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Food insecurity and the nutritional status of Mexican mother-child pairs

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Abstract

Background. Household Food Insecurity (HFI) has been associated with overweight mothers and underweight children living in the same households. Adult obesity has been linked to both obesity and undernutrition in children. **Objective.** The purpose of this article was, to examine the association between HFI and child stunting risk and to determine if maternal-child overweight/obesity modifies the relationship between HFI and stunting risk. **Methods.** We assessed the association of HFI with the nutritional status of mothers and their <11-year-old children based on data from the Mexican National Health and Nutrition Survey in (ENSANUT 2012). The study included 5,087 mother-preschool child pairs and 7,181 mother-school aged child pairs. HFI was measured with the Latin American and Caribbean Food Security Scale (ELCSA). A multiple logistic regressions were used to examine the associations of interest adjusting for pertinent covariates. **Results.** There was a higher prevalence of stunting among preschool children with moderate HFI (16.2%) or severe (16.8%) ($p=0.036$ and $p=0.007$, respectively), compared with mild or no HFI (13.2 and 10.7%). A significant interaction was found between maternal obesity status and HFI on stunting among preschoolers ($p<0.05$). Specifically, HFI severity increased the risk of child stunting among non-obese mothers but not among obese mothers. Among school aged children. **Conclusion.** A novel interaction between HFI and maternal obesity status on child stunting risk was uncovered. However this was not the case if their mothers were obese. Food security government policies and programs need to take into account these complex relationships in the context of an advanced nutrition transition.

Keywords. Food insecurity; obesity, under nutrition; nutrition survey; nutrition transition; Mexico

Strengths and limitations of this study

- Our study, its cross-sectional design restricts the drawing of causal inferences. Additionally, our findings refer specifically to Mexican children and adolescents and similar population but cannot be generalized to other population groups.
- Our findings contribute to the limited research available on the relationship between HFI and the nutritional status of mother-child pairs.
- This is one of the first studies in this area dealing specifically with the Mexican population.
- The large sample size of our study constitutes another strength which allowed us to introduce possible confounders in the statistical models.
- We found an important phenomenon of the nutritional transition in our country that is common in other countries of the world: the double burden of malnutrition that occurs in the same food insecure household that may be a shared mechanism for dual forms of malnutrition within the same individual.
- Our study documented an unusual interaction between HFI and maternal obesity status on child with risk of stunting. We believe these findings are a useful for improving nutrition guidelines that policies and programs need to be taken into account in the context of an advanced nutritional transition.

Introduction

Food security "exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life, and is supported by an environment of adequate sanitation, health services and care. [1, 2]

The term hunger, which describes a feeling of discomfort from not eating, has also been used to describe undernutrition, especially in relation to food insecurity [3]. Experience-based indices can be used to assess hunger directly at the household level [4].

Household Food Insecurity (HFI) has been defined as "limited or uncertain availability of nutritionally adequate and safe food or limited and uncertain ability to acquire adequate food in socially acceptable ways" [5]

Maternal and child undernutrition is highly prevalent in low- and middle-income countries, causing accounting for a substantial proportion of mortality and overall disease burden. Stunting, severe wasting, and intrauterine growth restriction, together, have been linked to 2.2 million deaths and to 21% of disability-adjusted life-years (DALYs) in children younger than five years [6].

Previous studies have suggested a link between obesity and HFI [7]; especially among adult women [8-10]. Specifically, it has been documented that women who experience food insecurity are more likely to be obese compared with food secure

women [11]; and those most affected by HFI include members of racial/ethnic minority groups and low-income households [12].

A possible explanation for the "paradoxical" link between HFI, low income and obesity lies in the fact that high-fat, high-calorie food products cost less than healthful foods [13] and these energy dense foods have been identified as risk factors for child and adult obesity [14]. Moreover, HFI may lead to disorderly eating patterns characterized by binging for consuming little food, according to the availability of supplies negatively affecting the body's metabolism [15].

Food insecurity in Mexico has evolved in complex and contrasting contexts where undernutrion and overweight/obesity coexist as part of the advanced nutrition transition the country is immersed in the context of widespread HFI. According to the most recent Mexican National Health and Nutrition Survey (ENSANUT 2012) nearly one out of three households suffers from moderate or severe HFI [16].

The last decades have witnessed alarming increases in the prevalence of overweight/obesity among Mexican children: from 7.8% in 1988 to 9.7% in 2012 for children under five; from 26.9% in1999 to 34.4% in2012 for 5-11-year olds; and from 11.1% in1988 to 35.8% in2012 for female adolescents aged 12-19 years. In the adult population aged 20 and older, this prevalence jumped from 61.8% to 71.3% in twelve years [17].

In 2012, children under five living in severely food insecure households had a 42% higher risk of stunting or chronic malnutrition compared with their counterparts

living in food secure households [18]. In the same year, the mean BMI of women aged 20 to 59 was 28.9, women living with mild HFI had a mean BMI of 28.3, compared with 29.3 and 29.4 among those living in households with moderate and severe food insecurity ($p<0.001$, $p=0.011$ and $p=0.007$, respectively) [10].

The double burden of malnutrition can occur not only within the same country, city or household (mother-child pairs), but also in the same individual at different stages of his or her life [19]. The purpose of this article was, to examine the association between HFI and child stunting risk and to determine if maternal-child overweight/obesity modifies the relationship between HFI and stunting risk.

Methods

Study design and population

Data were drawn from ENSANUT 2012, a cross-sectional, probabilistic and cluster survey with national, regional, urban-rural and state-level representativeness. Oversampling was directed to Mexican households of lower socioeconomic status. A sample of 50,528 household of an estimated 29,429,252 households nationwide was obtained between October 2011 and May 2012. Details of sample size and design have been described elsewhere [20].

A total of 5,087 preschoolers (1-4y), 8,401 schooler children (5-11y) and 9,581 mothers were included in the survey. A total of 5087pairs of mothers/ preschoolers were included, all mothers in this sample had only one child. A total of 7,181

mothers/schooler were included, 2,432 mothers had more than one schooler and 2,677 mothers had both a preschooler and schooler(s).

Our analytical sample included 5,087 mother-preschooler pairs and 7,181 mother-schooler pairs with complete data. When mothers had more than one school-aged child that met the study criteria, all the children were included in the analyses.

Informed consent was obtained from all respondents – or their parents/guardians in the case of children under 7 years – prior to their participation in the study. The survey protocol was approved by the Ethics Committee of the National Institute of Public Health, Mexico.

Variables and Data sources/ measurement

HFI measurement

Perceived HFI was measured with a version of the Escala Latinoamericana y Caribeña de Seguridad Alimentaria (ELCSA) previously validated in Mexico [21]. ELCSA included 15 questions targeting the head of the family or the woman in charge of preparing meals. Eight questions referred directly to HFI in the household or the adults within the household; the remaining seven referred to HFI in minors (<18y). HFI was categorized as mild, moderate or severe using recommended cut-off points. The reference time frame was three months prior to survey administration.

Anthropometric measurements

Weight and recumbent length measures were obtained from children under two, and standing height measures from children aged two to under five following standard recommended procedures [22, 23].

The anthropometric measures, together with the age, and sex of the children were used to calculate the weight-for-age, height-for-age, and weight-for-height z-scores using the WHO growth standards.

The prevalence of undernutrition in its different manifestations (underweight, wasting and stunting) was calculated using the <-2 z-score cut-off point [24].

