missing blood pressure measurements. In 1999, there was a discrepancy between the methodology of the survey, which specified measuring one woman per household, and the practice where all women in the household were measured for most households.

Table 4.1 Missingness in variables of interest (20 to 49 year old non-pregnant women)

Variable	1988	1999	2006	2012
N	11,993	15,589	17,624	15,125
	N (%)	**N (%)**	**N (%)**	**N(%)**
Age	0	0	0	0
Urban/rural	0	0	0	0
Education	73 (0.6)	108 (0.7)	48 (0.3)	0
Wealth index	635 (5.3)	343 (2.2)	47 (0.3)	33 (0.22)
Height	1,021 (8.5)	2,765 (17.6)	3,561 (20.2)	556 (3.7)
Weight	985 (8.2)	2,746 (17.4)	3,487 (19.8)	552 (3.7)
BMI	1,035 (8.6)	2,857 (18.2)	3,575 (20.3)	560(3.7)
Complete cases**	10,318 (86.0)	12,564 (80.6)	13,974 (79.3)	14,531(96)

** Individuals with complete information for all of the above variables

Women with a BMI measure and those without one were different in some baseline characteristics. Women with missing BMI were generally more educated, richer and younger than those with complete data. Table 4.2 shows the distribution of the sample of women with missing BMI next to the sample of women with BMI (non-missing column) by education, wealth, age and urban/rural. For example in 2006, 9.8% of the sample of women with complete BMI had higher education while in the sample of women with missing values for BMI, 20% had higher education. This shows that missing data were not missing completely at random (MCAR).

Missing BMI was not associated with perception of being overweight or obese, and perception of being overweight or obese was highly correlated with measured overweight or obesity (Spearman $\rho=0.55$, $p<0.001$). This shows that women did not make a decision on whether they consented to be weighed based on their weight. The missing not at random mechanism (MNAR) was rejected. MNAR occurs when even when accounting for all the available observed information, the reason for observations being missing still depends on the unseen observations themselves (e.g. missingness of weight depending on weight itself) (187). Based on these findings, missing data in this study were deemed missing at random (MAR).

Because exposure variables were almost complete, and the missingness in BMI was not thought to be associated with the missing BMI value, bias was not likely to be a problem arising from missing BMI. Multiple imputation was carried out to test whether the power and precision of the study could be improved (Appendix 7). Imputing the outcome in this study did not add any information to the association of interest. The sample size and hence power grew but the standard errors did not decrease probably because of the variability of imputed values.

Implications for the analysis

Multiple imputation for the sample used in this chapter (and next chapter) which was complete on the exposure variables and where missing outcome data was assumed to be MAR was not useful. Further analysis for this and the next chapter were carried out using complete cases.

Table 4.2 Characteristics of women with missing BMI vs women with BMI

	1988			1999			2006			2012		
	Missing	Non-missing		Missing	Non-missing		Missing	Non-missing		Missing	Non-missing	
	N(%)	N(%)	$X^{2\,b}$	N(%)	N(%)	X^2	N(%)	N(%)	X^2	N(%)	N(%)	X^2
Education												
Higher education	190 (18.6)	943 (8.7)	p<0.001	492 (17.6)	1179 (9.2)	P<0.001	712 (20.0)	1378 (9.8)	P<0.001	158 (28.2)	2083 (14.3)	P<0.001
High school	257 (25.2)	1840 (16.9)		575 (20.5)	1969 (15.3)		756 (21.3)	2050 (14.6)		131 (23.4)	2378 (16.3)	
Secondary school	176 (17.2)	1787 (16.4)		550 (19.6)	2701 (21.1)		923 (26.0)	3867 (27.6)		149 (26.6)	4846 (33.3)	
Primary or less	399 (39.0)	6328 (58.1)		1186 (42.3)	6983 (54.4)		1166 (32.8)	6724 (48.0)		122 (21.8)	5258 (36.1)	
Wealth												
Richest	475 (48.4)	3548 (34.2)	P<0.001	1411 (50.7)	4347 (34.5)	P<0.001	1590 (44.6)	4186 (29.9)	P<0.001	244 (43.8)	4742 (32.6)	
Middle	263 (26.8)	3080 (29.7)		772 (27.8)	4437 (35.2)		1129 (31.6)	4809 (34.3)		190 (34.1)	4906 (33.8)	
Poorest	244 (24.9)	3748 (36.1)		598 (21.5)	3809 (30.3)		850 (23.8)	5013 (35.8)		123 (22.1)	4887 (33.6)	P<0.001
Age, mean	30.3	32.4	P<0.001[a]	31.9	32.8	P<0.001[a]	33.3	34.2	P<0.001[a]	32.5	34.8	P<0.001[a]
Urban	9510 (86.8)	914 (88.3)	P=0.17	2236 (78.3)	8396 (65.2)	P<0.001	3078 (86.1)	9937 (70.7)	P<0.001	432 (77.1)	9615 (66.0)	P<0.001
Rural	1448 (13.2)	121 (11.7)		621 (21.7	4490 (34.8)		497 (13.9)	4112 (29.3)		128 (22.9)	4950 (34.0)	

a: ttest for difference between means; b: chi squared test for the hypothesis that observed cases (non-missing) and expected cases (missing) differ more than expected due to chance

4.3.2 Distribution of the sample

Table 4.3 presents selected characteristics of the study population (complete cases) according to survey year. The average age of women was 34 in each sample except in 1988 when it was 32. There was no age difference between urban and rural areas. In terms of attendance to education there were large differences between urban and rural areas. Urban women went further in the education system than their rural counterparts. In urban areas the proportion of women who entered higher education doubled to 23% between 1988 and 2012 and those with primary education or less halved to 23%. In rural areas there were smaller improvements in participation. In 1988, 80% of rural women had attended up to primary education declining to 47% in 2012. For descriptive characteristics of the national sample (not stratified by urban/rural) see Appendix 9.

Table 4.3 Descriptive characteristics of Mexican women aged 20 to 49

	URBAN				RURAL			
	1988	1999	2006	2012	1988	1999	2006	2012
Complete cases, N	8 995	8 244	9 906	9 588	1 323	4 320	4 068	4 943
Age, mean	32.4 (0.1)	33.8 (0.1)	34.0 (0.1)	33.8 (0.1)	32.2 (0.3)	33.8 (0.1)	33.7 (0.2)	33.4 (0.2)
Age group, %								
20-24.9	22.8 (0.6)	17.6 (0.5)	17.3 (0.6)	18.3 (0.7)	22.6 (1.5)	18.5 (0.6)	17.4 (0.9)	18.5 (0.9)
25-29.9	19.2 (0.5)	16.5 (0.5)	16.5 (0.6)	16.2 (0.6	20.1 (1.2)	15.9 (0.6)	17.1 (0.7)	19.0 (0.9)
30-34.9	17.6 (0.6)	17.8 (0.5)	17.7 (0.6)	19.5 (0.6)	17.3 (1.2)	17.2 (0.7)	19.0 (0.8)	18.6 (0.7)
35-39.9	16.5 (0.5)	19.5 (0.6)	18.3 (0.6)	16.9 (0.6)	17.1 (0.8)	19.3 (0.7)	17.6 (0.8)	16.3 (0.7)
40-44.9	13.0 (0.5)	16.8 (0.6)	16.5 (0.6)	15.0 (0.5)	12.3 (1.4)	16.9 (0.7)	17.2 (0.9)	14.4 (0.6)
45-49.9	10.8 (0.4)	11.8 (0.5)	13.6 (0.6)	14.1 (0.6)	10.6 (1.0)	12.3 (0.6)	11.7 (0.8)	13.3 (0.6)
Level of education, %								
Higher education	10.2 (0.6)	14.6 (0.6)	16.2 (0.8)	22.6 (0.8)	2.2 (0.6)	1.8 (0.3)	2.4 (0.4)	6.5 (0.7)
High school	17.4 (0.7)	20.5 (0.6)	20.8 (0.7)	22.7 (0.7)	8.4 (1.6)	5.8 (0.6)	5.6 (0.7)	13.0 (0.8)
Secondary	17.0 (0.6)	24.3 (0.6)	28.8 (0.8)	31.2 (0.8)	9.4 (1.4)	13.7 (0.8)	24.6 (1.2)	33.9 (1.3)
Primary or less	55.4 (1.3)	40.6 (0.8)	34.4 (0.9)	23.4 (0.8)	79.9 (3.2)	78.8 (1.2)	67.5 (1.3)	46.6 (1.4)
Weight (kg), mean	56.3 (0.2)	64.4 (0.2)	66.5 (0.2)	68.1 (0.3)	54.6 (0.7)	59.7 (0.4)	63.5 (0.4)	64.8 (0.3)
Height (cm), mean	153.5 (0.2)	153.6 (0.1)	154.2 (0.1)	154.9 (0.1)	152.0 (0.4)	150.5 (0.2)	151.9 (0.2)	152.4 (0.2)
BMI, mean	23.9 (0.1)	27.3 (0.1)	28.0 (0.1)	28.4 (0.1)	23.6 (0.2)	26.3 (0.1)	27.5 (0.1)	27.8 (0.1)
BMI categories[a], %								
<18.5 Underweight	9.3 (0.4)	1.9 (0.2)	1.6 (0.2)	1.9 (0.3)	10.0 (1.3)	2.9 (0.3)	1.3 (0.2)	1.7 (0.3)
18.5-24.9 Normal range	56.1 (0.7)	35.2 (0.6)	31.6 (0.8)	29.2 (0.8)	57.9 (2.6)	42.1 (1.0)	32.8 (1.1)	31.0 (1.1)
25-29.9 Overweight	25.1 (0.6)	37.1 (0.6)	35.8 (0.9)	34.3 (0.8)	24.1 (1.8)	33.5 (0.8)	38.0 (1.1)	36.7 (1.0)
≥30 Obese	9.5 (0.4)	26.3 (0.6)	30.9 (0.7)	34.5 (0.8)	8.1 (1.2)	21.3 (0.8)	27.9 (1.1)	30.7(1.0)
≥35 Class II & III obesity	2.2 (0.2)	8.1 (0.3)	11.1 (0.5)	12.5 (0.6)	2.0 (0.5)	5.6 (0.4)	8.3 (0.6)	9.6 (0.6)

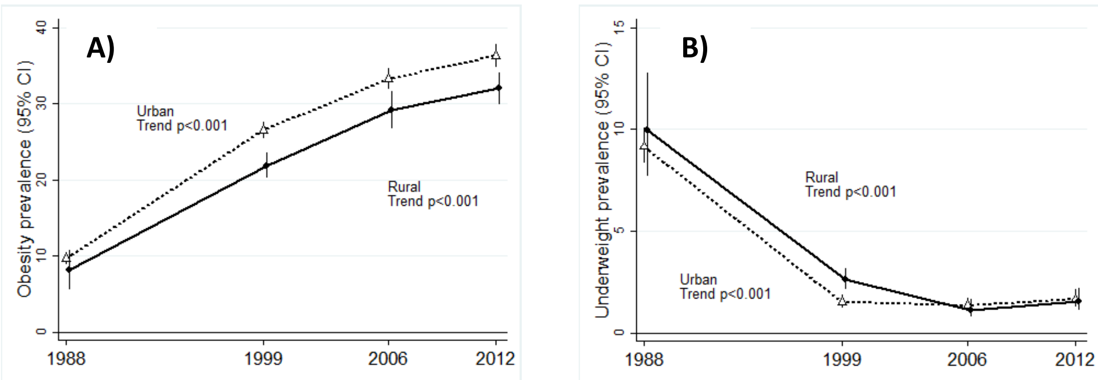
[a] Age standardised prevalence
Standard errors in parentheses

4.3.3 Obesity prevalence

The average weight of Mexican women increased by 12 kg in urban areas and 10 kg in rural areas in the period 1988-2012. Height increased by 1 cm in urban areas and remained constant in rural areas. Linked to these changes, the average BMI in urban areas increased from 23.9 to 28.4 kg/m^2 and from 23.6 to 27.8 kg/m^2 in rural areas (Table 4.3). The prevalence of underweight women, defined as individuals with a BMI below 18.5, declined significantly in the period 1988 to 1999 and remained stable thereafter (quadratic term $p<0.001$) (Table 4.3; Figure 4.1B). In 1999 women living in rural areas had a significantly higher underweight prevalence than women living in urban areas. In the last two survey years, there was no difference in prevalence of underweight women between urban and rural areas (Figure 4.1 B). Obesity prevalence increased steadily over the study period reaching 34.5 per cent among urban women in 2012 and 30.7 per cent among rural women (Table 4.3; Figure 4.1A). The rate of increase in obesity prevalence slowed down in more recent years in both urban and rural areas therefore the trend over time was curvilinear ($p<0.001$) (Figure 4.1A). Obesity was higher ($p<0.05$) in urban than rural areas in the years 1999 through to 2012 however only by a few percentage points.

Table 4.4 shows how obesity prevalence increased by age group in all surveys. The increase in obesity prevalence was particularly steep in the earlier years of adulthood and in subsequent years it began to plateau. The quadratic term for age was significant in all survey years. In the most recent survey, half of all women aged between 45 and 49 were obese in urban areas and 47% of the same age group were obese in rural areas (Table 4.4).

Figure 4.1 Obesity (A) and underweight trends (B) 1988-2012



Quadratic term $p<0.001$ in urban and rural areas for both obesity and underweight trends

Table 4.4 Obesity prevalence by age group and education level

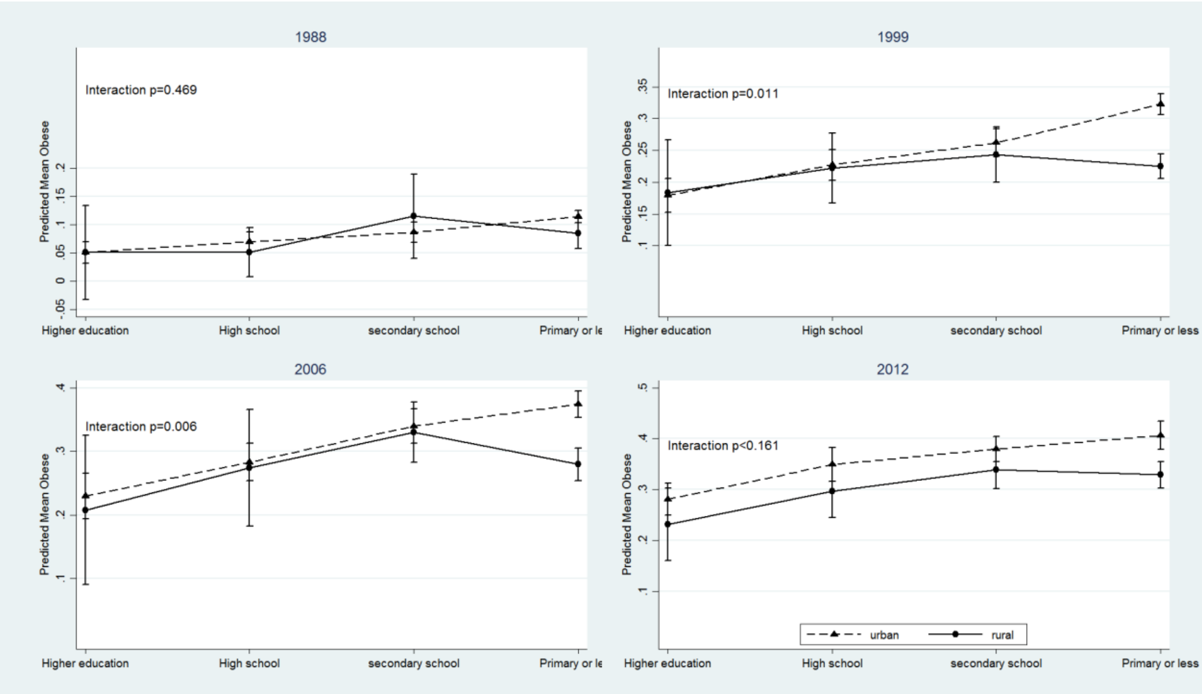
URBAN	1988 %(95%CI)	1999 %(95%CI)	2006 %(95%CI)	2012 %(95%CI)
Age group				
20-24.9	3.1 (2.2,3.9)	12.5 (10.8,14.2)	14.6 (12.0,17.2)	22.13 (18.7,25.6)
25-29.9	5.9 (4.5,7.2)	20.4 (18.3,22.4)	26.7 (23.5,30.0)	28.08 (24.5,31.7)
30-34.9	8.5 (7.1,9.9)	25.8 (23.6,28.1)	30.3 (27.2,33.4)	35.63 (32.2,39.0)
35-39.9	14.0 (12.0,16.0)	32.8 (30.3,35.3)	40.0 (36.8,43.2)	42.20 (38.9,45.5)
40-44.9	15.8 (13.3,18.4)	35.3 (32.7,38.0)	44.6 (40.8,48.4)	43.43 (40.1,46.8)
45-49.9	18.1 (15.4,20.9)	43.9 (40.6,47.2)	45.7 (41.6,49.8)	50.38 (45.9,54.8)
Trend p	<0.001[a]	<0.001[a]	<0.001[a]	<0.001[a]
Education [b]				
Higher education	5.1 (3.1,7.0)	17.75 (15.1,20.4)	21.8 (18.4,25.2)	26.7 (23.8,29.7)
High school	7.0 (5.2,8.8)	21.90 (19.6,24.2)	26.8 (23.9,29.6)	33.7 (30.3,37.0)
Secondary school	8.4 (6.6,10.2)	24.82 (22.8,26.9)	32.3 (29.7,34.9)	36.6 (34.1,39.1)
Primary school	11.2 (10.1,12.3)	31.06 (29.2,32.9)	36.5 (34.1,38.8)	38.5 (35.2,41.8)
Trend p	<0.001	<0.001	<0.001	<0.001
RURAL				
Age				
20-24.9	2.6 (0.8,4.4)	9.5 (7.5,11.5)	16.2 (12.0,20.5)	17.2 (13.7,20.7)
25-29.9	3.6 (1.2,6.0)	15.9 (13.9,18.0)	25.5 (20.9,30.2)	26.6 (22.5,30.8)
30-34.9	8.0 (3.8,12.1)	23.7 (20.1,27.2)	29.8 (25.4,34.2)	30.2 (26.5,33.9)
35-39.9	12.1 (6.3,18.0)	27.8 (24.6,31.0)	33.3 (28.7,37.9)	37.5 (33.2,41.7)
40-44.9	15.9 (8.6,23.1)	31.9 (28.1,35.8)	33.3 (28.4,38.3)	40.1 (35.2,45.0)
45-49.9	13.4 (5.9,20.9)	32.6 (28.5,36.7)	40.4 (34.1,46.7)	47.3 (42.2,52.4)
Trend p	<0.001[a]	<0.001[a]	<0.001[a]	<0.001[a]
Education [b]				
Higher education	3.7 (1.0,6.4)	18.0 (10.1,25.9)	27.8 (19.9,35.8)	21.6 (15.3,27.9)
High school	5.4 (0.3,10.5)	20.6 (15.7,25.6)	24.9 (16.4,33.4)	28.8 (23.9,33.7)
Secondary school	14.3 (5.6,23.0)	29.2 (25.0,33.5)	31.5 (26.8,36.2)	32.3 (28.8,35.7)
Primary school	8.1 (5.6,10.6)	21.6 (19.7,23.4)	27.6 (24.6,30.7)	31.0 (28.0,34.0)
Trend p	0.50	0.99	0.96[a]	0.11[a]

[a] Significant quadratic term
[b] age standardised obesity prevalence

4.3.4 Educational inequalities in obesity and time trends

Table 4.4 shows the distribution of obesity by education level. Obesity increased sharply in all education groups in both urban and rural areas in the period 1988 to 2012. In urban areas, obesity affected the least educated women disproportionately. There was an inverse linear socioeconomic gradient since 1988. A decline of one education level increased obesity prevalence by 30% (PR 1.30 95%CI 1.18, 1.44) in 1988 and by 12% (PR 1.12 95%CI 1.08, 1.16) in 2012. In rural areas, there was no association with education level in 1988 and 1999 and there was a significant non-linear association in 2006 and 2012. The secondary education group had the highest obesity prevalence throughout the period (Table 4.4). The association between education and obesity varied significantly by urban and rural areas in 1999 and 2006 (both interactions p<0.01 (Figure 4.2)). For this reason all analyses were conducted stratifying by urban/rural in this and the following chapters. Predicted obesity prevalence was not different between urban and rural areas among women in the higher education, high school and secondary school groups. Women from rural areas with primary education or less had a predicted obesity prevalence significantly lower than that of women from urban areas in 1999 through to 2012. However, women with primary education or less appeared to be catching up with those in the secondary education group in terms of obesity prevalence in the last survey wave (Table 4.4; Figure 4.2).

Figure 4.2 Effect modification of the association between education and obesity by urban or rural dwelling



Dashed line: urban areas; solid line: rural areas. Trend p in urban areas <0.001 in all survey years. Trend p in rural areas 0.50, 0.99, 0.96 and 0.11 in 1988, 1999, 2006 and 2012 respectively. Significant quadratic term in rural areas in the years 2006 and 2012 (see Table 4.4).

Table 4.5 Absolute and relative inequalities in obesity

	Urban		Rural	
Year	**RII (95%CI)**	**SII (95%CI)**	**RII (95%CI)**	**SII (95%CI)**
1988	2.74*(1.86,4.03)	6.7*(4.3,9.1)	1.10 (0.33,3.59)	0.0 (-6.6,6.5)
1999	2.09*(1.78,2.45)	16.9*(12.8,21.0)	0.90 (0.67,1.22)	2.8 (-2.7,8.3)
2006	1.73*(1.48,2.03)	17.4*(12.3,22.5)	0.88 (0.64,1.21)	-1.3 (-11.1,8.4)
2012	1.54*(1.33,1.79)	16.4*(10.6,22.2)	1.11 (0.88,1.41)	3.5 (-4.5,11.5)
Linear trend across surveys p	p<0.001	p=0.002a,b	p=0.935	p=0.392a,b

RII: Relative index of inequality
SII: Slope index of inequality
*p<0.001 in each survey year
[a] estimated using survey weighted linear regression
[b] quadratic term p<0.001

Absolute inequalities

In urban areas, there was a large increase in absolute inequalities measured by the slope index of inequality from 1988 to 1999, from 6.66 (95% CI 4.26, 9.06) to 16.86 (95% CI 12.76, 20.97). From 1999 to 2012 there was no significant change in the SII (Table 4.5; Figure 4.3). There was a curvilinear trend in the SII across the period 1988 to 2012 (p<0.001). Excess obesity cases in women with primary education or less ranged from over 300,000 in 1988 to close to 800,000 in 2006 when absolute inequalities reached their peak. Absolute inequalities were not statistically significant in rural areas.

In urban areas, absolute increases in obesity prevalence between 1988 and 1999 were greater among women with primary or less education than among women with more years in education (Table 4.6). Obesity prevalence increased 21.6 percentage points (95%CI 19.48, 23.72) among urban women that attended primary education or less in the period 1988-1999, compared to 11 percentage points (7.89, 14.07) among women that attended higher education. In the periods between 1999 to 2006 and 2006 to 2012 absolute increases in obesity prevalence were similar for all education groups. In rural areas, the largest increases in obesity prevalence were in the period 1988 to 1999 similar to urban areas. However the increase in obesity prevalence was not significantly different between education groups. From 1999 to 2006, obesity increases were only statistically significant for the secondary education group and primary education or less. In the more recent period from 2006 to 2012, increases in obesity were significant only for the group of women with primary education or less.

Figure 4.3 Trend in the slope index of inequality, 1988-2012

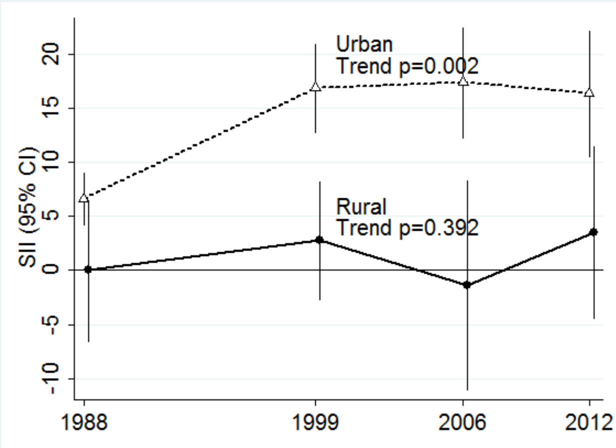


Table 4.6 Absolute increases in obesity prevalence by education level

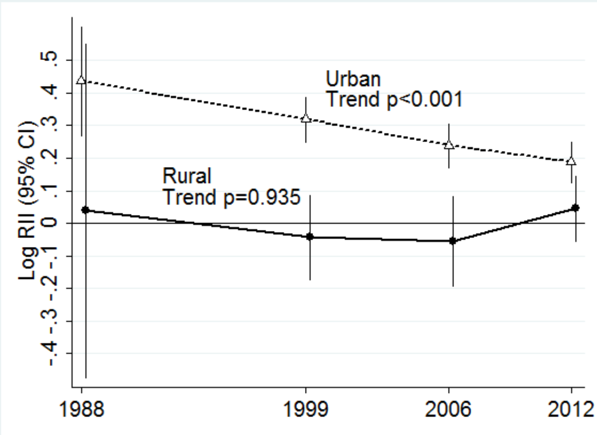
	1988-1999 PD[a](95%CI)	1999-2006 PD(95%CI)	2006-2012 PD(95%CI)	1988-2012 PD95%CI)
Urban areas				
Higher education	11.0 (7.9,14.1)	4.4 (0.2,8.6)	5.0 (0.6,9.5)	20.4 (17.1,23.8)
High school	13.5 (10.9,16.0)	5.3 (1.7,8.9)	6.8 (2.4,11.1)	25.5 (21.8,29.2)
Secondary	15.8 (13.3,18.2)	7.4 (4.1,10.7)	4.3 (0.7,7.9)	27.4 (24.5,30.3)
Primary or less	21.6 (19.5,23.7)	5.1 (2.3,8.0)	2.8 (-0.8,6.5)	29.6 (26.5,32.7)
Rural areas				
Higher education	12.3 (2.0,22.5)	1.1 (-11.0,13.3)	3.3 (-8.0,14.7)	16.8 (7.6,25.9)
High school	13.4 (8.0,18.8)	5.3 (-3.9,14.4)	2.2 (-7.0,11.4)	20.9 (15.3,26.5)
Secondary	10.1 (4.3,15.9)	7.9 (2.7,13.1)	0.1 (-5.2,5.5)	18.2 (12.2,24.1)
Primary or less	13.9 (10.7,17.1)	5.8 (2.4,9.3)	4.6 (0.6,8.7)	24.3 (20.5,28.2)

[a] Age adjusted prevalence difference

Relative inequalities

Relative inequalities declined in urban areas. The relative index of inequality in urban areas was 2.74 (95% CI: 1.86, 4.03) in 1988 and declined over the period to 1.54 (95% CI: 1.33, 1.79) in 2012, trend p<0.001 (Table 4.5; Figure 4.4). In rural areas the relative index of inequality was non-significant in all survey years.

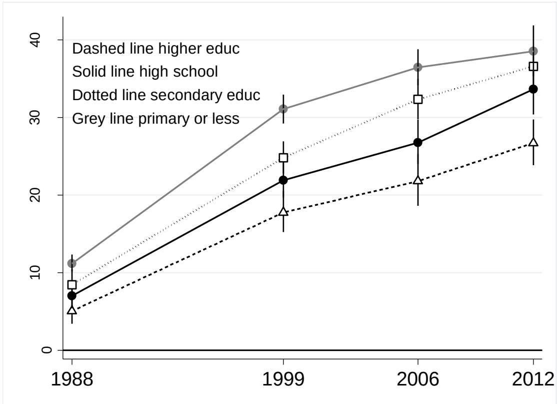
Figure 4.4 Trend in the relative index of inequality, 1988-2012



Relative increases were largest in the most educated women in urban areas (p<0.001 for the null hypothesis of homogeneity of rates across education levels). Obesity increased 5.89 fold (95% CI 4.01, 8.66) among urban women in the higher education group in the period 1988-2012 compared to 3.25 fold (95%CI 2.89, 3.65) for urban women with primary or no education. Between 2006 and 2012, the prevalence of obesity among urban women in the secondary education and primary or less groups did not increase significantly, while there was a 22% increase in obesity prevalence among women in the high school or higher education groups (PR 1.22 p<0.05 for both groups, Table 4.7). This resulted in the stepwise decline from 1988 to 2012 in the relative index of inequality as illustrated in Figure 4.4. Figure 4.5A further illustrates how obesity prevalence among women with primary education or less appeared to be plateauing while obesity prevalence continued to increase among women in the higher education group. Among rural women, there was a tendency to larger increases in the prevalence of obesity over time in the high school education group (PR 7.02 95%CI 2.94, 16.76) however, the increases across education levels were not statistically different (Table 4.7). Similar to urban areas, the prevalence of obesity appeared to be reaching a plateau among women in the secondary education group who had the highest prevalence of obesity (Figure 4.5B).

Figure 4.5 Increase in obesity prevalence by education level A) urban areas B) rural areas

A)



B)

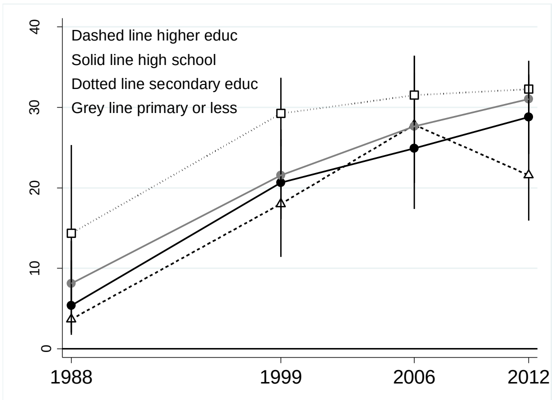


Table 4.7 Relative increases in obesity prevalence by education level

	1988-1999 PR[a] (95%CI)	**1999-2006 PR(95%CI)**	**2006-2012 PR(95%CI)**	**1988-2012 PR(95%CI)**
Urban areas				
Higher education	3.85 (2.59,5.73)	1.25 (1.01,1.55)	1.22 (1.01,1.47)	5.89* (4.01,8.66)
High school	3.53 (2.68,4.64)	1.25 (1.08,1.45)	1.22 (1.06,1.41)	5.41 (4.10,7.13)
Secondary	3.23 (2.57,4.05)	1.32 (1.18,1.49)	1.10 (0.99,1.22)	4.71 (3.77,5.88)
Primary or less	2.69 (2.42,3.00)	1.12 (1.04,1.21)	1.07 (0.99,1.17)	3.25 (2.89,3.65)
Rural areas				
Higher education	3.81 (0.67,21.65)	1.07 (0.50,2.28)	1.17 (0.58,2.33)	4.74ł (0.86,26.06)
High school	4.98 (2.05,12.07)	1.28 (0.84,1.95)	1.10 (0.76,1.61)	7.02 (2.94,16.76)
Secondary	2.36 (1.17,4.73)	1.35 (1.07,1.70)	0.99 (0.83,1.19)	3.17 (1.59,6.31)
Primary or less	2.59 (1.84,3.63)	1.24 (1.09,1.41)	1.15 (1.02,1.30)	3.69 (2.63,5.18)

[a] Age adjusted prevalence ratio
Test for homogeneity in PR increase 1988-2012 across education levels *p<0.001 ł p=0.50

4.4 Sensitivity analyses for temporal trends of the SII and RII

4.4.1 Cohort effects

Evidence presented in this chapter shows that relative inequalities in obesity declined in urban areas (Figure 4.4). The aim of this sensitivity analysis was to evaluate whether trends in relative inequalities in obesity in urban areas varied between birth cohorts. A priori, period effects such as changes in the food and built environment occurring in the late 1980s and 1990s, would probably have a more important role in inequality trends in the Mexican context than cohort effects. In the absence of cohort effects, the unstratified results presented earlier in this chapter would be valid.

There was a large shift in the distribution of attendance to education from one cohort to the next. There was a stepwise decline in the proportion of women attending up to primary education, from 77% to 62% to 42% to 29.5% among women born in the 1940s, 1950s, 1960s and 1970s respectively. There were large increases in the proportion of women attending secondary education, from 8.7% among those born in the 1940s to 32% among those born in the 1970s (Table 4.8).

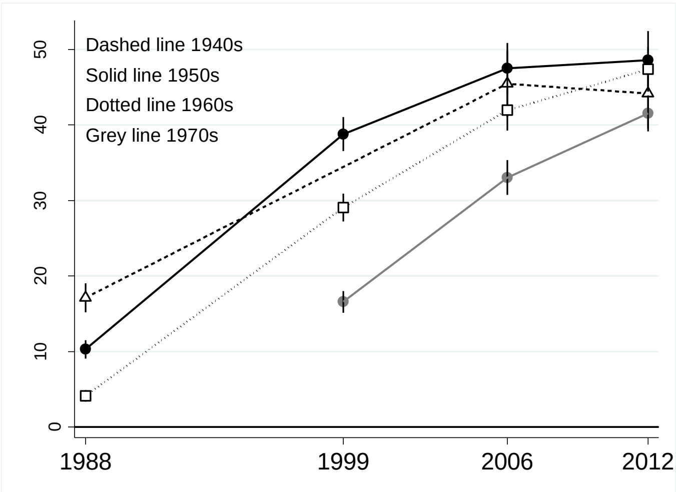
Table 4.8 Distribution of education in the different birth cohorts in urban areas

	Birth cohort			
	1940s	**1950s**	**1960s**	**1970s**
N	4,733	9,077	12,611	10,912
Higher ed	6.7 (5.4,8.0)	10.0 (8.9,11.1)	15.6 (14.5,16.6)	16.2 (15.0,17.4)
High school	7.7 (6.4,9.1)	12.5 (11.4,13.7)	19.2 (18.1,20.3)	22.0 (20.7,23.3)
Secondary school	8.7 (7.5,9.8)	15.5 (14.3,16.7)	23.5 (22.4,24.7)	32.3 (31.0,33.6)
Primary school	76.9 (74.7,79.0)	62.0 (60.2,63.8)	41.7 (40.3,43.2)	29.5 (28.1,30.9)

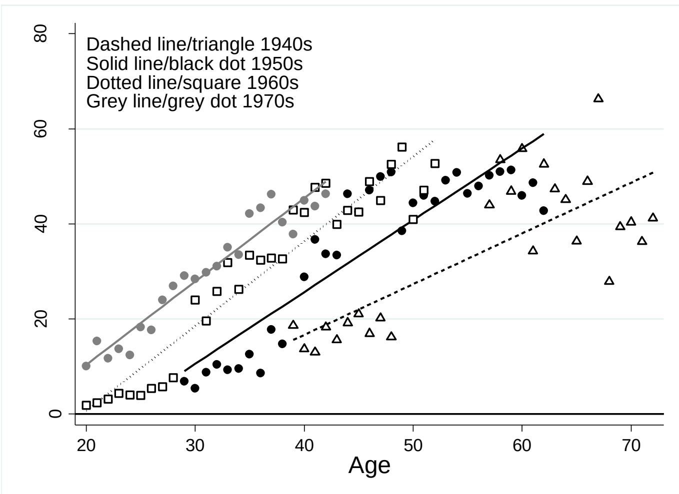
Increases in obesity prevalence over the period 1988 to 2012 were consistent for all cohorts; lines in Figure 4.6A run approximately parallel to each other. Obesity prevalence increased from 17.1% (95%CI 15.2, 19.1) in 1988 to 44.2% (95%CI 39.6, 48.8) in 2012 in the 1940s cohort. In the 1960s cohort obesity increased from 4.1% (95% CI 3.3, 4.9) to 47.3% (95%CI 44.4, 50.3) over the same period (Figure 4.6A). Figure 4.6A shows that older cohorts had a higher prevalence of obesity; however prevalence in this graph is confounded by age. The older cohorts were less obese than the younger cohorts at similar ages (Figure 4.6B). For example, women born in the 1950s had a prevalence of obesity of 5.4% (95%CI 3.04, 7.8) at age 30, whereas women born in the 1970s had a prevalence of 28.4% (95% CI 21.8, 35.0) at the same age. Successive cohorts became obese at earlier points in the life-course (Figure 4.6B). The stark differences in obesity prevalence at the same age for different cohorts and the consistent increases in obesity prevalence across all cohorts over time suggest an important period effect (as opposed to a cohort effect). Obesity in Mexico increased dramatically over the 1990s as was described earlier in this chapter.

Figure 4.6 Obesity prevalence trend stratified by birth cohort in urban areas (A) and obesity prevalence by age stratified by birth cohort (B)

A)



B)



Lines were fitted by linear regression

Table 4.9 shows the trends in the relative index of inequality from 1988 to 2012 in urban areas stratified by birth cohort. The magnitude of inequalities was similar for all cohorts with overlapping confidence intervals (Table 4.9; Figure 4.7). Except among the oldest cohort (1940s), there was a decline in relative inequalities for all cohorts in the period 1988 to 2012 ($p<0.01$). The inequality time trend models were not age adjusted due to collinearity of age with cohort and period (cohort=period-age). Confounding by age may be an issue. However,

Figure 4.7 provides supporting evidence of a declining trend in inequality for all cohorts and homogeneity in the trends over time.

There are methodological difficulties in trying to disentangle the independent effects of age, period and cohort due to their collinearity. Two methodologies that attempt to overcome these difficulties were tested with the Mexican surveys to further explore cohort effects in obesity prevalence; the median polish approach and the intrinsic estimator approach. Appendix 10 contains a description of the methodology and results.

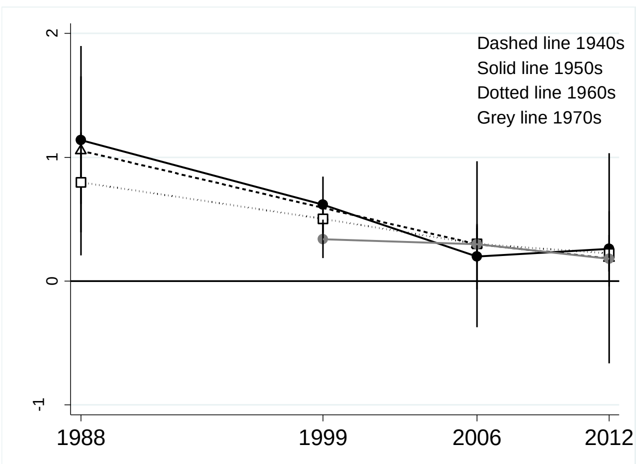
The Median Polish approach suggested that cohort effects were not present but this may have been due to a lack of power in the study. The number of times each cohort was measured was maximum 4 for the 1960s cohort but was only two for the cohorts in the extremes (1930s and 1980s). The intrinsic estimator methodology could not be applied successfully because it needed surveys conducted at more frequent and regular intervals in order to produce results. It was therefore concluded that, with the data available, more sophisticated age-period-cohort methodologies do not extend our understanding of age-period-cohort effects in obesity prevalence in Mexico beyond what has been described earlier in this section.

Table 4.9 RII stratified by birth cohort 1988-2012, urban areas

	1988	1999	2006	2012	
1940s	11.3 (1.6,79.0)	Nd	2.0 (0.4,9.3)	1.5 (0.2,10.8)	P=0.12
1950s	13.8 (4.2,45.0)	4.1 (2.5,7.0)	1.6 (0.9,2.9)	1.8 (0.9,3.7)	P<0.01
1960s	6.3 (2.5,15.9)	3.2 (2.3,4.4)	2.0 (1.4,2.8)	1.7 (1.2,2.3)	P<0.001
1970s	nd	2.2 (1.5,3.1)	2.0 (1.4,2.7)	1.5 (1.2,1.9)	P<0.04

nd: no data (women born in that decade were not measured in that survey).

Figure 4.7 Trend in the RII stratified by birth cohort over time



4.4.2 Adjustment for height

The sensitivity analysis aimed to test whether differential changes in height by education group over the study period could explain the observed trends in inequalities. If more disadvantaged women had larger increases in mean height than more advantaged women over the period 1988-2012, then this could explain the smaller relative increases in obesity prevalence among disadvantaged groups compared to more advantaged women.

Height was socially patterned in both urban and rural areas in all survey years (Appendix 11). There were on average 5 cm differences in height between women in the highest level of education and the lowest. There was a statistically significant ($p<0.001$) inverse linear gradient with education in all survey waves for both urban and rural areas. The change in height from 1988 to 2012 was not statistically significant for any education level for urban or rural areas. BMI was inversely associated with height in all survey years in urban areas but not rural areas. One cm increase in height was associated with a 0.1 kg/m^2 decline in BMI across the four surveys ($p<0.001$). The trends in the RII and SII were modelled again adjusting for height. The change in the trend coefficients shown in Figure 4.3 and Figure 4.4 was less than 1% in both urban and rural areas for the SII and RII. Statistical significance in the declining trend of the RII in urban areas was unaltered.

4.4.3 Absolute and relative inequalities in overweight (BMI≥25) and obesity class II and III (BMI≥35)

Analyses were repeated using overweight (BMI ≥25) and obesity class II and III (BMI≥35) as the outcome measures in order to examine the robustness of the findings using BMI≥30 as in the rest of this thesis. Age standardised overweight prevalence by education level is presented in Table 4.11. Prevalence of obesity class II and III is presented in Table 4.10.

Overweight prevalence and inequalities

Overweight prevalence increased from 34% in 1988 to 68% in 2012 on average in both urban and rural areas. There was a clear social gradient in urban areas; both absolute and relative inequalities were significant. Overweight prevalence reached 75% in 2012 among women with primary education or less. As in the main analysis using BMI ≥30 as outcome variable, there was a declining trend in relative inequalities in the period 1988 to 2012 which was highly significant ($p<0.001$). Absolute inequalities in urban areas were stable throughout the study period (Table 4.11).

In rural areas, overweight prevalence was high across education levels. There was a tendency of higher overweight prevalence among the more educated women in the first three survey waves. However, as in the main analysis of this chapter, there were no statistically significant absolute or relative inequalities in overweight prevalence in rural areas.

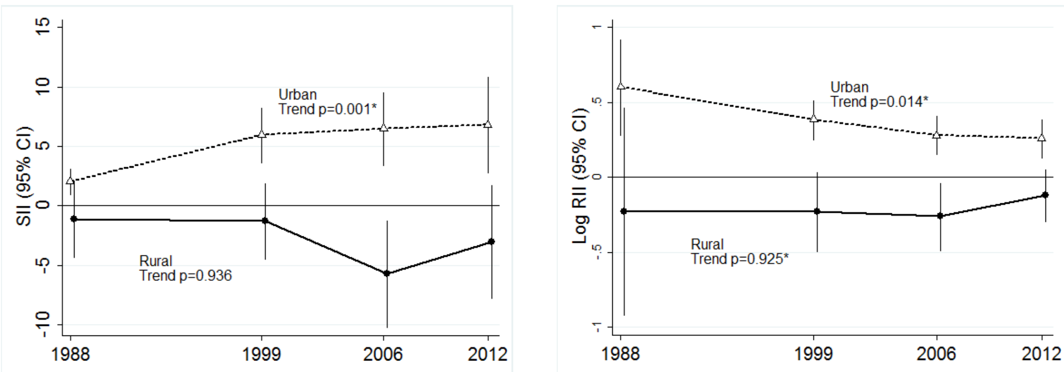
Obesity class II and III prevalence and inequalities

The prevalence of obesity class II and III was low in 1988, around 2% of women. The prevalence increased significantly among women of all education levels, especially over the period 1988 to 1999. Trends in relative and absolute inequalities were very similar to those described earlier in this chapter for obesity (BMI ≥30) (Table 4.5).

Absolute inequalities measured by the slope index of inequality increased in urban areas from 2.07 (95%CI 0.96, 3.18) in 1988 to 5.98 (95%CI 3.64, 8.32) in 1999 and remained constant thereafter Table 4.10; Figure 4.8A (curvilinear trend p<0.001). The burden of obesity class II and III was therefore largest for the most disadvantaged women in urban areas. In rural areas, the SII was only significant in 2006. Women at the top of the education hierarchy had an obesity prevalence 5.69 percent higher than those at the bottom of the educational hierarchy.

Relative inequalities measured by the relative index of inequality were of similar magnitude to those observed using BMI≥30 as outcome measure in urban areas (Table 4.5; Table 4.10). The RII was larger in 1988 in this analysis compared to the main one however confidence intervals were overlapping. There was a declining trend in relative inequalities in urban areas. The largest decline happened in the period 1988 to 1999. The trend was curvilinear (p<0.001). In rural areas, the RII was smaller than one in all years meaning the burden of class II and III obesity affected more advantaged women. However, the RII was only statistically significant in 2006 (0.55 95%CI 0.32,0.92). There was a significant curvilinear trend reflecting a change in the RII which appeared to be approaching one in the most recent survey.

Figure 4.8 Absolute (A) and relative (B) inequalities in obesity class II and III



*curvilinear trend p<0.05

Table 4.10 Prevalence of obesity class II and III by education level and summary inequality measures

	1988		1999		2006		2012	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Urban areas								
Sample N	**8 995**		**8 244**		**9 906**		**9 588**	
Higher education	1.2	(0.1, 2.3)	5.8	(4.2,7.3)	8.1	(5.8, 10.3)	9.6	(7.5, 11.7)
High school	1.4	(0.7, 2.0)	5.9	(4.8,7.1)	8.6	(6.8, 10.4)	10.7	(8.3, 13.1)
Secondary	1.7	(1.0, 2.4)	8.0	(6.6,9.4)	11.9	(10.2, 13.6)	13.8	(12.0, 15.5)
Primary or no education	2.8	(2.2, 3.3)	10.3	(9.1,11.6)	13.6	(12.1, 15.1)	14.1	(11.8, 16.4)
Summary measures of inequality								
Slope index of inequality	*2.1**	*(1.0, 3.2)*	*6.0**	*(3.6, 8.3)*	*6.5**	*(3.4, 9.6)*	*6.8**	*(2.8, 10.9)*
SII linear trend across surveys[b]	*p=0.001*[a]							
Relative index of inequality	*4.00**	*(1.91, 8.39)*	*2.43**	*(1.78, 3.31)*	*1.91**	*(1.41, 2.58)*	*1.82**	*(1.35, 2.45)*
RII linear trend across surveys	*p=0.014*[a]							
Rural areas								
Sample N	**1 323**		**4 320**		**4 068**		**4 943**	
Higher education	3.7	(1.0, 6.4)	4.2	(-1.2,9.6)	11.7	(4.6, 18.8)	6.4	(2.9, 9.9)
High school	0.6	(-0.5, 1.7)	8.2	(4.0,12.5)	15.5	(7.6, 23.4)	9.6	(6.4, 12.8)
Secondary	2.3	(-0.7, 5.3)	9.5	(6.5,12.5)	7.9	(5.9, 9.9)	11.8	(9.6, 14.1)
Primary or no education	1.9	(1.0, 2.9)	5.4	(4.6,6.2)	7.5	(6.2, 8.8)	8.4	(6.9, 9.9)
Summary measures of inequality								
Slope index of inequality	*-1.1*	*(-4.3, 2.2)*	*-1.3*	*(-4.5, 1.9)*	*-5.7**	*(-10.2, -1.2)*	*-3.0*	*(-7.8, 1.8)*
SII linear trend across survey[b]	*p=0.936*							
Relative index of inequality	*0.59*	*(0.12, 2.92)*	*0.59*	*(0.32, 1.09)*	*0.55**	*(0.32, 0.92)*	*0.76*	*(0.50, 1.14)*
RII linear trend	*p=0.925* [a]							

*p<0.001 in each survey year
[a] curvilinear trend p<0.05
[b] estimated using survey weighted linear regression

Table 4.11 Prevalence of overweight (BMI≥25) by education level and summary inequality measures

	1988	1999	2006	2012
	% (95% CI)	**% (95% CI)**	**% (95% CI)**	**% (95% CI)**
Urban areas				
Sample N	**8 995**	**8 244**	**9 906**	**9 588**
Higher education	22.3 (18.3,26.3)	51.0 (47.3,54.6)	55.7 (51.0,60.4)	59.2 (55.9,62.5)
High school	31.0 (27.7,34.2)	58.1 (55.5,60.7)	64.7 (61.1,68.2)	68.8 (65.8,71.8)
Secondary	33.1 (30.3,35.8)	67.0 (64.7,69.3)	68.3 (65.5,71.1)	71.9 (69.4,74.4)
Primary or no education	37.9 (35.9,39.9)	68.0 (66.0,70.0)	71.9 (69.4,74.3)	75.0 (71.7,78.3)
Summary measures of inequality				
Slope index of inequality	18.1 (12.6,23.6)	22.9 (17.8,28.0)	18.9 (13.0,24.8)	20.2 (14.3,26.2)
SII linear trend across surveys[a]	p=0.57			
Relative index of inequality	1.70 (1.43,2.03)	1.35 (1.26,1.45)	1.27 (1.18,1.37)	1.20 (1.13,1.29)
RII linear trend across surveys	p<0.001			
Rural areas				
Sample N	**1 323**	**4 320**	**4 068**	**4 943**
Higher education	52.1 (39.5,64.7)	60.6 (52.0,69.1)	78.7 (68.3,89.0)	63.2 (54.9,71.5)
High school	24.8 (16.4,33.2)	62.9 (57.6,68.2)	64.4 (56.6,72.3)	68.1 (63.3,72.9)
Secondary	43.3 (35.4,51.2)	62.7 (59.0,66.4)	68.9 (64.5,73.2)	69.1 (66.2,72.1)
Primary or no education	32.2 (26.7,37.6)	54.5 (52.2,56.8)	65.7 (62.6,68.9)	68.1 (64.4,71.7)
Summary measures of inequality				
Slope index of inequality	*1.4 (-16.3,19.0)*	*-3.4 (-12.1,5.4)*	*-3.4 (-13.1,6.4)*	*4.6 (-4.0,13.1)*
SII linear trend across survey[a]	*p=0.24*			
Relative index of inequality	*1.00 (0.57,1.75)*	*0.76 (0.66,0.89)*	*0.88 (0.78,1.01)*	*0.98 (0.89,1.09)*
RII linear trend	*p=0.53*			

[b] estimated using survey weighted linear regression

4.5 Summary of the chapter

This chapter presented time trends in educational inequalities in obesity among Mexican women over the period 1988 to 2012 separately for urban and rural areas. Obesity prevalence among Mexican women increased dramatically across all education groups over the study period (1988-2012) with the largest increases between 1988 and 1999. Although the difference in obesity prevalence between urban and rural areas was not large, the social patterning of obesity differed significantly. There was an inverse association between education level and obesity prevalence among urban-dwelling women in all survey years consistent with the first part of this chapter's hypothesis. However, contrary to the hypothesis, this study found strong evidence that relative inequalities in obesity declined over the period 1988-2012 as a consequence of a larger increase in obesity prevalence in more educated compared to less educated women in urban areas of Mexico. In rural areas, it was hypothesised that the association between education and obesity would be direct in the earlier years but that more disadvantaged women would have larger increases in obesity prevalence leading to a reversal in the social gradient. The study found that education was not associated with obesity in rural areas of Mexico. Obesity prevalence increased significantly among rural women of all education levels.

Three sensitivity analyses were carried out. The first examined trends in educational inequalities stratified by birth pseudo-cohort. This analysis showed that the magnitude of inequalities was similar over time in four cohorts born in the 1940s, 1950s, 1960s and 1970s. Secondly it suggested a tendency towards declining inequalities over the period of study (1988-2012) for all cohorts. These findings support the main results of the chapter; period effects (as opposed to cohort effects) appear to explain the trends in obesity inequalities among urban women.

The second sensitivity analysis explored a potential confounding role of height in the trend analysis. Height was socially patterned by education and inversely associated with BMI. Height did not change significantly for any education group over the period 1988 to 2012. The trend coefficients and statistical significance were unaltered when models were adjusted for height. The third sensitivity analysis tested whether trends were similar when using overweight or obesity class II and III as the outcome variables. Trends in inequality using both these variables were very similar to those described in the main analysis.

The results presented in this chapter including strengths and limitations are discussed in Chapter 8. In the next chapter, trends in obesity inequalities by household wealth will be examined. Wealth measures a material dimension of SEP. The correlation between education and wealth in LMIC appears to be lower than in HIC. Therefore the social patterning of obesity by wealth is expected to be different to that of education. Testing the nutrition transition proposition of a reversal of the social gradient with a different SEP indicator will help to better understand its generalizability.

Further the role of household wealth in the association between education and obesity will be examined. The association between SEP and obesity appears to be moderated by country economic development. The analysis in Chapter 5 will explore whether household wealth may modify the association between education and obesity. This will shed light on the role of material resources in the production of obesity inequalities.

Chapter 5 Educational inequalities in obesity by level of household wealth over time

5.1 Introduction

In the previous chapter, changes in educational inequalities in obesity over time were investigated. In urban areas, there was an inverse educational gradient in obesity in 1988 which became shallower over the period to 2012. In poorer rural areas, there was no gradient. Women with primary education or less had lower obesity prevalence than those with secondary education. There was some evidence that the reversal of the social gradient in rural areas could occur after 2012. This chapter aims to investigate inequalities in obesity by household wealth, as a measure of material circumstances, over time and to investigate educational inequalities in obesity by level of household wealth over time.

The correlation between education and wealth in less developed countries may be weaker than in more developed countries. It is not unusual to find inconsistent associations between education and obesity and wealth and obesity in LMIC. However, a reversal of the social gradient has been described using wealth or income as indicators of SEP (92, 99). A study using Mexican data from 2000 found no association between wealth and obesity among urban women and a direct association among rural women (106). It was hypothesised that, in Mexico, changes in the wealth-obesity association leading to the reversal of the social gradient, from direct to inverse, would be observed at a higher level of country GNI compared with education, and that poorer rural areas would be behind in the transition. Although there has been sustained economic development in Mexico over the last 25 years, high income inequality has meant that despite average economic progress, absolute poverty has persisted in some sections of the population. The reversal of the wealth gradient is hypothesised to occur at a level of country GNI where the poorest sections of the population have crossed a material threshold and become at risk of obesity.

Further, it was hypothesised that wealth would modify the association between education and obesity. Education would be protective of obesity at higher levels of wealth but not at lower where absolute poverty would preclude women from becoming obese. A reversal of the education gradient would be observed among poorer women in the period of study (1988-2012) due to improvements in the standard of living. If this hypothesis was true, the protective role of education in Mexico would be confirmed, and the hypothesis of the reversal of the social gradient in obesity in the context of the nutrition transition would be strengthened.

5.2 Methods

5.2.1 Analytic sample

This chapter presents analyses of the same sample as the previous chapter; n=51,387 non-pregnant, 20 to 49 year old women, after exclusion of missing data and extreme, implausible values for BMI (BMI<10, BMI>75; less than 0.5% of total sample). Detailed analysis of missingness was presented in the previous chapter.

5.2.2 Variables

The outcome of interest was a binary variable for obesity (0 =BMI<30, 1 =BMI≥30) and the main exposure variables were a categorical variable for attendance to education (1=higher education, 2=high school, 3=secondary education, 4=primary education or less) and a categorical variable for household wealth (1=richest, 2 =middle, 3=poorest). Chapter 3 described how the wealth index was constructed (page 67). Age was a confounder of the association between wealth and obesity therefore age-standardised prevalence estimates are presented and models were adjusted for age. A quadratic term for age was included in models given the curvilinear association of age with obesity. Consistent with the previous chapter, all analyses were stratified by a variable that identified women living in urban areas (>2,500 inhabitants) and rural areas (≤2,500 inhabitants).

5.2.3 Statistical analysis

The age standardised prevalence of obesity by wealth group in each survey year and by urban and rural areas was estimated as described in the methodology chapter (page 78). Linearity in the wealth gradient was assessed by regressing obesity on wealth as a continuous variable, adjusted for age and age squared (191, 192). Deviation from linearity in the wealth gradient was tested by adding a quadratic term of wealth to the model. As described elsewhere (page 78), the relative index of inequality and slope index of inequality were estimated in each survey wave. All models were adjusted for age and quadratic age and stratified by urban and rural areas.

Time trends in the RII and SII over the period 1988 to 2012 were tested by estimating the p value for an interaction term between wealth and calendar years since baseline. Obesity prevalence increases by wealth level were calculated by regressing obesity on survey wave in models stratified by wealth. GLM models with a logarithmic link function were used to estimate relative increases while conventional linear regression was used to estimate absolute increases.

Interaction between education and wealth

First the separate effects of education and wealth on obesity were estimated by regressing obesity on the categorical variable of education or wealth (rather than the rank variables used for the RII). Models were adjusted for age and age squared. The highest level of education and wealth were used as reference categories. Second, to test the hypothesis that wealth modifies the association between education and obesity, obesity was regressed on the continuous education variable 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. A Wald test rather than a likelihood ratio (LR) test was used because the latter is not valid with estimation procedures that adjust for design effect using STATA. This methodology was repeated for each survey year for urban and rural areas. For the analysis of the wealth-education interaction in rural areas, the first two and last two surveys were pooled together because of small numbers in some of the cells.

The RII was not used in this section because in order to compute the education RII in each level of wealth correctly, the education rank variable would have had to be constructed 72 times using the education proportions at each level of wealth for each year for urban and rural areas. This seemed cumbersome given that the main aim of this section (to show changes in the educational gradient by wealth level) could be achieved using a simpler methodology.

In order to aid the interpretation of the interaction, the predicted probabilities of obesity for each combination of education level and wealth tertile were plotted. Stata's *margins* command was used to predict obesity prevalence for the different combinations of wealth and education according to the model with the interaction. The *marginsplot* command was used to produce the graphs (on the y axis predicted obesity prevalence).

5.3 Results

5.3.1 Distribution of the sample

The distribution of the sample according to demographic characteristics was presented in chapter 4, Table 4.3. Table 5.1 presents the distribution of the sample according to level of wealth overall and within education levels. Rural areas were significantly poorer than urban areas in Mexico (158) and this was reflected in the level of household wealth. In urban areas, between 36 and 50 per cent of the population was classified in the richest wealth tertile and between 14 and 34 per cent in the poorest tertile. In rural areas, between 8 and 15 per cent was in the richest tertile while 51 to 70 per cent was classified in the poorest tertile.

Table 5.1. N for the different combinations of education and wealth and wealth proportions* within education level

	Urban			Rural		
	Richest	**Middle**	**Poorest**	**Richest**	**Middle**	**Poorest**
1988						
Higher education	683 (81.5)	162 (15.1)	37(3.4)	20 (55.2)	13 (34.3)	4 (10.5)
High school	981 (63.7)	491 (27.8)	162 (8.5)	48 (40.4)	53 (33.7)	36 (25.9)
Secondary	690 (48.7)	538 (32.3)	331(19.0)	46 (37.0)	53 (31.0)	58 (32.0)
Primary or no educ	1,003 (17.8)	1,582 (29.2)	2,335 (53.3)	62 (4.8)	173 (15.0)	757 (80.2)
Overall	3357 (36.4)	2773 (29.2)	2865 (34.4)	176 (10.6)	292 (19.6)	855 (69.8)
1999						
Higher education	879 (83.4)	165 (14.2)	30 (2.4)	39 (38.6)	37 (42.3)	16 (19.1)
High school	1,139 (72.1)	430 (23.6)	96 (4.2)	89 (32.2)	133 (47.1)	59 (20.7)
Secondary	882 (50.6)	817 (38.0)	279 (11.4)	120 (18.5)	304 (44.4)	249 (37.0)
Primary or no educ	965 (26.5)	1,593 (45.7)	953 (27.7)	219 (5.0)	936 (24.4)	2,111 (70.7)
Overall	3865 (50.5)	3005 (35.1)	1358 (14.4)	467 (8.3)	1410 (29.1)	2435 (62.6)
2006						
Higher education	1,007 (79.4)	248 (17.0)	50 (3.6)	24 (46.8)	24 (21.3)	23 (32.0)
High school	1,065 (60.6)	574 (31.4)	198 (8.0)	43 (19.1)	81 (40.0)	88 (40.8)
Secondary	965 (40.7)	1,202 (40.0)	670 (19.3)	104 (12.4)	372 (36.8)	547 (50.8)
Primary or no educ	830 (27.8)	1,579 (34.9)	1,518 (37.1)	142 (5.0)	715 (22.2)	1,905 (72.8)
Overall	3867 (45.0)	3603 (34.9)	2436 (20.1)	313 (8.2)	1192 (26.4)	2563 (65.4)
2012						
Higher education	1,436 (79.9)	324 (16.5)	66 (3.6)	140 (59.5)	78 (28.2)	36 (12.2)
High school	1,026 (57.2)	590 (31.6)	254 (11.2)	123 (28.3)	201 (38.9)	171 (32.8)
Secondary	1,075 (36.8)	1,274 (40.9)	780 (22.4)	230 (14.2)	670 (42.2)	806 (43.5)
Primary or no educ	538 (22.7)	1,091 (38.9)	1,134 (38.4)	174 (7.0)	674 (24.1)	1,640 (68.9)
Overall	4075 (47.3)	3279 (33.6)	2234 (19.0)	667 (15.3)	1623 (33.4)	2653 (51.3)

*Proportions are adjusted for survey design so may not be equal to the crude proportions calculated from n

The correlation of education and wealth was moderate as can be seen in Table 5.2. Up to 27 per cent of those with primary education or less in urban areas classified in the richest wealth tertile (see 1999 and 2006 in Table 5.1). However those with higher education in urban areas were most likely to be classified in the richest wealth tertile. Women with primary education or less in urban areas were less likely than their rural counterparts to be in the poorest wealth tertile suggesting that even with few qualifications, women in urban areas were able to live in richer households. In rural areas, the number of women with higher education was small and when stratified by wealth, most cells have n<25. For this reason, the first two and last two surveys were pooled for the analysis of the wealth education interaction in rural areas.

Table 5.2 Correlation between education and wealth by survey year

	Urban (Spearmans rho)	Rural (Spearmans rho)
1988	0.46	0.46
1999	0.42	0.33
2006	0.41	0.20
2012	0.44	0.31

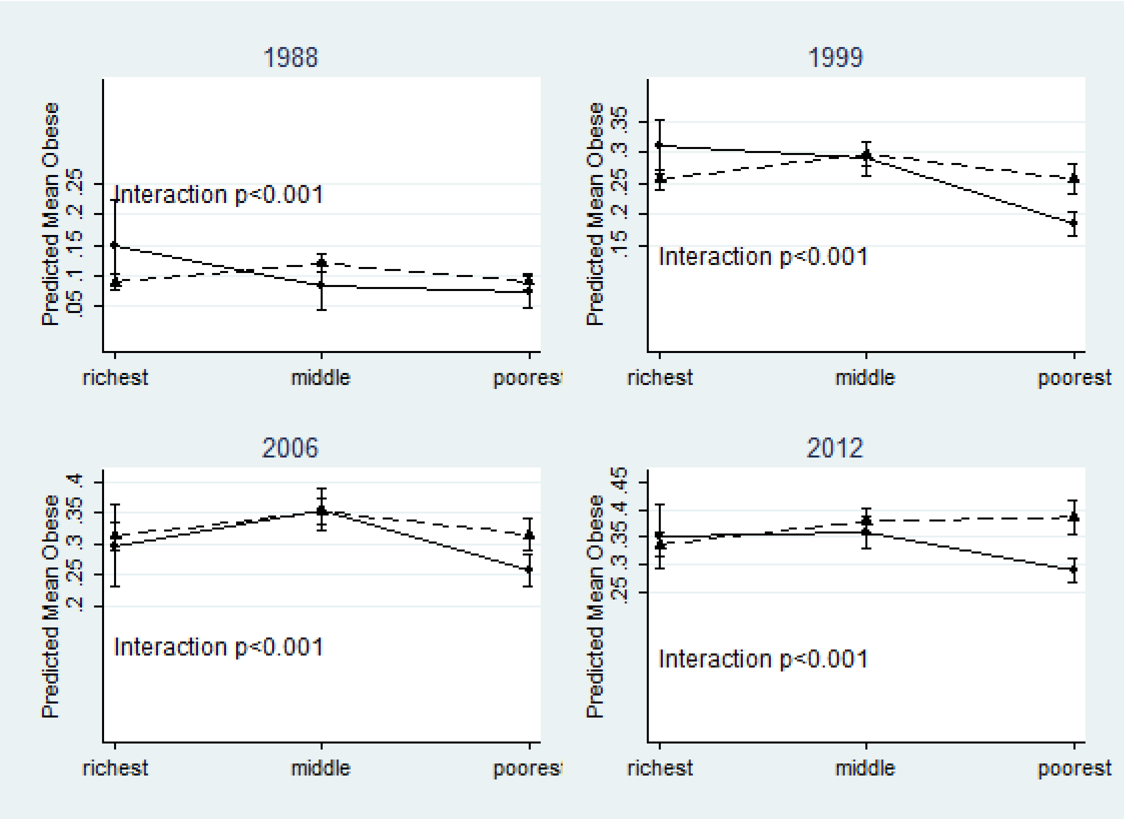
5.3.2 Inequalities in obesity by wealth

Table 5.3 shows the prevalence of obesity by wealth level for urban and rural women from 1988 to 2012. Obesity prevalence increased significantly in all wealth groups over the period 1988-2012. In urban areas, there was an inverted U shape association between wealth and obesity in the first three survey waves (1988, 1999 and 2006); the middle wealth group had the largest obesity prevalence (quadratic term for the first three years p<0.01). In the last survey (2012) an inverse linear gradient emerged (Table 5.3). One level decline in wealth increased obesity prevalence by 8% (PR: 1.08 95%CI 1.03, 1.13). Obesity prevalence among the poorest women increased enough to equal the prevalence of the middle wealth group.

In poorer rural areas wealth was directly associated with obesity in 1988 and 1999 (Table 5.3). The richest women had the highest obesity prevalence while being poor was protective. In 1999 for example, one step down in the wealth hierarchy (towards poorest) was associated with a 26% (PR 0.74 95%CI 0.68, 0.80) decline in obesity prevalence. From 2006 onwards an inverted U shape association emerged. The middle wealth group had a higher obesity prevalence than the richest and the poorest (quadratic term p<0.05).

Figure 5.1 illustrates the wealth gradient in urban and rural areas from 1988 to 2012. The interaction between wealth and urban and rural was highly significant at all survey waves (p<0.001). The reversal of the social gradient in urban areas can be observed in this figure (dashed line). There was a transition from an inverted U shape association between wealth and obesity in the first three surveys to an inverse association in 2012. In rural areas (solid line), a transition occurred from a direct association between wealth and obesity in 1988 and 1999 to an inverted U shape association in 2006 and 2012.

Figure 5.1 Social gradient by wealth in urban and rural areas, women 1988-2012



Dashed line: urban areas; solid line: rural areas.

Table 5.3 Age standardised obesity prevalence in women by wealth tertiles stratified by urban and rural areas

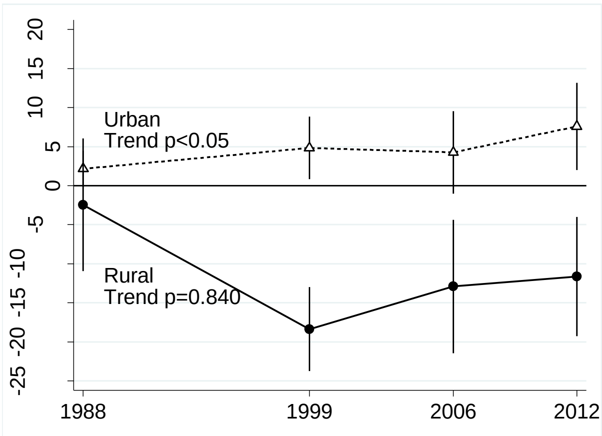
	1988			1999			2006			2012		
	%	95% CI		%	95% CI		%	95% CI		%	95% CI	
Urban areas												
N	***8,995***			***8,244***			***9,906***			***9,588***		
Richest	8.6	(7.4,	9.8)	24.1	(22.7,	25.6)	28.9	(26.7,	31.2)	32.5	(30.2,	34.7)
Middle	11.5	(10.1,	12.9)	28.6	(26.8,	30.4)	33.9	(31.6,	36.1)	36.8	(34.3,	39.2)
Poorest	8.9	(7.6,	10.2)	24.6	(21.2,	26.9)	30.1	(27.4,	32.7)	36.6	(33.5,	39.7)
Linear trend	*1.0*	*(0.9,*	*1.1)*	*1.0*	*(0=1.0,*	*1.1)*	*1.0*	*(1.0,*	*1.1)*	*1.1*	*(1.0,*	1.1)
Quadratic term	*p<0.001*			*p<0.001*			*P<0.01*			*p=0.10*		
Rural areas												
N	***1,323***			***4,320***			***4,068***			***4,943***		
Richest	15.0	(7.6,	22.4)	29.6	(25.4,	33.7)	27	(20.4,	33.0)	32.1	(26.3,	37.9)
Middle	8.5	(4.1,	12.9)	27.4	(24.9,	29.8)	34	(30.6,	38.0)	34.5	(31.3,	37.8)
Poorest	7.2	(4.5,	9.9)	17.6	(15.6,	19.6)	25	(22.7,	28.1)	27.4	(25.2,	29.6)
Linear trend	0.7	(0.5,	1.0)	0.7	(0.7,	0.8)	1	(0.8,	0.9)	0.9	(0.8,	1.0)
Quadratic term	p=0.30			P<0.01			p<0.001			p=0.05		

Absolute inequalities

Absolute inequalities in urban areas were significant in 2012 and marginally in 1999 (Table 5.4). In 2012, the poorest women in the wealth hierarchy had obesity prevalence approximately 7.6% higher than the richest. There was a significant trend in the SII which suggested increasing absolute inequalities over the period 1988 to 2012 (Figure 5.2). Absolute increases in obesity prevalence from 1988 to 2012 in urban areas were largest among the poorest wealth group compared to the middle and richest (Table 5.5). Although the increase in obesity prevalence from 1988 to 2012 was statistically homogeneous across wealth groups, this tendency explained the emerging inequalities and the significant trend in the SII.

In rural areas, absolute inequalities were significant in all survey waves except for 1988 (Table 5.4). The negative sign in the SII indicates that richer women were more obese than poorer women as has been described in the previous section. Figure 5.2 shows how the direct gradient increased from 1988 to 1999 and then declined slightly towards 2012 (curvilinear trend p <0.05). Absolute increases in obesity prevalence in rural areas were greatest among the middle wealth group followed by the poorest wealth group, however homogeneity in the rates could not be rejected (Table 5.5).

Figure 5.2 Wealth SII trend for obesity in women 1988-2012



Relative inequalities

There were no relative inequalities by wealth in urban areas in the first three survey waves (Table 5.4). In 1999 the RII was marginally significant however, as has been described earlier, there was an inverted U shape association between wealth and obesity (Table 5.3). In 2012 the RII was significant; the poorest women in the wealth hierarchy had obesity prevalence 25% higher than the richest women in the hierarchy. The linear trend in the RII across surveys was not statistically significant in urban areas however; there was a tendency of emerging and increasing inequalities over the period (see Figure 5.3). This was the result of obesity increasing more among the poorest urban women than the middle and richest women over the period 1988-2012 (Table 5.5).

In rural areas, the RII was significant in all survey waves except 1988, probably because of the small sample size. The RII in rural areas indicated that poorer women were 'protected' from obesity and therefore the burden of obesity continued to be among the richer groups. There was a significant linear trend towards 1 (the null) in the RII across surveys in rural areas (see Figure 5.3). This was the result of obesity prevalence increasing more among the middle and poorest groups than among the richest group as can be seen in Table 5.5.

Figure 5.3 Wealth RII trend 1988-2012

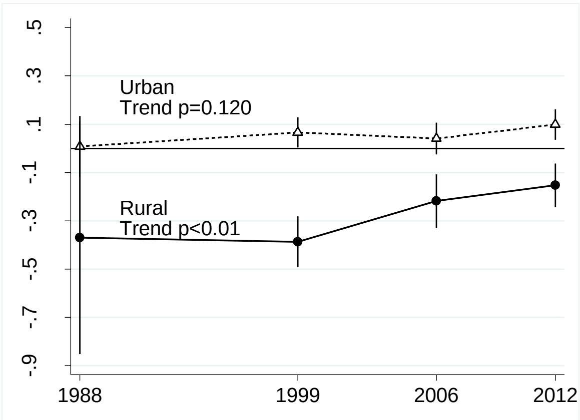


Table 5.4 Inequality trends in obesity by wealth

	URBAN		RURAL	
	RII (95%CI)	SII (95%CI)	RII (95%CI)	SII (95%CI)
1988	1.02 (0.76,1.36)	2.2 (-0.1,4.5)	0.43 (0.14,1.29)	-2.4 (-11.0,6.1)
1999	1.16* (1.01,1.34)	4.8* (0.8,8.8)	0.41ǂ (0.32,0.52)	-18.4ǂ (-23.8,-13.0)
2006	1.10 (0.94,1.28)	4.3 (-1.0,9.6)	0.61ǂ (0.47,0.78)	-12.9ǂ (-21.4,-4.4)
2012	1.25ǂ (1.08,1.45)	7.6ǂ (2.0,13.2)	0.70ǂ (0.57,0.86)	-11.6ǂ (-19.3,-4.0)
Linear trend across surveys	p=0.120 [b]	p=0.04 [a, b]	p=0.008 [b]	p=0.840 [a,c]

RII: Relative index of inequality
SII: Slope index of inequality
ǂ p<0.01 in each survey year
*p<0.05 in each survey year
[a] estimated using linear regression
[b] quadratic term p<0.001
[c] quadratic term p<0.05

Table 5.5 Age adjusted relative and absolute increases in obesity prevalence by level of wealth 1988-2012

	Relative increases 1988-2012		Absolute increases 1988-2012	
	Urban	**Rural**	**Urban**	**Rural**
	PR[a] (95%CI)	**PR[a] (95%CI)**	**PD[b] (95%CI)**	**PD[b] (95%CI)**
Richest	3.55* (3.03,4.17)	2.10 ł (1.25,3.54)	23.8¤ (21.2,26.3)	17.9§ (8.7,27.1)
Middle	3.12 (2.72,3.58)	4.25 (2.60,6.97)	25.2 (22.3,28.0)	26.6 (21.7,31.5)
Poorest	4.09 (3.46,4.83)	3.85 (2.62,5.65)	27.9 (24.6,31.3)	20.6 (17.2,24.0)

[a] age adjusted prevalence ratio
[b] age adjusted prevalence difference
Test for homogeneity across wealth levels *p=0.05; ł p<0.05; ¤ p>0.1; §p>0.05

5.3.3 Educational inequalities by level of wealth

Urban areas

Educational inequalities among women over the period 1988-2012 have been described in detail in the previous chapter. The first section of Table 5.6 recaps the findings. Education was inversely associated with obesity in all survey waves in urban areas (higher education-lower obesity prevalence). In 1988, one level decline in education level increased obesity prevalence 30% (PR 1.3 95% CI 1.18, 1.44) while in 2012, one level decline in education level increased obesity prevalence by 12% (PR 1.12 95% CI 1.08, 1.16). The next section of the table recaps the inequalities by wealth shown earlier in this chapter; there was an inverted U shape association between wealth and obesity in the first three surveys and an emerging inverse association in 2012.

The last section of Table 5.6 shows the education gradient in obesity by wealth level. The association between education and obesity varied by level of wealth in 1988 (interaction p<0.001) and marginally in 1999 (interaction p=0.06). In 1988, among the richest group, one level decline in education was associated with a 43% increase in the risk of obesity (PR 1.43 95% CI 1.25, 1.65); whereas among the poorest, education was not associated with obesity (PR 0.92 CI 0.71, 1.20). Likewise in 1999, among the richest, education was protective of obesity (p<0.001) while among the poorest group the association between education and obesity was not significant. In the last two survey waves, there was an emerging inverse association between education and obesity among the poorest women. The association between education and obesity did not vary by wealth group any longer (interaction p>0.05).

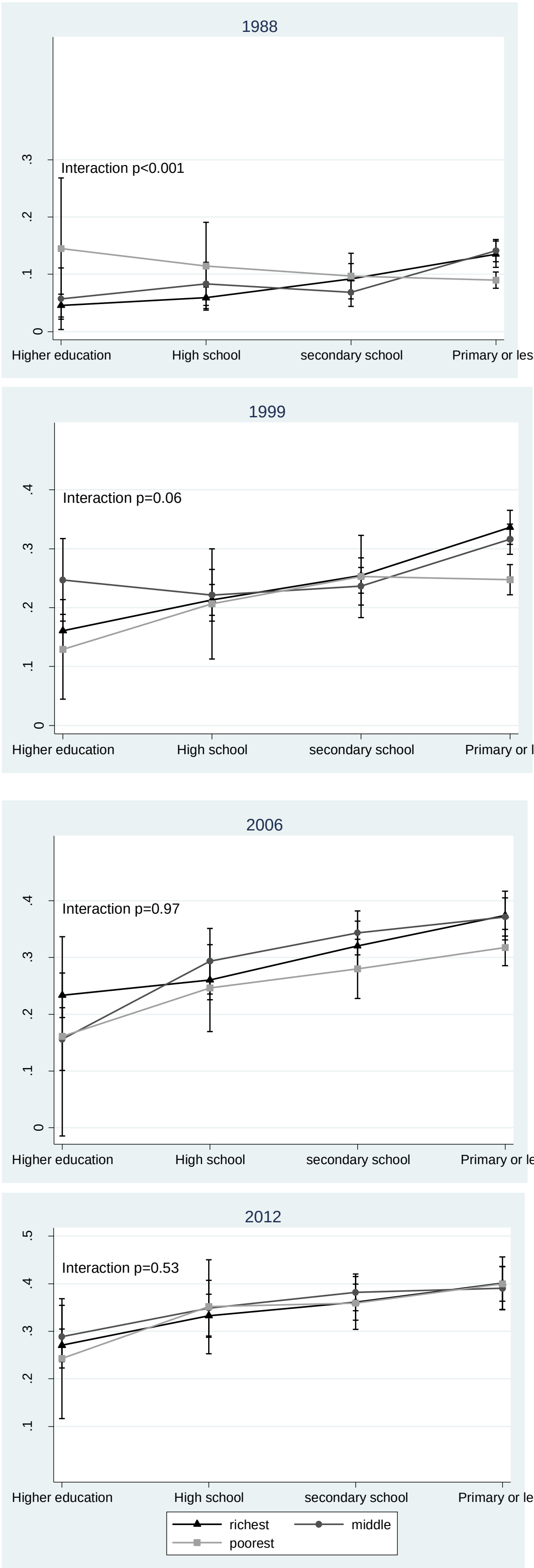
The last section of Table 5.6 further shows how the association between education and obesity among the richest and middle wealth women became weaker from 1988 to 2012. This finding adds to those from Chapter 4, where a decline in inequalities in obesity in urban areas was reported. The decline in inequality appeared to have occurred among middle wealth and richer women only.

Figure 5.4 illustrates the findings in Table 5.6. The Y axis denotes predicted mean obesity. In 1988, among the poorest women, those with more education had higher obesity prevalence than those with less education suggesting a direct association between education and obesity (not statistically significant; Table 5.6). Among the richest women, a clear inverse association can be seen in the figure, there was a stepwise decline in obesity prevalence with every step up in the education ladder. By 1999, the educational gradient among the poorest women had begun to change shape. There were larger increases in obesity prevalence among the less educated women in this group reversing the social gradient; those with higher education were no longer the most obese. At this stage, however, those with primary education or less among the poorest women were not the most obese either, the gradient showed a curvilinear trend. By 2006 the slope of the three lines, three wealth groups, was very similar and by 2012 the lines had joined. This suggests the completion of the reversal of the educational gradient in all wealth groups.

Table 5.6 Separate and joint effects of wealth and education on obesity in urban areas

	1988 **PR (95% CI)**	**1999** **PR (95% CI)**	**2006** **PR (95% CI)**	**2012** **PR (95% CI)**
Separate effects				
Education level				
Higher education	1.00	1.00	1.00	1.00
High school	1.37 (0.91,2.09)	1.26 (1.06,1.51)	1.23 (1.02,1.48)	1.25 (1.08,1.44)
Secondary	1.71 (1.12,2.59)	1.46 (1.23,1.72)	1.48 (1.24,1.76)	1.36 (1.19,1.55)
Primary or no educ	2.27 (1.55,3.33)	1.80 (1.54,2.11)	1.62 (1.37,1.91)	1.46 (1.28,1.66)
Education level (linear)	1.30 (1.18,1.44)	1.21 (1.16,1.26)	1.16 (1.11,1.21)	1.12 (1.08,1.16)
Wealth tertiles				
Richest	1.00	1.00	1.00	1.00
Middle	1.33 (1.10,1.60)	1.16 (1.07,1.26)	1.13 (1.03,1.24)	1.12 (1.03,1.23)
Poorest	1.01 (0.82,1.23)	1.01 (0.90,1.13)	1.01 (0.91,1.13)	1.15 (1.03,1.27)
Joint effects (education trend within wealth levels)				
Richest	1.43 (1.25,1.65)	1.26 (1.19,1.33)	1.16 (1.09,1.24)	1.14 (1.08,1.21)
Middle	1.41 (1.13,1.75)	1.19 (1.09,1.30)	1.20 (1.11,1.30)	1.09 (1.02,1.17)
Poorest	0.92 (0.71,1.20)	1.09 (0.95,1.25)	1.17 (1.02,1.34)	1.08 (0.97,1.20)
Interaction p	<0.001	0.06	0.97	0.53

Figure 5.4 Educational gradient by level of wealth in urban areas



Rural areas

The first two and last two surveys were pooled together in order to increase the sample size in each wealth by education cell and obtain more stable estimates. The first section of Table 5.7 shows the association between education and obesity in rural areas in the combined surveys. As was described in the previous chapter, there was evidence of a non-linear association between education and obesity where obesity prevalence was highest in the middle education groups (curvilinear trend 1988/1999 p=0.04 and 2006/2012 p<0.01). The next section shows the association between wealth and obesity in rural areas in the combined surveys. Consistent with the results presented earlier in this chapter, there was a direct association between wealth and obesity in both periods (lower wealth-lower obesity prevalence).

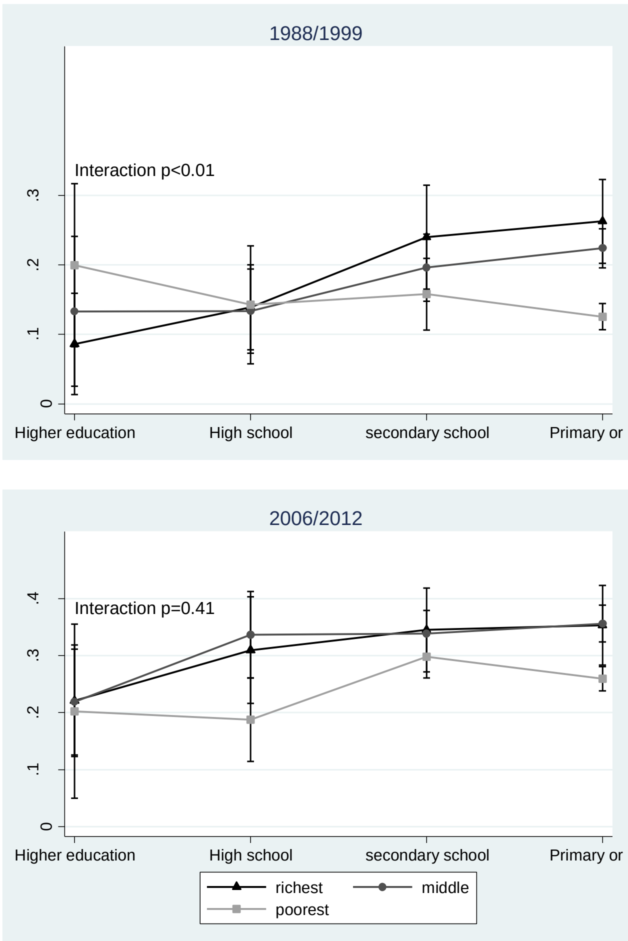
The last section of Table 5.7 presents the association between education and obesity by level of wealth in rural areas. In the period 1988/1999, the association between education and obesity varied by level of wealth (interaction p<0.01). For the richest group, one level decline in education was associated with a 33% increase in obesity prevalence (PR 1.33 95%CI 1.13, 1.57) while for the poorest group, the association between education and obesity was not statistically significant and it tended to be direct (PR 0.88 95%CI 0.72, 1.08). In the period 2006/2012, the education trend within wealth levels was very similar for all groups (interaction p=0.41).

Figure 5.5 illustrates the educational gradient by level of wealth in rural areas. In the period 1988/1999, there was a clear inverse association between education and obesity for the richest and middle wealth women. Among the poorest women, the gradient tended to be direct; women with primary education or less were the least obese. In the period 2006/2012, the middle and richest group's educational gradients merged. Obesity prevalence among the poorest women with primary education or less had increased substantially, making the prevalence of obesity in these groups no longer different to that among the richer women with primary education or less. The shape of the educational gradient among the poorest rural women appeared to be changing as it did in urban areas, from a direct association to an inverse association.

Table 5.7 Separate and joint effects of wealth and education on obesity in rural areas

	1988/1999 PR (95% CI)	2006/2012 PR (95% CI)
Separate effects		
Education level		
Higher education	1.00	1.00
High school	1.17 (0.68,2.02)	1.29 (0.95,1.74)
Secondary	1.64 (0.98,2.72)	1.48 (1.12,1.95)
Primary or no educ	1.30 (0.82,2.06)	1.32 (1.00,1.75)
Education level (linear)	1.01 (0.92,1.12)	1.02 (0.96,1.08)
Wealth tertiles		
Richest	1.00	1.00
Middle	0.97 (0.81,1.16)	1.07 (0.92,1.23)
Poorest	0.59 (0.47,0.73)	0.82 (0.71,0.95)
Joint effects (education trend within wealth levels)		
Richest	1.33 (1.13,1.57)	1.09 (0.98,1.21)
Middle	1.22 (1.03,1.43)	1.09 (0.99,1.19)
Poorest	0.88 (0.72,1.08)	1.03 (0.92,1.15)
Interaction p	<0.01	0.41

Figure 5.5 Educational gradient by level of wealth in rural areas



5.4 Summary of the chapter

This chapter presented trends in inequalities by wealth in urban and rural areas and evidence of a gradual reversal of the educational gradient over time by levels of household wealth. Rural women were significantly poorer than urban women in Mexico. At similar levels of education, urban women were wealthier than their rural counterparts, this was confirmed by the lower correlation between education and wealth in rural than urban areas.

It was hypothesised that changes in the wealth-obesity association leading to the reversal of the social gradient would be observed at a higher level of country GNI compared with education, and that poorer rural areas would be behind in the transition. This hypothesis was supported by the findings. In urban areas, there was an inverted U shape association between wealth and obesity in the first three survey waves. In 2012, an inverse association emerged. Absolute and relative inequalities showed similar trends in urban areas. There were *no inequalities* from 1988 to 2006 and emerging inequalities in 2012 as poorer women became obese faster than richer women over the period of study. The RII had limitations in this section because it masked the non-linear variation of obesity prevalence by wealth groups.

In rural areas, there was a direct association between wealth and obesity in 1988 and 1999 which had changed into an inverted U shape association in 2006 and remained this way up to 2012. The highest prevalence of obesity was among the richest women in rural areas but there was a tendency to larger increases in obesity prevalence among the poorest women. This led to a trend in the SII and RII towards the null (no inequalities).

The second hypothesis for this chapter was that the education gradient would vary by levels of wealth. Education would be protective of obesity at higher levels of wealth but not at lower where absolute poverty would preclude women from becoming obese. A reversal of the education gradient would be observed among poorer women in the period of study (1988-2012) due to widespread improvements in the standard of living. This hypothesis was supported by the findings. In the earlier surveys, education was protective of obesity at higher levels of wealth but not at lower in both urban and rural areas. In the recent surveys, education became protective at all levels of wealth (no effect modification). The reversal of the education gradient at low levels of wealth was shown in urban areas as well as the decline in educational inequalities among middle and richer women.

In the next chapter the social patterning of obesity will be investigated among men. The aim is to test the generalizability of the nutrition transition proposition to Mexican men. Both wealth and education will be used to calculate the RII and SII. Further, as in this chapter, the potential of a gradual reversal of the educational gradient by level of wealth will be investigated.