Overweight and obesity were determined according to the WHO Growth Reference charts [25], with BMI (kg/m^2) z-scores adjusted for age, values between -5.0 and +5.0 were considered as values outside this range were considered to be implausible. There were no implausible values for BMI z-score in children. For adults, the WHO standard BMI cut-off point was used to classify mothers into one of the following categories: underweight (<18.5 kg/m^2), normal weight (18.5 to 24.9 kg/m^2), overweight (25-29.9 kg/m^2) and obese (≥ 30 kg/m^2) [26]. For adults, only BMI values between 10 and 58 were to be considered, but there were also no implausible values for BMI in adults.

Covariates

The following covariates, described below, were included in the statistical analyses: sex of the child, residence location (urban/rural), region of residence (northern, central, Mexico City, and southern); and maternal education: none,

primary, secondary, senior high school ("preparatoria" according to its Spanish translation) and university (bachelor's degree and beyond). We also included food assistance program participation as a covariate.

Socioeconomic Index

We used a standard socioeconomic status (SES) index developed in Mexico based on a variety of household characteristics: type of floor, wall and ceiling materials; the ratio of number of rooms used for sleeping to number of persons residing in the household; basic service infrastructure including water source and water disposal; and possession of domestic appliances such as a refrigerator, washing machine, microwave oven, stove, boiler, radio, television, cable television signal, telephone and computer. This SES index was selected to facilitate comparison with previous surveys in Mexico [21].

Ethical considerations

All study procedures involving human participants were approved by the Ethics Committee of the National Institute of Public Health in Mexico. Written informed consent was obtained from all survey participants with parents serving as proxies of minors under 7 years.

Statistical methods

We calculated the prevalence (95% CI) of each HFI category by socioeconomic characteristic and maternal-child nutritional status. We then conducted logistic regression models for examining stunting and overweight among preschool children and for stunting, overweight/obesity among school-aged children, adjusting for pertinent covariates; taking into account the complex sampling design using the STATA 13 SVY module for complex surveys. The cluster effect at the mother level for mothers with more than one schooler was tested and it was non-significant, thus it was not adjusted for in the analyses. There were no mothers with more than one preschooler. Results were expressed as Adjusted Odds Ratios (AORs) with their corresponding 95% confidence intervals (95% CI).

Results

Our analytical sample included 5,087 mother-preschooler pairs and 7,181 mother-schooler pairs with complete data.

In the mother-preschooler pairs, moderate HFI was significantly more prevalent among those residing in the southern, as opposed to the northern or central regions of Mexico. As expected, severe HFI was five and six times more prevalent in the low and very low quintiles, respectively, than in the top quintile. Moderate and severe HFI were more prevalent in households where mothers had not studied beyond junior high school and also among those benefiting from government food-assistance programs (Table 1).

Similarly, in the mother-schoolers pairs, HFI in general was most prevalent among those living in southern Mexico and lower in the north of the country; HFI was higher in the low and very low socioeconomic quintiles. Moderate and severe HFI were significantly more prevalent among the pairs where mothers had not studied beyond junior high school, benefited from government food-support programs and belonged to indigenous population groups (Table 1).

Table 1. Food insecurity level according to the socio-demographic characteristics of the mother-preschooler and mother scholar pairs

	Total		Food Insecurity Level in preschooler							
			Secure		Mild		Moderate		Severe	
	n	N (thousands)	%	95% IC	%	95% IC	%	95% IC	%	95% IC
Child sex										
Female	2539	1452.9	24.2	(21.7,26.79)	43.8	(40.9,46.6)	21.6	(19.5,23.8)	10.5	(9.0,12.2)
Male	2548	1522.1	24.7	(22.3,27.13)	45.0	(42.4,47.7)	18.4	(16.5,20.6)	11.9	(10.3,13.8)
Residence location										
Urban	3142	2123.0	26.8	(24.6 ,29.1)	43.3	(40.9,45.8)	18.9	(17.1,20.9)	10.9	(9.4,12.6)
Rural	1945	851.9	18.5	(16.3,20.9)	47.0	(43.8,50.2)	22.4	(20.1,25.0)	12.0	(10.3,14.1)
Region										
Northern	1083	524.5	30.5	(27.2,34.0)	42.5	(38.9,46.2)	15.8	(13.3,18.6)	11.2	(9.2,13.5)
Central	1804	941.8	26.7	(24.0,29.6)	45.3	(42.2,48.4)	17.4	(15.1,20.0)	10.6	(8.8,12.6)
Mexico City	200	426.5	22.1	(15.6,30.4)	45.5	(37.9,53.4)	21.9	(16.3,28.8)	10.5	(6.3,16.9)
Southern	2000	1082.2	20.4	(18.1,22.8)	44.1	(41.1,47.1)	23.4	(21.2,25.9)	12.1	(10.3,14.2)
Wealth										
Very Low (Q1)	1319	666.0	12.4	(9.9,15.4)	45.8	(41.9,49.6)	23.8	(20.8,27.1)	18.0	(15.1,21.4)
Low (Q2)	1187	629.8	17.6	(15.0,20.6)	43.4	(39.3,47.7)	25.1	(21.5,29.2)	13.8	(11.2,16.9)
Medium (Q3)	1028	584.5	20.0	(17.1,23.4)	48.4	(44.8,52.1)	20.3	(17.3,23.8)	11.1	(8.7,14.2)
High (Q4)	879	575.7	29.1	(25.1,33.5)	44.2	(39.7,48.7)	18.5	(15.1,22.4)	8.2	(6.2,10.8)
Very High (Q5)	674	519.0	47.7	(42.3,53.2)	39.5	(34.4,44.7)	10.0	(7.2,13.6)	2.8	(1.8,4.6)
Maternal Education										
None	349	196.4	10.0	(6.8,14.4)	40.6	(34.2,47.4)	24.7	(19.4,30.9)	24.7	(18.9,31.5)
Primary and/or secondary school	3568	1951.6	19.1	(17.4,20.9)	46.1	(43.7,48.5)	21.5	(19.6,23.6)	13.3	(11.8,15.1)
Beyond secondary school	1165	823.0	40.4	(36.4,44.6)	41.4	(37.6,45.3)	15.1	(12.5,18.1)	3.0	(2.0,4.6)
Beneficiaries of Food Assistance Programs										
Beneficiaries	2246	1187.1	15.7	(13.6,18.1)	45.8	(42.7,48.8)	24.5	(22.1,27.1)	14.0	(12.0,16.3)
Non-beneficiaries	2400	1520.1	30.2	(27.6,33.0)	43.8	(41.1,46.6)	16.9	(14.9,19.1)	9.0	(7.6,10.8)
Indigenous										
Yes	101	1150.9	20.3	(11.7,32.8)	38.3	(27.8,50.1)	29.5	(20.1,40.9)	12.0	(6.4,21.2)
No	1906	41.9	23.5	(21.2,25.9)	44.1	(41.2,47.1)	20.3	(18.0,22.9)	12.0	(9.9,14.3)
	Total		**Food Insecurity Level in scholar**							
			Secure		**Mild**		**Moderate**		**Severe**	