Chapter 6 Inequalities in obesity among men compared to women

6.1 Introduction

Chapters 4 and 5 presented trends in inequalities in obesity for women in Mexico. The reversal of the educational gradient in obesity among women was described. Some evidence of the reversal of the wealth gradient in obesity was presented at a higher level of country GNI compared to education. The reversal of the social gradient occurred in richer urban areas and for richer groups first before it occurred in poorer rural areas and among poorer groups, consistent with the hypothesis that the reversal of the social gradient is linked to economic development (88). Obesity inequalities among men are explored in this chapter with the aim of testing the generalizability of the reversal of the social gradient hypothesis among men. Men were not included in chapters 4 and 5 because they were measured in the 2006 and 2012 surveys only.

The literature suggests that among men, the strength of the association between SEP and obesity is weaker than for women (1, 83). For example in Sobal and Stunkard's review, half of the studies from developed countries found either no association or a direct association between SEP and obesity among men. In the same review, among women, there were 85% inverse associations and only one study which reported a direct association between SEP and obesity in developed countries (83). It has been proposed that the reversal of the social gradient occurs at a higher level of economic development among men than among women (84, 91), however, the evidence to support this claim is not strong. In McLaren's review, there appeared to be a pattern of declining direct associations between SEP and obesity among men as country development increased, similar to that reported for women. However there was a much larger proportion of non-significant or curvilinear associations among men compared to women both with education and wealth at all levels of country development (1). Further, Monteiro's conclusions on the reversal of the social gradient among men may have been biased by data outliers at the higher end of the GNI distribution (84).

In Mexico in 2000, level of education was not associated with obesity prevalence among men. However, for both urban and rural men, higher wealth was associated with higher obesity prevalence (106). Obesity inequalities among adult men have not been studied in Mexico using more recent data. The aim of this chapter was to investigate inequalities in obesity among men and test the hypothesis of a reversal of the social gradient in obesity at a higher level of economic development compared to women. Further, this chapter aimed to compare the social patterning of obesity among men and women.

A sensitivity analysis was conducted to investigate whether the reversal of the educational gradient could be observed among richer men in richer urban areas as was the case among women (Chapter 5). This would support the hypothesis of the reversal of the social gradient among men.

6.2 Methods

6.2.1 Analytic sample

The total number of men and women aged 20 to 49 with demographic information across the two surveys (2006 and 2012) was n=32,749 women and n=25,650 men (n=58,399 total). After exclusion of missing data and extreme, implausible values for BMI (BMI<10, BMI>75; less than 0.5% of total sample) the analytical sample consisted of n=18,988 20 to 49 year old men and n=28,534 20 to 49 year old non-pregnant women (n=47,522 total). Analysis of missing values for this sample is presented in the results section of this chapter.

6.2.2 Variables

The outcome of interest was a binary variable for obesity (0 =BMI<30, 1 =BMI≥30) and the main exposure variables were a categorical variable for attendance to education (1=higher education, 2=high school, 3=secondary education, 4=primary education or less) and a categorical variable for household wealth (1=richest, 2 =middle, 3=poorest). Age was a confounder of the association between wealth/education and obesity therefore age-standardised prevalence estimates are presented. All models were adjusted for age and a quadratic term of age. Consistent with the previous chapters, all analyses were stratified by a variable that identified women and men living in urban areas (>2,500 inhabitants) and rural areas (≤2,500 inhabitants).

6.2.3 Analysis of missing data

An indicator variable flagging missing data for BMI (and hence the binary obesity variable) was created for men. Using chi-squared tests, systematic differences between respondents with a BMI measurement and without were assessed.

Consistent with Chapter 4, a questionnaire item on perceived body composition was analysed to try to better understand whether missing data was MAR or MNAR. This item was only available in 2006. BMI missingness was assessed across categories of perceived overweight status to gauge whether this could have influenced men's decision to be measured.

6.2.4 Statistical analysis

The age standardised prevalence of obesity by education and wealth group in each survey year and by urban and rural areas was estimated as described in the methodology chapter (page 78). Linearity in the education and wealth gradients was assessed by regressing obesity on education/wealth as continuous variables, adjusted for age and age squared (191, 192). Deviation from linearity in the education/wealth gradients was tested by adding a quadratic term of wealth/education to the models. The relative index of inequality and slope index of inequality were estimated in each survey wave. All models were adjusted for age and quadratic age and stratified by urban and rural areas.

The relative increases in obesity prevalence in the period 2006 to 2012 by education or wealth group were estimated using general linear models stratified by wealth or education levels. Absolute increases in obesity prevalence by SEP group were estimated using linear regression.

Interaction between gender and education/wealth

In order to test whether inequalities in obesity varied by gender, an interaction term between sex and education or sex and wealth was tested. The interaction term was examined for statistical significance using a Wald test. In order to aid the interpretation of the interaction, predicted probabilities of obesity for men and women were plotted for different levels of education or wealth.

Sensitivity analysis

To test the hypothesis that the reversal of the educational gradient may be observed at higher levels of household wealth first before it occurs throughout the population, obesity was regressed on the continuous education variable 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.

6.3 Results

6.3.1 Missing values

Missingness for exposure variables and covariates among this sample of men was very low (<1%). Missingness for BMI was 14.5% in the 2012 survey and 35.5% in the 2006 survey (Table 6.1). As discussed in Chapter 4, the 2006 survey did not distinguish between men that were selected to be measured and were not, from those that were not selected. Missingness due to refusal to be measured or other reasons which could introduce bias is thought to be significantly lower than reported in Table 6.1.

Table 6.1 Missing values for men aged 20 to 49

Variable	2006	2012
N	13,776	11,868
	N (%)	**N (%)**
Age	0	0
Urban/rural	0	0
Education	0	0
Wealth index	39 (0.3)	22 (0.2)
Height	4,886 (35.5)	1,716 (14.5)
Weight	4,832 (35.1)	1,712 (14.4)
BMI	4,894 (35.5)	1,718 (14.5)
Complete cases**	8,855	10,133

Table 6.2 presents the characteristics of men with a missing BMI value compared with those with complete data for BMI. In 2006, men who were missing BMI were more educated, richer, younger and urban. For example in 2006, 13.9% of the sample of men with complete BMI had higher education while in the sample of men with missing values for BMI, 17.6% had higher education. This suggests that missing data was not missing completely at random (MCAR). This pattern of missingess was similar to the one observed among 20 to 49 year old women described in chapter 4 although differences were smaller among men.

As with the women's sample, the missing data mechanism was unlikely to be missing not at random (MNAR). Men did not appear to have made a decision on whether they consented to be weighed based on their weight. Perception of being overweight or obese was not associated with missing BMI among men in the 2006 survey. Perception of being overweight or obese was correlated with measured overweight or obesity (Spearman $\rho=0.51$, $p<0.001$). Further, men with missing BMI were missing both weight and height, and additional measurements such as blood pressure, which were part of the same questionnaire. Missing data in this sample was deemed missing at random (MAR).

In 2012, men with missing values were younger and marginally poorer than men with complete data for BMI. However, the differences were not large (Table 6.2) and may suggest that data were missing completely at random (MCAR).

Because exposure variables were almost complete, and the missingness in BMI was not thought to be associated with the missing BMI value, bias was not likely to be a problem arising from missing BMI. Complete cases were used for all analyses.

Table 6.2 Characteristics of men with missing BMI vs men with BMI

	2006			2012		
	Missing N(%)	**Non-missing N(%)**	**$X^{2\,b}$**	**Missing N(%)**	**Non-missing N(%)**	**X^2**
Education						
Higher education	860 (17.6)	1,231 (13.9)		271 (15.8)	1,648 (16.2)	
High school	852 (17.4)	1,531 (17.2)		305 (17.8)	1,802 (17.8)	
Secondary school	1,430 (29.2)	2,684 (30.2)		615 (35.8)	3,408 (33.6)	
Primary or less	1,752 (35.8)	3,436 (38.7)	p<0.001	527 (30.7)	3,292 (32.4)	p=0.29
Wealth						
Richest	1,816 (37.2)	2,865 (32.4)		551 (32.2)	3,466 (34.2)	
Middle	1,598 (32.7)	3,055 (34.5)		613 (35.8)	3,329 (32.9)	
Poorest	1,468 (30.1)	2,935 (33.2)	P<0.001	549 (32.1)	3,338 (32.9)	P=0.05
Age, mean	33.5	34.2	p<0.001	33.5	34.3	p<0.001
Urban	3,895 (79.6)	6,518 (73.4)		6,750 (66.5)	1,148 (66.8)	
Rural	999 (20.4)	2,364 (26.6)	P<0.001	3,400 (33.5)	570 (33.2)	P=0.80

6.3.2 Distribution of the sample

The proportion of urban population was 79.3% and 78.8% in 2006 and 2012 respectively. Mean age was 33. Urban men were more educated than rural men. For example in 2012, 23.5% of urban men attended up to higher education compared to 6.3% of rural men (Table 6.3). A large proportion of rural men completed up to primary education only (46% in 2012) compared to 20% of urban men. Rural men were more likely to be classified in the poorest wealth tertile (60.9% in 2006 and 46% in 2012) compared to urban men (17.7% in 2006 and 16.9% in 2012). On the other hand, almost half of urban men were classified in the richest wealth tertile (47.5% in 2006 and 49.3% in 2012) compared to 10.1% and 15.7% of rural men (Table 6.3). For descriptive characteristics of the National sample (not stratified by urban/rural) see Appendix 9.

6.3.3 Obesity prevalence

Urban men were taller than rural men by approximately 2cm (p<0.001) and were heavier (Table 6.3). Mean BMI was greater in urban than rural areas and increased significantly in urban areas over the 6 year period (p<0.001). There was a large proportion of overweight and obese men in both urban and rural areas. In 2012, 69.5% of urban men and 60.1% of rural men had a BMI≥25. Overweight and obesity prevalence was very similar among men and women in urban areas. In 2012, 68.8% of urban women had a BMI≥25.

Obesity prevalence increased from 23.9% in 2006 to 29.5% in 2012 (p<0.001) among urban men. Among rural men, obesity prevalence increased from 17.5% to 20.3% over the same period (p=0.09) (Table 6.3). Obesity prevalence among men was lower than among women. Prevalence among women in 2006 was 30.9% in urban areas and 27.9% in rural areas. In 2012 it was 34.6% in urban areas and 30.7% in rural areas (Chapter 4).

Table 6.3 Characteristics of Mexican men aged 20 to 49

	URBAN		RURAL	
	2006	**2012**	**2006**	**2012**
Complete cases, N	6,513	6,734	2,342	3,399
Age, mean	33.3 (0.2)	33.2 (0.2)	34.9 (0.2)	33.3 (0.2)
Age group, %				
20-24.9	21.1 (0.9)	23.3 (0.8)	14.2 (1.1)	20.7 (1.1)
25-29.9	16.7 (0.8)	16.7 (0.7)	16.3 (1.0)	16.1 (0.8)
30-34.9	17.8 (0.8)	15.6 (0.6)	15.7 (1.0)	19.1 (0.9)
35-39.9	16.1 (0.7)	15.1 (0.6)	19.3 (1.0)	16.7 (0.8)
40-44.9	14.6 (0.6)	14.8 (0.6)	18.2 (1.1)	14.3 (0.8)
45-49.9	13.7 (0.7)	14.6 (0.6)	16.2 (1.0)	13.1 (0.7)
Level of education, %				
Higher education	19.6 (0.9)	23.5 (1.0)	3.4 (0.6)	6.3 (0.8)
High school	22.5 (0.9)	22.1 (0.8)	7.8 (0.9)	14.5 (1.0)
Secondary	32.3 (0.9)	34.7 (1.0)	28.0 (1.6)	33.2 (1.3)
Primary or less	25.5 (1.0)	19.8 (0.7)	60.9 (1.9)	46.0 (1.6)
Wealth, %				
Richest	47.5 (1.2)	49.3 (1.1)	10.1 (1.4)	15.7 (1.2)
Middle	34.8 (1.0)	33.8 (1.0)	28.0 (1.6)	32.3 (1.3)
Poorest	17.7 (0.8)	16.9 (0.8)	61.9 (2.2)	52.0 (1.7)
Weight (kg), mean	75.9 (0.3)	78.7 (0.3)	71.7 (0.6)	72.8 (0.4)
Height (cm), mean	167.3 (0.2)	167.9 (0.1)	165.0 (0.3)	165.3 (0.2)
BMI, mean	27.1 (0.1)	27.9 (0.1)	26.2 (0.2)	26.6 (0.1)
BMI categories[a], %				
<18.5 Underweight	1.9 (0.3)	1.1 (0.2)	2.3 (0.5)	0.9 (0.2)
18.5-24.9 Normal	32.2 (1.0)	29.3 (0.9)	39.3 (1.6)	39.0 (1.2)
25-29.9 Overweight	42.1 (1.0)	40.0 (0.9)	41.0 (1.5)	39.8 (1.0)
≥30 Obese	23.9 (0.8)	29.5 (0.9)	17.5 (1.3)	20.3 (1.0)
≥35 Class II & III obesity	5.3 (0.4)	8.2 (0.5)	4.5 (0.7)	4.4 (0.5)

a Age standardised prevalence; standard errors in parenthesis

There was a curvilinear association between obesity and age (Table 6.4). Obesity prevalence increased with age, however after age 45, obesity prevalence either plateaued or declined slightly (curvilinear trend p<0.001). The social patterning of obesity by level of education and wealth was different to that described for women. The next section details obesity inequalities among men.

6.3.4 Inequalities by education

Men with more education tended to be more obese than more disadvantaged men in both urban and rural areas (Table 6.4). However, the gradient was not steep (p for linear trend >0.05) except in rural areas in 2012 when there was a significant direct association between education and obesity (p<0.001). In rural areas in 2012, there was a stepwise decline in obesity prevalence with fewer years in education. Men with higher education had an obesity prevalence of 28.7% while men with primary education or less had a prevalence of obesity of 18.2%.

Table 6.4 Obesity prevalence by age group, education level and wealth

	Urban		Rural	
	2006 %(95%CI)	**2012** %(95%CI)	**2006** %(95%CI)	**2012** %(95%CI)
Age group				
20-24.9	15.6 (12.6, 18.5)	10.2 (5.1,15.4)	18.8 (15.6,22.0)	13.2 (8.5,17.9)
25-29.9	21.1 (17.0, 25.1)	13.7 (8.7,18.6)	27.0 (23.1,30.9)	20.1 (15.4,24.8)
30-34.9	22.9 (19.3, 26.5)	24.1 (17.5,30.8)	30.0 (25.8,34.1)	21.1 (16.7,25.5)
35-39.9	30.7 (26.6, 34.8)	18.4 (13.7,23.1)	35.9 (31.4,40.4)	26.2 (21.9,30.5)
40-44.9	32.8 (28.5, 37.1)	22.0 (16.8,27.3)	39.1 (35.0,43.1)	23.9 (19.5,28.3)
45-49.9	27.5 (23.2, 31.8)	22.3 (15.9,28.8)	35.9 (31.4,40.3)	21.2 (17.1,25.4)
Trend p	<0.001[a]	<0.001[a]	<0.001	<0.001[a]
Education [b]				
Higher education	27.4 (23.3,31.6)	30.6 (27.1,34.0)	15.5 (6.6,24.5)	28.7 (21.5,35.9)
High school	21.9 (18.8,24.9)	31.5 (27.9,35.1)	23.3 (13.3,33.2)	25.4 (19.0,31.9)
Secondary school	24.0 (21.2,26.8)	29.8 (26.7,33.0)	19.9 (14.3,25.4)	21.4 (18.4,24.4)
Primary school	23.1 (20.2,26.1)	26.6 (23.4,29.9)	15.9 (13.1,18.8)	18.2 (15.3,21.1)
Trend p	0.21	0.06	0.21	<0.001
Wealth [b]				
Richest	25.2 (22.8,27.7)	32.0 (29.3,34.8)	34.7 (22.9,46.5)	29.7 (24.1,35.4)
Middle	24.8 (22.2,27.3)	26.4 (23.7,29.0)	18.6 (15.0,22.2)	21.9 (18.3,25.6)
Poorest	19.4 (16.7,22.2)	28.0 (24.5,31.4)	14.1 (11.7,16.5)	16.7 (14.4,18.9)
Trend p	<0.01[a]	0.01	<0.001	<0.001

[a] Quadratic term p<0.05; [b] Age standardised prevalence

Table 6.5 shows the relative index of inequality and slope index of inequality. Consistent with what has been described so far, there were no relative or absolute educational inequalities among men in urban areas. The RII was lower than one and the SII was a negative number, indicating a tendency of higher prevalence of obesity among more educated men. In rural areas, the RII and SII were significant in 2012. More educated men, bore the greatest burden of obesity. Men at the bottom of the educational hierarchy had 50% lower prevalence of obesity than those at the top (RII 0.52 95% CI 0.38, 0.72). There were approximately 31,795 excess obesity cases among men with higher education.

Increases in obesity prevalence in urban areas were significant for the high school and secondary school groups where obesity increased 42% (95%CI 1.19, 1.70) and 24% (95%CI 1.07,1.45) respectively over the 6 year period from 2006 to 2012 (Table 6.6). In rural areas, the largest increases in obesity prevalence tended to be among the higher education group (PR 1.91 95%CI 1.01, 3.61). The increase in obesity prevalence from 2006 to 2012 was not statistically different between education groups in both urban and rural areas.

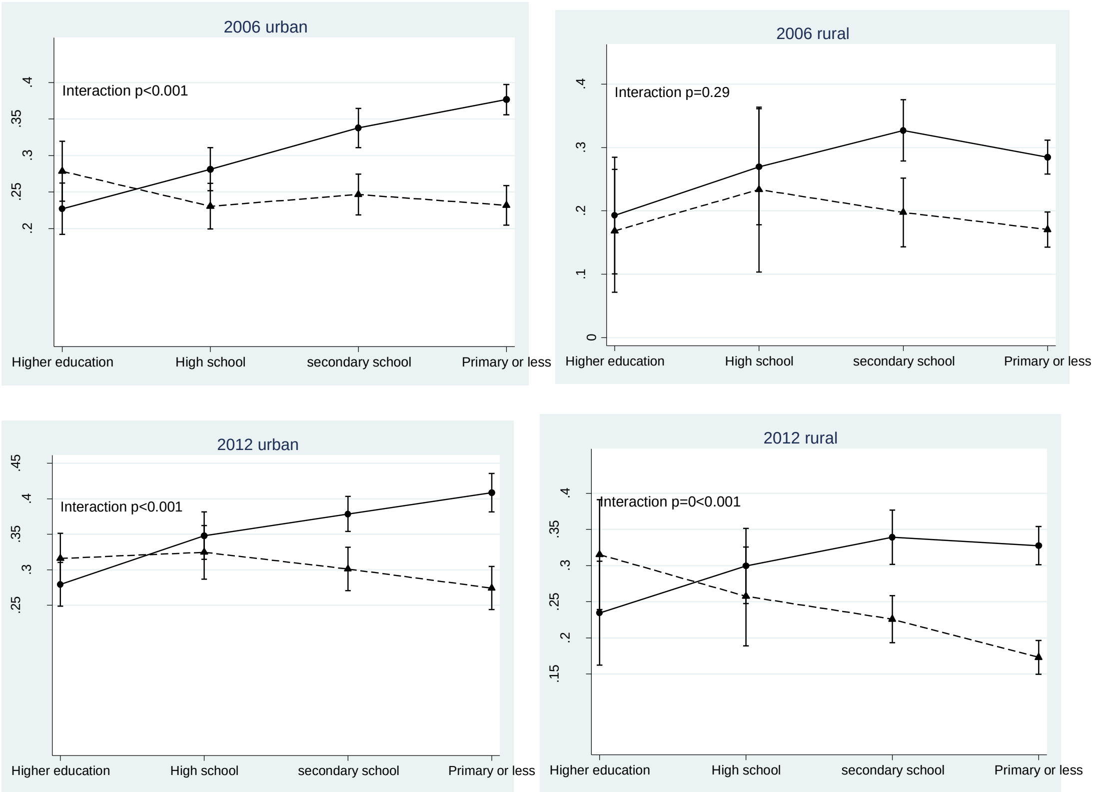
Table 6.5 Relative and slope index of inequality among men 2006-2012

	RII (95% CI)		SII (95% CI)	
	2006	2012	2006	2012
Education				
Urban	0.86 (0.68,1.10)	0.84 (0.70,1.01)	-3.0 (-8.8,2.8)	-4.3 (-10.2,1.6)
Rural	0.73 (0.45,1.17)	0.52 (0.38,0.72)	-7.0 (-16.2,2.1)	-11.2 (-17.8,-4.6)
Wealth				
Urban	0.76 (0.61,0.96)	0.74 (0.59,0.92)	-5.9 (-11.5,-0.3)	-7.0 (-13.3,-0.7)
Rural	0.26 (0.16,0.42)	0.45 (0.32,0.62)	-28.4 (-42.4,-14.5)	-18.8 (-27.0,-10.6)

Educational inequalities in obesity among men compared to women

The contrast in the educational gradient between women and men can be seen in Figure 6.1. The association of education with obesity varied significantly by sex in both survey years and for urban and rural areas (p<0.001), except for rural areas in 2006 in which the interaction term was not significant. While the association between education and obesity among women was inverse especially in urban areas, it was not significant among men; there was no social gradient (except among rural men in 2012).

Figure 6.1 Educational gradient in obesity for men and women 2006-2012



Dashed line is the men's educational gradient; solid line is women's educational gradient

Table 6.6 Absolute and relative increases in obesity prevalence 2006-2012

	Relative increases 2006-2012		Absolute increases 2006-2012	
	Urban	**Rural**	**Urban**	**Rural**
	PR[a] (95%CI)	**PR[a] (95%CI)**	**PD[b] (95%CI)**	**PD[b] (95%CI)**
Education				
Higher ed¤	1.14 (0.94,1.37)	1.91 (1.01,3.61)	3.6 (-1.7,9.0)	14.3 (2.6,26.0)
High school	1.42 (1.19,1.70)	1.13 (0.62,2.06)	9.1 (4.5,13.7)	3.0 (-9.3,15.2)
Secondary school	1.24 (1.07,1.45)	1.15 (0.84,1.57)	6.0 (1.8,10.2)	2.7 (-3.4,8.7)
Primary or less	1.17 (1.00,1.38)	1.02 (0.83,1.25)	4.3 (0.0,8.6)	0.4 (-3.5,4.2)
Wealth				
Richest	1.29 (1.14,1.46)	0.80 (0.55,1.17)	7.2 (3.6,10.8)	-7.0 (-20.1,6.2)
Middle	1.06 (0.92,1.23)	1.13 (0.89,1.44)	1.7 (-2.0,5.4)	2.8 (-2.4,7.9)
Poorest	1.46 (1.21,1.75)	1.16 (0.94,1.43)	8.9 (4.4,13.3)	2.4 (-1.0,5.7)

[a] Age adjusted prevalence ratio (relative increase in obesity prevalence from 2006 to 2012); [b] age adjusted prevalence difference (absolute increase in obesity prevalence from 2006 to 2012)
¤ Heterogeneity in the rates p>0.05

6.3.5 Inequalities by wealth

There was a direct association between wealth and male obesity prevalence in 2006 and 2012 in both urban and rural areas (p<0.01). Richer men had higher obesity prevalence than poorer men. In rural areas, the prevalence of obesity among the richest men was twice as high as that among the poorest men in 2006 (34.5% vs 14.1%) (Table 6.4). The gradient was steeper in rural than urban areas, for example, one step down in the wealth hierarchy was associated with a 10% decline in obesity prevalence in urban areas (PR 0.90 95%CI 0.83, 0.97) and to a 35% decline in obesity prevalence in rural areas (PR 0.65 95%CI 0.55, 0.76). The gradient did not change over the 6 year period to 2012 in urban areas (PR 0.90 95%CI 0.84, 0.97). In rural areas, it became slightly flatter however not statistically different to 2006 (PR 0.76 95%CI 0.68, 0.85).

Consistent with the gradients described, the RII was significant in both years for urban and rural areas (Table 6.5). In urban areas inequalities remained constant over the 6 year period, the RII was 0.76 (95%CI 0.61, 0.96) in 2006 and 0.74 (95%CI 0.59, 0.92) in 2012. The poorest men were approximately 25% less obese than the richest men. Increases in obesity prevalence between 2006 and 2012 were largest for the poorest men (PR 1.46) followed by the richest men (1.29). Among the middle wealth group, obesity appeared to increase very little (PR 1.06) (Table 6.6).

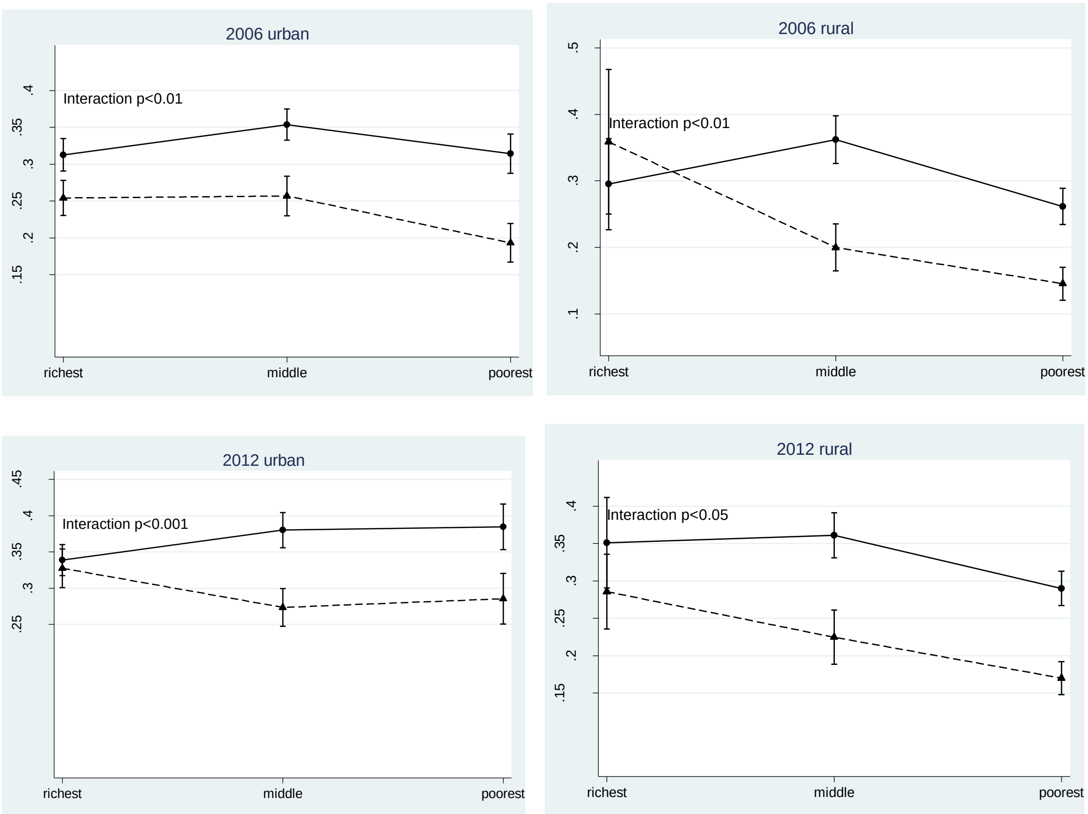
Inequalities were greater in rural than urban areas. In 2006, men at the bottom of the wealth hierarchy had an obesity prevalence 74% lower than men at the highest point of the wealth hierarchy (RII 0.26 95%CI 0.16, 0.42). In 2012 the RII in rural areas was 0.45 (95%CI 0.32, 0.62), therefore indicating a tendency of a closing of the gap between rich and poor (Table 6.5). This tendency was due to increases in obesity prevalence among the poorest rural men over the 2006 to 2012 period (PR 1.16 95%CI 0.94, 1.43) and to apparent decreases in obesity prevalence among the rural rich men (PR 0.80 95%CI 0.55, 1.17).

The SII provides an indication of the magnitude of the public health problem. Although inequalities in obesity were larger in rural areas, there were fewer men living in rural areas compared to urban areas and significantly fewer men in the richest wealth groups in rural areas compared to urban areas. Therefore, in terms obesity burden and number of excess obesity cases, urban areas fared worse. There were an estimated 605,583 excess obese men in urban areas in 2012 compared to 139,653 excess obese men in rural areas in the same year.

Wealth inequalities in obesity among men compared to women

Figure 6.2 shows the wealth gradient in obesity for men and women in 2006 and 2012 in urban and rural areas. There was a significant interaction in all four strata; the association between wealth and obesity varied by sex. Among urban women, there was a reversal of the wealth gradient in the period 2006-2012, as described in Chapter 5. The 2012 urban graph shows how poorer women were more obese than women in the richest tertile and there was a linear gradient (solid line). Among men in the same year, the richest men were more obese than the middle and poorest wealth groups. In rural areas, among women there was an inverted U shape association between wealth and obesity (quadratic trend p<0.05) as shown in Chapter 5 in both 2006 and 2012 while among men, the association of wealth with obesity was linear and direct.

Figure 6.2 Wealth gradient in obesity prevalence for men and women 2006-2012



Dashed line is the men's wealth gradient; solid line is women's wealth gradient

6.3.6 Sensitivity analysis

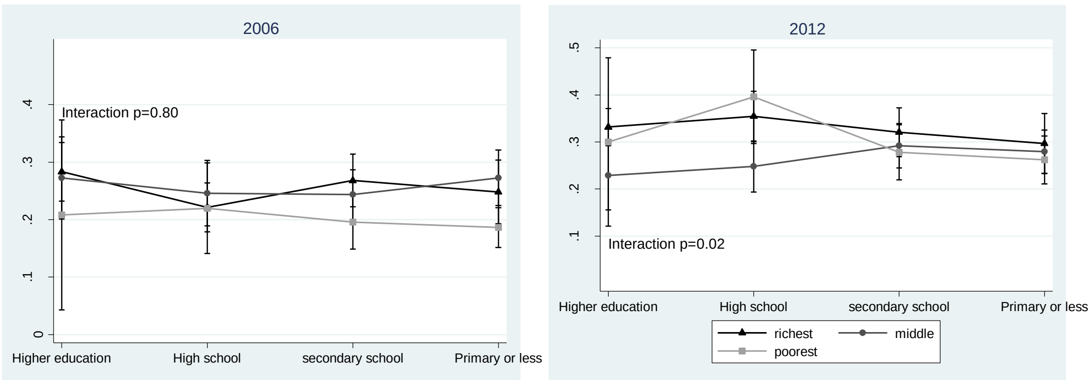
Table 6.7 shows the obesity prevalence ratio for a level decline in education stratified by wealth level. The effect of education on obesity did not vary by wealth level in 2006 (interaction p=0.80). In 2012, there was a significant interaction (p=0.02). Although the association between education and obesity was not significant in any of the wealth groups, among the middle wealth group, the coefficient indicated an incipient inverse association between education and obesity.

Figure 6.3 shows how the educational gradient in obesity for different levels of wealth was very similar in 2006. In 2012, the gradient for the middle wealth group (black dot, solid black line) suggested an inverse association compared to the richest and poorest groups in which no clear gradient was observed.

Table 6.7 Joint effect of education and wealth among men in urban areas

Educational trend within wealth levels	2006	2012
	PR (95% CI)	**PR (95% CI)**
Richest	0.97 (0.88,1.07)	0.97 (0.90, 1.04)
Middle	1.00 (0.91,1.11)	1.06 (0.96, 1.17)
Poorest	0.95 (0.79, 1.12)	0.91 (0.79, 1.05)
Interaction p	p=0.80	p=0.02

Figure 6.3 Education gradient in obesity by wealth level in urban areas 2006 and 2012



6.4 Summary of the chapter

This chapter analysed inequalities in obesity among men in the period 2006-2012 and compared them to inequalities among women. Overweight and obesity prevalence among men was as high as among women; in 2012 almost 70% of urban men and 60% of rural men had a BMI≥25. Obesity prevalence was lower among men than women however still very high. Obesity prevalence among men increased approximately five percentage points in the six year period to reach 29.5% in 2012 in urban areas. Obesity prevalence was significantly higher among urban than rural men.

The social patterning of obesity among men was significantly different to that among women. Among women, obesity was inversely associated with education especially in urban areas (Chapter 4) while among men, there was a tendency of higher obesity prevalence among more educated men compared to less educated men in urban areas and a significant direct association in rural areas in 2012. It was hypothesised that a reversal of the social gradient in obesity among men would occur at a higher level of economic development compared to women in urban areas. There was no evidence to support this hypothesis. The largest increases in obesity prevalence over the 2006 to 2012 period were among men with high school and secondary education. Further, in the sensitivity analysis, only a marginal interaction between wealth and education was observed and the results were not in the hypothesised order. It was expected that among the top wealth tertile in urban areas, an inverse association between education and obesity would be observed suggesting a reversal of the social gradient among the more advantaged men however this was not the case.

Wealth was directly associated with obesity among men in both survey years studied, in urban and rural areas. The gradient in rural areas was steeper than in urban areas. There was no change in inequalities between 2006 and 2012 in urban areas. In rural areas inequalities appeared to be declining (approaching the null), this could be an indication of the beginning of the reversal of the social gradient, however it was not possible to say whether this was a trend as only two points in time were available.

The association between wealth and obesity varied by gender, the interaction between wealth and gender was statistically significant in both survey years in urban and rural areas. In urban areas in 2012 there was an inverse association between wealth and obesity among women while among men there was a direct association.

The next chapter will investigate the drivers of the gender differences in inequality in order to better understand the drivers of obesity inequalities in Mexico.

Chapter 7 Potential mediators in the association between education and obesity for men and women

7.1 Introduction

Previous chapters described obesity inequalities among Mexican men and women. There were clear gender differences in the social patterning of obesity. While among women there was an inverse association between education/wealth and obesity especially in urban areas and in the more recent surveys, among men the association between education/wealth and obesity was direct. This chapter will investigate the differences in the social patterning by education of obesity risk factors among men and women in order to better understand what drives obesity inequalities in Mexico.

Gender differences in the social patterning of obesity may be the consequence of differences in attitudes with respect to body size between men and women (1, 83, 110, 111) and/or to differences in the physical activity demands of men's vs. women's occupations (111-115). Further, differences in obesity inequalities may be due to gender differences in some other explanatory pathway between SEP and obesity; for example, if parity is an important mediator among women.

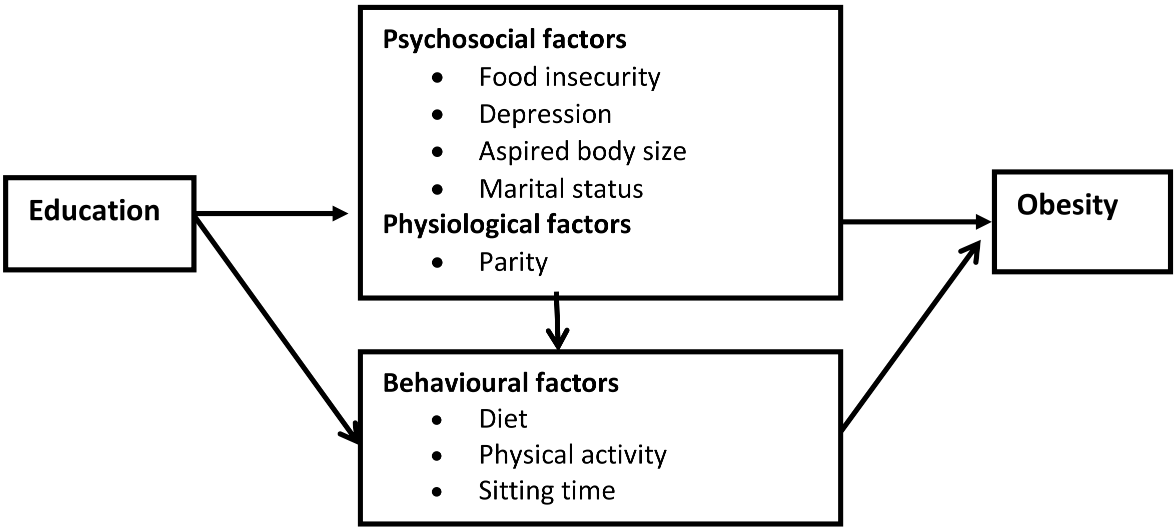
It was hypothesised that among women, obesity risk factors would be inversely associated with education. More advantaged women would be expected to have healthier lifestyles, and suffer less from psychosocial risk factors, for example depression. Among men, those living in rural areas and in more disadvantaged education groups would be expected to have higher physical activity levels than more educated urban men and women. Further, a flatter social gradient in aspired body size would be expected among urban men compared to women consistent with the literature that suggests that there is less stigma around obesity for men. In rural areas, a direct association between education and aspired body size is expected. Being larger in rural areas may signify less involvement in manual work and higher status.

Further, it was hypothesized that potential mediating factors in the inverse association between education and obesity among women would be similar to those identified in developed countries and could be grouped in psychosocial, behavioural and physiological. Potential mediating factors in the direct association between education and obesity among men would be physical activity and aspired body size.

Analytic model

From the literature review, psychosocial, physiological and behavioural factors associated with obesity were identified as potential explanatory factors for obesity inequalities (Figure 7.1). Psychosocial factors identified were food insecurity, depression, aspired body size and marital status. Parity was identified as a physiological risk factor among women. Diet (fruit and vegetable, soda, cakes and savoury snacks consumption), physical activity and sitting time were the behavioural factors identified for both men and women. In preliminary analysis the role of unemployment was also tested given its potential role as a mediator in the association between education and obesity (49, 51, 52, 54). Although theoretically education may affect body weight by affecting employment opportunities and income, this does not appear to be the case in the Mexican context (Appendix 13).

Figure 7.1 Analytic model for mediation analysis



Limitations of the analytic model

Ideally, a study of the causes of obesity inequality in adults would be based on a birth cohort study which tracked exposures and weight gain from infancy through childhood, adolescence and into adult life. In Mexico there are no birth cohort studies. Therefore, the interpretation of results from this chapter is limited by the use of cross-sectional data. Exposure, mediating and outcome variables were measured at the same point in time. Table 7.1 classifies variables according to the degree to which reverse causation is likely. Variables in which the likelihood of reverse causation is high include depression and food insecurity. A bidirectional association between depression and obesity has been documented (127-129). In terms of food insecurity, most research has studied the correlation of obesity and food insecurity using cross-sectional data (119). Several biologically plausible mechanisms by which food insecurity may cause obesity have been proposed (119, 125) and detailed in chapter 1 (page 41). However, reverse causation cannot be ruled out because there is not enough longitudinal evidence to confirm the direction of the association (119). Obese individuals are more likely to miss days at work and cost more to employers (204). As such their livelihood may be more insecure than that of normal weight individuals, increasing their risk of food insecurity. The association between aspired body size and obesity is prone to confounding by current BMI (205). Studies have found that more overweight individuals tend to select larger body ideals.

Table 7.1 Reverse causation likelihood of variables studied

Variable	Reverse causation (or reporting bias) likelihood
Food insecurity	High
Depression	High
Aspired body size	High
Diet	Medium
Physical activity and sitting time	Medium
Marital status	Low
Parity	Low

The direction of the association between certain aspects of the diet and obesity is well established. A low consumption of dietary fibre from fruits, vegetables and cereals and a high consumption of energy-dense micronutrient poor foods and sugar sweetened beverages have been found to cause obesity (73). However, obese individuals may modify their health behaviours as a result of being overweight or under report consumption of certain foods in food frequency questionnaires. The same is true for physical activity and sitting time which have been causally associated with obesity (73, 148). Obese individuals may systematically over report levels of physical activity. Reporting bias must be considered in the interpretation of the findings.

The association between marital status and obesity is relatively less likely to be affected by reverse causality. Longitudinal studies have shown that getting married is associated with weight gain, and transitions out of marriage are associated with weight loss for both men and women (139, 140). Parity is not likely to be affected by reverse causation as the number of children a woman has is determined in the early years of adulthood and obesity increases with age. In addition, evidence from longitudinal studies has linked parity with overweight and obesity several years on (154, 155).

This analysis is hypothesis generating.

7.2 Methods

7.2.1 Analytic sample

Three samples from the 2012 survey were used in the analyses for this chapter. The main sample consisted of n=27,534 men and women aged 20 to 49. The second was a subsample of n=7,601 randomly selected individuals from the main sample who responded to the physical activity questionnaire and the third was a subsample of n=1,811 individuals randomly selected from the main sample who responded to the food frequency questionnaire. After exclusion of pregnant women, missing data (in one or more covariates), and extreme, implausible values for BMI (BMI<10, BMI>75), sample sizes were n=21,756; n=6,651 and n=1,464 for the main sample, physical activity and nutrition subsamples respectively.

Analyses were repeated with the 2006 survey using available equivalent variables. This was done to test whether findings were consistent in the two surveys. Results are presented in Appendix 12. In 2006, the International Physical Activity Questionnaire (IPAQ) was administered to the entire main sample of men and women aged 20 to 49 (n=31,403). A subsample was randomly selected to respond to a food frequency questionnaire (n=13,697). After exclusion of pregnant women, missing data and extreme values, the main sample and nutrition subsample were n=21,255 and n=11,688 respectively.

The missing data patterns and implications for the analysis are presented in the results section below.

7.2.2 Variables

Obesity (defined ≥30 kg/m^2) was the outcome variable and attendance to education (1=higher education, 2=high school, 3=secondary education, 4=primary education or less) was the main exposure variable. Potential mediating variables were: food insecurity (1=food security, 2=mild food insecurity, 3=moderate food insecurity, 4=severe food insecurity), depression symptoms (1=clinically significant depression symptoms, 0= no clinically significant depression symptoms), aspired body size (1 to 9 ordinal), marital status (1=married or cohabiting, 2=separated, divorced or widowed, 3=single), parity (1=nulliparous, 2=1 to 2 live births, 3= 3 to 4 live births, 4=5 or more live births), fruit and vegetable consumption (1=higher, 2=lower), sugar sweetened beverage consumption (1=higher, 2=lower), cakes and snacks (1=higher, 2=lower), physical activity (1=low, 2=moderate, 3=high) and sitting time (1=low, 2=moderate, 3=high). A second variable for food insecurity was analysed utilizing only the first item of the Food Security Scale for Latin America and the Caribbean which measures the psychological dimension of food insecurity. This variable was coded 1=food insecure 0=food secure. The detailed description of the measurement instruments and construction of these variables can be found in chapter 3, page 72. Models were adjusted for age and age squared and stratified by sex and urban or rural dwelling.

In the 2006 survey, food insecurity and aspired body size were not measured. The depression scale was different to the one used in 2012. It comprised of yes/no answers to 7 depression symptoms. The analysis variable was coded 1=3 or more depression symptoms and 0 less than 3 depression symptoms. All other variables were equivalent to 2012.

7.2.3 Analysis of missing data

An indicator variable flagging observations with missing data in any of the study variables was created. Using chi-squared tests, systematic differences between respondents with complete and incomplete information were assessed.

7.2.4 Statistical analysis

Several steps were followed to identify variables that met the definition and conditions for a mediating variable. A mediating variable is hypothesised to be on the causal pathway between the exposure variable and the outcome variable, and, when controlled for statistically through adjustment, biases the main exposure- outcome association towards the null (44). To establish mediation, three conditions described by Baron and Kenny must be met a) the initial association between exposure and outcome must be significant b) variation in the exposure must account for variation in the potential mediating variable and c) variation in the potential mediating variable must account for variation in the outcome and this association must remain significant after adjusting for the exposure (45).

The first condition was tested using the relative index of inequality as measure of association between education level and obesity prevalence as before. To test the second condition, the association between education (categorical variable) and each potential mediator variable was investigated. For continuous variables, the potential mediator variable was regressed on education. For binary mediator variables, generalised linear models were used and a prevalence ratio was estimated. For categorical variables with more than two categories, multinomial logistic regressions were run and the overall effect of education on the mediating variable was tested with a Wald test. An interaction term between education and sex was added to separate models to test whether the effect of education on each potential mediator variable varied by sex.

To test the third condition, generalised linear models were used to investigate the association between potential mediator variables and obesity separately for men and women. Models were adjusted for age and age squared. An interaction term was included in separate models to test whether the association was modified by sex. Further, each potential mediator variable was included in the following basic model:

Y (obesity)= A + B(education rank variable)+ B(age)+ B(age squared)+e

The adjusted RII was compared to the crude RII (basic model). The difference in RII was calculated using the formula ((adjusted log RII-crude log RII)/crude log RII)*100. Potential mediator variables were ranked in order of their impact on the RII separately for men and women from urban and rural areas. Variables that accounted for some of the gradient and that remained significant in the model adjusted for education were selected for the multivariate regression. The overall contribution of selected variables to relative inequalities in obesity for men and women from urban and rural areas was assessed in the multivariate analysis.

7.3 Results

7.3.1 Missing values

Table 1 presents missing values separately for men and women in the three samples for this study. More men were missing observations than women. Variables with the highest missingness were aspired body size (19.2% of observations missing among men and 7.7% among women) and body mass index (14.5% of observations missing among men and 3.7% among women). Parity was missing for 1,167 women, 7.7%. Missingness was <2% for all other covariates. In the subsamples for physical activity and diet missingness was ≤4.0% for physical activity and diet variables.

Table 7.2 Missing values

	Men N (%)	Women N(%)
Main sample, N	***11,870***	***15,125***
Age	0	0
Urban/rural	0	0
Education	0	0
Height	1,716 (14.5)	556 (3.7)
Weight	1,712 (14.4)	552 (3.7)
BMI	1,718 (14.5)	560 (3.7)
Wealth	0	0
Aspired body size	2,282 (19.2)	1,167 (7.7)
Food insecurity	227 (1.91)	231 (1.5)
Depression symp	0	0
Marital status	0	0
Parity	-	1,173 (7.8)
Heavy drinking	0	0
Physical activity subsample, N	***2,959***	***4,459***
Physical activity	107 (3.6)	75 (1.7)
Sitting time	93 (3.1)	62 (1.4)
Diet subsample, N	***681***	***1,130***
Fruits and vegetables		
Soda	0	0
Cakes and snacks	0	0

Table 2 presents demographic characteristics for complete cases (complete information on all study variables) and excluded cases (at least one missing value). Men with complete observations were very similar to those with missing observations in terms of age, education and wealth. Among excluded men, there was a higher proportion living in urban areas (69.1% vs 65.5%). There were more single men in the excluded group compared with the complete cases group (24.7% vs 21.6%) and less married men, $p<0.001$. There were large differences between the complete case group and the excluded group in terms of depression symptoms. Excluded cases appeared to have much lower prevalence of depression symptoms (2.4% vs 7.8%).

Among women, consistent with the analysis of missingness from previous chapters, those who had missing values and were excluded were more educated, richer and more urban. There was a larger proportion of single women among those excluded due to missing values and similar to men there were large differences in depression symptoms prevalence. There were fewer women classified depressed in the excluded sample compared with the complete cases sample (6.3% vs 17.9%).

It is unlikely that missing values were missing completely at random because excluded and complete cases varied in some characteristics. Missing values were unlikely to be missing not at random as has been described in previous chapters. Missing BMI was unlikely to be associated with the BMI value itself, thus bias in the main findings was thought to be minimal. Complete cases were used for all analyses.

Table 7.3 Characteristics of men and women with complete observations vs. at least one missing value

	Men			Women		
	Excluded cases N(%)	Complete cases N(%)	X^{2} [b]	Excluded cases N(%)	Complete cases N(%)	X^2
N [c]	3,490	8,380		1,830	13,295	
Education						
Higher education	591 (16.9)	1329 (15.9)		452 (24.7)	1,789 (13.5)	
High school	628 (18.0)	1,479 (17.7)		364 (19.9)	2,145 (16.1)	
Secondary school	1,191 (34.1)	2,832 (33.8)		467 (25.5)	4,528 (34.1)	
Primary or less	1,080 (31.0)	2,740 (32.7)	0.23	547 (29.9)	4,833 (36.4)	<0.001
Wealth						
Richest	1,208 (34.7)	2,810 (33.6)		790 (43.3)	4,196 (31.6)	
Middle	1,180 (33.9)	2,763 (33.0)		566 (31.1)	4,530 (34.1)	
Poorest	1,094 (31.4)	2,793 (33.4)	0.11	464 (25.5)	4,546 (34.3)	<0.001
Age, mean	32.6	33.4	0.07[a]	33.6	33.7	0.8
Urban	2,411 (69.1)	5,488 (65.5)		1,344 (73.4)	8,703 (65.5)	
Rural	1,079 (30.9)	2,892 (34.5)	<0.001	486 (26.6)	4,592 (34.5)	<0.001
Married or cohab	2,510 (71.9)	6,232 (74.4)		1,036 (56.6)	9,547 (71.8)	
Divorced or widowed	117 (3.4)	335(4.0)		218 (11.9)	1,640 (12.3)	
Single	863 (24.7)	1,813 (21.6)	0.001	576 (31.5)	2,108 (15.9)	<0.001
Depression sympt	84 (2.41)	650 (7.8)	<0.001	116 (6.34)	2,380 (17.9)	<0.001

a: ttest for difference between means; b: chi squared test for the hypothesis that observed cases ('non-missing') and expected cases (missing) differ more than expected due to chance; c: denominator for all lines below
Not adjusted for survey design.

7.3.2 Distribution of the sample

Table 7.4 shows the population distribution by the variables of study that have not been described in previous chapters. Similar proportions of men and women reported being married or cohabiting. Urban men and women were less likely to report being married or cohabiting than rural men and women (67% vs. ≈76% p<0.001). There was no difference in the proportion of women classified as having clinically significant depression symptoms between urban and rural areas, (17.8% and 18.3%). Prevalence of depression symptoms was significantly lower among men than women, with the prevalence among men being 7.2% nationally.

Food insecurity was more common in rural areas. Thirty eight per cent of rural women were in a situation of moderate or severe food insecurity compared to 26.4% of urban women (p<0.001). Only 6.2% or rural women were fully food secure. Similarly, food insecurity was more common in rural than urban areas among men (p<0.001). Women tended to report higher levels of food insecurity than men in urban areas only. In terms of aspired body size, rural men aspired to a thinner body shape than urban men (p<0.001), conversely, among women, it was those living in urban areas that preferred a thinner body size compared to their rural counterparts (p<0.001). There was no difference in body size aspiration between men and women in urban areas, but in rural areas, men selected thinner body shapes compared to women (p<0.001).

Women living in rural areas had more children than women living in urban areas; 47.4% of rural women had 3 or more live births compared to 37.0% of urban women. In terms of behavioural factors, rural men and women were more active than urban men and women, and differences between urban and rural were larger among men. Sixty nine per cent of rural men were classified in the high physical activity category compared to 54% among urban men. Rural women sat the least (16.1% classified in high sitting), while urban men sat the most (33.2% classified high sitting). In terms of diet, urban women ate more fruits and vegetables compared to rural women (p<0.001). Rural and urban men ate similar amounts of fruits and vegetables. There were no differences in fruit and vegetable consumption between men and women. Men drank more soda than women in both urban and rural areas (p<0.001). Rural women drank the least soda compared to urban women and to men (32.4% classified in the high drinking category). Urban men were most likely classified in the high category for consumption of cakes and savoury snacks, they were followed by urban women. Rural women ate the least cakes and savoury snacks.

Table 7.4 Distribution of the sample 2012

	Urban areas		**Rural areas**	
	Men	**Women**	**Men**	**Women**
	% or mean	**% or mean**	**% or mean**	**% or mean**
Main sample, N	5,501	8,729	2,906	4,620
PSYCHOSOCIAL				
Marital status				
Married or cohabiting	6.7 (1.0)	67.1 (0.9)	75.4 (1.3)	76.6 (1.0)
Divorced or widowed	0.3 (0.3)	10.8 (0.5)	1.7 (0.3)	6.8 (0.4)
Single	2.9 (1.0)	22.1 (0.8)	23.0 (1.2)	16.5 (0.9)

	Urban areas		Rural areas	
	Men	Women	Men	Women
	% or mean	% or mean	% or mean	% or mean
Depression symptoms				
No symptoms	9.3 (0.5)	82.2 (0.7)	91.3 (0.8)	81.7 (0.9)
Clinically significant sympt	0.7 (0.5)	17.8 (0.7)	8.7 (0.8)	18.3 (0.9)
Food security				
Food security	1.4 (0.8)	8.9 (0.5)	8.0 (0.7)	6.2 (0.6)
Mild food insecurity	5.9 (1.0)	59.4 (0.8)	55.7 (1.4)	55.4 (1.1)
Moderate food insecurity	1.8 (0.8)	20.6 (0.7)	24.8 (1.2)	27.8 (1.0)
Severe food insecurity	0.9 (0.6)	11.1 (0.5)	11.5 (0.8)	10.6 (0.6)
Food security b				
Food secure	43.5 (1.1)	39.2 (0.9)	31.8 (1.3)	29.7 (1.0)
Food insecure	56.5 (1.1)	60.8 (0.9)	68.2 (1.3)	70.3 (1.0)
Aspired body size, mean	34.8 (2.5)	344.5 (2.3)	333.1 (3.7)	363.9 (3.1)
PHYSIOLOGICAL				
Parity				
No children		18.8 (0.7)		15.7 (0.9)
1-2 children		44.2 (0.8)		36.9 (1.1)
3-4 children		31.3 (0.8)		33.2 (1.0)
5 or more		5.7 (0.4)		14.2 (0.8)
BEHAVIOURAL				
Physical act subsample, N	1,613	2,676	904	1,458
Physical activity				
Low	20.5 (1.9)	20.5 (1.3)	18.0 (1.9)	22.2 (2.0)
Moderate	25.4 (2.1)	32.2 (2.0)	13.2 (1.8)	24.1 (2.1)
High	54.1 (2.5)	47.4 (1.9)	68.8 (2.4)	53.7 (2.7)
Sitting time				
Low	33.1 (2.2)	42.3 (1.9)	51.6 (2.8)	57.4 (2.1)
Moderate	33.7 (2.1)	28.6 (1.7)	29.5 (2.4)	26.5 (1.9)
High	33.2 (2.2)	29.1 (1.8)	18.9 (2.1)	16.1 (1.9)
Diet subsample, N	378	660	207	329
Fruit and vegetable				
Lower	44.9 (4.1)	39.7 (2.9)	51.6 (4.9)	59.0 (3.9)
Higher	55.1 (4.1)	60.3 (2.9)	48.4 (4.9)	41.0 (3.9)
Soda				
Lower	47.1 (3.8)	54.9 (3.3)	46.5 (4.8)	67.6 (3.5)
Higher	52.9 (3.8)	45.1 (3.3)	53.5 (4.8)	32.4 (3.5)
Cakes and savoury snacks				
Lower	33.2 (3.6)	41.7 (2.9)	48.6 (4.3)	56.1 (3.7)
Higher	66.8 (3.6)	58.3 (2.9)	51.4 (4.3)	43.9 (3.7)

7.3.3 Association of education with potential mediating variables

In urban areas (Table 7.5), all of the variables selected as potential mediating factors in the association between education and obesity were socially patterned by education with the exception of soda consumption and physical activity level. Being married or cohabiting was more likely among more disadvantaged men and women. There was a stepwise decline in the proportion of men and women who reported being married or cohabiting with every level increase in education. Conversely, there was a stepwise increase in the proportion of single men and women with every level increase in education. Clinically significant depression symptoms were inversely associated with education in both men and women. The gradient was steeper among men than women. One level decline in education was associated with a 62% increase in depression symptoms among men and a 26% increase among women (PR: 1.62 95%CI 1.40, 1.86 among men; 1.26 95%CI 1.17, 1.35 among women; interaction $p<0.01$). Food insecurity was socially patterned by education in both men and women ($p<0.001$). More disadvantaged individuals were more likely to be food insecure, for example, 42.7% of men in the primary education or less group reported being moderately or severely food insecure compared to 12.4% among men in the higher education group. Education level was associated with aspired body size in both men and women. However among men there was a direct association; more education- larger aspired body size, while among women the association was inverse; more education- thinner aspired body size (interaction $p<0.001$). Adjusting the model for current BMI did not alter the association between education and aspired body size among men but it attenuated the association among women. There was an inverse linear association between education and parity; women with primary education or less had on average 2.9 live births compared to 1.2 among women with higher education.

In terms of behaviours, there was a direct association between education and sitting time; the more advantaged women and men sat more than the less advantaged. Fruit and vegetable consumption was socially patterned with more advantaged men and women consuming more fruits and vegetables than more disadvantaged men and women. Unexpectedly, consumption of cakes and savoury snacks had the same social patterning of fruits and vegetables, the more advantaged, the higher their consumption.

In rural areas (Table 7.6), similar associations between education and potential mediating variables were found. Higher education was associated with a lower proportion of men and women married or cohabiting, with a lower prevalence of clinically significant depression symptoms and with a lower proportion of food insecure households. Aspired body size was socially patterned in opposite directions among men and women (interaction $p<0.001$); more educated women aspired to a thinner body size than less educated women while more educated men aspired to a larger body size than less educated men. These associations remained significant after adjusting for current BMI. Education was inversely associated with parity.

The association between physical activity and education was not statistically significant; however there was a clear pattern in the physical activity proportions by level of education. A larger proportion of men and women with primary education or less were classified in the higher physical activity category (73.4% men; 61.1% women), compared to men and women with higher education (55.7% men; 44.2%women). Diet variables were not socially patterned by education among men in rural areas but they were among women. Higher education was associated with a higher consumption of fruits and vegetables, cakes and snacks and, marginally, soda.

Table 7.5 Potential mediating variables by education in urban areas

	Men					Women				
	Higher education	High school	Secondary	Primary or less	Trend p[a]	Higher education	High school	Secondary	Primary or less	Trend p[a]
Marital status										
Married or cohabiting	54.8	63.0	72.9	75.5		53.8	64.2	72.3	74.1	
Separated, divorced, widow	2.7	2.4	4.7	3.4		6.2	11.9	12.0	12.1	
Single	42.5	34.6	22.4	21.1	p<0.001	40.0	23.9	15.7	13.8	p<0.001
Depression symptoms	2.7	5.3	7.1	12.5	p<0.001	12.1	14.7	19.3	23.7	p<0.001
Food insecurity										
Food security	26.8	15.5	8.6	9.1		15.9	8.5	5.9	7.3	
Mild food insecurity	60.8	63.9	61.3	48.2		67.0	65.2	58.3	49.5	
Moderate food insecurity	8.5	14.0	19.7	29.1		12.6	17.2	23.8	26.0	
Severe food insecurity	3.9	6.6	10.4	13.6	p<0.001	4.5	9.2	12.0	17.1	p<0.001
Food insecurity b	37.4	52.9	62.8	71.4	P<0.001	41.5	54.9	65.9	74.9	P<0.001
Aspired body size, mean	3.7	3.6	3.4	3.2	p<0.001	3.3	3.4	3.4	3.6	p<0.001
Parity, mean	-	-	-	-		1.2	1.7	2.2	2.9	p<0.001
Physical Activity										
Low	25.6	19.7	18.8	18.8		22.1	20.1	19.3	20.8	
Moderate	30.9	21.7	26.1	21.9		33.9	26.5	33.3	33.4	
High	43.5	58.6	55.0	59.3	p=0.40	44.0	53.3	47.4	45.9	p=0.66
Sitting time										
Low	16.4	31.0	38.8	43.1		23.8	41.5	45.8	53.8	
Moderate	26.1	37.5	34.6	36.6		31.0	29.0	28.8	25.9	
High	57.5	31.5	26.5	20.3	p<0.001	45.2	29.4	25.4	20.3	p<0.001
Higher F&V	73.1	60.1	51.4	44.3	p<0.01	82.7	63.9	52.5	49.5	p<0.001
Higher soda	48.1	68.1	54.4	46.7	p=0.62	36.8	47.1	42.5	52.4	p=0.15
Higher cakes and snacks	84.8	81.4	68.7	43.3	p<0.001	80.6	58.6	55.3	44.8	p<0.001

[a]For binary variables, GLM were used to test the null hypothesis of no linear educational gradient in the mediating variable. The association between education and categorical variables was tested using multinomial logistic regression. The null hypothesis tested was that all parameters associated with education level in the two or more logits (number of categories in the outcome variable -1) were not significantly different from zero. For continuous variables, linear regression was used to test for a linear gradient.

Table 7.6 Potential mediating variables by education in rural areas

	Men					Women				
	Higher education	High school	Secondary	Primary or less	Association p[a]	Higher education	High school	Secondary	Primary or less	Association p[a]
Marital status										
Married or cohabiting	54.6	63.1	75.6	81.1		52.5	66.6	78.2	81.0	
Separated, divorced, widow	1.7	1.2	1.4	1.9		5.3	6.4	6.5	7.4	
Single	43.6	35.6	23.0	17.0	p<0.001	42.2	27.0	15.3	11.6	p<0.001
Depression symptoms	6.1	4.8	8.1	10.6	p=0.02	14.4	16.9	15.5	21.0	p=0.01
Food insecurity										
Food security	14.8	8.7	7.9	7.2		11.7	4.3	5.8	6.3	
Mild food insecurity	61.9	62.0	56.1	52.7		66.1	64.6	58.6	49.4	
Moderate food insecurity	14.7	22.0	24.9	26.8		14.2	23.3	27.7	30.9	
Severe food insecurity	8.6	7.3	11.1	13.3	p=0.04	8.0	7.8	7.8	13.4	p<0.001
Food insecurity b	46.9	63.3	67.8	72.4	P<0.001	56.8	59.5	68.2	76.2	P<0.001
Aspired body size, mean	3.7	3.6	3.3	3.2	p<0.001	3.4	3.5	3.6	3.8	p<0.001
Parity, mean	-	-	-	-		1.1	1.4	2.3	3.3	p<0.001
Physical Activity										
Low	37.5	21.9	22.1	12.9		16.8	24.4	28.9	18.2	
Moderate	6.9	13.6	13.2	13.7		39.0	24.7	26.2	20.7	
High	55.7	64.5	64.6	73.4	p=0.10	44.2	50.9	44.9	61.1	p=0.09
Sitting time										
Low	21.6	42.7	47.0	59.1		38.2	48.9	52.9	64.8	
Moderate	31.9	26.1	32.1	28.7		25.7	24.2	28.8	25.7	
High	46.5	31.1	20.9	12.2	p<0.001	36.1	26.9	18.3	9.4	p<0.001
Higher F&V	54.5	54.2	50.6	44.5	p=0.47	64.2	58.6	43.5	33.7	p<0.01
Higher soda	62.5	57.5	49.8	54.5	p=0.86	42.6	45.2	36.6	26.2	p=0.06
Higher cakes and snacks	51.6	57.0	63.6	40.2	p=0.11	64.4	69.3	52.9	31.3	p<0.001

[a]For binary variables, GLM are used to test the null hypothesis of no linear educational gradient in the mediating variable. The association between education and categorical variables was tested using multinomial logistic regression. The null hypothesis tested was that all parameters associated with education level in the two or more logits (number of categories-1) were not significantly different from zero. For continuous variables, linear regression was used.

7.3.4 Association of potential mediators with obesity

Being married or cohabiting was associated with an increased prevalence of obesity among urban women compared to being single (PR 1.14 $p<0.05$). Among rural men and women, being married was marginally associated with a higher prevalence of obesity compared to being single (PR 1.42 $p=0.06$ men; PR 1.18 $p=0.08$ women). Being married was not associated with obesity among urban men. Clinically significant depression symptoms were associated with a higher prevalence of obesity among urban women ($p<0.01$). Urban men with depression had a higher prevalence of obesity (36.3%) than those without (28.5%), however the association was not statistically significant. In rural areas, depression was not associated with obesity (Table 7.7).

There was a direct linear association between food insecurity and obesity among urban women; higher food insecurity-higher obesity prevalence ($p<0.01$). Among rural women and men there was no association between food insecurity and obesity (Table 7.7). Sex was an effect modifier of the association between food insecurity and obesity (interaction $p<0.05$). Aspired body size was associated with obesity in the four strata ($p<0.001$). The larger the selected figure the higher obesity prevalence. In rural areas, the association between aspired body size with obesity was significantly stronger among men than women (interaction $p<0.05$).

Having 3 or 4 children was associated with a higher prevalence of obesity compared to having none ($p<0.01$). In rural areas, women with more children had a lower obesity prevalence than women with fewer children, however the association was not statistically significant.

Physical activity and sitting time were not associated with obesity. Although obesity prevalence was lower in the higher physical activity group in all strata, difference in prevalence across groups was not statistically different. The diet variables were not associated with obesity. Confidence intervals for obesity estimates in the diet subsample were large due to the small sample size. In general, obesity prevalence appeared to be lower among men who consumed more fruits and vegetables than among men who consumed less. Among women, obesity prevalence was almost identical in both fruit and vegetable groups. Obesity prevalence appeared higher among men and women in the high consumption group of soda (except among rural women) and cakes and snacks (except among rural men) but differences were not statistically significant.

Table 7.7 Age adjusted obesity prevalence by potential mediating variables

	Urban areas		Rural areas	
	Men	**Women**	**Men**	**Women**
	%(95%CI)	**%(95%CI)**	**%(95%CI)**	**%(95%CI)**
Overall obesity	28.9 (27.1,30.7)	35.0 (33.4,36.7)	20.7 (18.6,22.8)	30.9 (29.0,32.9)
PSYCHOSOCIAL				
Marital status				
Married or cohabiting	28.8 (26.5,31.0)	36.5 (34.4,38.7)	21.9 (19.4,24.3)	31.1 (28.9,33.2)
Divorced or widowed	28.8 (19.8,37.7)	32.8 (28.3,37.4)	28.4 (12.7,44.1)	33.4 (25.8,41.0)
Single	29.0 (24.6,33.4)	33.1 (29.4,36.9)	18.6 (12.7,24.4)	25.1 (20.4,29.7)
P[a]	*0.57*	*<0.05*	*0.06*	*0.08*
Depression symptoms				
No symptoms	28.5 (26.6,30.3)	34.1 (32.4,35.7)	20.6 (18.5,22.8)	30.0 (27.8,32.3)
Clinically significant sympt	36.3 (27.6,45.0)	40.0 (35.7,44.2)	20.4 (14.2,26.7)	35.8 (31.2,40.4)
p[b]	*0.11*	*<0.01*	*0.8*	*0.11*
Food security				
Food security	32.8 (27.3,38.4)	32.7 (28.1,37.4)	16.4 (10.7,22.1)	33.5 (26.2,40.8)
Mild food insecurity	27.6 (25.4,29.8)	33.9 (31.9,35.9)	21.8 (18.7,24.9)	31.9 (29.0,34.8)
Moderate food insecurity	29.7 (25.5,33.9)	38.0 (34.4,41.5)	21.0 (17.0,25.0)	30.2 (27.1,33.3)
Severe food insecurity	30.2 (23.4,36.9)	38.2 (33.0,43.4)	17.0 (11.1,23.0)	27.5 (22.6,32.4)
Trend p	*0.5*	*<0.01*	*0.5*	*0.1*
Food insecurity b				
Food secure	30.5 (27.7,33.4)	30.9 (28.5,33.3)	20.6 (16.7,24.4)	29.7 (26.0,33.3)
Food insecure	27.8 (25.4,30.2)	37.9 (35.8,40.0)	20.9 (18.4,23.4)	31.5 (29.2,33.78)
p[b]	*0.14*	*<0.001*	*0.99*	*0.49*
PHYSIOLOGICAL				
Parity				
No children		34.4 (30.2,38.6)		31.3 (25.8,36.9)
1-2 children		33.7 (31.4,36.1)		31.5 (28.1,35.0)
3-4 children		38.7 (34.8,42.5)		29.3 (25.3,33.3)
5 or more		28.7 (24.3,33.1)		27.6 (17.6,37.5)
Trend p		*<0.01*		*0.23*
BEHAVIOURAL				
Physical activity				
Low	30.8 (23.6,38.0)	35.0 (29.5,40.5)	18.6 (11.3,25.9)	30.0 (23.1,37.0)
Moderate	33.3 (26.0,40.6)	37.8 (30.6,44.9)	16.9 (10.0,23.8)	30.7 (22.6,38.8)
High	26.4 (21.8,31.1)	33.6 (28.9,38.3)	17.3 (12.9,21.6)	28.3 (22.3,34.4)
Trend p	*0.18*	*0.9*	*0.87*	*0.57*
Sitting time				
Low	25.0 (19.5,30.5)	32.9 (28.4,37.3)	16.9 (12.2,21.7)	30.7 (25.2,36.2)
Moderate	29.0 (22.9,35.1)	37.7 (31.7,43.7)	19.3 (12.6,26.0)	25.0 (19.1,30.9)
High	31.7 (25.1,38.3)	38.1 (30.2,46.0)	18.9 (12.4,25.4)	27.6 (20.1,35.2)
Trend p	*0.39*	*0.28*	*0.66*	*0.24*
Fruit and vegetable				
Lower	35.9 (25.4,46.3)	36.8 (28.5,45.2)	21.3 (12.9,29.7)	30.9 (22.8,39.0)
Higher	32.2 (22.4,42.1)	37.6 (31.5,43.7)	12.6 (5.6,19.6)	30.2 (19.2,41.2)
p[b]	*0.61*	*0.28*	*0.2*	*0.76*

	Urban areas		Rural areas	
	Men	Women	Men	Women
	%(95%CI)	%(95%CI)	%(95%CI)	%(95%CI)
Soft drinks (soda)				
Lower	31.6 (21.4,41.9)	31.4 (26.0,36.7)	15.4 (6.2,24.6)	31.5 (23.2,39.8)
Higher	35.0 (26.1,43.9)	44.6 (35.9,53.3)	19.5 (10.0,29.1)	30.5 (20.1,40.9)
p^b	*0.73*	*0.1*	*0.78*	*0.82*
Cakes and savoury snacks				
Lower	24.4 (15.5,33.2)	35.9 (29.2,42.6)	20.8 (11.2,30.4)	29.0 (20.8,37.2)
Higher	38.9 (28.9,49.0)	37.7 (29.9,45.4)	15.0 (5.1,24.8)	34.5 (24.3,44.7)
p^b	*0.06*	*0.85*	*0.62*	*0.79*

[a] p value for association between being married and obesity compared to being single; [b] p value for association between binary variable and obesity.

7.3.5 Mediation analysis

The crude RII among urban women was 1.46 (95%CI 1.25, 1.71). Psychosocial variables had the largest effect on inequalities. Aspired body size reduced the RII by 17.62%. Food insecurity (psychological dimension) and depression symptoms further decreased the RII and remained significant in the age and education adjusted models. Together these three variables explained 37% of educational inequalities among urban women. The multivariate adjusted RII was 1.27 (95%CI 1.09, 1.48). Therefore, most of the educational inequality among urban women remained unexplained after adjusting for potential psychosocial mediating variables.

Parity and behavioural factors did not explain educational inequalities in obesity among urban women. Parity marginally decreased the RII but was not significant in the age and education adjusted model, therefore was not a mediating variable. The RII increased when physical activity and sitting time were included in the model. This was due to physical activity and sitting time being socially patterned in the opposite direction to obesity. Findings from the diet subsample were not stable with very large confidence intervals due to the small sample. The crude RII was not significant therefore no further analyses were performed.

Among rural men, there was a direct association between education and obesity and the unadjusted RII was statistically significant; 0.52 (95%CI 0.36, 0.75). Obesity was more prevalent among men with higher education compared to men with primary or less. Potential mediating factors where thus defined as those variables that increased the RII taking it closer to one, the null. Aspired body size was the only variable studied that met the criteria for mediation, explaining 14.6% of the RII and remaining significant in the model with education and age.

The RII for rural men in the physical activity and diet subsamples was statistically significant and consistent in direction with the RII of the main sample although with larger confidence intervals as expected from a smaller sample. Behavioural factors had no effect on the RII; they did not explain the direct association between education and obesity.

Among rural women and urban men, the RII was not statistically significant therefore no further mediation analyses results are presented.

Table 7.8 Mediation analysis for the association between education and obesity

		Men				Women			
		RII (95% CI)	% change RII	Rank	Multivar analysis	RII (95%CI)	% change RII	Rank	Multivar analysis
	URBAN AREAS								
Model	Main sample, N	5,501				8,729			
1	Crude	0.86 (0.70,1.05)				1.46 (1.25,1.71)			
2	Marital status					1.47 (1.26,1.73)	1.68		n
3	Food insecurity					1.45 (1.24,1.70)	-1.77	ł	n
3b	Food insecurity b					1.40 (1.19,1.63)	-12.74	2	y
4	Depression symptoms					1.46 (1.25,1.72)	-0.21	3	y
5	Aspired body size					1.37 (1.17,1.60)	-17.62	1	y
6	Parity					1.45 (1.24,1.70)	-1.98	ł	n
7	Adjusted					1.27 (1.09,1.48)	-37.02		
	Physical Act subsample, N	1,613				2,676			
1	Crude	0.71 (0.46,1.11)				1.61 (1.13,2.29)			
2	Physical Activity					1.67 (0.31,2.79)	8.85		n
3	Sitting time					1.75 (0.34,2.93)	18.65		n
	Diet subsample, N	378				660			
1	Crude	0.56 (0.29, 1.06)				1.51 (0.82,2.79)		ł	
2	Fruits and vegetables					1.60 (0.87,2.93)	13.39		n
3	Soda					1.44 (0.78,2.66)	-11.61		n
4	Cakes and snacks					1.56 (0.85,2.86)	7.37		n

		Men				Women			
		RII (95% CI)	% change RII	Rank	Multivar analysis	RII (95%CI)	% change RII	Rank	Multivar analysis
	RURAL AREAS								
Model	Main sample, N	2,906				4,620			
1	Crude	0.52 (0.36,0.75)				1.09 (0.85,1.41)			
2	Marital status	0.52 (0.36,0.74)	1.73		n				
3	Food insecurity	0.53 (0.37,0.76)	-2.57	ɫ	n				
3b	Food insecurity b	0.52 (0.36,0.75)	-0.08	ɫ	n				
4	Depression symptoms	0.53 (0.37,0.76)	-1.57	ɫ	n				
5	Aspired body size	0.57 (0.40,0.82)	-14.59	1	y				
6	Parity				n				
7	Adjusted	0.57 (0.40,0.82)	-14.59						
	Physical Act subsample, N	904				1,458			
1	Crude	0.40 (0.17,0.97)				1.27 (0.70,2.29)			
2	Physical Activity	0.40 (0.16,0.96)	1.12		n				
3	Sitting time	0.40 (0.16,1.01)	0.62		n				
	Diet subsample, N	207				329			
1	Crude	0.09 (0.02,0.43)				1.58 (0.65.3.84)			
2	Fruits and vegetables	0.09 (0.02,0.40)	0.42		n				
3	Soda	0.09 (0.02,0.42)	0.87		n				
5	Cakes and snacks	0.08 (0.02,0.39)	2.17		n				

ɫ Potential mediator variable not significantly associated with obesity when included in the model with education therefore did not rank. Model 1: Reference RII, adjusted for age and age squared, Models 2-6: Adjusted for age, age squared, and the specified variable, Model 7: Adjusted for age, age squared, plus selected variables according to rank. “y” denotes yes, included in multivariate analysis (Model 7), “n” denotes not included. Variables are ranked according to how much they attenuate the RII. % change RII calculated as follows: ((adjusted log RII-crude log RII)/crude log RII)*100
Shaded in the table are the models run in the physical activity and diet subsamples. Model 1 is the crude model (reference RII), models 2+ are adjusted by the specified variable.

7.4 Summary of chapter

This chapter explored the social patterning of psychosocial, physiological and behavioural known risk factors of obesity and investigated, in cross-sectional data, whether they could be mediators in the association between education and obesity. Among both men and women, all potential mediating factors selected were socially patterned by education with the exception of soda consumption and physical activity in urban areas. In rural areas, fruit and vegetable and cakes and savoury snack consumption were not socially patterned by education among men.

Among urban women, the selected risk factors were associated with obesity as expected, with the exception of the behavioural risk factors in the small subsample in the 2012 survey. The analysis using 2006 data suggested that sitting time, consumption of fruit and vegetables, and cakes and snacks were associated with obesity. Among urban and rural men and rural women, only aspired body size was significantly associated with obesity, the larger the selected figure the higher prevalence of obesity.

As described in previous chapters, educational inequalities in obesity were not significant among urban men or rural women. Therefore mediation analysis was not carried out in those subgroups. Among rural men, there was a direct association between education and obesity which was partially explained by aspired body size (15% reduction in the RII). More advantaged men appear to prefer larger body sizes and this may lead to lifestyle choices which promote obesity. This finding was consistent with the hypothesis for this chapter. Physical activity, the other hypothesised mediator variable among men, was not associated with obesity in this sample.

Among urban women a moderate proportion of the inverse educational gradient was explained by aspired body size, food insecurity (psychological dimension) and depression symptoms. Together these three variables explained approximately 37% of educational inequalities. Physiological and behavioural variables hypothesised to be mediators among women did not meet the mediation conditions.

Chapter 8 Discussion and conclusion

This chapter summarizes the findings in this thesis and discusses them with reference to the social determinants of health framework and the nutrition transition literature. The interpretation of results is set in the context of the socioeconomic and cultural changes that occurred in Mexico over the study period.

Chapter 1 detailed the changing socioeconomic and cultural context in Mexico over the last 25 years. The economic policies of the 1980s and 1990s and the signing of NAFTA had an effect on food diversity and availability and consequently on cultural food preferences which resulted in an ongoing shift to a higher distribution of body weight (26, 28). This thesis has documented the dramatic increase in obesity prevalence over the period 1988 to 2012. The steady improvement in Mexican's health and life expectancy over the last century may be slowed or even come to a halt as a result of increasing obesity prevalence. Simulation studies from the USA and UK, both countries with high obesity prevalence like Mexico, have shown that obesity prevalence affects morbidity and mortality to the point of modifying projected life expectancy (206, 207). It has been argued that the Mexican government has responsibility for the health of its population and will need to address the social determinants of obesity (66, 67). This aspect of public health action is discussed below (section 8.9).

The detailed analysis of recent trends in obesity inequalities presented in this thesis is a significant advance on existing literature for Mexico. Previously only one wave of cross-sectional data had been used to study obesity inequalities in Mexico. Neither inequality time trends nor gender differences in inequalities in obesity had been studied. Evidence to inform health policy around inequalities in obesity was therefore incomplete and at times misleading, because it was out of context or out of date. Further, the conclusions reached by reviews and multicountry studies on the nutrition transition proposition were not entirely generalizable to Mexico as this thesis' findings have shown.

The main strength of this thesis is its use of four nationally representative surveys with a low non-response rate and measured weight and height. Further, by using two dimensions of socioeconomic position, wealth and education, it was possible to see the process of the nutrition transition. Its main limitation is that it relies on cross-sectional data therefore it cannot be conclusive about causative associations. The next section provides a summary of the findings. This is followed by a detailed discussion of the findings organised by objective.

8.1 Summary of findings

This thesis aimed to investigate socioeconomic inequalities in obesity in Mexico using four nationally representative cross-sectional surveys covering a period of 25 years. The hypotheses guiding the research were based on the nutrition transition proposition of a crossover to higher rates of obesity among the more disadvantaged adults as Mexico developed economically. Inequalities in obesity were expected to emerge and then widen due to larger increases in obesity prevalence among the most disadvantaged population groups throughout the study period.

In support of the nutrition transition proposition this thesis found an inverse association between education and obesity among urban dwelling women. Among rural dwelling women, Chapter 4 showed no educational inequalities and no evolution of the educational gradient over the period 1988 to 2012. However, when the analysis was stratified by household wealth in Chapter 5, the nutrition transition pattern became evident. An inverse association between education and obesity was clear among the richer rural women but not among the poorest women in the earlier period (1988/1999). A crossover to higher rates of obesity among the least educated women upon reaching a threshold level of household wealth was also shown.

An unexpected finding was the decline in relative educational inequalities among urban women over the study period due to deceleration in the obesity prevalence growth rate among women with primary education or less and a continued increase in obesity prevalence among the more educated women. This finding was not in line with the nutrition transition proposition and with the findings in other LMIC. However, the pattern of declining inequality found in Mexico was similar to that seen in the United States and Canada suggesting it may be characteristic of countries with very high prevalence of obesity.

Among men, higher education and wealth were associated with higher obesity prevalence especially in rural areas. There was no evidence of a crossover to higher rates of obesity among more disadvantaged men. This finding was not in line with multi-country studies on the nutrition transition proposition which have concluded that the reversal of the social gradient among men occurs at a higher level of economic development compared to women.

Psychosocial factors, specifically the psychological dimension of food insecurity and aspired body size, explained a proportion of the educational inequalities in obesity among urban women. Lower level of education was associated with worrying about having enough food which in turn was associated with an increased prevalence of obesity. Food insecurity may affect an individual's stress response and trigger coping mechanisms that lead to obesity. In terms of aspired body size, Chapter 7 showed that more advantaged women aspired to be thinner than more disadvantaged women. It is likely that women adopt lifestyles and patterns of consumption with the aim to maintain or achieve their aspired body size contributing in this way to the educational gradient in obesity.

A further finding of this thesis was that there were significant gender differences in educational inequalities in obesity. These were partially explained by differences in attitudes towards body shape. While more advantaged women valued thinness, more advantaged men appeared to prefer larger body sizes which may have led to lifestyle choices that promote obesity.

8.2 Trends in educational inequalities in obesity among women (Chapter 4)

Main findings

Chapter four examined time trends in educational inequalities in obesity over the period 1988 to 2012 among women. It was hypothesised that an inverse educational gradient would be observed in urban areas and inequalities would increase in the study period. In rural areas, a direct association between education and obesity was expected and faster increases in obesity prevalence among the lower education groups would show a reversal of the social gradient in the future was likely. These hypotheses were only partially supported by the findings.

Urban areas

Consistent with the hypothesis and with the nutrition transition proposition, the crossover from lower to higher rates of obesity among the least educated women in urban areas appeared to have occurred prior to 1988. There was an inverse educational gradient throughout the study period, such that obesity disproportionately affected the most disadvantaged women. Chapter 5 gave further evidence in support of the nutrition transition proposition by showing that the reversal of the educational gradient among poor urban women occurred over the period of study.

Contrary to the hypothesis and the nutrition transition proposition, there was strong evidence that relative inequalities declined in the period 1988 to 2012. The same trend in inequalities was observed using BMI≥35 as outcome variable. Absolute inequalities increased from 1988 to 1999 and plateaued thereafter.

There was clear evidence that the inequality trend among women resident in urban areas was a period effect, generated by environmental changes which influenced women regardless of age. Sensitivity analysis for potential cohort effects showed that the magnitude of inequalities was similar in four cohorts born in the 1940s, 1950s, 1960s and 1970s. It further showed a tendency towards declining inequalities over the period of study 1988 to 2012, for all cohorts.

Rural areas

In rural areas there was no educational gradient at any survey wave. Obesity prevalence increased similarly in relative terms among women of all education levels. The urban-rural difference did not appear to be an artifact due to small sample sizes in the rural education strata, or to selection bias because response rates were similar in both types of area.

Main findings compared to previous studies

Obesity prevalence among Mexican women trebled in the period 1988 to 2012. In 2012, obesity prevalence was 34.5% in urban areas and 30.7% in rural areas ($p<0.05$), demonstrating the continuing link between urbanization and obesity in Mexico (87, 208). This is the typical pattern in countries undergoing a nutrition transition.

The reversal of the educational gradient in urban areas prior to 1988 was consistent with previous Mexican studies using one wave of cross-sectional data. Martorell *et al* described an inverse association between education and obesity among women in Mexico using nationally representative data from 1987 (87). Monteiro subsequently confirmed an inverse association between education and obesity using data from 1999 (88). Both these studies adjusted but did not stratify by urban and rural dwelling. Their findings masked the different association between education and obesity in rural areas compared to urban areas which was evident in this study.

Some results from Chapter 4 were consistent with the nutrition transition proposition. The reversal of the social gradient in obesity reportedly occurs at a country GNI per capita of $2,500 USD (84). In 1990, Mexico had a mean GNI per capita of approximately, $2,790 USD (13) while in urban areas estimated GNI per capita was approximately 41% higher (158). Therefore, urban areas in Mexico were well above the income threshold for reversal of the social gradient at the time of the first survey (1988). In rural areas, GNI per capita was estimated to be 73% lower than national average (158). The GNI per capita in rural areas may have been approximately $2,603 in 2012 (the national average being $9,640), just over the threshold. There was some evidence that the reversal of the social gradient in rural areas may occur in the near future if obesity prevalence continues to increase among the most disadvantaged women. A possible reversal of the social gradient was supported by findings of a gradual reversal of the educational gradient by level of household wealth (Chapter 5).

Based on the nutrition transition experience of other LMIC (93, 101), it was hypothesised that inequalities in obesity in urban areas would increase over the course of the study period as obesity prevalence increased faster among disadvantaged women. However, this study found strong evidence that inequalities in urban areas declined in the period 1988 to 2012, following a similar pattern to inequalities in North America. In the USA and Canada, the inverse association between SEP and obesity was attenuated over the 1980s and 1990s due to greater increases in the prevalence of obesity in more compared to less advantaged groups (94, 95, 97). The decline in inequality in the USA and Canada coincided with large increases in obesity prevalence such as it did in Mexico.

Interpretation of findings

Absolute and relative educational inequalities

From 1988 to 1999 there was an increase in absolute inequalities in obesity prevalence in urban areas. This was due to larger absolute increases in obesity prevalence among the most disadvantaged women, for example, among women with primary education or less, obesity prevalence increased 21.6 percentage points compared to 11 percentage points among women with higher education.

Relative inequalities over the same period decreased. This was because in relative terms, increases in obesity prevalence were larger among women with higher education compared to women with primary education or less. Obesity prevalence increased nearly four-fold among the most advantaged women compared to almost three-fold among the most disadvantaged women.

In the period from 1999 to 2012 the decline in relative inequalities continued in urban areas. The high school or higher education groups had larger relative increases in obesity prevalence compared to those with secondary or less education. In the period between 2006 and 2012 the increase in obesity prevalence was not significant for the two most disadvantaged groups while it continued to be significant for the two more advantaged groups. Absolute inequalities over the same period (1999 to 2012) remained stable. Absolute increases in obesity prevalence were similar across education groups.

In rural areas neither absolute nor relative inequalities were significant, in the study period. Absolute increases were marginally larger among women with primary education or less in whom obesity prevalence increased 24.3 percentage points over the period 1988 to 2012 compared to 16.8 percentage points among women with higher education. This is an indication that absolute inequalities may emerge in the near future. Relative increases in obesity prevalence were marginally larger for women with high school and higher education over the period 1988 to 2012.

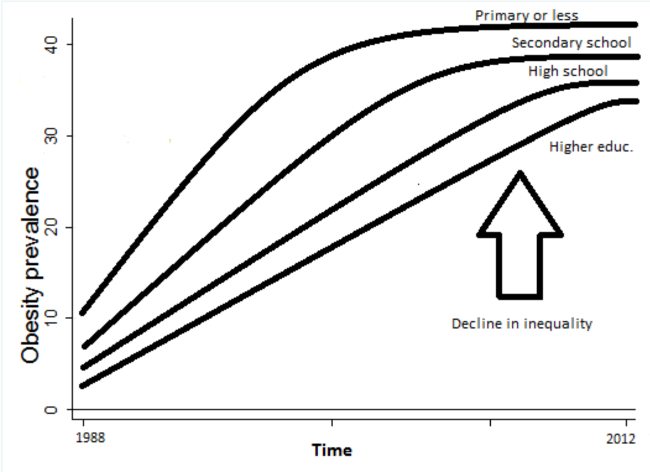
The public health burden of obesity inequalities will be discussed in a later section (section 8.9). The following sections provide an interpretation of the trends in relative inequalities.

Potential explanations for the decline in relative educational inequalities

This thesis' hypothesis about emerging and increasing inequalities was based on the experience of other LMIC such as Brazil and China in which disadvantaged groups were becoming obese faster than advantaged groups and inequalities appeared to be widening. However, the prevalence of obesity in other LMIC and specifically in these two countries is significantly lower than it is in Mexico; 13% in Brazil (2003) and approximately 4% in China (2006). Mexico is an outlier in the association between GNI and obesity prevalence (209). The obesity prevalence in Mexico was 33.7% (2012) which is similar to the obesity prevalence in the USA and higher than that of many more developed countries (209). Obesity prevalence among women with primary education was 38.5% in 2012.