	n	N (thousands)	%	95% IC	%	95% IC	%	95% IC	%	95% IC
Child sex										
Female	4269	2413.0	23.1	(21.3,25.1)	42.3	(40.4,44.3)	20.1	(18.4,22.0)	14.4	(12.9,15.9)
Male	4132	2337.1	24.0	(21.9,26.2)	43.6	(41.3,45.9)	19.8	(18.1,21.6)	12.6	(11.1,14.2)
Residence location										
Urban	5267	3444.7	26.2	(24.3,28.1)	42.0	(39.9,43.9)	18.4	(16.8,20.1)	13.5	(12.1,15.1)
Rural	3134	1306.3	16.7	(14.8,18.8)	45.8	(43.2,48.3)	24.2	(22.1,26.4)	13.4	(11.8,15.3)
Region										
Northern	1796	884.6	29.5	(26.4,32.8)	42.3	(39.2,45.4)	16.2	(13.9,18.8)	12.0	(10.2,14.2)
Central	2928	1446.1	25.8	(23.2,28.5)	45.1	(42.3,47.9)	16.8	(14.8,19.0)	12.3	(10.6,14.2)
Mexico City	353	717.3	25.6	(20.4,31.7)	36.2	(30.4,42.4)	21.6	(16.7,27.5)	16.6	(12.0,22.3)
Southern	3324	1738.9	18.0	(16.2,19.9)	44.2	(42.1,46.5)	23.8	(21.8,25.9)	14.0	(12.4,15.7)
Wealth										
Very Low (Q1)	1977	980.7	9.6	(7.9,11.6)	42.5	(39.1,46.1)	26.2	(23.3,29.4)	21.7	(18.7,25.1)
Low (Q2)	1874	947.06	15.0	(12.9,17.5)	39.6	(36.3,42.9)	25.5	(22.4,28.9)	19.9	(17.1,22.9)
Medium (Q3)	1717	914.6	16.0	(13.6,18.7)	50.5	(46.8,54.2)	19.7	(17.1,22.6)	13.9	(11.5,16.6)
High (Q4)	1583	995.9	29.8	(26.4,33.4)	43.8	(40.4,47.2)	17.4	(14.7,20.5)	9.05	(7.3,11.1)
Very High (Q5)	1250	912.7	48.2	(43.8,52.7)	38.5	(34.7,42.4)	10.7	(8.0,14.1)	2.6	(1.6,4.4)
Maternal Education										
None	651	339.1	13.4	(10.0,17.7)	40.9	(35.8,46.2)	21.6	(17.6,26.1)	24.1	(19.5,29.5)
Primary and/or secondary school	5970	3212.5	18.7	(17.2,20.3)	44.0	(41.9,45.9)	22.0	(20.4,23.7)	15.4	(13.9,16.9)
Beyond secondary school	1780	1199.4	39.5	(35.9,43.1)	41.0	(37.8,44.4)	14.1	(11.8,16.8)	5.4	(4.2,6.9)
Beneficiaries of Food Assistance Programs										
Beneficiaries	4527	2362.1	16.5	(14.9,18.2)	44.9	(42.5,47.3)	22.2	(20.5,24.1)	16.4	(14.6,18.4)
Non-beneficiaries	3299	2032.0	30.8	(28.2,33.4)	41.6	(39.1,44.1)	17.4	(15.4,19.6)	10.2	(8.8,11.9)
Indigenous										
Yes	595	228.1	10.8	(8.0,14.3)	44.4	(39.2,49.8)	26.1	(21.8,30.9)	18.7	(14.7,23.5)
No	7806	4522.9	24.2	(22.7,25.8)	42.9	(41.2,44.5)	19.7	(18.3,21.1)	13.2	(12.1,14.5)

Table 2 describes the nutritional status of the population by household food security/insecurity level. Stunting in preschoolers was more prevalent in households with severe/moderate HFI (over 16% respectively) than in households with mild (13.2%) or no HFI (10.7%). Likewise, wasting was more prevalent in households with severe (3.7%) than in those with mild (1.7%) or moderate (1.9%) HFI or living in food secure households (2.2%).

In preschool children, there were no significant differences in overweight prevalence by HFI level.

While the prevalence of stunting among school-aged children was 10% in households with severe HFI, overweight and obesity were much more prevalent in households with food security (40%) compared with households with mild (34.5%), moderate (32.1%) or severe (28.6%) HFI. The prevalence of maternal obesity was high regardless of HFI status: >70% overall, reaching 77% in mild food insecure households.

Table 2. Prevalence of nutritional status by level of food insecurity

Nutritional status	Food Security			Food Insecurity in Preschool-Age Children								
				Mild			Moderate			Severe		
	N (thousands)	%	(95% IC)	N (thousands)	%	(95% IC)	N (thousands)	%	(95% IC)	N (thousands)	%	(95% IC)
Underweight	8.3	1.1	(0.6,2.1)	40.6	3.0	(2.3,4.1)	18.8	3.1	(2.2,4.6)	15.8	4.7	(2.7,8.1)
Stunting	77.6	10.7	(8.6,13.2)	175.4	13.2	(11.4,15.4)	96.2	16.2	(13.1,19.8)	56.0	16.8	(12.8,21.6)
Wasting	15.8	2.2	(1.1,4.1)	23.1	1.7	(1.0,2.8)	11.1	1.9	(1.1,3.1)	12.5	3.7	(2.0,6.9)
Overweight	75.9	11.0	(8.8,13.5)	120.7	9.7	(8.2,11.5)	47.6	8.3	(6.1,11.2)	31.5	9.6	(6.8,13.3)
Nutritional status	**Food Security**			**Food Insecurity in Schoolers**								
				Mild			**Moderate**			**Severe**		
	N (thousands)	**%**	**(95% IC)**	**N (thousands)**	**%**	**(95% IC)**	**N (thousands)**	**%**	**(95% IC)**	**N (thousands)**	**%**	**(95% IC)**
Stunting	48.4	4.4	(3.3,5.8)	128.7	6.4	(5.4,7.4)	75.8	8.0	(6.3,10.3)	64.2	10.10.1	(7.9,12.7)
Overweight	250.4	23.0	(20.4,25.7)	377.2	18.9	(17.2,20.8)	161.3	17.4	(15.1,19.9)	112.5	17.8	(14.9,21.0)
Obesity	190.6	17.5	(15.1,20.2)	310.8	15.6	(14.0,17.3)	136.4	14.7	(12.5,17.3)	68.6	10.8	(8.3,14.0)
Overweight and Obesity	441.0	40.4	(37.3,43.7)	688.0	34.5	(32.3,36.8)	297.7	32.1	(28.9,35.5)	181.1	28.6	(24.8,32.6)
Nutritional status	**Food Security**			**Food Insecurity in Women**								
				Mild			**Moderate**			**Severe**		
	N (thousands)	**%**	**(95% IC)**	**N (thousands)**	**%**	**(95% IC)**	**N (thousands)**	**%**	**(95% IC)**	**N (thousands)**	**%**	**(95% IC)**
Underweight	20.9	1.2	(0.6,2.1)	22.7	0.69	(0.5,0.9)	19.1	1.2	(0.6,2.5)	12.9	1.3	(0.8,2.3)

Overweight	683.5	37.9	(35.1,40.7)	1301.7	39.8	(37.7,41.9)	563.9	37.2	(33.9,40.8)	344.7	35.6	(31.9,39.5)
Obesity	589.9	32.7	(29.9,35.5)	1206.9	36.9	(34.9,38.9)	584.1	38.6	(35.3,41.9)	365.7	37.8	(33.6,42.3)
Overweight and Obesity	1273.4	70.5	(67.7,73.3)	2508.7	76.7	(74.8,78.6)	1148.0	75.9	(73.1,78.4)	710.4	73.5	(69.8,76.8)

In the logistic regression model for preschool children, the highest prevalence of stunting occurred in households with moderate or severe HFI ($p<0.05$) (Table 3).