Modelling of US and UK data suggests that obesity prevalence will reach a plateau. The level at which obesity prevalence will plateau has been estimated to be 32% in the USA and of 39% in the UK (210). A leveling in the obesity prevalence has already been recorded in the USA and a slowdown in the rate of increase among adults in the UK (211). If obesity prevalence in Mexico followed a similar trajectory, the narrowing of inequalities may be the result of obesity prevalence among the more disadvantaged women reaching said plateau. Based on this logic, women with higher education, who had much lower obesity prevalence at the beginning of the study period, may continue on a linear trajectory for some years. Speculatively, obesity prevalence will plateau at a lower prevalence level for more advantaged individuals and inequalities will stabilise. This potential explanation is illustrated in Figure 8.1. Consistently, obesity inequalities in the USA where the prevalence of obesity is higher than in Mexico appear to be declining too.

Figure 8.1 Stylised presentation of trends in obesity prevalence by level of education, urban areas



The causes of plateauing obesity prevalence are unclear. One potential explanation is that public health programmes aimed at preventing obesity are having the desired effect especially among more disadvantaged population groups (212). Population wide interventions targeting diet and obesity are very recent in Mexico. The federal government's strategy to tackle overweight and obesity was signed only in 2009 (45). However, it may be possible that the nutrition education component of *Oportunidades* which has been around for much longer has had a positive effect on the diet of the families it reaches.

An alternative explanation for plateauing trends is the saturation equilibrium hypothesis (212). This hypothesis proposes that the proportion of overweight and obese individuals will depend on interactions between the distribution of resilience in the population and the degree to which the environment promotes unhealthy behaviours leading to obesity (212). Resilience can be defined as the "dynamic process encompassing positive adaptation within the context of significant adversity" (213). It can be influenced by a combination of genetic and psychosocial factors. Studies investigating the characteristics of those who manage to engage in obesity prevention behaviours and maintain a healthy weight despite adverse environments suggest that characteristics such as ability to prioritize time for healthy eating, social support from families and self-efficacy may play an important role (214, 215). Mexico may be reaching saturation equilibrium with respect to obesity prevalence.

The plateau effect is consistent with trends in obesity prevalence among less educated Mexican women and may explain some of the decline in inequalities. However, the trend in obesity prevalence among more educated women continued to increase throughout the study period. The changes to the food and built environment which occurred in the late 1980s and 1990s may have had greater impact on more advantaged women. This explanation contradicts the suggestion that more advantaged women are relatively resistant to environmental influences and more able to take compensatory action, thereby maintaining their relative advantage with time (97). It also contradicts the technological change hypothesis which suggests that rising obesity prevalence is caused mainly by jobs becoming less strenuous leading to declining physical activity (23). Women with higher education are unlikely to have been doing manual jobs in the late 1980s. The nature of skilled jobs being done by women with higher education is unlikely to have changed over the 25 year period. Calorie consumption probably played a more important role in rising obesity prevalence among more advantaged women.

In the Mexican context, women with more education might have been the first to access processed/North American foods in the early days of market liberalization. These foods were novel and added variety to the traditional Mexican diet. Chains selling energy dense foods and beverages that target upper middle income groups have had very high sales growth. For example convenience stores targeting the time-poor middle and upper income urban population, grew at a rate close to 1000 new stores per year during the 1990s and 2000s (26). Chapter 7 further showed that consumption of soda was equally high in all education groups and consumption of savoury snacks and cakes was higher in more educated women. Although more advantaged women aspire to thinner body sizes as shown in Chapter 7, health behaviours do not appear to match these ideas yet. Moreover, the environment may be so conducive of obesity that it overpowers the effect of body size preferences.

Further, women's participation in the labour force increased substantially from 17% in the 1970s to 43% in 2010 (216). This may have caused considerable changes in food purchase and preparation patterns at household level contributing to increased calorie intake (44). Working women, who have tended to be more educated than those who do not work (216), may have relied more heavily on convenience foods with the consequence of increasing calorie intakes.

Alternative explanations for declining obesity inequalities

Compositional effect of education

Educational attainment improved over the course of the study period. Education up to secondary level became compulsory in 1994 and further years in education including higher education became more accessible as new universities, both private and public, opened. The high school and higher education groups became more inclusive and probably more heterogeneous with each subsequent survey. Achieving a higher level in education may have become less dependent on other characteristics or advantages of origin such as father's social class, intelligence and or individual motivation. Such variables have been previously proposed in the literature as potential confounding factors of the association between education and health.

A potential explanation for the trends observed could therefore be that women who achieved higher education in 1988 could have been more motivated, more intelligent or more advantaged in terms of SEP of origin and that in turn protected them from obesity. In the more recent surveys, women may on average have been less motivated, intelligent or advantaged because a higher level of education was the norm, therefore they appear to be less protected from obesity. Although this hypothesis could not be tested directly with the available Mexican data, it is not supported by the cohort effect analysis. Education became less protective over the course of the study period for older cohorts, presumably more motivated, just as it did for younger cohorts. Further, the declining trends in inequality for different cohorts run in parallel suggesting that period effects, or environmental changes over the period, were more important than these personal characteristics.

Intelligence and other traits such as self-control have been contested elements in the study of the association between education and health. It has been proposed that individuals who do well in education do so because they have other attributes such as higher intelligence, coping skills or delayed gratification and that it is these attributes which are the real determinants of health. Empirically, there is a lack of support for this proposition. Childhood cognitive ability was not associated with adult health in the 1958 British birth cohort; therefore, intelligence did not confound the association between education and health in this case (217). Link *et al* found that controlling for intelligence did not significantly change the relationship between SEP and health in an American cohort. Likewise, they found little evidence of a direct effect of intelligence on health once adult education and income had been held constant (218).

The role of education as a protective factor of obesity in urban areas

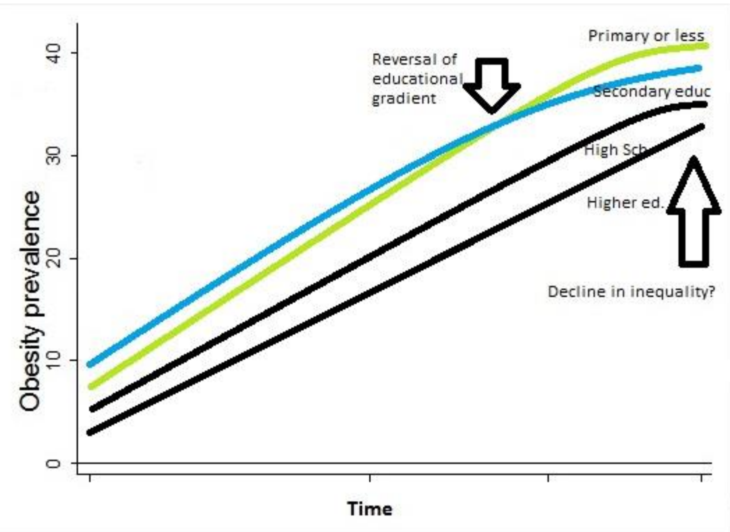
Education attainment at aggregate level improved substantially in Mexico over the study period while at the same time obesity prevalence increased dramatically. The ecological evidence therefore suggests that education leads to obesity. This thesis showed that, at an individual level, education is protective of obesity as expected. However; there was strong evidence that the protective effect of education was diluted over the course of the study period specifically among urban women. The main analysis in Chapter 4 showed the educational gradient becoming shallower from 1988 to 2012. Further, in the birth cohort stratified analysis, the protective role of education declined within the same cohort over the years. And, although the younger cohorts were significantly more educated, they were not more protected from obesity than the older less educated cohorts. It appears that education as a protective factor for obesity may have lost ground against emerging environmental risk factors.

The social determinants of health model suggests that socioeconomic advantage is linked with better health and nutrition outcomes (74). More advantaged individuals may have more flexibility in their choice of diet and activity patterns for example, compared to disadvantaged groups that are more constrained. The findings from this thesis do not support this argument entirely. The rate of increase in obesity prevalence across all SEP groups has been similar or larger among more advantaged groups. It remains to be seen whether obesity prevalence will plateau at a lower level for more advantaged women. This would provide evidence of a continued advantage provided by increasing education.

Rural areas- no educational inequalities

The data for women (Chapter 4) shows that rural women with high school and higher education had lower obesity prevalence throughout the study period than more disadvantaged women. Obesity prevalence among women with primary education or less was lower than the obesity prevalence among women with secondary education. However, the prevalence among women with primary education or less appeared to be catching up with that among women with secondary education (Figure 8.2). Speculatively, obesity prevalence among women with primary education or less will continue to increase and there will be a crossover to higher prevalence of obesity among this group compared to the secondary education group as illustrated in the figure. Absolute inequalities in obesity may emerge.

Figure 8.2 Stylised presentation of trends in obesity prevalence by level of education, rural areas



An important difference with the reversal of the social gradient in rural areas compared to urban areas is that it will occur at a much higher prevalence of obesity (i.e. >31% vs <9.5%). If obesity prevalence plateaus (as suggested in Figure 8.2), inequalities in rural areas are likely to remain narrow.

The absence of educational inequalities in rural areas may have been due to widespread absolute poverty, especially among women with primary education or less, throughout the period of study. The analyses of the educational gradient stratified by level of household wealth (Chapter 5) suggested that absolute poverty may 'protect' women from obesity. Chapter 5 further gave evidence of a gradual reversal of the educational gradient by level of wealth. Explanations for the reversal of the educational gradient in rural areas will be given under Chapter 5 headings.

8.3 Wealth inequality trends among Mexican women 1988 to 2012 (Chapter 5)

Main findings

Chapter 5's first aim was to investigate the social patterning of obesity by wealth among women over the period 1988 to 2012. This aim complements the findings above to provide an understanding of the effect of different dimensions of SEP on obesity. It was hypothesised that poorer women in both urban and rural areas would exhibit larger increases in obesity prevalence over the period 1988 to 2012 compared to more advantaged women. This would lead to a reversal of the wealth gradient in urban areas and a shift from a direct association between wealth and obesity to an inverted U shape association in rural areas. The reversal of the wealth gradient would be observed at a higher level of country GNI compared to education. This hypothesis was supported by the findings.

Obesity prevalence increased significantly across all wealth groups, ranging from two-fold to four-fold over the period 1988 to 2012. In urban areas, there was an inverted U shape association between wealth and obesity in the first three survey waves (1988, 1999 and 2006). The RII approached one and the SII approached zero, meaning no relative or absolute inequalities. In 2012 an inverse linear association emerged as poorer women became obese faster than richer women. Both absolute and relative inequalities emerged. Consistent with the hypothesis, the reversal of the wealth gradient in Mexico occurred at a much higher GNI per capita than has been quoted in the literature. Between 2006 and 2012, Mexico's GNI per capita was between $5,010 and $6,940 USD (13).

In rural areas, there was a direct association between wealth and obesity throughout the period 1988 to 2012. The richest women were the most obese. Absolute and relative inequalities were significant (SII<0 & RII<1) from 1999 through to 2012. The RII showed a significant increasing trend; the direct association between wealth and obesity weakened. Absolute inequalities showed a similar tendency.

Main findings compared to previous studies

The findings in Chapter 5 were consistent with previous Mexican studies which investigated inequalities in obesity by wealth at one point in time and found a direct association between wealth and obesity in rural areas and no association in urban areas. The most recent study used data from 2000 (106). Previous studies had not investigated inequality trends.

The direct association between wealth and obesity found in rural areas in Mexico was consistent with findings from a large multi-country study by Subramanian *et al* which reported that in 52 out of 54 LMIC the association between wealth and obesity was direct. Subramanian's study included >18 countries with a GNI per capita ≥2,500 USD (89).

This thesis further found that the direct association between wealth and obesity was weakened in rural areas with each subsequent survey. In urban areas a change in the wealth gradient was described (from an inverted U shape association to an inverse linear association). These findings challenge those of a second multi-country study using repeated DHS surveys which concluded that the direct association between wealth and obesity was not weakened over time (219).

In general, there was evidence of a dynamic association between wealth and obesity in Mexico, both in urban and rural areas. This is consistent with the nutrition transition proposition which suggests that as countries develop economically individuals from lower *SEP* groups become obese faster than individuals from higher *SEP* groups (99) and inequalities emerge. However, the emergence of the inverse wealth gradient occurred at a significantly higher level of economic development compared to education. The level of per capita GNI at which the reversal of the social gradient occurs may be dependent on income inequality especially for wealth, a measure of material living standard. The key studies describing the transition have not distinguished between SEP indicators and have not given much consideration to income inequality within countries (83, 84).

Interpretation of the findings

Direct association between wealth and obesity in rural areas

Wealth measures the dimension of SEP concerning material resources. Wealth is understood to be associated with health through its conversion into health enhancing commodities through expenditure (46). At the lowest level of wealth, absolute poverty is 'protective' of obesity by limiting the amount and types of food that can be purchased.

Increased wealth may allow for a shift in purchases from the traditional cheaper staples to the slightly more expensive but socially desirable industrially processed, energy dense foods and beverages (38). These foods are also palatable for their high sugar and fat content (33) and increasingly accessible in rural areas (220). It has previously been shown that cash transfers from the Mexican conditional cash transfer programme, aiming to lift people out of extreme poverty, led to excess weight gain among poor Mexican women (221).

Higher prevalence of obesity among more advantaged women in rural areas may also be linked to cultural norms that favour larger body sizes. This was supported by the findings in Chapter 7 which suggested that higher education was associated with a larger body ideal among rural-dwelling women. Further, more disadvantaged rural-dwelling women may be involved in labour intensive activities which protects them from obesity.

Reversal of the wealth gradient in urban areas

The reversal of the wealth gradient is determined by general improvements in the standard of living so that the relative poorest are no longer poor in absolute terms. The relative poorest become vulnerable to the obesity promoting environment. Country GNI per capita is assumed to capture the improvement in general standard of living. However, GNI per capita represents average wealth. If high income inequality exists, like it does in Mexico, increases in country wealth are unequally distributed. The transition may appear to happen at much higher level of country GNI because the poor remain poor in absolute terms even at apparently high levels of country GNI.

The reversal of the wealth gradient in urban areas in Mexico between 2006 and 2012 may have been due to a large proportion of the relative poorest crossing the absolute poverty threshold and becoming at risk of obesity. The largest increase in obesity prevalence in urban areas over the period 1988 to 2012 was among the poorest women (PR: 4.09).

The most disadvantaged women may have been the most vulnerable to the combination of increased economic resources in an adverse food and built environment. Early life disadvantage leading to low birth weight and childhood malnutrition may have contributed to irreversible physiological consequences which increase an individual's risk of adult obesity (222). In Mexico, disadvantaged women were on average five cm shorter than more advantaged women (Appendix 11). Low stature in adulthood is strongly related to circumstances during the childhood grow period (223).

Moreover, marketing and advertising by the food industry has made processed energy dense foods highly desirable to consumers. Anthropological studies suggest that processed foods and drinks have acquired meanings to do with progress and hospitality in some communities and among disadvantaged groups (37, 38).

8.4 Educational inequalities by level of wealth (Chapter 5)

Main findings

The second aim of Chapter 5 was to investigate the role of wealth as an effect modifier in the association between education and obesity over the period 1988 to 2012 among women. It was hypothesised that the education gradient would vary by levels of wealth. Education would be protective of obesity at higher levels of wealth but not at lower where absolute poverty would preclude women from becoming obese. A reversal of the education gradient would be observed among poorer women in the period of study (1988-2012) due to widespread improvements in the standard of living.

The hypothesis was supported by the findings. In the earlier surveys, education was protective of obesity at higher levels of wealth but not at lower in both urban and rural areas. In the recent surveys, education became protective at all levels of wealth (no effect modification). The reversal of the education gradient at low levels of wealth was shown in urban areas.

Interpretation

The correlation between education and wealth appears to be less strong in LMIC compared to HIC (117). In Mexico the correlation between education and wealth among women was moderate, Spearman's rho ≈ 0.4. It was not necessary to have a high education to be wealthy, for example on average 20% of those classified richest by the wealth index had achieved up to primary education or less in urban areas and 38.2% in rural areas. Further, it was possible to have a high level of education and still be poor. On average 11% of those classified poorest by the wealth index had high school or higher education in urban areas and 5.6% in rural areas.

The potential explanations for the low correlation were discussed in the first chapter (page 23). They include declining returns to education, the lack of qualifications needed in the informal economy and the lower monetary rewards for the same level of education for women compared to men. Further, educational investment may be less likely to pay off in the form of higher income in markets that are not fully developed like Mexico's (86).

Two findings from this thesis may be explained by this low correlation. The first is the different association between wealth and obesity, and education and obesity. Wealth and education measure different aspects of SEP. A recent review of the literature suggested that in 20 to 30% of studies from low and middle income countries the association between education and obesity and wealth and obesity was different (86). Second, the material pathway between SEP and obesity that has been described in more developed countries not being salient in Mexico. Vast literature has linked higher wealth/income with access to healthier foods and lifestyles which are preventive against obesity (32-34, 224). In Mexico there does not appear to be health benefits of increased wealth except in the last survey wave among urban women. Therefore, the indirect pathway by which education protects from obesity by influencing job prospects and income does not hold in Mexico.

Wealth-education interaction

In the earlier surveys, when absolute poverty was more widespread, wealth was an effect modifier of the association between education and obesity. Education appeared protective among the relatively richer groups but not among the poorest. The poorest groups were poor in absolute terms and 'protected' from obesity by their poverty. In the more recent surveys as the country has continued to develop economically, the relatively poorest women have crossed the wealth threshold and education has become protective for them as well as for richer women.

This analysis may have explained why in rural areas there appeared to be no educational inequalities in the period 1988 to 2012 (Chapter 4). In rural areas the women with primary education or less were likely to be below the wealth threshold throughout the period. The primary education or less group was the most numerous in all survey waves in rural areas. Therefore, the average educational inequalities in rural areas reflected the situation of this group. The results in Chapter 5 give evidence of a reversal of the educational gradient in rural areas. The education gradient for the middle and richer groups became almost identical (from 88/99 to 06/12) and suggestive of an inverse association. As the poorest group becomes richer, it is likely that education will be a consistent protective factor for all women in rural areas.

Findings in Chapter 5 were consistent with Mexican studies conducted among low income populations (108, 109). Fernald *et al* reported that education was directly associated with obesity among women living in poor communities in 2003. These findings seemed at odds with contemporaneous Mexican studies using nationally representative data which found an inverse association between education and obesity. The findings from Chapter 5 provide a context for low income population studies conducted in Mexico.

8.5 Inequalities in obesity among men compared to women (Chapter 6)

Main findings

The aim of Chapter 6 was to investigate inequalities in obesity among men over the period 2006 to 2012 and compare them to women's inequalities in obesity. It was hypothesised that the reversal of the social gradient in male obesity would occur at a higher level of economic development compared to women as suggested by multicountry studies (84).

Urban men had an overweight and obesity prevalence approximately ten percentage points higher than rural men. The prevalence of overweight and obesity among men was high especially in urban areas; 69.5% were overweight and 29.5% were obese in 2012. Obesity prevalence increased over the period 2006 to 2012 in both urban and rural areas.

More educated men tended to have higher obesity prevalence than less educated men but the gradient was not steep. Increases in obesity prevalence tended to be higher for the high school education group in urban areas and for the higher education group in rural areas. There was a significant interaction by gender in the association between education and obesity in both urban and rural areas.

There was a direct association between wealth and obesity in both urban and rural areas. The gradient was steeper in rural areas. There was a weakening of the direct association between wealth and obesity in rural areas. Gender modified the association between wealth and obesity.

There was no evidence to suggest that the hypothesised reversal of the social gradient in obesity was occurring among men.

Main findings compared with previous studies

The hypothesis for Chapter 6 was based on the findings from large literature reviews (1, 83) and multi-country studies (84, 91) that suggested that there was a pattern of declining direct associations between SEP and obesity among men as country economic development proceeded. However the evidence was not strong (Chapter 1, section 1.5.1). Among men there was a large proportion of non-significant or curvilinear associations compared to women at all levels of economic development. The findings from Chapter 6 are therefore consistent with individual country studies which have found no association between SEP and obesity.

Interpretation of findings

Obesity prevalence among Mexican men was significantly higher than the OECD obesity prevalence average for men (27.6% in Mexico in 2012 vs. 16.6% among OECD countries in 2009) (22). As for women, the prevalence of obesity among men was higher than expected based solely on the county's level of economic development. The changes in the food and built environment described in Chapter 1 are likely to have affected men as well as women.

Rural-dwelling men had lower obesity prevalence than urban-dwelling men. This may have been the result of more limited economic resources in rural areas combined with higher levels of physical activity from work. Chapter 7 shows that rural men were more likely to be classified in the high physical activity category and to sit less compared to urban men (page 148).

Direct association between SEP and obesity among men and contrast with women

The absence to date of a crossover to higher rates of obesity among disadvantaged men is not consistent with the social determinants of health model that suggests that in general, lower SEP is linked with adverse health status. Usually in more developed countries, disadvantage is associated with adverse living conditions, psychosocial risk factors and less healthy behaviours which lead to increased risk of diseases. In the case of obesity among men, higher physical activity, which is one of the key determinants of obesity, is associated with disadvantage. Manual jobs such as agriculture in rural areas, building and construction in urban areas involve intense physical effort and may be protective of obesity.

Gender differences in inequalities were driven mostly by substantially higher rates of obesity in the lower education groups in women. Obesity prevalence among higher educated/richer men and women was similar. This may be a further indication that the lack of a gradient and of a reversal of the social gradient among men results from disadvantaged men's characteristics or behaviours which are presumably different (protective of obesity) to those of disadvantaged women.

Further, aspired body size appears to differ between men and women. There is less stigma around obesity for men than for women. A study in Mexican adolescents found that eating disorders were more common among girls than boys and among higher SEP groups than lower (225). Eating disorders are characterized by "behaviours oriented to achieve or maintain a slim body shape and the attribution of a great importance to thinness as a requisite for self-esteem" (225). Eating disorders were more common in urban than rural areas in Mexico (225).

This is an indication that in Mexico, obesity is more stigmatized among women of higher SEP groups and in more developed areas. This may help to explain the different gradients observed in urban and rural areas and for men and women. Chapter 7 explored this concept and although the analysis has limitations it is supportive of different cultural norms with respect to weight by gender and SEP.

8.6 Potential mediators in the association between education and obesity for men and women (Chapter 7)

Main findings

The first objective of Chapter 7 was to explore the educational gradient of selected psychosocial, behavioural and biological obesity risk factors among Mexican men and women. It was hypothesised that among women, obesity risk factors would be inversely associated with education. Among men, those living in rural areas and in more disadvantaged education groups would have higher physical activity levels and different body size aspirations than more educated urban men and women. This would explain why they were relatively protected from obesity.

As hypothesised, among women, most psychosocial and physiological risk factors for obesity were inversely associated with education. Women with fewer years in education were more likely to report depression symptoms, food insecurity, preferring a larger body size and to have more children compared to women with more years in education. The association of behavioural factors with education was less consistent. Fruit and vegetable consumption was directly associated with education but unexpectedly cake and snack consumption was also directly associated with education. More disadvantaged women sat less than more advantaged women but differences in physical activity were not statistically significant. Soft drinks were not associated with education. The social patterning of obesity risk factors was very similar in urban and rural areas.

Among men, as hypothesised, those with fewer years in education reported shorter mean sitting time. Disadvantaged men preferred thinner body sizes and ate fewer cakes and snacks than advantaged men consistent with a pre-transition (traditional) diet. However, disadvantaged men also ate fewer fruits and vegetables. In terms of other obesity risk factors studied, men with fewer years in education were more likely to be married, more likely depressed and food insecure than more advantaged men. Soft drinks and physical activity were not associated with education.

The second objective of Chapter 7 was to investigate potential mediating factors in the association between education and obesity. It was hypothesized that potential mediating factors in the inverse association between education and obesity among women would be similar to those identified in developed countries where there is a consistent inverse association between SEP and obesity. Mediating factors could be grouped in psychosocial, behavioural and physiological. Potential mediating factors in the direct association between education and obesity among men would be physical activity and aspired body size.

Educational inequalities were significant among urban women (higher education-lower obesity) and rural men (higher education-higher obesity) only. Psychosocial variables i.e. aspired body size, the psychological dimension of food insecurity and depression symptoms, explained approximately 37% of educational inequalities among urban women. A large proportion of the inequalities remained unexplained by the set of variables studied. Among rural men, aspired body size met the criteria for mediation explaining 14% of the RII and remaining significant in the adjusted model.

The hypothesised behavioural and physiological pathways between education and obesity among women were not significant. Neither was physical activity a mediator in the direct association between education and obesity among men. The validity of these findings will be discussed further in this section.

Main findings compared with previous studies

Women

Most studies investigating the pathways between SEP and obesity come from developed countries where there is a consistent inverse association between SEP and obesity. A material explanation which suggests that healthier foods and diets are more expensive than unhealthier ones (33-35) is important in those settings. The association between SEP and diet appears to be mediated in part by the low cost of highly palatable energy dense foods (32). Cutler & Lleras-Muney, using a variety of datasets from the USA and the 1958 UK birth cohort, attribute roughly 18% of the education gradient in obesity to economic resources (48). In Mexico, the material explanation does not explain the inverse association between education and obesity among urban women as has been discussed already.

Psychosocial factors have also been studied as mediators in developed countries. For example, the mediating role of food insecurity and depression among women found in this thesis was consistent with findings from two American studies. In the USA, food insecurity and depression explained a small proportion of the association between SEP and obesity (56, 57). Measurements of food insecurity and depression between these studies and the Mexican surveys differ. The consistent results may be an indication of robustness of the association in different settings.

The social patterning of aspired body size among women was consistent with findings from HIC and other middle income countries like Colombia (50, 138). More advantaged women reported preferring a thinner body size than more disadvantaged women.

Behaviours have also been frequently studied as potential mediators in the association between SEP and obesity in more developed countries. Behaviours such as diet, sitting time and physical activity were found to explain a proportion of the social gradient in obesity in HIC (77-80). In Mexico, behaviours did not explain the inverse association between education and obesity among urban women. The reasons why this could be will be further discussed later in this section.

The physiological pathway studied in this thesis was the effect of parity on obesity. The literature suggested that in middle and high income countries parity was associated with obesity (153). In Mexico, parity was associated with obesity among urban women only (section 7.3.4), consistent with previous research. Parity was socially patterned. However in the adjusted models, parity was not a significant mediator in the association between education and obesity.

Men

Studies which empirically investigate the direct association between SEP and obesity among men are not common. Men are assumed to follow different cultural norms with respect to body shape compared to women. The findings from Chapter 7 are consistent with this assumption. Aspired body size was socially patterned in the opposite direction compared with women.

Further, more disadvantaged men may take part in more physically demanding manual jobs compared to women. There was some evidence that this might be the case in Mexico; more disadvantaged men were more likely to be classified in the high physical activity group compared to more advantaged men and to similarly disadvantaged women. However, physical activity was not a mediator in the association between education and obesity in this sample.

Interpretation of findings

Explanation for educational inequalities in obesity among women

Psychosocial factors

Aspired body size explained 17.6% of the educational gradient in obesity among urban women. Urban Mexican women are likely to be exposed to western media and to value thinness. In Mexico, as in developed countries, cultural norms about thinness and attractiveness are socially patterned. More advantaged women aspire to be thinner than more disadvantaged women (50). The proposed mechanism by which aspired body size mediates the association between education and obesity suggests that women will try to conform to their ideal body shape influenced by their status group, in this context by education (1, 40, 49). Therefore, women will adopt lifestyles and patterns of consumption with the aim to maintain or achieve their aspired body size and set them apart from other status groups.

Although the findings are consistent with such mechanisms, the analysis in Chapter 7 has limitations. BMI and aspired body size were measured at the same point in time. It has been reported that ideal body size is influenced by current body size (205). Therefore it is possible that the size of apparent education obesity mediation by aspired body size is inflated because it is confounded by current BMI. Research using longitudinal data would be needed to confirm this mechanism.

The psychosocial component of food insecurity further explained approximately 13% of the educational gradient in obesity and remained significant in the adjusted models. The variable which incorporated the four dimensions of food insecurity (psychological, quantity and quality of foods and hunger) was not a significant mediator in the analysis. This finding gives weight to the proposition that food insecurity is a psychosocial (not material) risk factor for obesity. Food insecurity may be associated with obesity by affecting an individual's physiological stress response. Coping mechanisms for food insecurity have been found to be consumption of high-calorie nutrient poor foods to avoid hunger, eating irregular meals and skipping breakfast (123). These behaviours have all been linked with obesity.

Depressive symptoms explained less than one percent of the educational gradient but met Baron and Kenny's mediation criteria (226). There were large inequalities in clinically significant depression symptoms. Almost a quarter of women with primary education or less where classified as depressed based on the abbreviated CESD used in the Mexican surveys, compared to 12% among higher educated women. Disadvantaged women in Mexico are likely to be chronically exposed to stress and negative life events which increase their risk of depression. Depression may cause obesity by causing a long-term activation of the HPA axis. Excess cortisol may stimulate hunger and feeding.

The most important limitation of Chapter 7 was that it used cross-sectional data. It was therefore not possible to ascertain whether more obese women perceived their household food insecurity differently to non-obese women. Further, reverse causality cannot be ignored in interpreting the findings. Obesity may have caused food insecurity by affecting women's livelihoods because of consequent ill health. The same is true for the association between depression and obesity. Plausible mechanisms have been proposed by which depression causes obesity. The direction of the association cannot be confirmed from this study. These findings are hypothesis generating and should be further explored.

The social patterning of marital status was not as expected. In Mexico, marriage was associated with lower SEP in contrast to what is found in the USA and other developed countries. Being married was only marginally associated with higher obesity prevalence. Marital status was therefore not a mediating factor in the association between education and obesity.

Behavioural factors

Behavioural variables were not associated with obesity in men or women in this study. Therefore, behavioural variables did not meet the mediation criteria in the association between education and obesity. These results were unexpected because the dietary components studied, physical activity and sitting time are well known obesity risk factors as detailed in Chapter 1 (page 41). Further as already described in this Chapter, behavioural factors explain part of the educational gradient in obesity in more developed countries.

There are two potential explanations for the null findings between behaviours and obesity in Mexico. These explanations concern measurement problems and statistical power. The association between behavioural factors and obesity could be affected by recall bias. In self-reported measures of diet like the FFQ used in this study, there is a tendency to underreport energy intake (227). More importantly, underreporting tends to vary systematically by BMI. Obese individuals tend to underreport food consumption more than non-obese individuals (228, 229). This type of bias leads to an underestimation of the association between exposure (behaviours) and outcome (obesity). Further, but related to this point, the FFQ used in Mexican surveys may have not been reliable because it has not been validated in the Mexican population. A second explanation for the null findings is that the diet subsample from 2012 is too small to detect significant associations. In the analysis of the larger 2006 diet subsample, dietary factors (with the exception of cakes and snack consumption), physical activity and sitting time were associated with obesity among urban women (Appendix 12).

The social patterning of dietary risk factors was not consistent with the social patterning of obesity especially among women. Women in the higher education group ate more fruits and vegetables presumably protective of obesity. However, they also ate more cakes and snacks presumably causative of obesity. Cakes and snacks include high-sugar high-fat processed foods. Consumption of soft drinks was not socially patterned. These finding while not helpful to explain inequalities in obesity at one point in time may explain the large increase in obesity prevalence across socioeconomic groups over time. They also may help to explain Chapter 4 findings which showed that more educated women became obese faster than less educated women.

One of the limitations of the diet variables used is that they may be unable to fully reflect the characteristics of the diet for more versus less advantaged individuals. Other dietary components may be key, as is the total energy intake with respect to individual's energy needs.

Physical activity and sitting time were not mediators in the inverse association between education and obesity among Mexican women. More educated women sat more than less educated women. Physical activity, as measured, was not socially patterned. Although measurement imprecision and recall bias may have affected the findings, these results seem plausible for several reasons. The IPAQ used in the survey was deemed reliable and valid in several countries including Guatemala and Brazil and was recommended for use more widely (184). Further, the social patterning of physical activity and sitting time may reflect the types of occupations and the built environment for the stage of development in Mexico. For example, manual jobs in *maquiladoras*, may require long hours standing compared to office jobs. *Maquiladoras* are assembly plants that employ over one million low skilled workers in Mexico, mostly women. Commuting times in urban areas may be much longer and active for more disadvantaged groups who do not own cars. More educated women may be making up for more sedentary lifestyles by exercising during leisure time. This may be the reason why they appear to sit more than less advantaged women but are equally likely to be classified in the high physical activity category.

The conceptual framework for this thesis proposed that psychosocial factors would affect obesity directly and indirectly by affecting behaviours such as diet and physical activity. The indirect pathway through behaviours was not supported by the results from Chapter 7.

Significant associations may have been missed due to the small sample size and or due to recall bias especially in the food frequency questionnaire.

Physiological factors

Parity was socially patterned as expected. The average number of children per women has declined as part of the demographic transition. However the gap in parity between advantaged and disadvantaged women persists. Women in the higher education group had on average 1.1 live births in 2012 compared to 3.3 live births among women with primary education or less. Parity was associated with an increased prevalence of obesity but the effect was not large (PR 1.04 for every additional child 95%CI 1.02, 1.07). Therefore, parity did not explain educational inequalities in obesity among women.

Other potential explanations not measured

After adjusting for the three psychosocial variables meeting the mediation conditions, the relative index of inequality among urban women remained significant. The decline in the RII was modest, 37%. Many studies using longitudinal data and larger samples have consistently showed that health behaviours explain a proportion of the education gradient (48, 217). As has been discussed already, the measurements of health behaviours in this study had many limitations. It is thus a possibility that better measurements of health behaviours in a larger sample would have explained a further proportion of the gradient. Additional mediating factors or confounders of the association between education and obesity were not available in this study.

A variety of potential mediators of the link between education and health may be relevant here. For example, Chandola *et al* find that sense of control mediated a large part of the association between education and adult health both among men and women in the 1958 British birth cohort (217). Cutler *et al* find that social and emotional support and cognitive ability resulting from increased schooling (both information processing abilities and health knowledge) are key mediators in the education-health association (48). Group membership, and the characteristics of individuals within communities, can also affect health behaviours and ultimately obesity (76). For example it has been suggested that obesity spreads through social ties as people influence each other and promote unhealthy behaviours (230).

Explanation for educational inequalities in obesity among men

The direct association between education and obesity in rural areas among men was partially explained by aspired body size (15% reduction in the RII). More educated, more obese men selected larger ideal body sizes. In rural areas a larger body size among men may be a sign of prosperity. As was described in Chapter 1, page 38, cultural norms with respect to thinness may be different in rural and urban areas, between men and women. Larger women were preferred as life partner by men in rural communities (38) and it may be the case that larger men are also more attractive to women.

The RII among rural men remained significant after adjusting for aspired body size. Physical activity, which was a hypothesised mediator, was socially patterned in the expected direction but its association with obesity was not significant. The reason why physical activity was not associated with obesity could have been the small sample size (n=904 men in rural areas).

An explanation for the direct educational gradient in rural areas among men is the distribution and role of absolute poverty and wealth. Wealth was a consistent risk factor for obesity among men as described in Chapter 6. Although the correlation between education and wealth was moderate rather than strong, the association of wealth and obesity was strong enough to mediate the association between education and obesity among rural dwelling men.

What drives gender differences in inequalities in obesity?

The findings from Chapter 7 suggest that it is differences in aspired body size between men and women which drive gender differences in inequalities in obesity. However as mentioned above, findings from Chapter 7 are hypothesis-generating and not conclusive because they arise from cross-sectional data. The association between education and aspired body shape differed qualitatively in men and women. Among men, the more educated selected larger ideal body sizes while more educated women selected the thinner. The associations and interaction term remained significant after adjusting for BMI.

8.7 Public health significance of findings

There were approximately 8,237,929 obese women and 6,166,833 obese men aged 20 to 49 in Mexico in 2012. In the same year, based on population attributable risk and assuming the excess obesity prevalence was preventable, approximately 739,028 obesity cases among urban women could have been avoided if women in the lowest education group had the same obesity prevalence as those in the highest education group. There were 31,795 excess obesity cases among rural-dwelling men with higher education. The largest burden of obesity inequalities is therefore among women resident in urban areas with few years in education.

High body mass index has been ranked as the most important risk factor in Central Latin America based on its attributable burden of disease (231). Given the strong links between obesity and chronic diseases it is expected that inequalities in obesity will translate into inequalities in morbidity and mortality in Mexico. The greatest burden of chronic diseases is therefore expected among the most disadvantaged women. Reducing the socioeconomic gradient in obesity is a key step towards addressing the socioeconomic gradient in morbidity and mortality from chronic disease.

8.8 Policy implications

This thesis has highlighted the extent of the obesity problem in Mexico. Obesity has increased dramatically in both men and women of all socioeconomic groups. Inequalities in obesity were described among Mexican women. Among men, the largest burden of obesity was among the most advantaged. The results of this thesis suggest that universal interventions, those that target the entire population distribution, are needed to tackle the obesity epidemic in Mexico. Focusing only on the most disadvantaged in terms of obesity prevalence would be impractical, because the most obese group varies depending on gender and urban/rural dwelling, and not sufficient to tackle inequalities because it would fail to address the obesity prevalence of the intermediate groups across the socioeconomic gradient (232).

It has been argued that economic policy which tackles income and social inequality more generally is necessary to reduce health inequalities (55). However in the Mexican context, wealth is not consistently protective of obesity, therefore, wealth redistribution to the poor is unlikely to be an effective way to tackle existing inequalities in obesity (it may decrease inequalities by making poor men more obese). Improvement in education as a national health policy is desirable and may aid in reducing health inequalities by increasing people's knowledge and enabling better health decision making (especially among women). However, as was shown in this thesis, regardless of education level, obesity prevalence increased significantly among Mexican women and men, defying the social determinants of disease model and other theoretical frameworks that place socially advantaged groups in an advantaged position in terms of health. In the context of obesity prevalence in Mexico, obesity prevention specific policies are needed. These should take into account how they may influence obesity inequalities. Obesity prevention interventions range from those which rely on the conscious action of the individual to the ones that stress that an individual behaves within the constraints of opportunities of the environment (233). Further, interventions aimed at preventing obesity can be targeted at a macro level (national, state, or community) or at meso/micro levels (schools, worksites, clinical or home environments) (233). Within this spectrum some interventions are expected to increase the socioeconomic gradient of obesity while other have the potential to decrease it. This will depend on the country context and the existing social patterning of obesity.

Recent obesity related legislation in Mexico includes a combination of macro and micro level interventions: an excise tax on sugar sweetened beverages (SSBs) and energy dense ultra-processed foods, the regulation of foods sold in schools and the introduction of mandatory water fountains in schools. Further efforts are being directed to front of pack labelling, food reformulation, regulation of marketing of foods to children and mass media campaigns on healthy eating. Some of these interventions rely on attempting to modify individual choice while others are of a structural nature.

Given the characteristics of the obesity epidemic in Mexico all types of universal effective interventions could be beneficial both for reducing overall obesity prevalence and for decreasing inequalities. Interventions focusing on personal choice and health information such as mass media campaigns, front of pack labelling and healthy eating guidelines (Figure 8.3) may help to level the obesity gradient among men. Generally the more advantaged groups are more health literate and have the resources to adopt healthy eating recommendations earlier than disadvantaged groups (234). On the other hand, structural interventions such as the tax on sugar sweetened beverages and reformulation of foods, may help to narrow obesity inequalities among women. This type of interventions rely less on individual decisions and have been shown to have an equal or greater benefit for lower socioeconomic groups (235). It will be important to monitor and evaluate the effect of new interventions in order to get the balance right and achieve an equitable decline in obesity prevalence.

Figure 8.3 Mexican population healthy eating and drinking guidelines

8.9 Strengths and limitations

Strengths

This thesis used nationally representative data from four comparable health surveys. Its main strength is the detailed analysis of the nutrition transition for Mexico which significantly develops existing literature on the topic. Two dimensions of SEP were used, education and wealth, with a clear theoretical underpinning. By making sense of the different meaning of each indicator and by using them separately and in combination, it was possible to explore the nutrition transition proposition in more depth than previous studies.

The sensitivity analyses presented in Chapter 4 and Chapter 6 strengthened the conclusions in this thesis. Specifically, the opportunity to conduct cohort as well as period-based analyses further developed the findings and supported the original hypothesis of period effects.

The use of the RII and SII as measures of inequality is a methodological strength. These measures are superior to conventional relative ratios because they take into account the proportion of the population in each SEP level rather than only comparing the prevalence of disease of the most and least advantaged groups. Estimates are therefore less influenced by extremes of the exposure distribution. For the RII/SII the different exposure variables (wealth/education) were transformed to the same scale, 0 to 1. This facilitated comparisons of the magnitude of inequality by education or wealth.

A further methodological strength was the careful analysis of missing values for the different samples and the use of multiple imputation to impute missing BMI. Multiple imputation produces sounder parameter estimates than single imputation methods because it is based on several imputations.

In terms of the data, the main strengths of the surveys were identified in Chapter 3 (page 60). Surveys had high response rates and large sample sizes. In terms of the variables of interest, height and weight were measured by trained personnel in household visits. The main outcome variable, obesity, which was based on BMI is likely to be reliable. The main exposure, attendance to education, is minimally prone to recall bias. Education is frequently used as an indicator of SEP in low and middle income countries therefore; its use allows comparability with previous studies. The wealth index was constructed for this study. Assets and household characteristics where carefully selected based on a priori criteria. Two different approaches to construct the index were tried as described in section 3.2.2. yielding very similar results and suggesting the index was robust. Further, a range of explanatory variables for the mediation analysis were available. Validated measurement instruments were used for food insecurity, depression, physical activity and aspired body size.

Limitations

The Mexican surveys had some limitations. The 1988 survey was not large enough to be representative of urban and rural areas separately. The estimates for rural areas in 1988 in Chapters 4 and 5 may not be fully representative of the rural population in that year. This limitation is unlikely to have influenced the inequality trends findings. If the 1988 RII for rural areas had been disregarded, the conclusions would have been the same.

The content of the surveys changed throughout the years. The lack of comparable variables in the older surveys limited the analysis of mediators to only one survey therefore it was not possible to investigate explanations for the trends in inequalities. A further limitation of the data was that men were only included in the last two surveys (2006 and 2012). Therefore it was not possible to study time trends in inequalities in obesity among men.

The surveys were cross-sectional and therefore have the expected limitations. Exposure, mediators and outcome variables were measured at the same point in time. In general, temporality cannot be established 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 as was reported in Chapter 4. Education may be affected by childhood or adolescent obesity but the proportion of obese adults who were obese as children or adolescents in Mexico among the cohorts studied was likely to be small. In 1999, for example, 5.1% of children under 5 were overweight or obese, 18.8% of children 5 to 11 were overweight or obese compared to 62% overweight or obese women (236). The prevalence of childhood obesity in 1999 is likely to be an overestimation of the prevalence of childhood obesity of the women measured in 1999. Childhood obesity prevalence in the 1950s, 1960s and 1970s was likely very low.

The association between wealth and obesity among urban women in Chapter 5 could potentially be explained by reverse causation. Evidence from the field of economics suggests that the inverse association between income and obesity among women, but not men, may be due to a wage penalty associated with obesity for women (86, 237). Increased BMI may affect earnings because of labour marked discrimination against overweight/obese workers and or because of productivity differences between obese and healthy individuals. Because there is more stigma around obesity in women, women may be worst affected. Given the cross-sectional nature of the Mexican surveys this hypothesis cannot be tested. However, as obesity is so widespread in Mexico it is unlikely that stigma is very important.

The cross-sectional nature of the data was the main limitation of the analysis of Chapter 7. The potential for reverse causality between mediator variables and obesity was discussed at the beginning of Chapter 7 and above. Further research using longitudinal data is needed to confirm or reject the hypothesis generated by this study on the mechanisms explaining educational inequalities.

The limitations of the exposures of interest are detailed below.