Table 3. Logistic regression model for mother-preschooler pairs: Stunting in children <5

	AOR*	P>t	95% CI
Mild HFI	1.261	0.232	(0.9,1.8)
Moderate HFI	1.663	0.036	(1.0, 2.7)
Severe HFI	1.993	0.007	(1.2,3.3)
Maternal obesity	1.402	0.266	(0.8,2.5)
Mild HFI and maternal obesity	0.622	0.207	(0.3,1.3)
Moderate HFI and maternal obesity	0.463	0.069	(0.2,1.1)
Severe HFI and maternal obesity	0.219	0.011	(0.1,0.7)
Age of children	0.889	0.007	(0.8,0.9)
Beneficiaries of food assistance programs	1.239	0.119	(0.9,1.6)
Urbanicity			
Rural	1.421	0.006	(1.1,1.8)
Maternal Education			
Primary school	0.534	<0.001	(0.4,0.8)
Secondary school	0.465	0.001	(0.3,0.7)
Senior high school (*Preparatoria*)	0.342	<0.001	(0.2,0.6)
Bachelor or higher	0.481	0.042	(0.2,0.9)
Const	0.256	0.000	(0.2,0.4)

*Model included all independent variables listed in table.

An interaction between HFI and maternal obesity status was found among preschoolers (Figure 1). Specifically, severe HFI increased the risk of stunting among children with non-obese mothers but not among children with obese mothers. Among preschoolers, there were no significant associations between overweight, HFI and maternal characteristics.

Among school-aged children the logistic regression model revealed a significantly lower prevalence for overweight and obesity among those living in households with mild, moderate and severe HFI ($p<0.05$) (Table 4). A lower prevalence of child overweight/obesity was also found ($p<0.05$) in rural areas ($p=0.007$) and among those with mothers of higher levels of education (bachelors or more) ($p<0.001$).

The logistic regression model for stunting in school age children documented significant associations with maternal characteristics, but not with HFI (data not shown).

Table 4. Logistic regression model for mother-schooler pairs: both mother and child with overweight/obesity: Overweight and obesity in school-aged children

	AOR*	P>t	95% CI
Mild HFI	0.79	0.017	(0.6,0.9)
Moderate HFI	0.72	0.005	(0.57,0.90)
Severe HFI	0.67	0.004	(0.51,0.9)
Maternal Overweight	2.25	<0.001	(1.8,2.8)
Maternal Obesity	3.96	<0.001	(3.3,4.8)
Child age	1.12	<0.001	(1.1,1.2)
Beneficiaries of food assistance programs	0.85	0.039	(0.7,0.9)
Urbanicity			
Rural	0.79	0.007	(0.7,0.9)
Maternal Education			
Primary school	0.87	0.342	(0.6,1.2)
Secondary school	1.11	0.484	(0.8,1.5)
Senior high school (*Preparatoria*)	1.12	0.485	(0.8,1.6)
Bachelor or higher	1.93	<0.001	(1.3,2.9)
Const	0.12	0.000	(0.1,0.2)

*Model included all independent variables listed in table.

Discussion

We sought both to describe the nutritional status of <11-year-old-children and their mothers, and to explore the relationship between their nutritional status and HFI. An important strength of this study is that our research sample is representative of the Mexican population.

Many countries face an increasing prevalence of adult overweight while still struggling with childhood stunting. Our study found, first, that moderate and severe HFI was associated with low height in children under five with mothers who were overweight or obese. Similar results have been obtained by other studies on the double burden of malnutrition, where stunted children live with overweight mothers in the same – particularly in poor - households [27,28]. The problem has been analyzed at the household and individual levels both globally and locally in several countries, Mexico among them [29].

A possible explanation for this phenomenon lies in the fact that excess weight in mothers indicates sufficient income for a diet rich in energy but not necessarily in nutrients. [30]

It can be reasonably inferred that the association between HFI and energy deficit is attributable to variable intra-household resource allocations - especially in poor rural areas - involving less food for children. The diets of overweight mothers suggest a low content of micronutrients alongside a high percentage of energy from saturated fat and refined sugars. These mothers are clearly eating “enough” in terms of energy. Nutritional status is therefore influenced by the quality, diversity,

availability and accessibility of food and the association of these conditions with food security/insecurity [31].

It documented an HFI-weight status correlation which has been labeled a "paradox," in that HFI, which results from insufficient economic resources to purchase food, is associated with obesity, a consequence of overconsumption [15, 32].

Our results agree with those of a previous study where children from HFI weighed less than did their peers from food-secure households. Indeed, their average body weight was within the normal range, whereas their peers from food-secure households were at risk of becoming overweight. In other words, children in HFI do not necessarily need more calories from food to sustain adequate growth.

Furthermore, adequate growth is not the only indicator of nutritional well-being among children living in HFI [28]. Nutritional status is also influenced by the quality of foods consumed. The perception that, on one hand, the HFI-obesity association is a paradox and, on the other, that children and adolescents are protected from HFI by their parents should be replaced by new knowledge from qualitative and quantitative research. It has now been demonstrated that obesity is an expected consequence of HFI for some subpopulations and at certain ages. Moreover, it has been shown that children and adolescents are often affected by HFI through both nutritional and non-nutritional pathways despite parental intentions or beliefs to the contrary [33].

A recent analysis of 16 Latin American countries revealed that all of them were running programs aimed at preventing undernutrition, and most were in the process of implementing obesity prevention strategies as part of their policy agendas [34]. According to the literature, cash transfers and food distribution programs may be prompting increased energy intake at the household level [35, 36] and exacerbating the HFI-obesity link in populations that do not need assistance programs that focus on caloric intake. This has led to concerns about the possible contribution of these programs to obesity in populations who are not energy deficient, and evidences the need for countries with the double burden of malnutrition to include obesity prevention strategies as an essential component of their cash and food transfer programs.

The principal findings of our study are particularly relevant for countries undergoing nutritional transition. Mexico has been witnessing rapid epidemiological and demographic changes with nutritional and environmental components. The health profile of the Mexican population is undergoing a shift from high rates of mortality and infectious diseases - typical of poor countries - to low rates of mortality and high rates of non-communicable diseases - the main cause of mortality in wealthy countries [37].

Our study was subject to several limitations. First, its cross-sectional design restricts the drawing of causal inferences. Additionally, our findings refer specifically to Mexican children and adolescents and similar population but cannot be generalized to other population groups.

Nevertheless, our study also has a number of strengths. Among these, our findings contribute to the limited research available on the relationship between HFI and the nutritional status of mother-child pairs. In addition, this is one of the first studies in this area dealing specifically with the Mexican population. The large sample size of our study constitutes another strength which allowed us to introduce possible confounders in the statistical models.

Recognizing the apparently contradictory co-existence of adult overweight/obesity and child underweight in the same household and understanding its HFI association is a prerequisite for planning effective and integral nutritional strategies. Efforts to abate overnutrition, undernutrition and inadequate dietary quality must be anchored in this knowledge if households at different HFI levels are to see an actual positive change in their nutritional status.

An intriguing finding from our study is that among preschoolers HFI severity increased their risk of stunting if their mothers were not obese. However this was not the case if their mothers were obese. This may be because with the surge of urbanization, household incomes increase and food becomes more available in terms of quantity, but not quality [38]. Specifically the foods available to poor urban households are likely to be high in energy, and it is possible that lack for maternal obesity in food insecure households may indicate that there isn't adequate food quality for the child leading to micronutrient deficiencies and protein quality issues negatively affecting the child's growth, especially height. By contrast, it is possible that maternal obesity indicates better access to calories and nutrients that the child

needs to grow well and hence the lower levels of stunting and relatively lack of responsiveness of stunting to HFI severity among obese mothers.

Conclusions

The double burden of malnutrition in Mexico occurs most notably among mother-child pairs living with HFI. Crafting a sound approach to dealing with malnutrition is complex because of its multi-dimensional character [39]. Policies and programs must tackle chronic under-nutrition and over-nutrition according to the food and nutritional needs of each age group, rather than assuming that these needs will be met by targeting the household as a homogenous unit. This study adds to the evidence emphasizing the importance of monitoring household food security using experience-based scales such as ELCSA that have been deemed highly useful for improving food security governance [40].

List of abbreviations

BMI-Body Mass Index

ELCSA - Caribbean Food Security Scale

ENSANUT 2012 - Mexican National Health and Nutrition Survey in Latin American

HFI - Household Food Insecurity

WHO- World Health Organization

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Availability of data and materials

https://drive.google.com/a/cimat.mx/folderview?id=0BzGYRm5Poz8OdWhGWUhadENBSDA&usp=sharing

Data sharing statement: No additional data available.

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Authors' contributions: The responsibilities of the authors were distributed as follows: TSL and IMGH contributed to data analysis and interpretation. They drafted the manuscript based on the input and feedback of all the co-authors. VMR, LCN and MCMR contributed to the study design and critical review of the manuscript. TSL and RPE contributed to the study design, interpretation of results and critical review of the manuscript. All the authors read and approved the final version of the manuscript.

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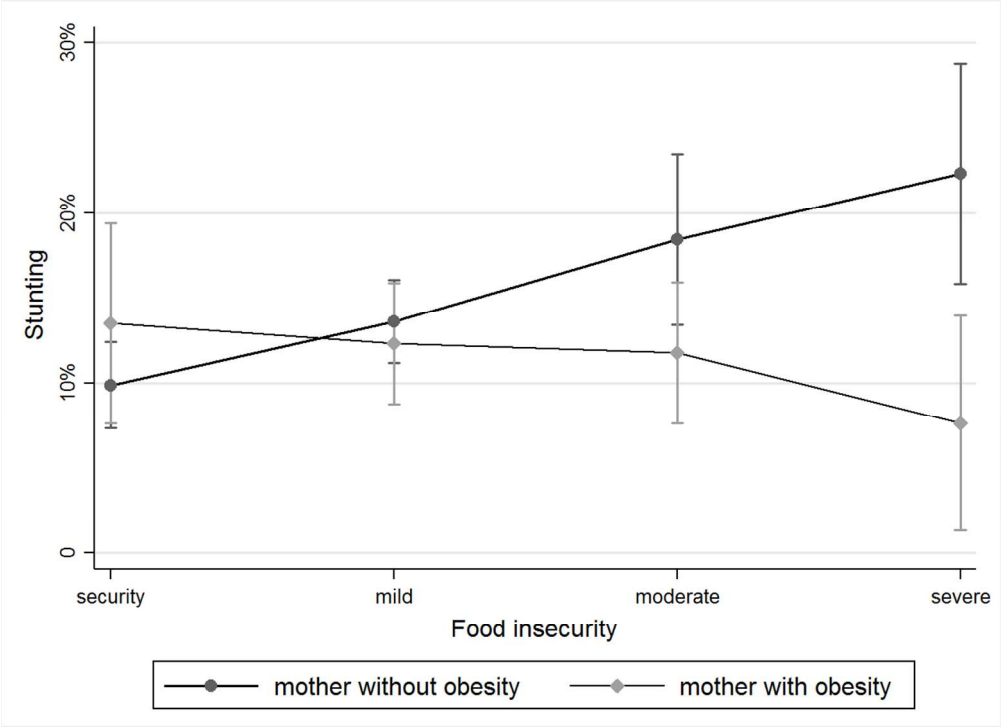

Figure 1. Effect of HFI-maternal obesity interaction on stunting among children <5 years

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Food insecurity and the nutritional status of Mexican mother-child analysis of the National Health and Nutrition Survey 2012

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Abstract

Background. Household Food Insecurity (HFI) has been associated with the presence of overweight mothers and underweight children in the same household. Furthermore, adult obesity has been linked to both child obesity and child undernutrition. The twofold purpose of this article was to examine the association between HFI and risk of childhood stunting, and to determine whether this association is modified by maternal-child overweight/obesity. **Methods.** We assessed the association between HFI and the nutritional status of mothers and their <11-year-old children based on data from the Mexican National Health and Nutrition Survey (*ENSANUT 2012* by its initials in Spanish). Our study sample included 5,087 mother-preschool child pairs and 7,181 mother-schoolchild pairs. HFI was measured according to the Latin American and Caribbean Food Security Scale (*ELCSA* by its initials in Spanish). Multiple logistic regression models were used to examine relevant associations, adjusting for pertinent covariates. **Results.** Stunting proved more prevalent in preschool children with moderate or severe HFI (16.2% and16.8%, respectively) (p=0.036 and p=0.007, respectively) than in their counterparts with mild or no HFI (13.2% and 10.7%, respectively). Furthermore, the interaction between HFI and maternal obesity had a significant impact on stunting in preschool children ($p<0.05$). Specifically, severe HFI increased risk of stunting in children with non-obese mothers but not in those with obese mothers. **Conclusion.** We have discovered a new relationship between HFI and maternal obesity on the one hand and risk of childhood stunting on the other. This may reflect a shared mechanism involving dual forms of malnutrition. Mexico urgently needs anti-HFI policies and programs that prevent chronic child undernutrition coupled with maternal overweight/obesity in the same household.

Keywords. Food insecurity; obesity; undernutrition; nutrition survey; nutrition transition; Mexico

Strengths and limitations of this study

Our study was subject to several limitations. Its cross-sectional design restricts the drawing of causal inferences, and our results cannot be generalized, as they refer specifically to children, adolescents and similar population groups in Mexico.

However, our work also presents a number of strengths. First, our findings provide a significant contribution to the limited research available on the relationship between HFI and the nutritional status of mother-child pairs. Second, this is a pioneering study in the field, dealing specifically with the Mexican population. Third, our large sample size allowed us to introduce possible confounding variables in our statistical models and draw conclusions at the national level. Finally, we identified a phenomenon which is distinctive of the ongoing nutritional transition in Mexico, and is also common to numerous other countries in the world: the double burden of malnutrition in food insecure households.

Our study documents an interesting interaction between HFI and maternal obesity on the one hand and the risk of childhood stunting on the other. This finding could be useful to those who design and implement strategies for improving the health and nutritional status of vulnerable populations. Evidence from our research can serve to craft novel approaches within households suffering from food insecurity, that is, strategies that respond to the needs of people afflicted by overweight/obesity and children with malnutrition.

Introduction

Background

Food security "exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life, and is supported by an environment of adequate sanitation, health services and care" [1, 2].

The term hunger refers both to a feeling of discomfort from not eating and to the state of undernutrition, particularly within the context of food insecurity (FI) [3]. Experience-based indices can serve to assess hunger directly at the household level [4].

Household Food Insecurity (HFI) has been defined as "limited or uncertain availability of nutritionally adequate and safe food and also as limited and uncertain ability to acquire adequate food in socially acceptable ways" [5].

FI is a growing concern worldwide. It is estimated that over one billion people suffer from insufficient availability of dietary energy, and at least twice that number suffer from micronutrient deficiency [6].