Limitations of education

A woman's education is strongly determined by her parental socioeconomic position and potentially by her health as a child and other early life factors (46, 51, 238). Given that the data used was cross-sectional and that information on parental SEP and other childhood characteristics was not available, empirical tests to separate the effect of early life environments and characteristics from the effect of education on obesity were not possible. This may have overestimated the real effect of education on obesity. However, evidence suggests that after accounting for family background characteristics and other childhood capabilities, education continues to have a strong causal effect on most health outcomes (217, 238).

Further the meaning of education may vary for different cohorts with differing distributions of knowledge, skills and opportunities that affect health (46). This potential limitation of education was addressed in the cohort effect analysis. The cohort effect analysis suggested that the protective effect of education was not significantly different for women born earlier in the century (less educated) than later (more educated). It was not possible to carry out a more robust cohort effect analysis because the data did not span enough years for each birth cohort. As more surveys are carried out in Mexico in the future, cohort effects in inequality trends could be further explored.

Another limitation of education in this study was that it was not possible to distinguish between good and poor quality education with the available datasets. The quality of education is likely to influence knowledge, cognitive skills and analytical abilities in the health domain (46).

Limitations of the wealth index

The wealth index had some limitations as a measure of SEP. It was used as a proxy for consumption expenditure however, some studies have found disagreement between the two measures (61, 239). This however, may not be an important limitation because consumption expenditure may be volatile and inaccurate especially in LMIC. LMIC are more prone to economic shocks and seasonality in consumption patterns (61). In Mexico, the wealth index may provide a more stable and reliable measure of material resources than consumption expenditure itself.

Further, the wealth index measured relative wealth in each survey but absolute levels of wealth were higher with each subsequent survey. A sensitivity analysis using a wealth index constructed from the same assets and household characteristics across surveys (Appendix 3) showed similar results.

The wealth index may have had an urban bias (239). Urban areas were more likely than rural areas to have access to publicly provided services such as water and sewage system. Therefore, urban households may have been classified richer than they really were according to the wealth index. On the other hand, some characteristics that may differentiate households in rural areas such as size of land or livestock were not included in the surveys. The index may have misclassified richer households in rural areas as relatively impoverished. By including a wide range of assets and household characteristics to construct the wealth index in this thesis, this limitation may have been minimized (239). Table 3.5 and Table 3.6 show that the wealth index did identify poor households in urban areas and rich households in rural areas.

8.10 Future work

Monitoring obesity and obesity inequality trends in countries with high obesity prevalence

This thesis speculated that one of the reasons why inequalities in obesity were declining in Mexico and in the USA and Canada was that obesity prevalence was reaching a plateau. There is some indication from North American studies that a plateau in obesity prevalence has already been reached. It would be interesting to investigate whether this occurs in Mexico and other middle income countries with high obesity prevalence. Further, it is of interest to see whether obesity prevalence plateaus at different levels for different SEP groups. If a plateau in obesity prevalence continues to be observed across countries, further investigation of the explanations for this plateau would be of interest. For example, studies would need to test the saturation equilibrium hypothesis and the concept of resilience to obesity at a population level.

Along the same lines, simulation studies such as the one carried out in the USA which suggested a plateau in obesity prevalence could be carried out in different countries (210). It may be possible to extend these studies so that the obesity prevalence trajectories for different SEP groups are predicted.

Longitudinal analysis of mechanisms by which SEP is associated with health in LMIC

As has been pointed out above, the study of mechanisms by which SEP causes ill health, in this case obesity, using cross-sectional data has many limitations. The number of longitudinal studies in LMIC are increasing and could be well suited to further this research. Cohort studies or panel studies such as the Mexican Family Life Survey (240) which incorporate information about parental SEP and other early life characteristics may allow to overcome one of the limitations of this study by separating the effect of education from early life confounders.

Further, longitudinal studies could incorporate detailed information on cultural norms with respect to thinness and attractiveness among both men and women. These could provide better evidence on whether differences in cultural norms between men and women are the key drivers of the observed gender differences in obesity inequalities as has been suggested in this study. In the absence of longitudinal data, statistical methodologies used in the field of econometrics could be used to increase causal inference using cross-sectional data (241). For example, instrumental variable regression has been used in econometrics to test mediation pathways. Instrumental variables deal with issues of unmeasured confounding (omitted variable bias) and reverse causality. The usefulness of this methodology depends on finding appropriate instruments (variables which are not part of the explanatory model). Instruments must meet several conditions for example they must have a causal effect on the mediator, they must affect the outcome only through the mediator (no direct effect of the instrument on the outcome) and they must not share a common cause with the outcome (242, 243).

Qualitative research on the effect of trade agreements and globalisation on individual's cultural norms and behaviours

The evidence available to explain the trends in obesity inequalities in Mexico was very limited. An ecological link was made between NAFTA and an increased availability of fat and sugar. A further assumption was made that because the types of food available changed the diet changed too and SEP groups were affected in different ways. Qualitative research to better understand the drivers of food consumption at different levels of SEP would be interesting and informative. This information is not captured by large surveys which tend to be superficial. Studying countries which have been exposed to globalisation more recently would allow for more meaningful observations.

Evaluation of the impact of interventions such as the tax on sugar-sweetened beverages on obesity inequalities

An extension of this work would be to evaluate the effect of current interventions aimed at preventing obesity on obesity inequalities. For example, the tax on sugar sweetened beverages (SSB). Research suggests that increases in the price of SSBs lead to larger reductions in consumption among the poorest population groups (244). Based on the results of this study, this intervention may help to avoid increasing obesity inequalities among women. However; among men, the tax will most affect the poorest and least obese group.

8.11 Conclusion

This thesis presented a detailed analysis of obesity inequalities in Mexico, and their recent trends, which significantly develops existing literature on the topic. By using two dimensions of SEP, education and household wealth, it was possible to explore the nutrition transition proposition in more depth than previous individual country studies.

Obesity prevalence increased substantially among Mexican adults over the study period. The largest burden of obesity was among women with up to primary education especially in urban areas however, obesity prevalence increased significantly across all socioeconomic groups in both men and women in the period 1988 to 2012. The structural determinants of obesity and obesity inequalities included rapid changes to the food environment and changing cultural norms with respect to food and body image as a result of globalisation and economic development.

This thesis found evidence of the nutrition transition proposition among women. There was a crossover from lower to higher prevalence of obesity among the most disadvantaged women as the country developed economically. More specifically, Chapter 5 showed that upon reaching a threshold level of household wealth, the relatively poorest became the most vulnerable to the obesogenic environment.

The decline in relative educational inequalities among urban women from 1988 to 2012 was an unexpected finding. It was due to larger increases in obesity prevalence among more educated compared to less educated women over the period. Further research on the social patterning of obesity in countries with high obesity prevalence was recommended to understand high and rising obesity prevalence in advantaged groups of women.

Among Mexican men, higher education and wealth were associated with higher obesity. There was no evidence of a reversal of the social gradient. This was despite the fact that economic development in Mexico, especially in urban areas, was high compared to other middle income countries and taking into account that the reversal of the social gradient among women occurred more than 25 years ago. There is significantly less evidence on the social patterning of obesity among men in LMIC. This study contributes valuable information which challenges the conclusions arising from multicountry studies on the social patterning of obesity among men.

This thesis further explored the mediating factors in the association between education and obesity. Psychosocial factors, specifically food insecurity and aspired body size, explained a proportion of the educational inequalities in obesity among urban women. The gender differences in the social patterning of obesity were partially explained by differences in aspired body size. This analysis was limited by the use of cross-sectional data, however it was one of the first attempts to explain how education is associated with obesity in a LMIC. It generated hypotheses which should be tested using longitudinal datasets.

In conclusion, the nutrition transition proposition fitted the educational inequality pattern among Mexican women but not men. The decline in educational inequalities among urban women may be a North American exception to the nutrition transition or a subsequent phase in countries with high obesity prevalence. Based on the findings in this thesis, universal obesity prevention strategies that target the entire social gradient are recommended to prevent obesity equitably in Mexico.

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Appendix 1 Literature search methodology and table of relevant studies

Literature search methodology

Search terms used:

Socioeconomic disparities OR socioeconomic inequalities OR health inequalities OR socioeconomic factors (MeSH Term)

Nutrition disorders (MeSH term)

Eligibility of studies

Inclusion criteria

Specific to Mexico and Latin American countries

- Studies that stratify by some indicator of SEP or use SEP as a determinant of health or disease (SEP: social class, education, occupation, income, poverty, wealth index)
- Adults
- Presents estimates of obesity, overweight or weight gain

Not specific to Mexico

- Reviews on the association between SEP and obesity for adults
- Multicountry studies investigating the association between SEP and obesity

Exclusion criteria

- Studies relating to Mexican-American populations living in the US
- Studies which focus on small communities
- Studies that use SEP measures as covariates in other associations
- Studies that look at inequalities in access to health care or medication

Table 1 Reviews of studies on the association between SEP and obesity

Study	Population and sample size	Measures of SEP	Association found by SEP indicator for women	Association found by SEP indicator for men	Gender difference explanation	Other explanations of SEP- obesity association
Sobal, J. And Stunkard, A.J. Phsychol Bull, 1989 (1)	144 studies. Developed and developing countries	mixed	***Women from developed countries*** Inverse association: 85% of studies No association: 13 % Direct association: 2% (one study) **Developing countries all gender/age groups** Majority of direct associations	***Men from developed countries (66 studies)*** Inverse association: 51% of studies No association: 17% Direct association: 30% **Developing countries all gender/age groups** Majority of direct associations	"Societal attitudes to obesity" are different among men and women Obesity severely stigmatized among women. Shift to thinner body shape since 60s. Relative affective neutrality among men (several references from the 80s). Discusses when and how the preference for body shape develops- childhood, adolescence. And the difference between boys and girls. Among boys being thin was as not desirable as being overweight. Internalization of social norms about thinness and attractiveness key determinant. And this is also socially patterned	**Developing societies** Low prevalence obesity in low SEP groups- lack of food coupled with high energy expenditure. High prevalence- high SEP better food supply coupled with favouring fat body shapes (sign of health and wealth) "evolutionary history" **Developed societies** SES acts in a "different and more complex manner" in these societies compared to developing. Four "mediating variables" dietary restraint, exercise, social mobility (selecting for thinness), inheritance (both social through learned behaviours and attitudes from parents and genetic- explanation about low SEP having bad genes to do with IQ and obesity…). These are socially patterned. All this in an environment where thinness is preferred ("societal attitudes to obesity") Dietary restraint socially patterned explanations: high SEP= high access to resources that facilitate dieting, better organised, higher knowledge about nutrition, personally motivated.
Ball, K., Crawford D. Soc Sci Med, 2005 (2)	Review of 34 longitudinal studies on the	Varied: occupation, education,	30 low SEP greater weight gain, 4 opposite, 30 no	19 "tests" low SEP greater weight gain. 3 tests opposite	Does not discuss it.	Observed cross-sectional associations may be attributable to greater weight gain throughout adult life among lower SEP.

	relationship between SEP to weight change over time. Only developed countries	income	assoc. Support for an inverse association especially when using occupation as SEP indicator. Less consistent results for education and inconsistent results for income.	direction. 37 tests no assoc		Differences probably starting in childhood (see Parsons et al Int J Obes 1999). Mechanisms: behavioural, poor knowledge about diet/pa, poorer behavioural skills (managing weight/dietary restraint), differing social norms related to obesity (Jeffery & French Am J PH1996), area level factors.
Monteiro, C.A., Moura, E.C., et al Bull World Health Organ, 2004 (3)	Review of 15 cross sectional studies published between 1989 and 2004 from developing countries		**Women** Direct association: 14% of studies Inverse association: 71% The burden of obesity in developing countries shifts towards the lower SEP groups as countries' GNP increases	**Men** Direct association: 50% of studies No association:50%	**Shift** of obesity towards poor occurs at earlier stages of the economic development among women than among men	Direct association: food scarcity and high energy expenditure common among poor, greater capacity of elite to obtain adequate food, cultural values favouring fat body shapes. Inverse or no association findings "more complex to explain and more research needed". Low SEP= less educ, less knowledge plus economic constraint to buy healthier food (Drewnoski theory). High SEP more able to "resist" obesogenic environments (self-efficacy?)- more flexibility in choices and PA than poor
McLaren, L. Epidemiologic Reviews, 2007 (4)	Studies published from 1988 to 2004 on the association between SEP and adult obesity in both developed and developing countries	Mixed: education, occupation, income, material possessions	**Women** **High Human Development Index countries** Direct association: 3% of studies **Medium Human Development index countries** Direct association:	For adult **men**, there isn't a clear social gradient with respect to obesity	From Bordieu's theory suggests: Body size and shape has symbolic value for both men and women but the dimensions of the valued body differ between the sexes. For men, larger body size is likely to be valued as a "sign of physical dominance and	S&S found 93% and 75% inverse associations for women in high development countries. McLaren 63% negative and down to 59% when only studies with measured weight data included. Attributes to "widespread and relatively non-discerning nature of obesity epidemic…. All SEP groups are increasingly affected" Behavioural mechanisms- diet/access to

			43% **Low Human Development index countries** Direct association: 94% of studies. Across the three HDI strata, education was the SEP indicator more commonly used.		prowess". While girls want to be thinner boys want to be larger and more muscular (McVey, Prev Med, 2005) Argues that associations for men are less consistent because "contrary forces are at work" on one hand social stigma and discrimination of obesity on the other valuation of large body size	(material) Bordieu- habitus = embodiment of social structures in individuals. Body (appearance, style and behavioural affinities) is a social metaphor for a person's status. Banked on the idea that thinness is socially desirable. Education is SEP indicator most strongly assoc with body dissatisfaction (McLaren Kuh soc sci med 2004). "income and material possessions direct assoc may reflect the relatively more important role of the economic or material dimension of SEP in the developing world: where food is less ubiquitous the ability to afford food is an important factor in socioeconomic patterning of weight.
(Dinsa et al., 2012)	Studies published from 2004 to 2010 on the association between SEP and obesity in low and middle income countries in men, women and children.		Low income countries association between SEP and obesity direct middle income countries Association becomes largely negative Reversal appears to happen at lower levels of GDP than suggested by	Low income countries association between SEP and obesity direct middle income countries Association becomes mixed	There may be a wage penalty associated with obesity for women (but not for men) in the labour market. Women who were nutritionally deprived as children are significantly more likely to be obese (and still socioeconomically deprived) as adults while there is a weaker link for these issues among men.	The choice of SEP indicator matters in the association between SEP and obesity in about 20 to30% of studies. This is likely due to a weaker correlation between wealth and education in some developing countries. Educational investment may not pay off in the labour market in the form of higher earnings and income because of the underdeveloped nature of a competitive market.

			Monteiro (approx. US$1000)			

Multicounty studies

Study	Population and sample size	Measures of SEP and outcome measure	**Association found by SEP indicator for women**	**Association found by SEP indicator for men**	**Gender difference explanation**	**Other explanations of SEP- obesity association**
(Jones-Smith et al., 2012)	**Women** age 18-49 with young children. 39 lower income countries (at least 2 surveys per country) (does not include Mexico).	Wealth quintile Educational attainment Overweight-outcome	31/35 countries direct association with wealth 24/39 countries higher overweight prevalence growth rate among richest 35/39 direct association with education 21/39 overweight prevalence increased faster for the lowest education group Country level GDP positively correlated with faster prevalence growth of overweight for the lowest vs highest wealth quintile but NOT for the lowest	**n/a**	**n/a**	Explanations for obesity growth among lower SEP groups Low-wealth/education groups just more recently experiencing same environmental changes (accessibility of energy-dense foods, labour-saving devices and sedentary occupations)that high-SEP groups experienced <10 years ago OR Difference in SEP specific response to current condition. Higher SEP lowering their overweight prevalence growth rate by responding to changing conditions.

			vs highest education group			
(Mendez et al., 2005)	**Women aged 20-49 from 36 countries**	Underweight (BMI<18.5) and overweight (BMI >25) Education	GNI and high levels of urbanisation are associated with high prevalence of overweight and small urban-rural differences in overweight prevalence	**n/a**	**n/a**	“the proportion of the population residing in urban areas may serve as an indicator of rural development. In these countries, residents of areas officially designated as rural may have access to infrastructure and services that facilitate the more “urbanized” lifestyles that may increase risk of obesity…”
(Jones-Smith et al., 2011)	**Women aged 18-49 from 37 developing countries. Repeated cross sections**	Overweight	In 27/37 countries higher SEP vs lower associated with higher gains in overweigh prevalence. In 10/37 lower SEP vs higher SEP. GDP positively related to faster increase among lower wealth groups. Lower income inequality associated with faster overweight growth among the poor.	**n/a**	**n/a**	“faster overweight prevalence increases could stem from a contextual change felt disproportionately by lower income groups (i.e. occupational change) with changing economies. Alternatively it could stem from a different response to the same environment”
(Fleischer et al., 2012)	**70 countries World Health Surveys, adult**	Education (standard deviations)	In least urban countries, direct assoc education-	In least urban countries, direct assoc education-	Gender differences in desirable body image. In high income countries, women	Difficult to separate the impacts of urbanization and development (urbanization and GNI per capita highly correlated =0.83).

	men and women	and BMI	BMI, opposite in most urban, inverse association especially pronounced among women.	BMI, opposite in most urban, inverse association especially pronounced among women. Exceptions were Mexico and Brazil where direct association regardless of high urbanicity	consider smaller body sizes or desirable and it is particularly sensitive to high SEP women (Feingold, psychol sci 1998; mclaren, kuh soc sci med 2004)	(urbanisation may be a confounder for development or the other way around)
(Pampel et al., 2012)	**67 countries World health surveys, men and women**	Education, occupation group and income (wealth index)	Higher SEP direct association with BMI in low GDP countries, but assoc becomes inverse in high GDP countries. Evidence for a social gradient reversal.	Shift from direct to inverse association between SEP and weight more clear for women than men but both sexes showed larger SEP disparities at higher levels of economic development.	n/a	High SEP individuals in high income countries may have the most to lose from excess weight (because they live longer) and may respond with healthy eating and exercise. In low income countries, high SEP may enable the consumption of high calorie foods while allowing the avoidance of physically demanding tasks.
(Subramanian et al., 2011)	**54 surveys DHS only women of reproductive age**	Wealth and education	Globally a one-quartile increase in wealth was associated with a 0.54 increase in BMI and a 33% increase in overweight. Strength of association varied by countries. Only weak evidence of an interaction	n/a	n/a	Cultural norms may favour larger body sizes. Higher income and wealth has historically been associated with diets rich in animal fats, which in turn are associated with higher prev of overweight among high SEP groups. Women of low SEP are more likely to be involved in daily activities that are substantially more labour intensive. Food remains expensive in several countries.

			between GDPpc and wealth.			

Mexican studies

Authors, journal & year	Population and sample size	Study design and outcome measures	Measures of SEP	Association found by SEP indicator for women	Association found by SEP indicator for men	Gender difference explanation	Other explanations of SEP- obesity association
Martorell R, Khan LK, Hughes ML, Grummer-Strawn LM. J Nutr 1998(5)	3,681 women of reproductive age 1987 Mexican DHS	Multi-country study of cross sectional surveys in Latin America	Education Wealth index	Prevalence of obesity in urban and rural areas of Mexico was not significantly different The odds of obesity for women of higher education compared to women of lower education was 0.58 p<0.001 There was no significant association between wealth and obesity prevalence in Mexican women	n/a		
Martorell R, Khan LK,	3,681 women of reproductive age	Multi-country study of cross sectional	Education	The odds of obesity for women of higher education	n/a		

Hughes ML, Grummer-Strawn LM. Eur J Clin Nutr 2000 (6)	1987 Mexican DHS	surveys from different regions in the world		compared to women of lower education was 0.50 p<0.001			
Monteiro CA, Conde WL, Lu B, Popkin BM. Int J Obes Relat Metab Disord 2004(7)	Non pregnant 20 to 49 year old women 1999 Mexican Nutrition Survey	Multi-country study of cross sectional surveys from different regions of the world	Education quartiles by years of education	The highest education quartile had a prevalence ratio of 0.82 (0.77-0.88) of being obese compared to the lowest education quartile. The association was not linear however; the second quartile had a higher age adjusted prevalence of obesity than the first. The prevalence ratio of the fourth quartile compared with the second would be 0.72.	n/a		
Buttenheim, A.M., Wong, R., Goldman,	39,129 Mexican adults (Nationally representative)	Cross Sectional Outcome variables	Educational attainment Wealth index	Association between obesity and SEP varies depending on	**Obesity and educational attainment association**	Doesn't give much explanation	Direct assoc between wealth (assets) and obesity- they speculate that it arises from

N., & Pebley, A.R. Global Public Health 2010 (8)	Mexican health survey 2000	smoking and obesity Logistic regression- odds of smoking and of being obese by educational attainment and by household wealth	(using asset ownership only) divided into tertiles	which SEP measure is used by gender and for rural and urban areas. **Obesity and educational attainment association** *Urban women* Negative association *Rural women* Non linear association **Obesity and wealth** *Urban women* Non linear association *Rural women* Positive association	*Urban and rural men* No association **Obesity and wealth** *Urban and rural men* Positive association		sedentary occupation and lack of exercise outside of work…
Smith, K.V. & Goldman, N. Soc.Sci.Me	9,518 Fifty year olds or older representative of this age group at a national level	Cross sectional Outcome measures Self-rated	**Education** (years of completed schooling) **Income** (sum of income from	**Education and obesity** *Urban population* Negative	Analysed men and women together…		Differences between urban and rural areas attributed to: cultural beliefs and practices and quality of education

d 2007 (9)	Mexican health and aging study 2001 Men and women analysed combined!	health, two measures of physical functioning, behavioural indicators (obesity, smoking and alcohol consumption)	respondent's and spouse's/partner's labour, pension, business, real estate, financial assets and private transfers and subtracting business and property expenditures) **Wealth** (estimated net value of assets owned by respondent or partner in the form of homes, businesses, rental properties, capital, vehicles, other assets and debts)	association *"Less urban" population* Positive association **Income and wealth** Positive association with obesity in both urban and rural areas Income inequalities decline with age but not educational or wealth inequalities			differences btw urb and rur areas. Conventional SEP measures may not be good in rural areas because even high education groups may have poor living standards.
Beltran-Sanchez, Crimmins, Teruel, Thomas JAH 2011	MxFLS 2002, men and women 20 years old or older (N=14,280)	Cross sectional Obesity and hypertension as outcome measures	Early life circumstances (place of birth-city/elsewhere, having a toilet inside the house at 12 and stunting) Education as adult SEP	Inverse association between education and obesity among women in cities and among younger women Having a toilet in childhood assoc with higher odds of obesity in	Direct association between education and obesity among men, stronger in rural than urban	Doesn't provide gender difference explanation	Toilet/ stunting associations explained by higher lower exposure to disease in childhood so promoting or not becoming obese

				adulthood in rural areas Stunted less likely to be obese in rural			
Fernald, L.C. Soc.Sci.Med. 2007 (10)	12,873 adults from a sample representative of the poorest (bottom quintile of income distribution), rural communities in seven of Mexico's 31 states Mexican Social Welfare Survey 2003	Cross sectional Outcome variable BMI Beverage consumption 1.Linear regressions (BMI as dependent variable) using each of SEP indicators separately and then together 2. Linear regression (BMI as dependent var) behaviours as independent with and without SES 3.Soda and alcohol consumption	**Educational attainment** **Occupation** (categories: housewife, day labourer or domestic servant, working in a family or small business, owner of a small business) **Household income** (self reported measures of income in the past year contributed by all working members of the family) **Housing and assets**- two separate indexes constructed with primary component analysis **Subjective social**	Positive association with **all measures of SEP** for both men and women except with household income (significantly associated for women but not for men) Positive association between BMI and consumption of carbonated, sugar beverages in both sexes. Positive association between SEP and the consumption of carbonated beverages and alcohol. Strongest and most consistent associations were with education and	Positive association with **all measures of SEP** for both men and women except with household income (significantly associated for women but not for men) Positive association between BMI and consumption of carbonated, sugar beverages in both sexes. Positive association between SEP and the consumption of carbonated beverages and alcohol.		

		(as dependent vars, 2 separate models) SEP measures simultaneously as independent variables	**status** (MacArthur scale of subjective social status) Note: all participants of this study were considered low – income	occupation and for housing and asset measures. Weakest associations with household income and subjective social status.			
Neufeld, L.M., ndez-Cordero, S., Fernald, L.C., & Ramakrishnan, U. Obesity 2008 (11)	683 Poor women from semi urban community in Morelos INSP data from micronutrient supplementation trial from 1997-2000	Longitudinal (baseline and follow-up approx 6 years apart) Objective: to document the changes in BMI and the prevalence of overweight and obesity in young women living in poverty in a semi urban community in Mexico Outcome variables: annual rate of change in BMI and absolute difference	Education	**Education** and annual rate of change of BMI above the sample median Negative association The prevalence of obesity tripled over the follow up period (from 9.8% to 30.3%).	n/a	n/a	

		between BMUI at baseline and follow up					
Rosas, L.G., Guendelman, S., Harley, K., Fernald, L.C., Neufeld, L., Mejia, F., & Eskenazi, B. J.Immigr. Minor.Health 2010 (12)	Mother child <5 years old pairs. 316 from Mexico 287 from California Poorest 20% of population, receiving either Oportunidades or WIC. In California mother and children participants of CHAMACOS study longitudinal birth cohort and in Mexico participants from Proyecto Mariposa- meant to be similar pop as chamacos	2 cross sectional surveys (Mexico and California- Mexican immigrants)	**Wealth index** (housing characteristics and assets)- primary component analysis and divided into tertiles. Note that all participants of this study were considered “poor” as defined by being in receipt of Oportunidades In California continuous scale (family income)	For the Mexican sample: **Wealth** Positively associated with obesity **Obese mother** Positively associated with obesity **Lower food insecurity** Positive association with obesity Prevalence of obesity higher in US than mex	n/a	n/a	
(Buttenheim et al., 2010)	Mexican men and women immigrants to the USA and from high migrant sending communities	Cross sectional, obesity and smoking	**Education attainment**	Higher obesity prevalence in high-migration regions of Mexico compared to low migration for both men and women	Higher obesity prevalence in high-migration regions of Mexico compared to low migration for both men and	Because association between education-obesity in the USA does not resemble that seen in Mexico, propose selective migration among the	No explanation

	National health interview survey USA 6 waves 2000-2005 pooled and 2000 ENSA (MEx			No evidence that gradients differ between high and low migration areas. Compared to American "white" men Mexican immigrants have a weaker/non-existent educational gradient. In whites it is inverse No association between education and obesity in men basically	women No evidence that gradients differ between high and low migration areas. Inverse association in US born Mexicans (steeper gradient) and long stay migrants. Among short stay Mexican women with 11 years or more of education obesity prevalence sharply increases with additional schooling "hockey stick effect" But this same association is not found in ENSA data.	most educated Mexican women (?), changes in diet and PA after arrival	
(Colchero and Sosa-Rubi, 2012)	ENSANUT 2006, women	ENSANUT 2006 women only	Household income: sum of earned income, benefits and non-labour income.	N/A	Direct non significant association between income and BMI in	N/a	Conceptual framework based on Philipson and colleagues: technological change reduced food prices and cost of

			Outcome BMI. Stratified by urban rural. Use of covariates: education, indigenous, age, parity number of children in household, marital status, occupational status, chronic illnesses, depression, height		national and urban samples but a significant direct assoc among rural women. Inverse J shape with education		calories. Also technological advances make occupations less physically demanding. Poor people at risk of being obese because as their income increases they tend to demand other type of goods that contribute to reduce PA and increase calorie consumpt. (works in rural areas). Supported with oportunidades finding the more accumulated transfers higher bmi. In urban areas people more concerned about "ideal weight" then inverse assoc between income and weight but if increases in income result from earned income i.e. jobs requiring less pa then positive effect. Thus mixed assoc in urba areas.

Middle income country studies and USA

Authors, journal & year	Population and sample size	Study design and outcome measures	Measures of SEP	Association found by SEP indicator for women	Association found by SEP indicator for men	Gender difference explanation	Other explanations of SEP- obesity association

(Zhang and Wang, 2004b)	NHANES from 1971-2000 28,543 individuals 20 to 60 year old	Obesity outcome Trends analysed	Education level exposure	Inverse but declining inequality. High-education group had highest rate of increase in obesity. More striking for women	Inverse but declining inequality. High-education group had highest rate of increase in obesity		With more minority individuals moving into the high-education group, the association between SEP and obesity in the whole population was likely to be weakened because minority groups tend to have higher prev of obesity than whites. Socioenvironmental factors shaping obesity epidemic rather than personal attributes.
(Singh et al., 2011)	National Health interview surveys 1976-2008	Obesity (self reported) and overweight Inequality trends by ethnic group and SEP analysed	Education Occupation Family income Poverty status Ethninc group	Analysed men and women together SE inequalities decreased over the period. Consistent findings using education, and income and obesity or overweight as outcome. Higher SEP groups had larger increases in obesity	n/a	n/a	Decreasing social class gradients also reported in Canada and England (see references). SEP differences in diet quality appear to have narrowed over time with individuals in higher SEP groups losing relative advantage (see kant & graubard).
(Chang and Lauderdal e, 2005)	NHANES 1971-2002 for men and women	Obesity	Poverty income ration to measure income status.	Consistent findings with the two studies above. Obesity increasing across SEP groups		Possible that low income men engage in more manual occupational labour so higher PA.	Any substantive contribution from genetic mechanisms would have to be sex specific.

				and in some ethnic groups, more in the high SEP than low. Mexican American women weak association between income and obesity. Mexican American men direct association between income and obestiy		Influence of obesity on SEP generally weaker or absent among men i.e. obesity having negative effect on wages, or education. Third, the association between income and weight related ideals (often cited to explain an inverse assoc among white women) may vary across groups.	Sex and race differences suggest that the material benefits of income are not the only factors at stake. Ethnic disparities persist at broadly equivalent levels of income, so these are not reducible to income effects (argument against drenowstki theory).
(Monteiro et al., 2007)	Men and women form National surveys from 1975, 1989 and 2003	obesity	income	Curvilinear (inverted U) association between obesity and income. Obesity increased among the poorest women but not among the richer. There appears to be a decline in obesity prevalence among richer women	Direct association between income and obesity. Obesity increased more among poorest compared to richest men.		Brazil does not have reliable data to assess SES specific secular trends in patterns of food intake and physical activity. One study actually suggests more obesogenic diet among high income families. Argues that education has increased for all groups during the period but that the impact of the improvement among the high income groups may be stronger as a protective factor for health. I.e more people with university degrees

							versus going from "illiterate to semiliterate" And public health strategy to combat unhealthy behaviours relies on information giving so higher educated/income people benefit more
(Monteiro et al., 2001)	1996/97 world bank living standard measurement survey, from northeast and southeast brazil	Obesity	Income and education	Less developed region: direct association with income inverse assoc with education. More developed region: inverse assoc with education no association with income	Direct association income obesity in the two regions. No association with education in the less developed region and an inverse assoc in more developed		Income risk factor and education protective of obesity. Gender and economic development are modifiers of the association. Direct assoc income obesity, absolute poverty limits food availability and high energy expend… Inverse assoc with education knowledge and behaviours, standards of physical attractiveness
(Monteiro et al., 2000)	1975, 1989 and 1997 surveys from northeast and southeast areas of brazil. Men and women	obesity	Income	Consistent with results from two studies above.			Similar discussion

Gender differences in socioeconomic inequalities (papers were gender difference in socioeconomic inequalities were the focus)

Reference	Population	SEP measure	Finding	Gender difference explanation
(Wardle et al., 2002)	1996 Health survey for England	Education, occupation and 2 economic markers. Controls for age, marital status and ethnicity.	Inverse association of education and poorer economic circumstances with obesity for both men and women. For women only inverse association with occupation.	No gender difference for education so suggests education has similar protective effect and pathways (behavioural) to obesity in both men and women Explanation of occupation gradient differences, lower occupational status assoc with restrictions in time and opportunity to make healthy eating and activity choices as well as high stress, but further research needed to see if this could account for gender diff. Manual occupations more physically demanding for men which could prevent lower SEP men from gaining weight
(Matthews et al., 1999)	British 1958 birth cohort. Information from birth to age 33	Social class (British registrar generals classification of occupations) and education. Outcome measure: self rated health, limiting long-standing illness, psychological distress, respiratory symptoms, asthma, height and obesity	Inverse association with obesity for both men and women. Magnitude of inequality decreases with age i.e. OR 4.30 at age 23 and 2.17 at age 33 in men. Similar in women. For the occupational classification, inequalities larger in women but significant inverse association in men No significant gender differences with obesity at either age 23 or 33.	Argues that occupation may vary in meaning between men and women but "education is more appropriate for the purpose of comparing gender differences in SEP inequalities because it has a similar meaning for men and women" Concludes that there are gender differences for some health outcomes (but not obesity in this study) and that inequality varies by age. Empirically tests difference in explanations of SEP differences for men and women. For self-rated health. Concludes no difference… (but good methodology!)
(Khlat et al., 2009)	French life history survey 2003. 35-59 year olds	Childhood socioeconomic status (retrospectively reported) based on fathers occupation when participant was 15 years old, own occupation. Mothers	In women after adjusting for early life SEP factors, occupation and parity there was an inverse association between education and obesity. In men there was no association after adjusting for the same factors (except parity..)	Critical period model based on two mechanisms- behavioural and physiological. Regarding behavioural- concept of habitus (Bourdieu). Culture and person's beliefs and dispositions are developed in response to determining structures (such as class, family, education) and are anchored in the body or daily practices of individuals. Individuals embody those beliefs and culture. So this explains why women's obesity is socially patterned by their childhood SEP.

		labor market status when they were 15 (working/not working), whether they had experienced significant money shortage (at least one year=early economic hardship), intact family vs non-intact family (single parent etc). Parity and age included as covariates.	For women inverse association between obesity and father's occupation and economic hardship in childhood. Also finds higher odds of obesity among high parity (4+) In women, after adjusting for adult SEP, fathers occupation remained significant. Authors argue in favour of the critical period model for women. For men childhood SEP not associated with obesity	Gender difference to do with different valuation of "corpulence" in men and women. Men value larger body size as indication of dominance and strength (McLaren, 2007). The fact that manual occupation are physically demanding may contribute to counteract any social gradient in obesity (Wardle et al., 2002). For women, valuation of corpulence depends on SEP. Also weight based stigma more salient among women. Physiological mechanism refers to "thrifty phenotype", the association of early undernutrition with adult obesity- irreversible physiological scarring. Or behavioural (but associated with above) "feast-famine" where when faced with food insecurity, there is bingeing when food becomes available However it is "puzzling" that physiological mechanism only evident in women… some support for this from other studies (see (Robinson, 2012) quasi-experiments from famines supporting this). But more support about the potential effect of lifetime gender discrimination i.e. different opportunities of education and employment. Parity- in a study of Swedish women, reproductive history was the factor that explained the largest proportion of social variation (wamala, wolk &orth-gomer 1997)
(Zhang and Wang, 2004a)	NHANES III 1988-1994, men and women age 19 to 60	Family income. Inequalities measured with the concentration index	Inverse association of income with SEP for both men and women but not significant in men. For overweight direct association for men, inverse association for women. In minorities (black and Mexican americans) direct association between income and obesity in men. No association among	Different attitudes towards body weight and different practices for controlling body weight among men and women.

			minority women. Inequality was significant in all age groups among women but not men. The magnitude of inequality varied by age, being larger in middle ages.	
(Leigh et al., 1992)	NHANES I 1971-1975 men and women stratified in black and white.	Education and occupation	Inverse association between education and obesity in white women, inverted U shape association in men.	Explanations of inverse association fall in two hypothesis education as “human capital” and education as surrogate for the main cause (i.e. as a confounder). Within former: schooling teaches self discipline which is transmitted to dieting and exercise, schooling improving self-efficacy i.e. what happens to a person is a result of their own doing. Within education as a surrogate: higher levels of schooling achieved by those with greater self efficacy, schooling associated to delayed gratification. Explanation for gender difference, low educated men’s occupation more physically active. Supports hypothesis that education is associated to health in its own right and not through occupation

Appendix 2 Sampling design of Mexican surveys

Figure 1 National Nutrition Survey 1988

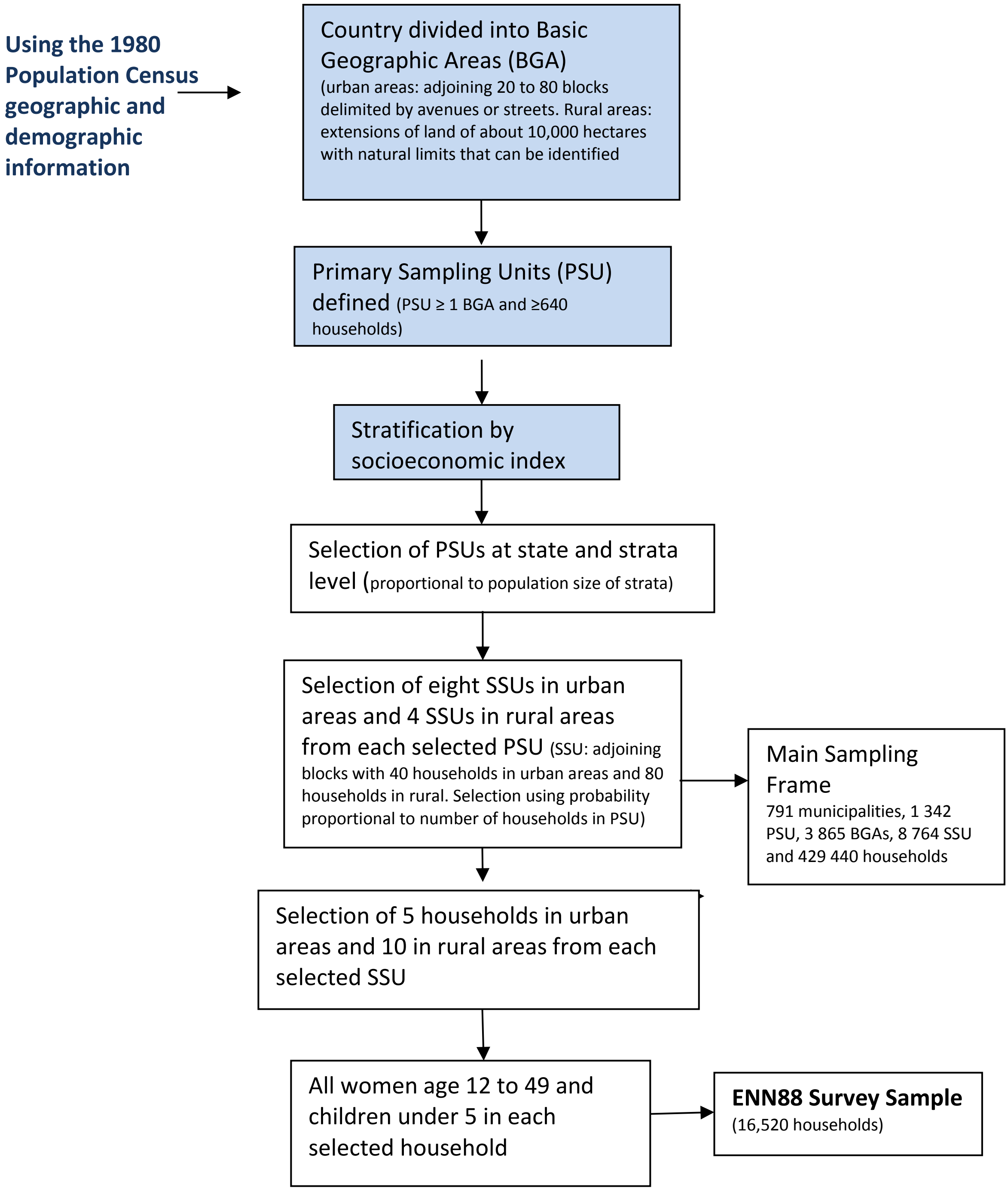


Figure 2 National Nutrition Survey 1999

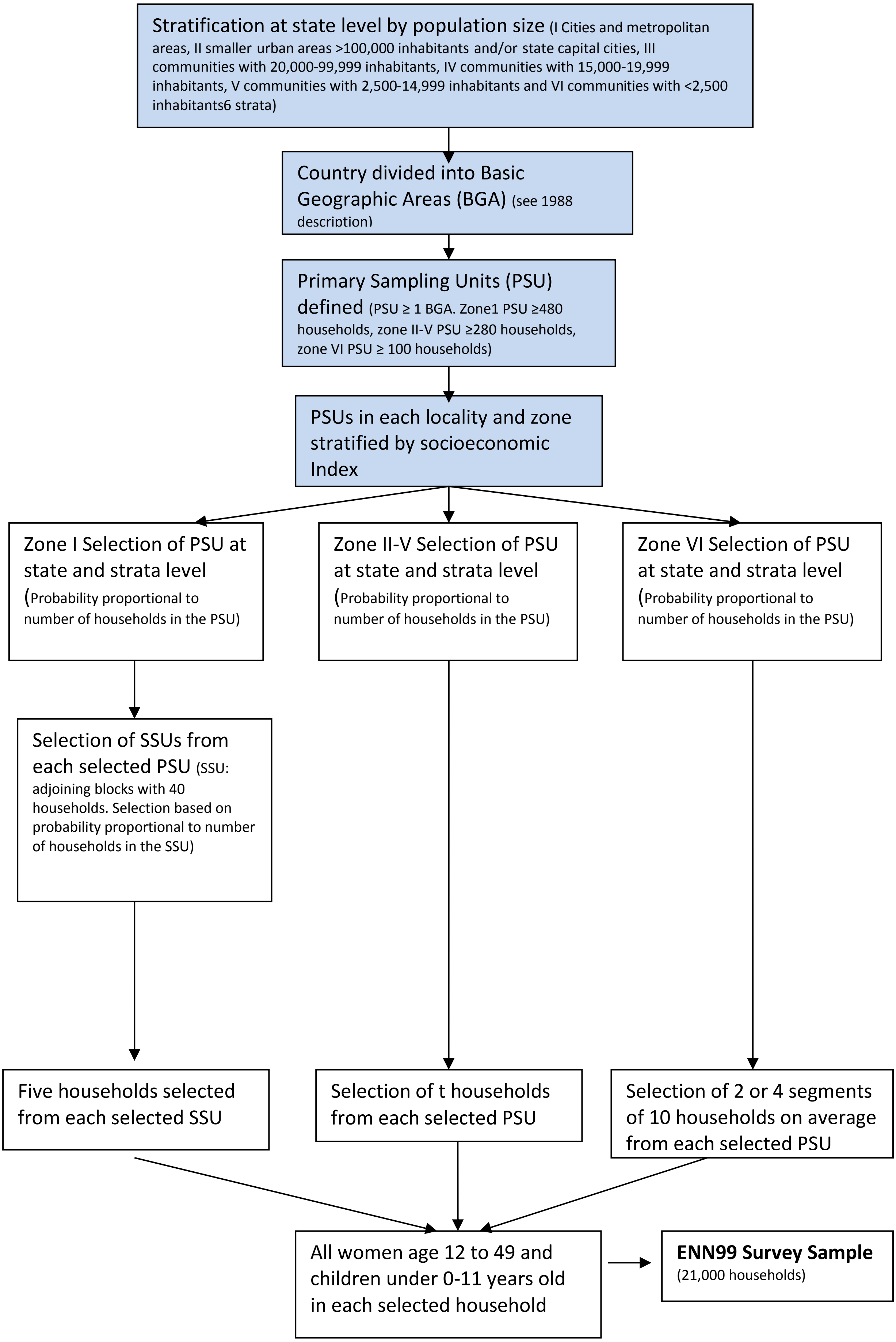


Figure 3 National Health and Nutrition Survey 2006

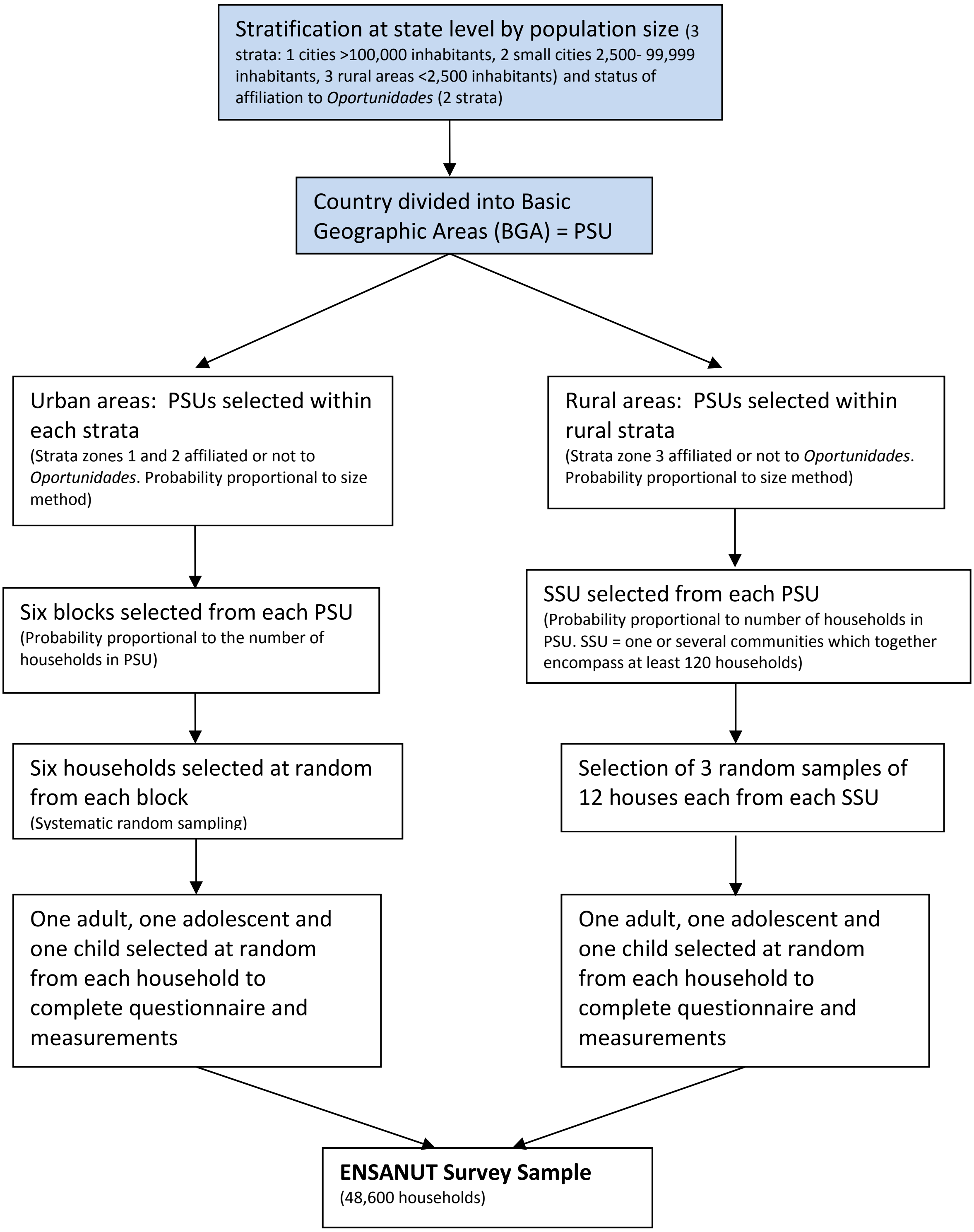
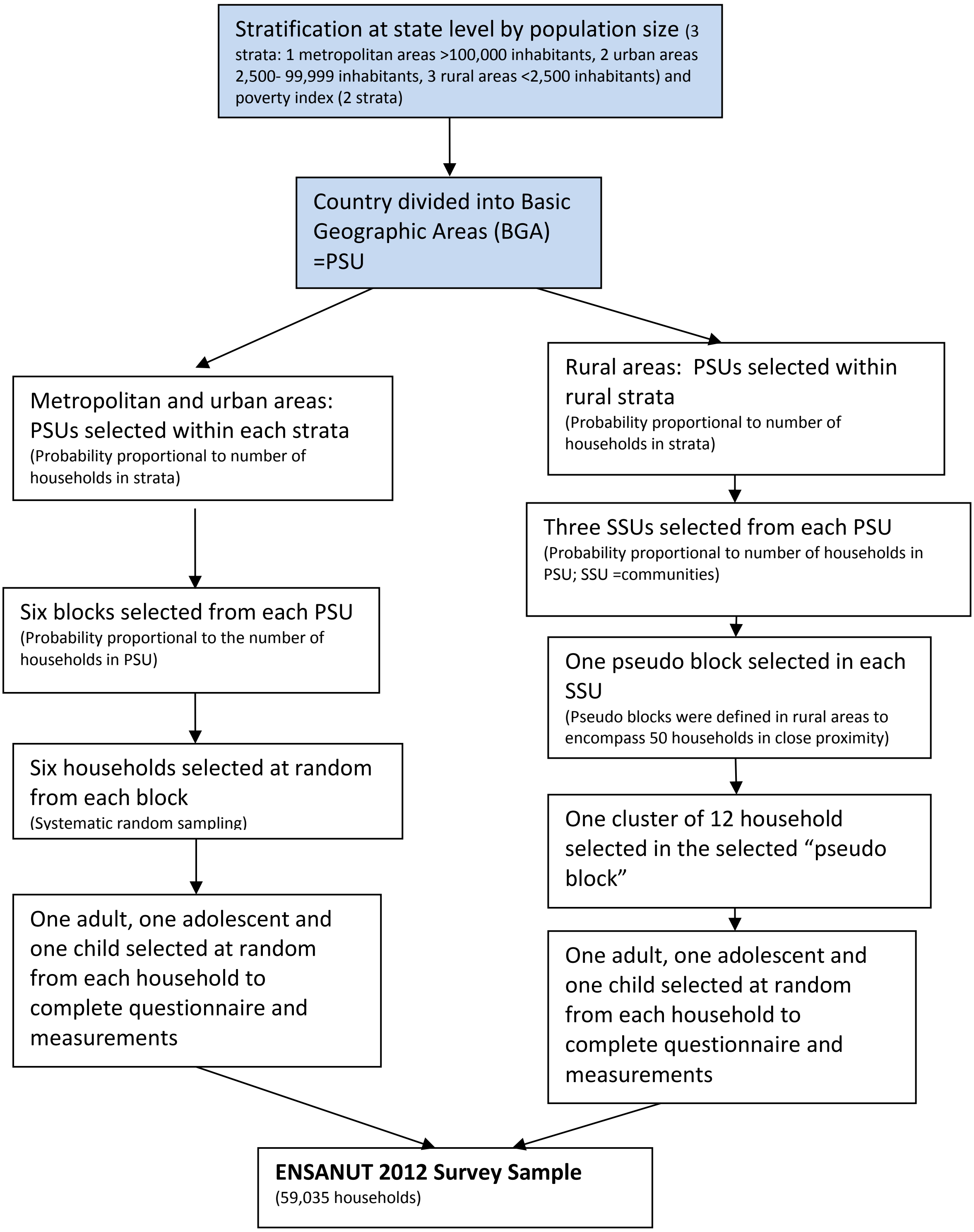


Figure 4 National Health and Nutrition Survey 2012



Appendix 3 Alternative wealth index

A different approach to the wealth index would have been to construct it across surveys in order to take into account changes in wealth over time (Houweling et al., 2006). This approach applied to Mexican data was considered inadequate because mean ownership of assets and households characteristics improved substantially from 1988 to 2012 (Table 2). For example, in 1988 59.3% of households in Mexico owned a refrigerator whereas in 2012 86% of households did. The same occurred for state provided public services, for example piped water provision which increased from 85% in 1988 to 93% in 2012. The group of assets and household characteristics that correctly discriminated between wealth groups in 1988, no longer did so in 2012 especially for urban areas (Table 2).

Table 2 Average ownership of assets and household characteristics 1988-2012 by urban and rural areas, adjusted for survey design

	1988	1999	2006	2012
	%	%	%	%
All households				
N	***12,517***	***17,503***	***47,013***	***50,426***
TV	78.0	87.4	92.2	94.4
Fridge	59.3	69.7	80.9	86.0
Telephone	24.0	34.2	52.9	78.2
Vehicle	26.7	32.3	34.3	39.7
Radio	88.9	86.9	52.5	56.0
Floor material*	2.1	2.2	2.2	2.4
Water source	85.6	89.9	92.2	93.3
Sewage type	1.6	1.5	1.4	1.3
Toilet	82.4	89.6	94.8	97.0
Households in urban areas				
N	***10,749***	***11,305***	***34,770***	***34,375***
TV	82.3	93.6	96.0	97.0
Fridge	64.9	79.2	87.4	90.2
Telephone	27.8	43.5	61.3	85.2
Vehicle	29.4	36.8	38.1	42.2
Radio	90.3	90.6	53.9	58.1
Floor material*	2.1	2.4	2.3	2.4
Water source	88.9	97.0	97.0	96.5
Sewage type	1.5	1.2	1.2	1.1
Toilet	84.3	96.6	98.3	98.4
Households in rural areas				
N	**1,768**	***6,198***	***12,243***	***16,051***
TV	58.7	67.7	78.6	85.6
Fridge	34.5	39.0	57.9	71.1
Telephone	7.1	4.3	23.0	52.8
vehicle	14.5	17.9	21.2	30.5
Radio	82.6	75.2	47.8	48.3
Floor material*	1.8	1.8	1.9	2.1
Water source	70.4	67.2	75.7	81.5
Sewage type	2.2	2.2	2.2	1.8

Toilet	71.0	77.5	85.1	91.6

* Floor material and sewage type presented as means. Variables coded in the following way. floor material: 1 dirt, 2 cement 3 other better materials; sewage type: 1 connected to main public sewage, 2 connected to septic tank, 3 not connected

For comparison purposes, a wealth index constructed using the common assets across the surveys was compared to the one used in this thesis.

Table 3 Correlation of a wealth index constructed using common assets across 4 surveys and a wealth index using period relevant assets

	Correlation
1988	0.9839
1999	0.9329
2006	0.8798
2012	0.8271

Table 3 shows the correlation between a wealth index constructed with 9 shared assets (listed in Table 2) across the 4 surveys and divided into quintiles in each survey and a wealth index constructed independently in each survey with period relevant assets (detailed in methodology section of the thesis). The variables resulting from the different methods were highly correlated. They became less correlated in the more recent surveys because the survey specific index was able to discriminate better between wealth groups given that it incorporated more information about the participating households.

Table 4 Distribution by wealth level comparing survey specific index vs common denominator wealth index

	Wealth quintile, survey specific index				**Wealth quintile, common denominator wealth index**			
	1988*	**1999**	**2006**	**2012**	**1988**	**1999**	**2006**	**2012**
Urban								
Richest	22.1 (1.2)	32.0 (0.9)	25.8 (0.9)	31.0 (1.0)	17.3 (1.1)	25.0 (0.8)	20.4 (0.9)	30.9 (1.1)
2	22.6 (0.9)	26.8 (0.7)	27.0 (0.8)	24.0 (0.7)	15.0 (0.7)	19.7 (0.7)	29.1 (0.8)	35.2 (0.9)
3	20.7 (0.8)	21.7 (0.6)	21.3 (0.7)	20.9 (0.8)	13.1 (0.6)	13.9 (0.5)	17.2 (0.6)	15.8 (0.6)
4	18.0 (0.8)	21.7 (0.6)	21.3 (0.7)	20.9 (0.8)	30.2 (1.2)	30.0 (0.7)	24.9 (0.8)	14.1 (0.7)
Poorest	16.7 (1.5)	6.1 (0.4)	9.4 (0.6)	9.6 (0.6)	24.4 (1.7)	11.4 (0.6)	8.5 (0.6)	4.0 (0.4)
Rural								
Richest	4.2 (1.1)	3.0 (0.4)	3.1 (0.5)	5.6 (0.6)	3.5 (1.2)	1.0 (0.1)	2.4 (5.4)	6.5 (0.7)
2	11.4 (2.2)	9.7 (0.8)	8.2 (0.8)	14.8 (0.9)	5.4 (1.2)	3.7 (0.5)	6.6 (0.7)	17.5 (1.0)
3	14.2 (2.2)	16.4 (1.0)	14.4 (0.9)	20.4 (0.9)	7.8 (1.5)	7.8 (0.6)	11.2 (0.9)	21.3 (1.0)
4	22.9 (2.4)	28.4 (1.2)	25.9 (1.3)	26.2 (1.0	21.2 (3.0)	21.4 (1.4)	28.5 (1.3)	27.1 (1.0)
Poorest	47.3 (5.4)	42.6 (2.0)	48.4 (2.1)	33.0 (1.4)	62.1 (5.1)	66.0 (1.9)	51.3 (2.0)	27.7 (1.5)

*Proportions and standard errors in parenthesis

Table 4 shows the distribution of the population by wealth using the survey specific index (as in this thesis) on the left and the common denominator index on the right. There were no important differences. In terms of its association with obesity, Table 5 shows prevalence ratios of obesity for the effect of one level decline in wealth among women. The results were very similar and lead to the same conclusions.

Table 5 Prevalence ratios for one level decline in wealth using the common versus the survey specific wealth indexes

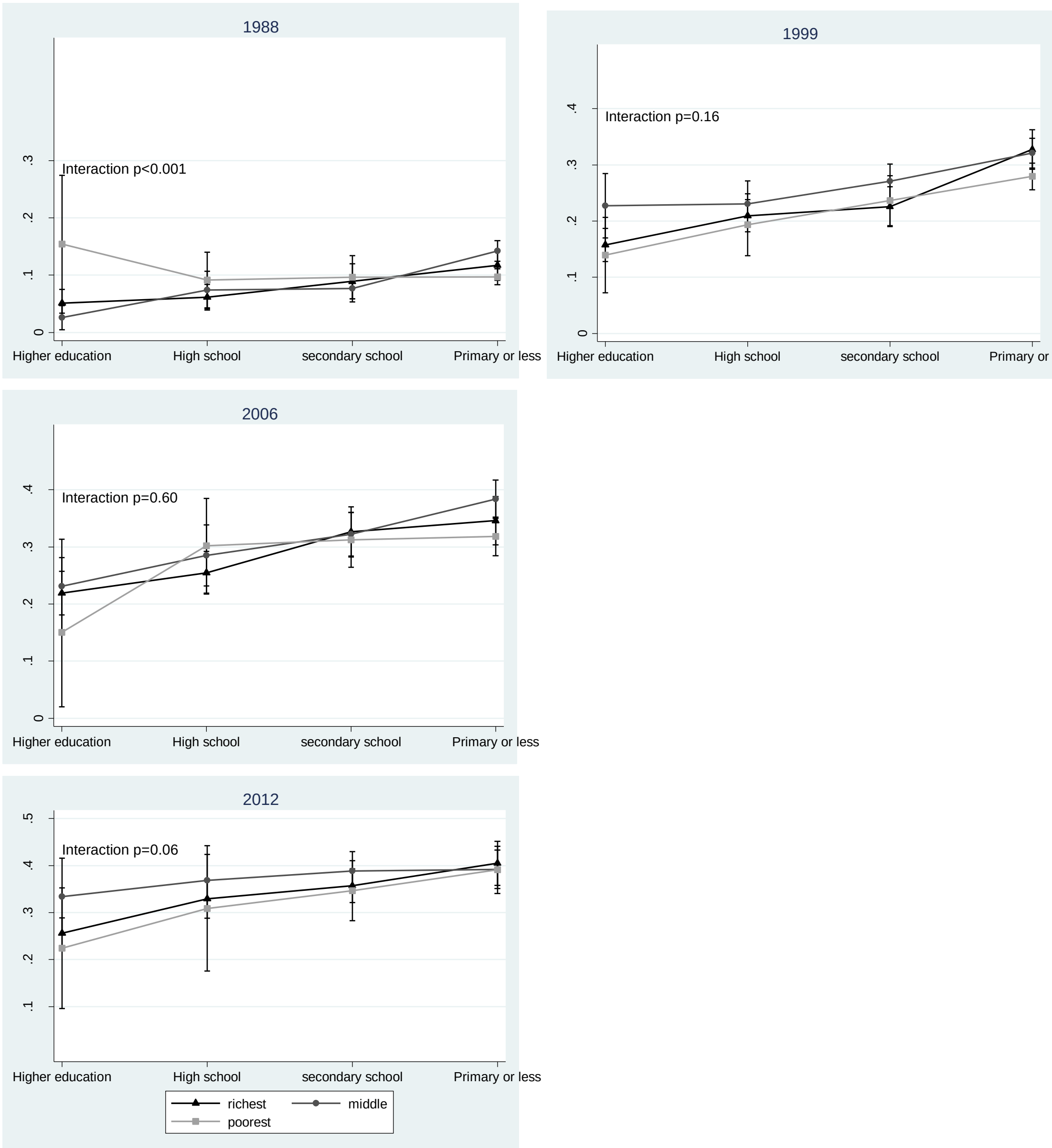
	1988			1999			2006			2012		
	PR	95%CI		PR	95%CI		PR	95%CI		PR	95%CI	
urban												
survey WI	1.00	(0.94,	1.05)	1.02	(0.99,	1.05)	1.01	(0.98,	1.04)	1.05	(1.02,	1.08)
common WI	1.03	(0.97,	1.09)	1.04	(1.01,	1.08)	1.03	(1.00,	1.06)	1.05	(1.02,	1.08)
rural												
survey WI	0.78	(0.64,	0.95)	0.83	(0.79,	0.87)	0.91	(0.86,	0.96)	0.94	(0.91,	0.98)
common WI	0.78	(0.64,	0.95)	0.83	(0.79,	0.87)	0.93	(0.87,	1.00)	0.91	(0.87,	0.95)

In conclusion, a survey specific wealth index was theoretically more appropriate because it incorporated period relevant information which potentially made the wealth index more robust to distinguish between wealth groups. However, when compared, the wealth index using the common assets appeared to be similar to the one using survey specific information.

Interaction wealth education using common wealth index

Urban areas

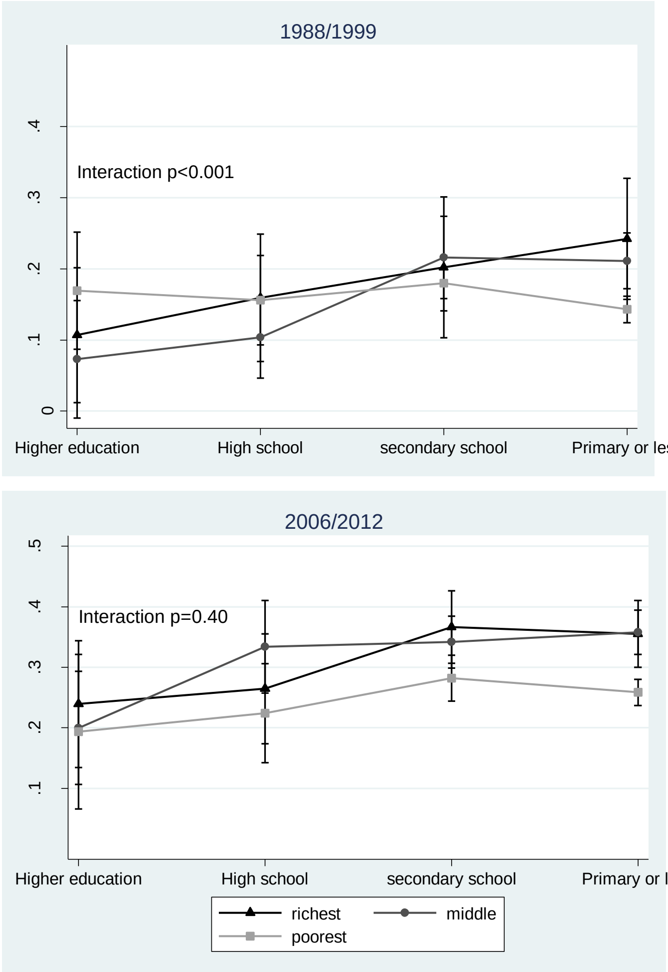
Figure 5 Educational gradient by level of wealth in urban areas- using common wealth index



Results were similar using the common wealth index and the survey specific index. However, the interaction in urban areas was significant in 1999 using the survey specific index, whereas it was not using the common index (Figure 5). Women in the poorest tertile with primary education or less appeared to have a lower obesity prevalence when the survey specific index was used compared to when the common index was used. This was likely due to the survey specific index being more sensitive at this end of the wealth distribution and identifying poorer women in the poorest category.

In rural areas results using either of the indices were very similar (Figure 6).

Figure 6 Education gradient by wealth levels in rural areas- using common wealth index



Appendix 4 Food Security Scale for Latin America and the Caribbean

Table 6 FSSLC items translated to English from Spanish

Item	During the last 3 months….	Dimension
1	Were you worried that you would run out of food before being able to buy or receive more food?	Psychological – household
2	Did you run out of food before having money to buy more?	Quantity of food- household
3	Did you run out of money to have a healthy and varied diet?	Quantity of food and quality of diet- household
4	Did you have to consume just a few foods because you ran out of money?	Quantity of food and quality of diet- household
5	Did you or any adult in your household ever skip meals because there wasn't enough money to buy food?	Quantity of foods- adults
6	Did you ever eat less than what you thought you should because there wasn't enough money to buy food?	Quantity of foods- adult
7	Did you ever feel hungry but didn't eat because there wasn't enough money to buy food?	Hunger- adults
8	Did you or any other adult in your household ever go without eating for a whole day or just had one meal in a whole day because there wasn't enough money to buy food?	Hunger- adults
9	Did your children/adolescents stop having a healthy diet because there wasn't enough money to buy food?	Quantity and quality of foods- children and adolescents
10	Did your children/adolescents have to consume just a few foods because you ran out of money?	Quality of diet- children and adolescents
11	Did your children/adolescents ever skip meals because there wasn't enough money to buy food?	Quantity of foods- children and adolescents
12	Did your children/adolescents ever eat less than what you thought they should because there wasn't enough money to buy food?	Quantity of foods- children and adolescents
13	Did you ever reduce the size of meals of your children/ adolescents because there wasn't enough money to buy food?	Quantity of foods- children and adolescents
14	Were your children/adolescents ever hungry but you just couldn't buy more food?	Hunger- children and adolescents
15	Did your children remain without food for a whole day because there wasn't enough money to buy food?	Hunger- children and adolescents

Table 7 cut points for classifying food insecure households

		Food insecurity categories		
Type of household	**Food security**	**Mild food insecurity**	**Moderate food insecurity**	**Severe food insecurity**
Only adults	0	1 to 3	4 to 6	7 to 8
Adults and under 18 year olds	0	1 to 5	6 to 10	11 to 15

Appendix 5 Abbreviated Centre for Epidemiologic Depression Studies scale (CESD-7)

Table 8 Items in the CESD-7

CES-D 20 Item number	Item, During the last week:	Depression dimension measured
3	I felt that I could not shake off the blues even with help from my family or friends.	Dysphoric mood
6	I felt depressed.	Dysphoric mood
18	I felt sad.	Dysphoric mood
7	I felt that everything I did was an effort.	Motivation
5	I had trouble keeping my mind on what I was doing.	Concentration
16	I enjoyed life.	Loss of pleasure
11	My sleep was restless.	Poor sleep

Appendix 6 Food items included in variables

Table 9 FFQ items included in the variables

Food item	Standard portion
Fruits	
Banana	1 medium size piece (176g)
Jicama	½ small piece (113g)
Orange or mandarin	1 large piece (206g)
Apple or pear	1 medium size piece (140g)
Melon or watermelon	1 medium size slice or ¾ cup (115g)
Guava	1 medium size piece (75g)
Mango	1 medium size piece (185g)
Papaya	1 medium size slice or ½ cup (100g)
Pineapple	1 medium size slice (150g)
Grapefruit	1 small piece (270g)
Strawberry	1 cup (140g)
Grapes	10 pieces (60g)
Peach or nectarine	1 medium size piece (50g)
Canned fruit	½ cup (80g)
Dried fruit	¼ cup (25g)
Vegetables	
Tomato	1/2 small piece (30g)
Green leaves	½ plate if cooked (85g) 1 plate if uncooked
Chayote (vegetable pear)	¼ small piece (50g) or 1/3 cup
Carrots	1 medium size piece or ½ cup
Courgette	½ medium size piece (50g)
Broccoli or cauliflower	¼ cup (35g)
Cabbage	¼ cup (35g)
Green beans	¼ cup or 5 pieces (30g)
Lettuce	½ cup (30g)
Cactus leaves	1 large piece (100g) or 1 cup
Cucumber	½ large piece (150g)
Avocado	1 slice or 1 piece of small variety (33g)
Pepper	1 medium piece or 1/3 cup
Onion (in salads and fast food)	1 tablespoon or 3 slices (7g)
Canned vegetables	1/3 cup or 1 small can
Frozen vegetables	1/3 cup
Soda	1 glass (240ml)
Cakes and snacks	
Chocolate	1 tablespoon or "chunk" (10g)
Candy/sweets	1 piece (30g)
Sweets with chilli	1 piece (30g)
Crisps and similar snacks	1 small bag (35g)
Marshmallows	2 small pieces or 1 large piece (35g)
Jelly/flan	1 slice (125g)
Cakes or pies	1 medium slice (125g)
Water based ice creams (similar to sorbet)	1 piece or 1 scoop (80g)
Cream/milk based ice creams	1 piece or 1 scoop (80g)
Nuts	1 handful (35g)
Popcorn	1 medium bag (100g)
Industrialized cakes and doughnuts	1 piece (70g)
Sweet biscuits	2 pieces (32g)
Cereal bars	1 piece (25g)

Appendix 7 Multiple imputation for missing values

Multiple imputation was done in the 1999 survey dataset (18.2% missing BMI). Because exposure variables were almost complete, and the missingness in BMI was not thought to be associated with the missing BMI value, multiple imputation in this study was aimed at increasing power and precision. MI was not expected to change estimates significantly as bias was not likely to be a problem arising from missing BMI.

Two imputation models were run for 1999 using Stata 11 command 'ice'. In the first model, all analysis variables were included. In addition other auxiliary variables that predicted BMI or predicted the missingess of BMI were included. These were employment (working, home maker, not working), region of the country (north, south, centre, Mexico City), self-identifying as indigenous, marital status (married or living with a partner, widow or divorced, single) and social security affiliation (none, 3 different types of social security). In the second model (sensitivity analysis), variables associated with socioeconomic position, the main exposure of interest in this study were excluded. Thus education, wealth index, self-identifying as indigenous and social security affiliation were not included.

The association between BMI and education or wealth was tested in the complete cases dataset and in the two sets of imputed datasets. Regression coefficients and their standard errors were compared.

Results and discussion

The results from the complete case analysis and from the two sets of imputed datasets were not different (Table 10). MI did not decrease standard errors. MI attenuated estimates slightly in the first model and more significantly in the second. However confidence intervals of the different analyses were overlapping. Model 1 results were very similar to the complete case analysis as expected. The slight difference in the estimates was probably due to auxiliary variables providing some additional information about the missing values in the imputation model.

Standard errors and confidence intervals were expected to be smaller in the analysis of imputed datasets because of the larger sample sizes however they were not. This may have been due to a large variability in imputed values from one imputed dataset to the other. In model 2, estimates were closer to the null as expected because SEP indicators were not included in the imputation model. This biased the model because it wrongly assumed no association of the missing values with SEP.

Table 10 Complete case analysis, model 1 and model 2 results for regression of BMI on education and wealth index adjusted for age and for complex survey design for urban and rural areas

	Complete cases N= 12,564		Model 1 N=15,400		Model 2 N=15,400	
	Coef.	**95% CI**	**Coef.**	**95% CI**	**Coef.**	**95% CI**
Education						
Urban	0.60**	(0.48, 0.73)	0.58**	(0.46,0.70)	0.47**	(0.36,0.58)
Rural	-0.38**	(-0.59, -0.17)	-0.31*	(-0.54,-0.07)	-0.29*	(-0.51,-0.06)
Wealth						
Urban	0.10	(-0.01, 0.20)	0.15*	(0.04,0.26)	0.10*	(0.01,0.21)
Rural	-0.73**	(-0.88, -0.58)	-0.73**	(-0.90,-0.56)	-0.68**	(-0.83,-0.52)

** p<0.001 *p<0.05
Education coded 1 higher education, 2 high school, 3 secondary school, 4 primary school, 5 no education
Wealth index coded 1 richest- 5 poorest

Conclusion

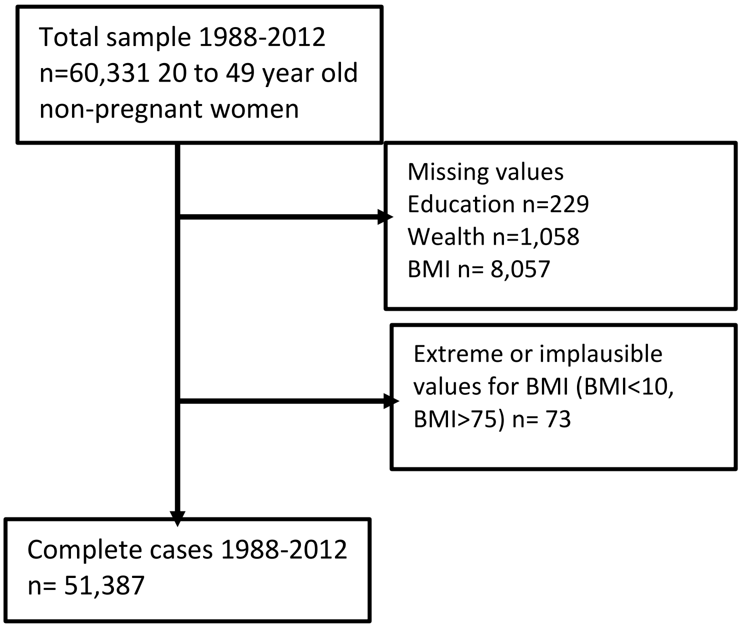
Imputing the outcome in this study did not add any information to the association of interest. The sample size and hence power grew but the standard errors did not decrease probably because of the variability of imputed values. In the second model, the estimates were biased towards the null. This was consistent with the literature that suggests that all analysis variables must be included in the imputation model to avoid bias.

In conclusion, using multiple imputation in this study which was complete on the exposure variables and where missing outcome data was assumed to be MAR was not useful. A complete case analysis is appropriate.

Appendix 8 Sample sizes in each chapter

Chapter 4 and 5

Figure 7 Sample size used in chapters 4 and 5



Sample size for the cohort effect sensitivity analysis

Figure 8 Sample size for cohort sensitivity analysis in chapter 4

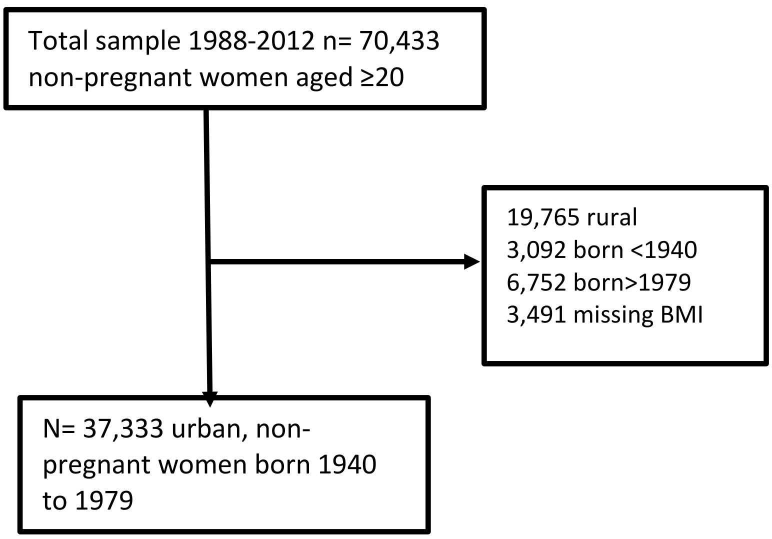


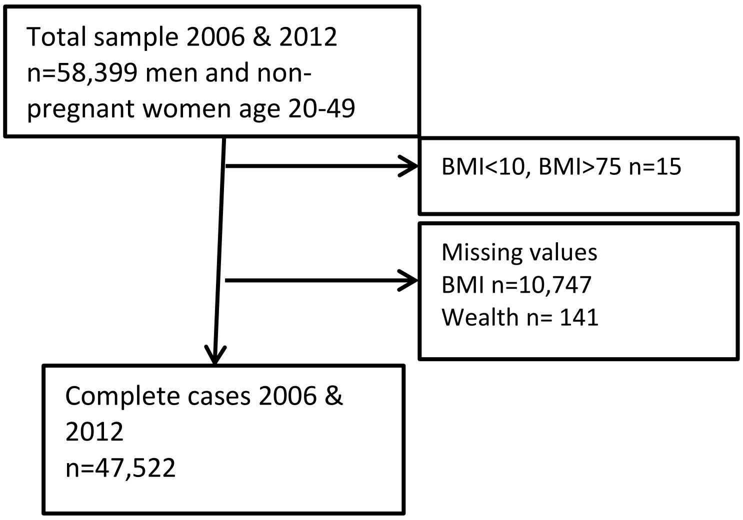
Table 11 N for cohort effect sensitivity analysis

	Survey year				
cohort	**1988**	**1999**	**2006**	**2012**	**Total**
1940s	2,208	0	1,355	1,170	4,733
1950s	3,150	1,997	2,030	1,900	9,077
1960s	3,486	2,984	3,377	2,764	12,611
1970s	0	3,247	3,830	3,835	10,912
Total					37,333

Light shading: 100% new observations gained from using complete 2006 and 2012 samples. Dark shading, 90% increase in sample size compared to original chapter 1 sample.

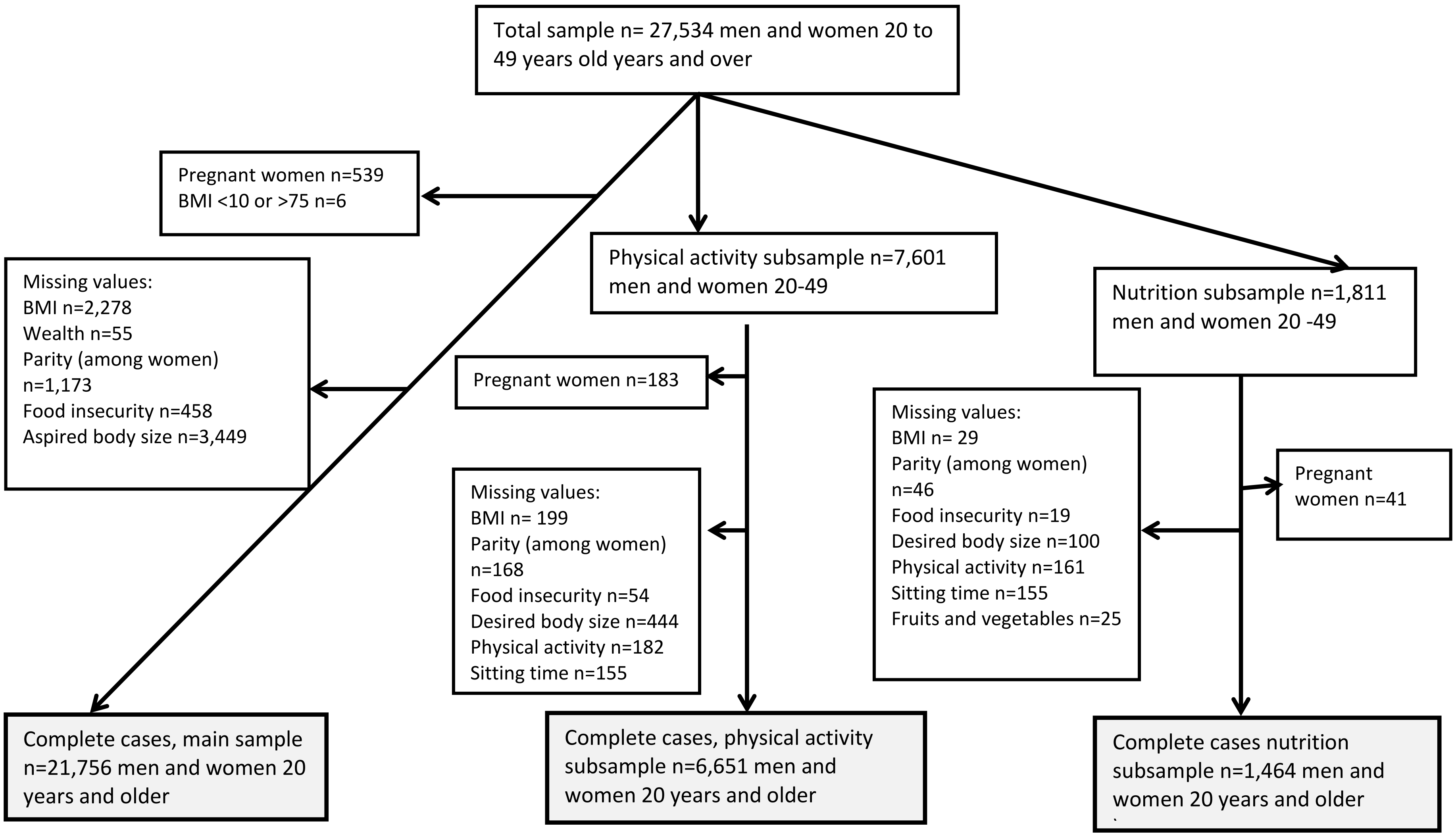
Chapter 6

Figure 9 Sample size for chapter 6



Chapter 7

Figure 10 Sample sizes for chapter 7



Appendix 9 Descriptive characteristics of the national sample

Table 12 Descriptive characteristics of Mexican women aged 20 to 49 (1988-2012) and Mexican men aged 20 to 49 (2006-2012)

	Women				Men	
	1988	**1999**	**2006**	**2012**	**2006**	**2012**
Complete cases, N	10,318	12,540	13,974	14,531	8,882	10,150
Age, mean	32.3	32.8	33.9	33.7	33.61055	33.21096
Age group, %						
20-24.9	22.8 (0.6)	19.7 (0.4)	17.3 (0.5)	18.4 (0.6)	19.7 (0.7)	22.9 (0.7)
25-29.9	19.4 (0.5)	20.3 (0.4)	16.6 (0.5)	16.8 (0.5)	16.6 (0.7)	16.5 (0.6)
30-34.9	17.5 (0.5)	18.8 (0.4)	18.0 (0.5)	19.3 (0.5)	17.4 (0.7)	16.3 (0.5)
35-39.9	16.6 (0.4)	16.9 (0.4)	18.1 (0.5)	16.8 (0.5)	16.8 (0.6)	15.4 (0.5)
40-44.9	12.9 (0.4)	14.0 (0.3)	16.7 (0.5)	14.9 (0.4)	15.4 (0.5)	14.7 (0.5)
45-49.9	10.8 (0.4)	10.3 (0.3)	13.2 (0.5)	13.9 (0.5)	14.2 (0.6)	14.2 (0.5)
Level of education, %						
Higher education	8.8 (0.6)	12.1 (0.5)	12.2 (0.6)	18.3 (0.6)	15.9 (0.7)	19.4 (0.7)
High school	15.8 (0.7)	17.1 (0.5)	16.5 (0.6)	19.9 (0.6)	18.9 (0.7)	20.1 (0.7)
Secondary	15.7 (0.6)	21.9 (0.5)	26.7 (0.6)	31.4 (0.7)	30.4 (0.8)	34.3 (0.8)
Primary or less	59.7 (1.3)	49.0 (0.8)	44.6 (0.8)	30.3 (0.7)	34.7 (1.0)	26.2 (0.7)
Wealth, %						
Highest	32.2 (1.4)	40.9 (0.8)	37.1 (0.9)	40.8 (0.9)	40.0 (1.1)	42.5 (0.9)
Middle	27.5 (1.0)	33.6 (0.6)	32.8 (0.7)	33.7 (0.7)	33.2 (0.8)	33.5 (0.8)
Lowest	40.2 (1.8)	25.5 (0.8)	30.1 (0.9)	25.5 (0.7)	26.8 (0.9)	24.0 (0.7)
Weight (kg), mean	56.0 (0.2)	63.3 (0.2)	65.9 (0.2)	67.4 (0.2)	75.0 (0.3)	77.4 (0.3)
Height (cm), mean	153.2 (0.2)	153.0 (0.1)	153.7 (0.1)	154.4 (0.1)	166.8 (0.1)	167.4 (0.1)
BMI, mean	23.8 (0.1)	27.0 (0.1)	27.9 (0.1)	28.3 (0.1)	26.9 (0.1)	27.6 (0.1)
BMI categories[a], %						
<18.5 Underweight	9.4 (0.4)	2.1 (0.1)	1.5 (0.2)	1.9 (0.2)	2.0 (0.2)	1.1 (0.2)
18.5-24.9 Normal range	56.4 (0.7)	36.9 (0.5)	31.9 (0.7)	29.6 (0.6)	33.6 (0.8)	31.3 (0.7)
25-29.9 Overweight	25.0 (0.6)	36.3 (0.5)	36.3 (0.7)	34.8 (0.6)	41.9 (0.8)	40.0 (0.7)
≥30 Obese	9.3 (0.4)	24.8 (0.5)	30.3 (0.6)	33.7 (0.6)	22.5 (0.7)	27.6 (0.7)
≥35 Class II & III obesity	2.2 (0.2)	7.5 (0.3)	10.5 (0.4)	11.9 (0.5)	5.1 (0.3)	7.4 (0.4)

Appendix 10 Age-period-cohort analysis

In epidemiology a cohort effect is generally understood as a period effect that is differentially experienced through age-specific exposure or susceptibility to that cause (Keyes et al., 2010). Cohorts of individuals born in different decades will not necessarily share the same life experiences and be exposed to similar environmental risk factors for disease. In order to investigate a cohort effect, the effect of the cohort must be separated from the effect of age and period on the health outcome of interest. However, no statistical model can simultaneously estimate age, period and cohort effects because of collinearity among the three variables (Cohort=Period-Age) (Keyes et al., 2010). Several techniques have been proposed to overcome this methodological challenge. As an extension to the descriptive obesity trends presented in Chapter 4 by cohort, age and period, two different methodologies to disentangle age, period and cohort effects were tested with Mexican data. The median polish approach conceptualizes the cohort effect as a partial multiplicative interaction quantified in the non-linear component of age and period effects and has been used in epidemiological research (Keyes and Li, 2010, Keyes et al., 2011, Keyes et al., 2010, Robinson et al., 2012). The intrinsic estimator method has been used by economists to study cohort effects in obesity prevalence (Sassi et al., 2009, Yang et al., 2004, Devaux et al., 2011). It considers an orthogonal decomposition of the parameter space into a null space for the singular design matrix and a non-null space, where the intrinsic estimator is obtained by the Moore-Penrose generalized inverse (Yang et al., 2004, Sassi et al., 2009).

Median Polish

The median polish analysis explicitly defines cohort effects as age by period interactions. It captures non-linearities in the age and period effects and partitions this non-linear variance into a systematic component (cohort effect) and an unsystematic component (random error) (Keyes and Li, 2010).

Methodology

An age-by- period contingency table was constructed (Table 13). Obesity prevalence was log transformed. The additive effect of age (row) and period (column) was removed by iteratively subtracting the median value of each row and column. After several iterations, the row and column medians approximate zero meaning the residuals have stabilized and can be considered to contain the cohort effect plus error. The residuals were then regressed on cohort categories using the 1950s cohort as reference (Keyes 2013, pers.comm., 12 March).

Table 13 Obesity prevalence by age group and period

Age group	1988	1999	2006	2012
29-29.9	4.3	16.6	20.5	24.9
30-39.9	11.2	30.9	35.2	38.6
40-49.9	16.9	38.3	45.1	46.8
50-59.9			46.8	48.6
60-69.9			44.0	45.9

Results

Results of the median polish approach are presented in Table 14. They suggest that cohort effects were not significant in the context of obesity trends in Mexico. However, these results could be due to lack of power in the study. The number of residuals per cohort (i.e. the number of times each cohort was measured) is maximum 4 for the 1960s cohort but is two for the cohorts in the extremes (1930s and 1980s).