FI in Mexico has evolved within a complex and contrasting environment where undernutrition and overweight/obesity, together, form part of an advanced nutritional transition characterized by widespread HFI. One out of three Mexican households suffers from moderate or severe FI. This condition heightens not only

the risk of malnutrition in children, but also the incidence of diabetes, overweight and obesity in adults, principally among women [7].

Recent studies have suggested a link between HFI and obesity [8], especially in adult women [9-11]. For instance, it has been documented that women with FI are more likely to suffer from obesity than women without FI [12]. It has also been reported that racial/ethnic minority communities and low-income households are the population groups most severely affected by HFI [13].

Generally viewed as separate public health problems, there is growing concern that FI and obesity may be related. FI can lead to weight gain because high-fat, high-calorie and energy-dense foods offer the least expensive option for obtaining calories [14], and these products, available at lower prices than healthful foods [15], have been identified as risk factors for child and adult obesity [16]. Furthermore, HFI can trigger disorderly eating patterns characterized by binging and restricted eating, depending on the availability of supplies, thus negatively affecting the body's metabolism [17].

Recent decades have witnessed alarming increases in prevalence of overweight/obesity among Mexican children: from 7.8% in 1988 to 9.7% in 2012 for children under five; from 26.9% in1999 to 34.4% in 2012 for 5-11-year olds; and from 11.1% in1988 to 35.8% in 2012 for female adolescents aged 12-19 years. In the adult population aged 20 and older, prevalence jumped from 61.8% to 71.3% in twelve years [18].

In 2012, children under five living in severe-FI households indicated 42% higher risk of stunting or chronic malnutrition than did their counterparts living in food secure households [19]. That same year women aged 20 to 59 had an average BMI of 28.9. More specifically, those living in mild, moderate and severe HFI had BMIs of 28.3, 29.3 and 29.4, respectively ($p<0.001$, $p=0.011$ and $p=0.007$, respectively) [11].

The double burden of malnutrition can occur not only within the same country, city or household (mother-child pairs), but also within the same individual at different stages of his or her life [20]. The fact that HFI may be associated with both undernutrition and obesity has been documented [17].

The twofold purpose of this article is to examine the association between HFI and risk of childhood stunting, and to determine whether this association is modified by maternal-child overweight/obesity.

Methods

Study population

Data were drawn from *ENSANUT 2012*, a cross-sectional, probabilistic and cluster survey with national, regional, urban-rural and state-level representativity. Oversampling was directed to Mexican households of lower socioeconomic status. A sample of 50,528 households of an estimated 29,429,252 households nationwide was obtained between October 2011 and May 2012. Details of sample size and design have been described elsewhere [21].

Our study consisted of a secondary analysis based on *ENSANUT 2012*. A total of 5,087 preschool children (1-4y), 8,401 schoolchildren (5-11y) and 9,581 mothers were included in the survey. We used a matching process to identify mother-preschool child and mother-schoolchild pairs, and included a total of 5,087 mother-preschool child pairs in our analysis. None of the mothers in this group had more than one child. A total of 7,181 mother-schoolchild pairs were included, with 2,432 mothers having more than one schoolchild, in which cases only one schoolchild was used in the matching process. Finally, the 2,677 mothers in the sample who had preschool children and schoolchildren were included in both pair groups.

Our analytical sample included 5,087 mother-preschool child pairs and 7,181 mother-schoolchild pairs with complete data. Where mothers had more than one schoolchild meeting the study criteria, analysis considered all their children.

Informed consent was obtained from all respondents – or their parents/guardians in cases of children under seven years – prior to their participation in the study. The survey protocol was approved by the Ethics Committee of the National Institute of Public Health in Mexico.

HFI measurement

HFI was measured using a version of the Latin American and Caribbean Food Security Scale (*ELCSA* by its initials in Spanish). The scale included 15 questions targeting the head of the family or the woman in charge of preparing meals. Eight questions referred directly to HFI either in the household or specifically in the adults within the household; the remaining seven referred to HFI in minors (<18y).

The reference time frame was three months prior to survey administration. Based on the number of positive responses, and depending on whether or not households included people under 18, they were grouped into the following categories: households with no HFI (0 positive responses), mild HFI (1 to 3), moderate HFI (4 to 6), and severe HFI (7 to 8); and households with adults and minors under 18: no HFI (0 positive responses), mild HFI (1 to 5), moderate HFI (6 to 10), and severe HFI (11 to 15)[22]. The ELCSA has been validated in populations in the United States as well as in Mexico and other Latin American countries [23-25].

Anthropometric measurements

Weight and recumbent length measures were obtained from children < 2 and standing height measures from children aged 2 to < 5 following standard recommended procedures [26,27].

The anthropometric measures together with the age and sex of the children were used to calculate the weight-for-age, height-for-age, and weight-for-height z-scores according to the WHO growth standards [28]. Prevalence of undernutrition in its different forms (underweight, wasting and stunting) was calculated using the < -2 z-score cut-off point using the WHO growth standards.

Overweight and obesity were determined according to the WHO Growth Reference charts [29], with BMI (kg/m^2) z-scores adjusted for age: values between -5.0 and +5.0 were considered outside this range and regarded as implausible. There were no implausible values for BMI z-scores in children. For adults, the WHO standard BMI cut-off points were used to classify mothers into the following categories:

underweight (<18.5 kg/m^2), normal weight (18.5 to 24.9 kg/m^2), overweight (25-29.9 kg/m^2) and obese (≥ 30 kg/m^2) [30]. Only BMI values between 10 and 58 were considered; no BMI values were regarded as implausible.

Covariates

The following covariates were included in our statistical analyses: sex of the child, urbanicity (urban/rural), region of residence (northern, central, southern and Mexico City), and maternal education: none, primary, secondary, high school (*preparatoria* according to its Spanish equivalent) and university (bachelor's degree and beyond). Benefiting from a food assistance program was also included.

Socioeconomic Index

We used a standard socioeconomic status (SES) index developed in Mexico on the basis of various household characteristics: type of floor, wall and ceiling materials; the ratio of number of rooms used for sleeping to number of persons residing in the household; basic service infrastructure including water source and water disposal; and possession of domestic appliances such as a refrigerator, washing machine, microwave oven, stove, boiler, radio, television, cable television signal, telephone and computer. This SES index was selected to facilitate comparison with previous surveys in Mexico [31].

Ethical considerations

All study procedures involving human participants were approved by the Ethics Committee of the National Institute of Public Health in Mexico. Written informed

consent was obtained from all survey participants. Parents/guardians served as proxies for minors < 7 years.

Statistical analyses

We calculated the prevalence (95% CI) of each HFI category by socioeconomic characteristic and maternal-child nutritional status. We then conducted logistic regression models for stunting and overweight among preschool children and for stunting and overweight/obesity among schoolchildren, adjusting for pertinent covariates. The cluster effect for mothers with more than one schoolchild was tested and proved non-significant. No mothers had more than one preschool child. Results were expressed as Adjusted Odds Ratios (AORs) with their corresponding 95% confidence intervals. Prevalence estimates and logistic regression models considered clustered sample effects and sampling weights using STATA 13 SVY procedures for complex surveys.

Results

Our analytical sample included 5,087 pairs of mother-preschool children and 7,181 mother-schoolchild pairs with complete data.

In the mother-preschool child pairs, moderate HFI was significantly more prevalent among those residing in the southern, as opposed to the northern or central, regions of Mexico. As expected, severe HFI was five and six times more prevalent in the low and very low quintiles, respectively, than in the top quintile. Moderate and severe HFI were more prevalent in households with mothers who had not

studied beyond junior high school, and with beneficiaries of government food-assistance programs (Table 1).

Similarly, in the mother-schoolchild pairs, general HFI was more prevalent among those living in southern Mexico than among those living in the north. In addition, HFI was higher in the low and very low socioeconomic quintiles. Prevalence of moderate and severe HFI was significantly higher among those pairs where the mothers had not studied beyond junior high school, benefited from government food-assistance programs and belonged to an indigenous population group (Table 1).

Table 1. FI level according to the socio-demographic characteristics of the mother-preschool child and mother-schoolchild pairs

	Total	N* (thousands)	Food Insecurity Level in preschool children							
			Secure		Mild		Moderate		Severe	
	n		%	95% CI	%	95% CI	%	95% CI	%	95% CI
Sex of child										
Female	2539	1452.9	24.2	(21.7,26.79)	43.8	(40.9,46.6)	21.6	(19.5,23.8)	10.5	(9.0,12.2)
Male	2548	1522.1	24.7	(22.3,27.13)	45.0	(42.4,47.7)	18.4	(16.5,20.6)	11.9	(10.3,13.8)
Urbanicity										
Urban	3142	2123.0	26.8	(24.6 ,29.1)	43.3	(40.9,45.8)	18.9	(17.1,20.9)	10.9	(9.4,12.6)
Rural	1945	851.9	18.5	(16.3,20.9)	47.0	(43.8,50.2)	22.4	(20.1,25.0)	12.0	(10.3,14.1)
Region										
Northern	1083	524.5	30.5	(27.2,34.0)	42.5	(38.9,46.2)	15.8	(13.3,18.6)	11.2	(9.2,13.5)
Central	1804	941.8	26.7	(24.0,29.6)	45.3	(42.2,48.4)	17.4	(15.1,20.0)	10.6	(8.8,12.6)
Mexico City	200	426.5	22.1	(15.6,30.4)	45.5	(37.9,53.4)	21.9	(16.3,28.8)	10.5	(6.3,16.9)
Southern	2000	1082.2	20.4	(18.1,22.8)	44.1	(41.1,47.1)	23.4	(21.2,25.9)	12.1	(10.3,14.2)
SES										
Very Low (Q1)	1319	666.0	12.4	(9.9,15.4)	45.8	(41.9,49.6)	23.8	(20.8,27.1)	18.0	(15.1,21.4)
Low (Q2)	1187	629.8	17.6	(15.0,20.6)	43.4	(39.3,47.7)	25.1	(21.5,29.2)	13.8	(11.2,16.9)
Medium (Q3)	1028	584.5	20.0	(17.1,23.4)	48.4	(44.8,52.1)	20.3	(17.3,23.8)	11.1	(8.7,14.2)
High (Q4)	879	575.7	29.1	(25.1,33.5)	44.2	(39.7,48.7)	18.5	(15.1,22.4)	8.2	(6.2,10.8)
Very High (Q5)	674	519.0	47.7	(42.3,53.2)	39.5	(34.4,44.7)	10.0	(7.2,13.6)	2.8	(1.8,4.6)
Maternal Education										
None	349	196.4	10.0	(6.8,14.4)	40.6	(34.2,47.4)	24.7	(19.4,30.9)	24.7	(18.9,31.5)

Primary and/or secondary school	3568	1951.6	19.1	(17.4,20.9)	46.1	(43.7,48.5)	21.5	(19.6,23.6)	13.3	(11.8,15.1)
Beyond secondary school	1165	823.0	40.4	(36.4,44.6)	41.4	(37.6,45.3)	15.1	(12.5,18.1)	3.0	(2.0,4.6)
Beneficiaries of Food Assistance Programs										
Beneficiaries	2246	1187.1	15.7	(13.6,18.1)	45.8	(42.7,48.8)	24.5	(22.1,27.1)	14.0	(12.0,16.3)
Non-beneficiaries	2400	1520.1	30.2	(27.6,33.0)	43.8	(41.1,46.6)	16.9	(14.9,19.1)	9.0	(7.6,10.8)
Indigenous										
Yes	101	1150.9	20.3	(11.7,32.8)	38.3	(27.8,50.1)	29.5	(20.1,40.9)	12.0	(6.4,21.2)
No	1906	41.9	23.5	(21.2,25.9)	44.1	(41.2,47.1)	20.3	(18.0,22.9)	12.0	(9.9,14.3)

		N*	Food Insecurity Level in schoolchildren							
	Total n	(thousands)	Secure %	Secure 95% CI	Mild %	Mild 95% CI	Moderate %	Moderate 95% CI	Severe %	Severe 95% CI
Sex of child										
Female	4269	2413.0	23.1	(21.3,25.1)	42.3	(40.4,44.3)	20.1	(18.4,22.0)	14.4	(12.9,15.9)
Male	4132	2337.1	24.0	(21.9,26.2)	43.6	(41.3,45.9)	19.8	(18.1,21.6)	12.6	(11.1,14.2)
Urbanicity										
Urban	5267	3444.7	26.2	(24.3,28.1)	42.0	(39.9,43.9)	18.4	(16.8,20.1)	13.5	(12.1,15.1)
Rural	3134	1306.3	16.7	(14.8,18.8)	45.8	(43.2,48.3)	24.2	(22.1,26.4)	13.4	(11.8,15.3)
Region										
Northern	1796	884.6	29.5	(26.4,32.8)	42.3	(39.2,45.4)	16.2	(13.9,18.8)	12.0	(10.2,14.2)
Central	2928	1446.1	25.8	(23.2,28.5)	45.1	(42.3,47.9)	16.8	(14.8,19.0)	12.3	(10.6,14.2)
Mexico City	353	717.3	25.6	(20.4,31.7)	36.2	(30.4,42.4)	21.6	(16.7,27.5)	16.6	(12.0,22.3)
Southern	3324	1738.9	18.0	(16.2,19.9)	44.2	(42.1,46.5)	23.8	(21.8,25.9)	14.0	(12.4,15.7)
SES										
Very Low (Q1)	1977	980.7	9.6	(7.9,11.6)	42.5	(39.1,46.1)	26.2	(23.3,29.4)	21.7	(18.7,25.1)
Low (Q2)	1874	947.06	15.0	(12.9,17.5)	39.6	(36.3,42.9)	25.5	(22.4,28.9)	19.9	(17.1,22.9)
Medium (Q3)	1717	914.6	16.0	(13.6,18.7)	50.5	(46.8,54.2)	19.7	(17.1,22.6)	13.9	(11.5,16.6)
High (Q4)	1583	995.9	29.8	(26.4,33.4)	43.8	(40.4,47.2)	17.4	(14.7,20.5)	9.05	(7.3,11.1)
Very High (Q5)	1250	912.7	48.2	(43.8,52.7)	38.5	(34.7,42.4)	10.7	(8.0,14.1)	2.6	(1.6,4.4)
Maternal Education										
None	651	339.1	13.4	(10.0,17.7)	40.9	(35.8,46.2)	21.6	(17.6,26.1)	24.1	(19.5,29.5)
Primary and/or secondary school	5970	3212.5	18.7	(17.2,20.3)	44.0	(41.9,45.9)	22.0	(20.4,23.7)	15.4	(13.9,16.9)
Beyond secondary school	1780	1199.4	39.5	(35.9,43.1)	41.0	(37.8,44.4)	14.1	(11.8,16.8)	5.4	(4.2,6.9)
Beneficiaries of Food Assistance Programs										
Beneficiaries	4527	2362.1	16.5	(14.9,18.2)	44.9	(42.5,47.3)	22.2	(20.5,24.1)	16.4	(14.6,18.4)
Non-beneficiaries	3299	2032.0	30.8	(28.2,33.4)	41.6	(39.1,44.1)	17.4	(15.4,19.6)	10.2	(8.8,11.9)
Indigenous										
Yes	595	228.1	10.8	(8.0,14.3)	44.4	(39.2,49.8)	26.1	(21.8,30.9)	18.7	(14.7,23.5)
No	7806	4522.9	24.2	(22.7,25.8)	42.9	(41.2,44.5)	19.7	(18.3,21.1)	13.2	(12.1,14.5)

* N refers to the sample population size.