Table 14 Cohort effects

	RR	95%CI	
1930s	0.99	0.93	1.07
1940s	1.01	0.95	1.08
1950s	ref	ref	ref
1960s	0.97	0.91	1.02
1970s	1.00	0.94	1.06
1980s	1.02	0.95	1.10

Intrinsic estimator

Methodology

The intrinsic estimator methodology to conduct APC analysis should ideally be applied only to datasets including surveys undertaken at regular intervals. This is so that the diagonal elements of the age-by-period matrix reflect the aging of individual cohorts (Table 15) (Devaux 2015, pers. comm., 22 May). Mexican surveys do not meet this condition; however an assumption was made that they did. The years 1985, 1995, 2005 and 2015 were used as indicators for period instead of 1988, 1999, 2006 and 2012. The process and commands used in Stata by Sassi et al were used (Sassi et al., 2009, Devaux 2015, pers. comm., 22 May).

Table 15 Age-by-period matrix (N)

Age group	1985	1995	2005	2015
20	3,786	3,247	4,115	2,914
30	3,078	2,984	5,179	3,858
40	2,131	1,997	3,709	3,248
50	0	0	2,239	2,231
60	0	0	1,613	1,430
70	0	0	1,080	893
80	0	0	518	418

Ageing cohort

Results

The intrinsic estimator methodology as used by the OECD was not useful or informative with Mexican data because there were too many empty cells in the age by period matrix (Table 15). The Stata intrinsic estimator programme did not run. In order for this methodology to give reliable cohort effect estimates, surveys must be carried out at more frequent intervals.

Conclusion

More sophisticated age-period-cohort methodologies did not extend our understanding of age-period-cohort effects in obesity prevalence in Mexico. The Median Polish approach suggested that cohort effects were not present but this may have been due to a lack of power in the study. The intrinsic estimator methodology could not be applied successfully.

Appendix 11 Height differences by education level

Table 16 Mean height by education level

	1988	1999	2006	2012
Urban areas				
Higher education	157.4 (0.3)[a]	156.5 (0.3)	157.0 (0.3)	157.3 (0.2)
High school	156.0 (0.2)	155.2 (0.2)	155.6 (0.2)	155.6 (0.2)
Secondary school	154.4 (0.2)	153.8 (0.2)	154.1 (0.2)	154.7 (0.2)
Primary or less	151.7 (0.2)	151.6 (0.1)	152.2 (0.2)	152.3 (0.3)
Linear trend (p)	*-1.98 (<0.001)*	*-1.65 (<0.001)*	*-1.66 (<0.001)*	*-1.68 (<0.001)*
Rural areas				
Higher education	156.0 (1.0)	155.3 (0.5)	154.4 (0.9)	156.6 (0.6)
High school	154.5 (0.7)	153.8 (0.5)	155.6 (0.5)	154.0 (0.4)
Secondary school	154.1 (0.7)	152.5 (0.5)	153.2 (0.3)	153.4 (0.3)
Primary or less	151.5 (0.5)	149.9 (0.2)	150.9 (0.3)	150.6 (0.3)
Linear trend (p)	*-1.49 (<0.001)*	*-2.11 (<0.001)*	*-2.17 (<0.001)*	*-2.08 (<0.001)*

[a]Height in cm, standard error in parenthesis

Appendix 12 Potential mediators in the association between education and obesity, 2006 survey

Table 17 presents the prevalence of obesity by potential mediator variables in 2006 for urban and rural men and women. In 2006, the behavioural factors were associated with obesity among urban women for example, sitting more was associated with higher obesity prevalence (p<0.05), eating more fruits and vegetables was associated with lower prevalence (p<0.001) and drinking more soft drinks was associated with a higher obesity prevalence (p<0.001) (Table 17). Among urban men, sitting more was associated with obesity (p<0.05) (Table 17). Consistent with the 2012 survey, being married (vs single) and depressed were risk factors for obesity among urban women only.

The relative index of inequality was not significant for urban or rural men and for rural women. The RII for women was larger in 2006 than 2012 as was described in Chapter 4. Table 18 shows the results of the mediation analysis for urban women using the diet subsample in 2006. The unadjusted RII was 1.79 (95%CI 1.37, 2.35). The only variable that met the mediation criteria was fruit and vegetable consumption which reduced the RII by 7.5%. The adjusted RII was 1.66 (95%CI 1.26, 2.17). Most of the inequality was unexplained by the set of covariates available in this survey.

Table 17 Obesity prevalence by potential mediator variables, 2006 survey

	Urban areas		Rural areas	
	Men	**Women**	**Men**	**Women**
MAIN SAMPLE, N	6,172	9,179	2,227	3,677
Obesity, %	23.4 (21.8,25.0)	30.6 (29.2,32.0)	17.7 (15.3,20.2)	28.1 (25.5,30.6)
PSYCHOSOCIAL				
Marital status				
Married or cohabiting	24.5 (22.4,26.6)	32.2 (30.3,34.1)	17.1 (14.5,19.6)	30.7 (27.8,33.7)
Divorced or widowed	21.8 (11.0,32.6)	31.0 (26.0,36.1)	11.8 (4.8,18.8)	20.8 (13.6,27.9)
Single	20.6 (16.7,24.5)	28.7 (25.4,32.1)	20.1 (13.1,27.1)	21.0 (14.8,27.1)
Depression symptoms[a]				
Less than 3 symptoms	23.5 (21.7,25.3)	29.3 (27.5,31.1)	19.0 (16.2,21.8)	28.4 (25.3,31.6)
3 or more symptoms	22.9 (19.3,26.5)	32.4 (30.4,34.5)	13.4 (9.7,17.0)	27.9 (24.4,31.3)
Trend p	0.73	<0.05	0.13	0.4
PHYSIOLOGICAL				
Parity				
No children	-	28.1 (24.5,31.6)	-	19.6 (14.1,25.1)
1-2 children	-	28.3 (26.1,30.6)	-	28.4 (24.8,32.1)
3-4 children	-	32.5 (29.8,35.3)	-	35.0 (29.3,40.8)
5 or more	-	36.9 (30.4,43.5)	-	30.0 (21.0,39.0)
Trend p	-	<0.001	-	<0.05
BEHAVIOURAL				
Physical activity				

Low	25.6 (21.6,29.5)	28.2 (24.2,32.3)	18.7 (11.7,25.7)	28.9 (21.9,36.0)
Moderate	22.3 (18.9,25.6)	27.7 (24.9,30.5)	22.7 (16.4,28.9)	30.8 (26.0,35.6)
High	23.3 (21.2,25.3)	31.9 (30.2,33.7)	16.9 (14.3,19.5)	27.5 (24.7,30.3)
Trend p	0.3	<0.05	<0.05	0.39
Sitting time				
Low	20.8 (17.7,23.8)	27.7 (25.6,29.9)	14.9 (11.6,18.2)	27.4 (24.0,30.8)
Moderate	23.3 (20.5,26.1)	32.3 (30.0,34.5)	17.2 (13.8,20.7)	28.7 (25.2,32.1)
High	25.1 (22.5,27.8)	32.0 (29.3,34.7)	25.1 (18.2,32.0)	28.1 (22.9,33.3)
Trend p	0.08	<0.05	<0.01	0.06
DIET SUBSAMPLE, N	2,467	4,354	1,706	3,161
Fruit and vegetable				
Lower	22.6 (19.3,25.9)	35.6 (31.8,39.4)	15.9 (12.5,19.3)	32.7 (28.9,36.5)
Higher	23.6 (19.4,27.7)	28.9 (26.1,31.7)	16.0 (12.5,19.5)	27.6 (23.4,31.7)
Trend p	0.82	<0.001	0.44	0.76
Regular soda				
Lower	22.0 (16.7,27.3)	26.6 (23.8,29.4)	14.3 (11.0,17.6)	29.7 (25.4,34.0)
Higher	22.9 (19.9,25.9)	34.8 (31.3,38.3)	17.5 (13.9,21.1)	30.6 (25.7,35.5)
Trend p	0.9	<0.001	0.32	0.82
Cakes and savoury snacks				
Lower	25.4 (20.5,30.3)	33.6 (29.6,37.7)	15.7 (12.4,19.0)	29.1 (24.4,33.8)
Higher	22.0 (19.0,25.0)	30.8 (27.9,33.7)	17.1 (13.6,20.6)	30.9 (27.4,34.5)
Trend p	0.27	0.4	0.41	0.46

[a] Different item to 2012. Seven depression symptoms listed with possible answer yes, no.

Table 18 Mediation analysis for urban women, 2006 survey

		RII (95% CI)	% change RII	Rank	Multivar analysis
	Diet subsample, N	4396			
1	Crude	1.79 (1.37,2.35)			
2	Marital status	1.75 (1.32,2.31)	-2.48	ł	n
3	Depression sympt	1.81 (1.39,2.37)	1.24		n
4	Parity	1.72 (1.30,2.29)	-3.71	ł	n
5	Physical Act	1.77 (1.35,2.32)	-0.99		n
6	Sitting time	1.90 (1.45,2.49)	6.14		n
7	Fruits and vegetables	1.66 (1.26,2.17)	-7.53	1	y
8	Normal soda	1.80 (1.37,2.36)	0.61		n
9	Cakes and snacks	1.79 (1.36,2.35)	-0.06	ł	n
10	Adjusted	1.66 (1.26,2.17)	-7.53		

Model 1: Reference education RII, adjusted for age and age squared, Models 2-9: Adjusted for age, age squared, and the specified variable, Model 9: Adjusted for age, age squared, plus selected variables according to rank. “y” denotes yes, included in multivariate analysis (Model 10), “n” denotes not included. Variables are ranked according to how much they attenuate the RII. % change RII calculated as follows: ((adjusted RII-crude RII)/crude RII)*100

Appendix 13 The role of unemployment in obesity inequalities in the Mexican context

Unemployment was included in preliminary analyses for chapter 7 given its potential role as a mediator in the association between education and obesity. The survey enquired whether participants worked, and if they didn't, some reasons for it (for example because the person was a full time student or home maker). The variable was recoded into a binary variable: employed=1; unemployed=0. Employed in this context includes all people that reported working whether in the formal or informal sectors.

Table 19 presents the proportion of adults who reported being employed. More men than women were employed in both urban and rural areas. Women in urban areas were more likely to be employed than women from rural areas. Men with higher education were more likely to be unemployed than men with less education in both urban and rural areas (p<0.01). Among women, those with higher education were less likely to be unemployed (p<0.001) (Table 20). Unemployment was not associated with obesity among men or women (Table 21). Hence unemployment did not meet the mediation criteria established in the methodology of Chapter 7. Although theoretically education may affect body weight by affecting employment opportunities and income, this does not appear to be the case in the Mexican context.

Table 19Proportion employed and unemployed among 20 to 49 year olds in Mexico, 2012

	Employed %(SE)	**Unemployed %(SE)**
Urban		
Men	85.1(0.8)	14.9(0.8)
Women	43.7(0.9)	56.3(0.9)
Rural		
Men	86.4(0.9)	13.6(0.9)
Women	21.4(1.1)	78.6(1.1)

Table 20 Distribution of unemployment by level of education, 2012

	Higher education	High school	Secondary	Primary or less	Trend p[a]
URBAN					
Men					
Unemployed, %	25.4	15.0	8.6	13.4	<0.001
Women					
Unemployed, %	43.6	54.5	59.8	63.7	<0.001
RURAL					
Men					
Unemployed, %	27.7	16.1	11.8	12.5	<0.01
Women					
Unemployed, %	53.5	68.2	78.6	84.2	0.001

Table 21 Obesity prevalence by unemployment/employment and association of obesity with unemployment

	Urban areas		Rural areas	
	Men	**Women**	**Men**	**Women**
	%(95%CI)	**%(95%CI)**	**%(95%CI)**	**%(95%CI)**
Overall obesity	28.9 (27.1,30.7)	35.0 (33.4,36.7)	20.7 (18.6,22.8)	30.9 (29.0,32.9)
Unemployed	32.7 (26.9,38.6)	35.9 (33.9,38.0)	16.2 (11.5,21.0)	31.2 (33.3,0.0)
Employed	28.7 (26.8,30.7)	34.2 (31.8,36.6)	21.2 (19.1,23.4)	30.0 (34.1,0.0)
P[a]	0.75	0.13	0.06	0.39

[a]*P for the null hypothesis that obesity prevalence is the same in both employment groups*

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Appendix 14 PLoS One paper

Perez-Ferrer C, McMunn A, Rivera J, Brunner E. *Educational inequalities in obesity among Mexican women: Time trends from 1988 to 2012*. Plos One, 2014; 9(3):e90195

Educational Inequalities in Obesity among Mexican Women: Time-Trends from 1988 to 2012

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Abstract

Background: Obesity is one of the leading causes of global morbidity and mortality. Trends in educational inequalities in obesity prevalence among Mexican women have not been analysed systematically to date.

Methods: Data came from four nationally representative surveys (1988, 1999, 2006, and 2012) of a total of 51 220 non-pregnant women aged 20 to 49. Weight and height were measured during home visits. Education level (higher education, high school, secondary, primary or less) was self-reported. We analysed trends in relative and absolute educational inequalities in obesity prevalence separately for urban and rural areas.

Results: Nationally, age-standardised obesity prevalence increased from 9.3% to 33.7% over 25 years to 2012. Obesity prevalence was inversely associated with education level in urban areas at all survey waves. In rural areas, obesity prevalence increased markedly but there was no gradient with education level at any survey. The relative index of inequality in urban areas declined over the period (2.87 (95%CI: 1.94, 4.25) in 1988, 1.55 (95%CI: 1.33, 1.80) in 2012, trend $p<0.001$). Obesity increased 5.92 fold (95%CI: 4.03, 8.70) among urban women with higher education in the period 1988–2012 compared to 3.23 fold (95%CI: 2.88, 3.63) for urban women with primary or no education. The slope index of inequality increased in urban areas from 1988 to 2012. Over 0.5 M cases would be avoided if the obesity prevalence of women with primary or less education was the same as for women with higher education.

Conclusions: The expected inverse association between education and obesity was observed in urban areas of Mexico. The declining trend in relative educational inequalities in obesity was due to a greater increase in obesity prevalence among higher educated women. In rural areas there was no social gradient in the association between education level and obesity across the four surveys.

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Introduction

Obesity is one of the leading causes of global mortality and morbidity[1]. It is associated with cardiovascular disease, diabetes, some cancers such as oesophagus, pancreatic, colorectal and postmenopausal breast cancer, and mortality [2–5]. Obesity prevalence has increased dramatically in all regions of the world including the poorest nations [6]. Inequalilties in obesity will translate into inequalities in morbidity and mortality.

In developed countries, there tends to be an inverse association between obesity prevalence and socioeconomic position (SEP), especially among women, while in developing countries the association is direct [7,8]. Generally, as a country develops economically, obesity increases faster among the more disadvantaged women compared to the more advantaged ones and inequalities emerge and widen [9–14]. In China and Brazil, for example, inequalities in obesity became larger in the 1980s and 1990s because BMI increased faster among the least educated Chinese women and the poorest Brazilian women compared to more advantaged women [13,14]. A different trend has been observed in the United States and Canada where the initial inverse association between SEP and obesity attenuated over the 1980s and 1990s especially among women [15,16]. This was due to greater increases in the prevalence of obesity in more advantaged compared with less advantaged groups [15–18].

Mexico is an upper middle income country that experienced a rapid nutrition transition, from a traditional to a Western pattern food supply. Obesity prevalence among adult women trebled in 25 years [19]. Mexico ranks second behind the United States in a 2010 OECD report ranking 40 countries according obesity prevalence [20]. The overall increase in obesity prevalence in Mexico has been similar to that experienced by industrialized countries like the United States[21–23] and greater than that experienced by other middle income countries like Brazil [24].

It is not well understood how obesity is distributed across socioeconomic groups and to what extent inequalities in obesity are changing in Mexico. Previous studies assessing the association between socioeconomic position and obesity in Mexico have used one wave of cross-sectional data and have found an inverse association in urban areas and a direct or non-linear association in rural areas [25–29]. The aim of this study was to evaluate the trend in inequalities in obesity by education level for adult Mexican women for the period 1988–2012, utilizing four waves of nationally representative data. We assess whether Mexico follows the characteristic middle income country trend, where inequalities in obesity emerge and increase as the country transitions, or if it follows the North American trend, where relative inequalities have declined. In addition, we explore heterogeneity in the nutrition transition within Mexico by analysing findings for urban and rural areas separately.

Methods

Data sources

Data were extracted from four nationally representative cross-sectional surveys conducted in 1988, 1999, 2006 and 2012[30–33]. All were designed to collect information on nutrition and the latter two on health and health related services and interventions (National Health and Nutrition Survey). The first two surveys focused on women ages 12 to 49 and children. The last two focus on men and women age 20 and older, children and adolescents. We selected women age 20 to 49 years old as our study population because this group was measured in the four surveys. The design of the sample was similar in all surveys and included stratification and probabilistic selection of clusters in different stages. Stratification variables included degree of urbanicity (except for 1988) and socioeconomic factors. The primary sampling units (PSU; municipal subdivisions) were defined across the entire country. A sample of PSUs was selected in each stratum at state level, with probability proportional to population size. Secondary sampling units (SSU), smaller geographic units within each PSU, were defined and a sample of these was selected following the same procedures. Within SSUs a given number of households were selected. Within each household all women were interviewed and measured in the 1988 and 1999 survey or one woman was randomly selected to be interviewed and measured in the 2006 and 2012 surveys. Each individual in the dataset carries 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 13 263 in 1988 to 50 528 in 2012. The total number of women with demographic information across the four surveys was n = 60 331. Missing values for BMI in the achieved sample of women were n = 1 035 (8.6%), n = 2 857 (18.2%), n = 3 575 (20.3%) and n = 560 (3.7%) respectively for each survey. The 1999 and 2006 datasets did not distinguish between women who refused to be measured and those not selected to be measured. Missingness due to refusal to be measured is lower than the overall missingness level in these surveys. 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. Missing BMI was not associated with perception of being overweight or obese, and perception of being overweight or obese was highly correlated with measured overweight or obesity (Spearman $\rho = 0.55$, $p<0.001$) in the survey with the largest proportion of missing data (2006). After exclusion of missing data and extreme, implausible values for BMI (BMI<10, BMI>75; less than 0.5% of total sample) our analytical sample consisted of $n = 51\ 220$ non-pregnant, 20 to 49 year old women.

Ethics statement

Written consent was obtained from adults participating in the study, including the parents or tutor of children. Verbal consent was obtained from children. The study protocol, data collection instruments and consent forms and procedures were approved by the ethics committee of the National Institute of Public Health in Mexico.The present study was based on an anonymous, public-use data set with no identifiable information on the study participants.

Outcome, exposure and covariates

Body mass index (BMI) was calculated as weight (kg) divided by the square of height (m^2). 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 [19,30–32]. The main exposure variable was level of education defined as self-reported attendance to higher education, high school, secondary, or primary education or less. These categories refer to well-known milestones in the Mexican education system. Age (in years) was included as an adjustment covariate in all models, given the linear association of age with BMI. Area of residence has been identified as effect modifier of the association between education and obesity in previous studies [34], thus analyses are stratified by this variable. Urban areas were defined as communities with more than 2 500 inhabitants and rural areas with less than 2 500 inhabitants.

Statistical Analysis

A pooled dataset of the four surveys was created. All analyses were adjusted for survey design and weighted using the STATA 12 survey commands (svy). We first computed the age-standardised obesity prevalence in each survey. We then calculated the age standardised prevalence of obesity by education group in each survey. The Mexican 2000 census population was used as the standard population. The linear trend in the education gradient was assessed in a regression where the outcome was obesity, the exposure education as a continuous variable, adjusted for age [35,36]. Deviation from linearity in the education gradients was tested by adding a quadratic term to the model. We used generalised linear models (log binomial regression) rather than logistic regression as has been recommended when modelling frequent outcomes [35,36]. Generalised linear models estimate the prevalence ratio.

The relative index of inequality is a standard summary measure of inequality. It is recommended when making comparisons of health inequality over time or across populations [37].The slope index of inequality measures absolute inequalities using similar methodology. To estimate these measures of inequality, education level was transformed onto a scale from 0 (highest level of education) to 1 (lowest level of education) and weighted to reflect the share of the population at each educational level by calculating the midpoint of the proportion in the population in each category. This was done separately for urban and rural areas of each survey wave. For example, 16.2% of the study participants in urban areas in 2006 were in the higher education group and 20.8% were in the high school group. Participants in the higher education group were assigned a score of 0.08 (0.16/2) meaning 92% of the urban population of 2006 had lower education than the average person in this group. Those in the high school group were assigned a score of 0.27 (0.16+(0.21/2)) and so on for each education level [38]. To obtain the relative index of inequality and slope index of inequality, obesity was regressed on the new education variable in a model adjusted for age. We used generalised linear models, with a logarithmic link function to calculate the relative index of inequality (rate ratio) and with an identity link function to calculate slope index of inequality (rate difference)[39]. The relative index of inequality is interpreted as the prevalence *ratio* between the two ends of the educational hierarchy – obesity prevalence at the bottom divided by obesity prevalence at the top. The slope index of inequality is the prevalence *difference* between top and bottom. Using the slope index of inequality and the total population (weighted expanded sample), excess obese cases in the most disadvantaged groups were estimated for urban areas. Linear trends of the relative index of inequality and slope index of inequality over the period were tested by estimating the p value for an interaction term between education and years since baseline, i.e. 1988 survey was coded 1, 1999 11 and so on, to account for the different time intervals between surveys. The model was adjusted for age in addition to year and education rank [40,41].

Relative increases in obesity prevalence over time by education level were estimated by generalised linear models where obesity was the dependent variable and survey year was the independent variable [13]. Analyses were stratified by education level, and age was used as a covariate. These models estimate an age-adjusted prevalence ratio that reflects the magnitude and statistical significance of the increase in obesity prevalence by education level in the period 1988–2012. Mantel-Haenszel x^2 tests for homogeneity were calculated to assess statistical differences in obesity prevalence ratios across education levels in urban and rural areas[42]. Absolute increases in obesity prevalence by education level were estimated by linear regression using the same stratification and adjustment variables described above. These models estimate an age adjusted prevalence difference by education level in the period 1988–2012.

Sensitivity analysis

In order to test whether inequalities in obesity differ between and within birth cohorts over time, we compared the relative index of inequality trends for an older, less educated and a younger, more educated cohort over the period 1999–2012 among women living in urban areas. A variable for year of birth was created by subtracting the age of the woman from the year of the survey. Individuals born between 1963 and 1979 were included because they had data available for three time points (1999, 2006 and 2012; n = 17 695). Two "pseudo cohorts" were created, the older cohort (women born between 1963 and 1971, n = 9 031) and the younger cohort (women born between 1972 and 1979, n = 8 664). The education rank variable was constructed again with the education proportions in the two cohorts. The relative index of inequality was calculated as previously described for each period stratified by cohort. The trend of the relative index of inequality for each cohort was then estimated and compared using a three way interaction term composed of education rank, year and cohort [14]. This analysis examined whether the inequality trend in urban areas differed by cohort.

Further sensitivity analyses were conducted, fitting models to estimate relative index of inequality and slope index of inequality adjusted for height, given that height was inversely correlated with BMI and directly correlated with education, and using obesity class II and III (BMI≥35) as the outcome.

Results

The proportion of urban population in the survey samples was 83.7%, 75.5%, 77.0% and 78.6% for 1988, 1999, 2006 and 2012 respectively. Except for 1988, the proportion of urban dwellers in each sample was similar to the nearest census estimate[43]. Table 1 presents selected characteristics of the study population according to survey year. The average age of women increased from 32 to 33 from 1988 to 2012, there was no age difference between urban and rural areas. In urban areas the proportion of women who entered higher education doubled to 23% between 1988 and 2012 and those with primary education or less halved to 23%. In rural areas there were smaller improvements in participation. The average weight of Mexican women increased by 12 kg in urban areas and 10 kg in rural areas in the period 1988–2012 while height increased by 1 cm in urban areas and remained constant in rural areas. Height was socially patterned in both urban and rural areas (Table S1). The change in height from 1988 to 2012 was not statistically significant for any education level for urban or rural areas. Obesity prevalence more than trebled in the 24 year period with urban areas being especially affected. The largest increase took place in the period 1988–1999. A third of the population in this demographic group was obese in 2012.

There was an inverse linear association between obesity and education in urban areas (Table 2). One step lower education level was associated with 32% higher obesity prevalence (prevalence ratio (PR) 1.32 95%CI 1.19, 1.46) in 1988 and by 12% (PR 1.12 95%CI 1.08, 1.17) in 2012. Absolute inequalities measured by the slope index of inequality increased from 6.4 (95%CI 4.1, 8.8) in 1988 to 18.36 (95% CI 13.70, 23.03) in 1999 and then levelled off (Table 3 and Figure 1). Excess obesity cases in women with primary education or less ranged from over 300,000 in 1988 to over a million in 1999 (table 3). Relative inequalities decreased. The relative index of inequality in urban areas was 2.87 (95% CI: 1.94, 4.25) in 1988 and declined over the period to 1.55 (95% CI: 1.33, 1.80) in 2012, trend $p<0.001$ (Table 3 and Figure 2). After adjusting for height, the trend coefficient changed by less than 1% and statistical significance was unaltered. In rural areas, obesity prevalence increased markedly overall but there was no gradient with education level at any survey wave, and both the relative index of inequality and slope index of inequality were non-significant. However, there is evidence of a significant non-linear variation in obesity prevalence by education level in some survey waves (Table 2). The same declining trend in relative inequalities in urban areas and no trend in rural areas is observed when the outcome is class II and III obesity (BMI≥35) (Table S2).

Absolute increases in obesity prevalence between 1988–1999 were greater among women with primary or less education in both urban and rural areas, compared with women with higher education. From 1999 to 2012 absolute increases in obesity prevalence were similar for all education groups therefore the slope index of inequality remains largely unchanged as ilustrated in figure 1. In contrast, relative increases where largest in the most educated women in urban areas ($p<0.001$ for the null hypothesis of homogeneity of rates across education levels). Obesity increased 5.92 fold (95% CI 4.03, 8.70) among urban women with higher education in the period 1988–2012 compared to 3.23 fold (95%CI 2.88, 3.63) for urban women with primary or no education (Table 4). Between 2006 and 2012, the prevalence of obesity among urban women with secondary education, primary or less did not increase significantly, while there was a 22% increase in obesity prevalence among women with high school or higher education (PR 1.22 $p<0.05$ for both groups). This resulted in the stepwise decline from 1988 to 2012 in the relative index of inequality as illustrated in figure 2. Among rural women, there appears to be larger increases in the prevalence of obesity over time in the group with high school education (PR 6.96 95%CI 2.92, 16.55) however homogeneity in the rates across education levels could not be rejected.

Table 1. Age standardised distribution of women for selected characteristics 1988–2012.

	URBAN				RURAL			
	1988	**1999**	**2006**	**2012**	**1988**	**1999**	**2006**	**2012**
Complete cases, N	8 887	8 205	9 906	9 588	1 315	4 308	4 068	4 943
Age, mean	32.4 (0.1)	33.8 (0.1)	34.0 (0.1)	33.8 (0.1)	32.2 (0.3)	33.8 (0.1)	33.7 (0.2)	33.4 (0.2)
Age group, %								
20–24.9	22.8 (0.6)	17.6 (0.5)	17.3 (0.6)	18.3 (0.7)	22.6 (1.5)	18.5 (0.6)	17.4 (0.9)	18.5 (0.9)
25–29.9	19.2 (0.5)	16.5 (0.5)	16.5 (0.6)	16.2 (0.6	20.1 (1.2)	15.9 (0.6)	17.1 (0.7)	19.0 (0.9)
30–34.9	17.6 (0.6)	17.8 (0.5)	17.7 (0.6)	19.5 (0.6)	17.3 (1.2)	17.2 (0.7)	19.0 (0.8)	18.6 (0.7)
35–39.9	16.5 (0.5)	19.5 (0.6)	18.3 (0.6)	16.9 (0.6)	17.1 (0.8)	19.3 (0.7)	17.6 (0.8)	16.3 (0.7)
40–44.9	13.0 (0.5)	16.8 (0.6)	16.5 (0.6)	15.0 (0.5)	12.3 (1.4)	16.9 (0.7)	17.2 (0.9)	14.4 (0.6)
45–49.9	10.8 (0.4)	11.8 (0.5)	13.6 (0.6)	14.1 (0.6)	10.6 (1.0)	12.3 (0.6)	11.7 (0.8)	13.3 (0.6)
Level of education, %								
Higher education	10.2 (0.6)	14.6 (0.6)	16.2 (0.8)	22.6 (0.8)	2.2 (0.6)	1.8 (0.3)	2.4 (0.4)	6.5 (0.7)
High school	17.4 (0.7)	20.5 (0.6)	20.8 (0.7)	22.7 (0.7)	8.4 (1.6)	5.8 (0.6)	5.6 (0.7)	13.0 (0.8)
Secondary	17.0 (0.6)	24.3 (0.6)	28.8 (0.8)	31.2 (0.8)	9.4 (1.4)	13.7 (0.8)	24.6 (1.2)	33.9 (1.3)
Primary or less	55.4 (1.3)	40.6 (0.8)	34.4 (0.9)	23.4 (0.8)	79.9 (3.2)	78.8 (1.2)	67.5 (1.3)	46.6 (1.4)
Weight (kg), mean	56.3 (0.2)	64.4 (0.2)	66.5 (0.2)	68.1 (0.3)	54.6 (0.7)	59.7 (0.4)	63.5 (0.4)	64.8 (0.3)
Height (cm), mean	153.5 (0.2)	153.6 (0.1)	154.2 (0.1)	154.9 (0.1)	152.0 (0.4)	150.5 (0.2)	151.9 (0.2)	152.4 (0.2)
BMI, mean	23.9 (0.1)	27.3 (0.1)	28.0 (0.1)	28.4 (0.1)	23.6 (0.2)	26.3 (0.1)	27.5 (0.1)	27.8 (0.1)
Obese, %	9.5 (0.39)	26.3 (0.6)	30.9 (0.68)	34.5 (0.76)	8.1 (1.22)	21.3 (0.83)	27.9 (1.12)	30.7(0.99)

Standard errors in parenthesis.
doi:10.1371/journal.pone.0090195.t001

Sensitivity analysis

There was a large shift in the distribution of attained level of education between the two birth cohorts. The younger cohort was significantly more educated than the older cohort; among the younger cohort 28.2% (95% CI 26.7, 29.6) had primary education or less vs. 39.8% (95%CI 38.2,41.4) among the older cohort ($F = 38.4$ $p < 0.001$).

Table 5 shows the relative index of inequality trend from 1999 to 2012 in urban areas stratified by birth cohort. For the older cohort, there was a non-significant tendency towards declining inequality similar to that described in the unstratified analysis. There was no trend in the relative index of inequality for the younger cohort. The older and younger cohort relative index of inequality trends were significantly different from each other ($p = 0.005$).

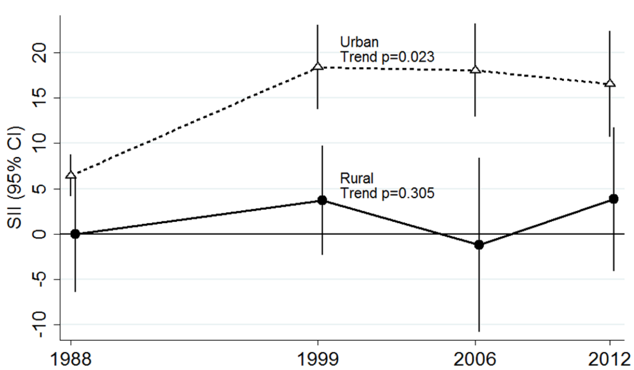

Figure 1. Trend in absolute inequalities in obesity for urban and rural Mexican women 1988–2012. Each point represents the slope index of inequality (SII) for the particular year. Error bars represent the 95% confidence intervals of the SII. Plotted estimates are adjusted for age.
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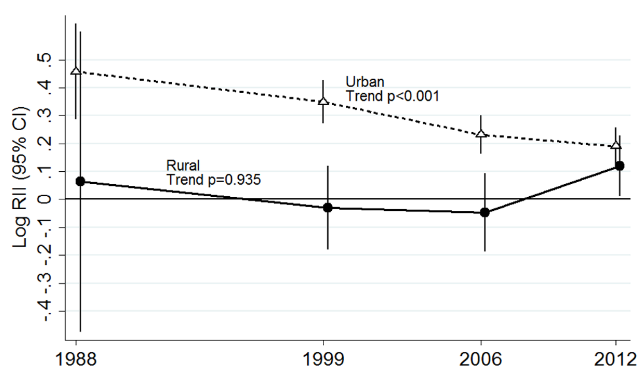

Figure 2. Trend in relative inequalities in obesity for urban and rural Mexican women 1988–2012. Each point represents the relative index of inequality (RII) for the particular year. Error bars represent the 95% confidence intervals of the RII. Plotted estimates are adjusted for age.
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Table 2. Age standardised obesity prevalence by education level stratified by urban and rural areas.

	1988		1999		2006		2012	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Urban areas								
Higher education	5.05	(3.09,7.00)	17.77	(14.9,20.66)	21.79	(18.43,25.15)	26.70	(23.76,29.65)
High school	7.03	(5.22,8.83)	21.32	(18.80,23.83)	26.77	(23.91,29.63)	33.65	(30.30,37.0)
Secondary	8.43	(6.63,10.24)	24.78	(22.50,27.09)	32.32	(29.72,34.91)	36.59	(34.13,39.06)
Primary or no education	11.18	(10.09,12.27)	31.65	(29.60,33.70)	36.45	(34.13,38.78)	38.52	(35.24,41.80)
Rural areas								
Higher education	3.67	(0.96,6.38)	14.51	(7.12,21.89)	27.83	(19.89,35.78)	21.57	(15.27,27.88)
High school	5.38	(0.27,10.48)	20.17	(16.64,25.69)	24.91	(16.40,33.41)	28.79	(23.94,33.65)
Secondary	14.34	(5.64,23.04)	30.44	(26.50,34.37)	31.52	(26.81,36.22)	32.26	(28.81,35.71)
Primary or no education	8.10	(5.56,10.63)	21.62	(19.76,23.50)	27.64	(24.63,30.66)	31.02	(28.00,34.04)

doi:10.1371/journal.pone.0090195.t002

Discussion

Our study is the first to examine time trends in inequalities in obesity among Mexican women using a unified analytic method. Previous studies used single waves of data, showing an inverse association between education and obesity in urban areas and a direct or non-linear association in rural areas [25–29]. Obesity prevalence among Mexican women increased dramatically across all education groups over the period 1988–2012 with the largest increases between 1988 and 1999. Although the difference in obesity prevalence between urban and rural areas was not large, the social patterning of obesity differed significantly. There was an inverse association between education level and obesity prevalence among urban-dwelling but not rural-dwelling Mexican women. In urban areas there was strong evidence that relative inequalities in obesity declined over the period 1988–2012 as a consequence of a larger increase in obesity prevalence in more educated compared to less educated women.

In urban areas, where most Mexican women live, obesity has disproportionately affected those with the least education for the last 25 years. The declining trend in relative educational inequalities observed is similar to that in North America, and differs from the female obesity inequality trend typical of other low and middle income countries [10,15,17]. We tested whether this trend could be the result of differential changes in height across education groups over the period but found no evidence for this. Absolute inequalities increased from 1988 to 2012. In 2012, based on PAR and assuming the excess obesity prevalence was preventable, 744 437 obesity cases could have been avoided if the lowest education group had the same health experience as those in the highest education group.

In rural areas there was no educational gradient at any survey wave. Women with primary education or less had a lower prevalence of obesity than more educated women at the first two survey waves. More recently, obesity prevalence in women with primary education or less has caught up with the prevalence of more advantaged groups. It is likely that women with primary education or less were protected from obesity by their limited resources in the earlier period of the surveys. As living conditions improved and low-cost processed food and calorific drink products penetrated rural areas [44], disadvantaged women lost this protection. Speculatively, there may be a crossover to an inverse association between education and obesity in the near future, as has been observed in numerous middle income countries [25]. In Mexico, economic development has concentrated in urban areas [45] and it is likely that the nutrition transition is lagging behind in rural areas [46].

This study uses education as an indicator of socioeconomic position. The meaning of education may differ for the older and younger birth cohorts studied here, with differing distributions of

Table 3. Absolute and relative inequalities in obesity.

	Urban		Rural	
	RII (95%CI)	SII (95%CI)	RII (95%CI)	SII (95%CI)
1988	2.87*(1.94,4.25)	6.44*(4.12,8.77)	1.16 (0.34,3.98)	−0.04 (−6.0,6.0)
1999	2.22*(1.86,2.66)	18.36*(13.70,23.03)	0.93 (0.66,1.32)	4.0 (−2.3,9.7)
2006	1.71*(1.45,2.00)	18.03*(12.91,23.15)	0.90 (0.65,1.24)	−1.2 (−11,8.0)
2012	1.55*(1.33,1.80)	16.52*(10.72,22.33)	1.13 (0.89,1.44)	4.0 (−4.0,11.0)
Linear trend across surveys p	$p<0.001$	$p=0.023$[a,b]	$p=0.935$	$p=0.305$[a]

RII: Relative index of inequality.
SII: Slope index of inequality.
*$p<0.001$ in each survey year.
[a]estimated using survey weighted linear regression.
[b]quadratic term $p<0.001$.
doi:10.1371/journal.pone.0090195.t003

Table 4. Absolute and relative increases in obesity prevalence by education level from 1988 to 2012.

	Relative increase		Absolute increase	
	1988–2012		1988–2012	
	PR[a]	95% CI	%[b]	95% CI
Urban areas				
Higher education	5.92*	(4.03, 8.70)	20.41	(17.04, 23.78)
High school	5.45	(4.14, 7.16)	25.39	(21.72, 29.06)
Secondary	4.74	(3.81, 5.91)	27.37	(24.47, 30.27)
Primary or no educ	3.23	(2.88, 3.63)	29.29	(26.17, 32.40)
Rural areas				
Higher education	4.82†	(0.90, 25.80)	16.49	(7.19, 25.78)
High school	6.96	(2.92, 16.55)	20.58	(14.93, 26.22)
Secondary	3.16	(1.61, 6.22)	17.57	(11.56, 23.57)
Primary or no educ	3.70	(2.64, 5.18)	24.30	(20.43, 28.17)

[a]Age adjusted prevalence ratio.
[b]Age adjusted prevalence difference.
Test for homogeneity across education levels *p<0.001 † p = 0.50.
doi:10.1371/journal.pone.0090195.t004

knowledge, skills and opportunities that affect health [47]. We tested whether the period variation in the effect of education on obesity reflected a change in the meaning of education for the different cohorts. This was not supported by our findings. The birth cohort stratified analysis suggested that the protective role of education varied within the same cohort over the years. The cohort stratified analysis also showed that although the younger cohort was significantly more educated, it was not more protected from obesity than the older cohort. These observations led us to believe that changes to environmental or cultural factors cutting across all socioeconomic groups had a more powerful effect on women's choices and possibilities, reducing the protective effect of personal characteristics such as education [15].

The food and built environment in Mexico changed substantially over the 1980s and 1990s leading to changes in diet, increase in calorie intake and a decrease in physical activity and energy expenditure[48]. Highly processed foods became widely available partly due to a 25 fold increase in foreign direct investment to the Mexican food industry from 1989 to 1999 [49] facilitated by the signing of the North American free trade agreement (NAFTA) in 1994. Over this period, women's participation in the labour force also increased substantially from 17% in the 70s to 43% in 2010 [50_ENREF_52]. This may have caused considerable changes in food purchase and preparation patterns at household level contributing to increased calorie intake [51_ENREF_53]. Physical activity at a population level has likely decreased as a result of urbanisation, changes in occupation, car ownership, increased time spent watching television and using computers. These changes affected the entire population and might explain the large increases in obesity. Speculatively, these environmental changes may have affected SEP groups differentially.

Although the literature suggests that in general those most affected by increased availability of processed foods are disadvantaged SEP groups [52_ENREF_54,53_ENREF_55], this does not seem to be the case in Mexico. Our study suggests that increases in obesity prevalence were greatest for women with more education especially in urban areas. Women with more education might have been the first to access processed/North American foods in the early days of market liberalization. These foods were novel and added variety to the traditional Mexican diet. Chains selling energy dense foods and beverages that target upper middle income groups have had high growth. For example convenience stores targeting urbanites with limited time, have grown at a rate close to 1000 new stores per year during the 1990s and 2000s [49]. Working women, who have tended to be more educated than those who do not work [50_ENREF_52], may have relied more heavily on convenience foods with the consequence of increasing calorie intakes.

The trends in inequalities in obesity prevalence in Mexico may be an exception to the middle income country pattern and particular to Mexico, USA and Canada due to their unique relationship. NAFTA has facilitated market integration with North America and promoted a regional food system [54_ENREF_56]. Demographically there are extensive social networks between the USA and Mexico due to immigration. Mexican migrants in the USA send remittances and also social and cultural norms back to Mexico [55_ENREF_57]. Similar environmental factors may be shaping the social distribution of obesity in the three countries.

Strengths and Limitations

Our study strengths include using nationally representative data from comparable health surveys. Height and weight were measured by trained personnel and the main exposure, attendance to education, is minimally prone to recall bias. Education is frequently used as an indicator of SEP in low and middle income countries; its use allows comparability with previous studies. This study also has limitations. We performed a complete cases analysis, losing observations in each survey. Missing data patterns were examined carefully. Women with missing BMI were more educated, richer and younger than those with complete data. It is likely that missingness is due to operational issues such as health teams not visiting some households or women not being available to be measured due to work or study. It is less likely the refusal was associated with their weight, based on an analysis of perceived

Table 5. Relative index of inequality (RII) stratified by birth cohort in urban areas.

	Survey year			
Birth cohort	1999	2006	2012	trend p
	RII (95% CI)	RII (95% CI)	RII (95% CI)	
Older 1963–1971	2.31* (1.77,3.00)	1.71* (1.35, 2.17)	1.61* (1.25,2.06)	0.062
Younger 1972–1979	1.63~ (1.02,2.61)	2.06* (1.46,2.92)	1.39* (1.10,1.74)	0.179

*p<0.001.
~p<0.05.
doi:10.1371/journal.pone.0090195.t005

weight. For the two middle surveys, missing values reported are likely to be an overestimation of true missingness given that the datasets do not distinguish between women who refused or could not be measured and those not selected to be measured. The proportion of urban/rural dwellers from the 1988 sample is significantly different to the 1980 census estimate (66.3% urban; 33.7% rural). The 1988 survey was the first nutrition survey to ever be undertaken in Mexico and did not stratify by urban and rural dwelling in the sampling design. The representativeness of findings especially for rural areas in this survey is thus a limitation. Our analysis was limited to education level as indicator of socioeconomic position. A woman's education is strongly determined by her parental socioeconomic position [47,56_EN-REF_58] and because it is set at an early age, it is not sensitive to changes in SEP thereafter. The pattern of inequalities in obesity could be different if other socioeconomic position measures such as income or wealth are used because each indicator is associated with obesity through different pathways. It was beyond the scope of this study to study other exposures. It was not possible to carry out a more robust cohort effect analysis because the data do not span enough years for each birth cohort. As more surveys are carried out in Mexico in the future, cohort effects in inequality trends could be further explored. Lastly, the cross sectional nature of the data precludes exploration of causal directions in the relationship between SEP and obesity.

Conclusions

Obesity increased substantially in Mexico across all education groups in both urban and rural areas over the study period. In urban areas, the most disadvantaged women have the largest burden of obesity however, relative educational inequalities decreased from 1988 to 2012. This was due to higher increases in obesity among women with high school or higher education compared with women with primary education or less. In rural areas there was no educational gradient in obesity prevalence. These findings have important implications for public health nutrition policy in Mexico and suggest that structural and population-wide approaches to obesity prevention may be as important as targeting high risk groups.

Supporting Information

Table S1 Mean height by education level 1988–2012.
(DOCX)

Table S2 Age standardised class II and III obesity (BMI≥35) prevalence by education level and summary inequality measures 1988–2012.
(DOCX)

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Author Contributions

Conceived and designed the experiments: CPF AM EJB. Analyzed the data: CPF. Contributed reagents/materials/analysis tools: JRD. Wrote the paper: CPF AM JRD EJB. Interpreted findings: CPF AM JRD EJB.

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