Table 2 describes the nutritional status of the population by household food security/insecurity level. Stunting in preschool children was more prevalent in households with severe/moderate HFI (over 16% respectively) than in those with mild (13.2%) or no HFI (10.7%). Likewise, wasting was more prevalent in households with severe (3.7%) than in those with mild (1.7%), moderate (1.9%) or no HFI (2.2%).

Preschool children presented no significant differences in prevalence of overweight by HFI level.

While prevalence of stunting among schoolchildren was 10% in households with severe HFI, prevalence of overweight/obesity was markedly higher in households with food security (40%) as compared to households with mild (34.5%), moderate (32.1%) or severe (28.6%) HFI. Prevalence of maternal obesity was high regardless of HFI status: > 70% overall and 77% in mild HFI households.

Table 2. Prevalence of nutritional status by level of food insecurity

Nutritional status	Food Security			Food Insecurity in Preschool Children								
				Mild			Moderate			Severe		
	N* (thousands)	%	(95% CI)	N* (thousands)	%	(95% CI)	N* (thousands)	%	(95% CI)	N* (thousands)	%	(95% CI)
Underweight(1)	8.3	1.1	(0.6,2.1)	40.6	3.0	(2.3,4.1)	18.8	3.1	(2.2,4.6)	15.8	4.7	(2.7,8.1)
Stunting(2)	77.6	10.7	(8.6,13.2)	175.4	13.2	(11.4,15.4)	96.2	16.2	(13.1,19.8)	56.0	16.8	(12.8,21.6)
Wasting(3)	15.8	2.2	(1.1,4.1)	23.1	1.7	(1.0,2.8)	11.1	1.9	(1.1,3.1)	12.5	3.7	(2.0,6.9)
Overweight(4)	75.9	11.0	(8.8,13.5)	120.7	9.7	(8.2,11.5)	47.6	8.3	(6.1,11.2)	31.5	9.6	(6.8,13.3)

Nutritional status	Food Security			Food Insecurity in Schoolchildren								
				Mild			Moderate			Severe		
	N* (thousands)	%	(95% CI)	N* (thousands)	%	(95% CI)	N* (thousands)	%	(95% CI)	N* (thousands)	%	(95% CI)
Stunting(2)	48.4	4.4	(3.3,5.8)	128.7	6.4	(5.4,7.4)	75.8	8.0	(6.3,10.3)	64.2	10.1	(7.9,12.7)
Overweight(5)	250.4	23.0	(20.4,25.7)	377.2	18.9	(17.2,20.8)	161.3	17.4	(15.1,19.9)	112.5	17.8	(14.9,21.0)
Obesity(4)	190.6	17.5	(15.1,20.2)	310.8	15.6	(14.0,17.3)	136.4	14.7	(12.5,17.3)	68.6	10.8	(8.3,14.0)
Overweight and Obesity	441.0	40.4	(37.3,43.7)	688.0	34.5	(32.3,36.8)	297.7	32.1	(28.9,35.5)	181.1	28.6	(24.8,32.6)

Nutritional status	Food Security			Food Insecurity in Women								
				Mild			Moderate			Severe		
	N* (thousands)	%	(95% CI)	N* (thousands)	%	(95% CI)	N* (thousands)	%	(95% CI)	N* (thousands)	%	(95% CI)
Underweight(6)	20.9	1.2	(0.6,2.1)	22.7	0.69	(0.5,0.9)	19.1	1.2	(0.6,2.5)	12.9	1.3	(0.8,2.3)
Overweight(7)	683.5	37.9	(35.1,40.7)	1301.7	39.8	(37.7,41.9)	563.9	37.2	(33.9,40.8)	344.7	35.6	(31.9,39.5)
Obesity(8)	589.9	32.7	(29.9,35.5)	1206.9	36.9	(34.9,38.9)	584.1	38.6	(35.3,41.9)	365.7	37.8	(33.6,42.3)
Overweight and Obesity	1273.4	70.5	(67.7,73.3)	2508.7	76.7	(74.8,78.6)	1148.0	75.9	(73.1,78.4)	710.4	73.5	(69.8,76.8)

* N refers to the sample population size.
(1) Z-score cut-off point of <-2 standard deviations to classify low weight-for-age, WHO
(2) Z-score cut-off point of <-2 standard deviations to classify low height-for-age, WHO
(3) Z-score cut-off point of <-2 standard deviations to classify low weight-for-height-, WHO
(4) Z-score cut-off point of >+2 standard deviations to classify body mass index (BMI)-for-age, WHO

(5) Z-score cut-off point of >+1 and ≤+2 standard deviations to classify body mass index (BMI)-for-age, WHO
(6) BMI <18.5 kg/m2
(7) BMI 25-29.9 kg/m2
(8) BMI ≥ 30 kg/m2

In the logistic regression model for preschool children, prevalence of stunting was significantly higher (AOR>1, p<0.05) in households with moderate or severe HFI as opposed to mild HFI (Table 3).

Table 3. Logistic regression model for mother-preschool child pairs: Stunting in children < 5 years old

	AOR*	p-value	95% CI
Mild HFI	1.261	0.232	(0.9,1.8)
Moderate HFI	1.663	0.036	(1.0, 2.7)
Severe HFI	1.993	0.007	(1.2,3.3)
Maternal obesity	1.402	0.266	(0.8,2.5)
Mild HFI and maternal obesity	0.622	0.207	(0.3,1.3)
Moderate HFI and maternal obesity	0.463	0.069	(0.2,1.1)
Severe HFI and maternal obesity	0.219	0.011	(0.1,0.7)
Age of children	0.889	0.007	(0.8,0.9)
Beneficiaries of food assistance programs	1.239	0.119	(0.9,1.6)
Urbanicity			
Rural	1.421	0.006	(1.1,1.8)
Maternal Education			
Primary school	0.534	<0.001	(0.4,0.8)
Secondary school	0.465	0.001	(0.3,0.7)
Senior high school (*Preparatoria*)	0.342	<0.001	(0.2,0.6)
Bachelor or higher	0.481	0.042	(0.2,0.9)
Const	0.256	0.000	(0.2,0.4)

*Model included all independent variables listed in the table.

We identified an interaction between HFI and maternal obesity. Estimated marginal prevalence rates and confidence intervals obtained from the logistic regression model are plotted in Figure 1. Severe HFI raises the risk of stunting in children with non-obese mothers but not in children with obese mothers. Preschool children showed no significant interaction between HFI, overweight and maternal characteristics.

For schoolchildren, the logistic regression model revealed a significantly lower prevalence of overweight and obesity among those with mild, moderate or severe HFI ($p<0.05$) (Table 4), mothers having higher levels of education (bachelor's and beyond) ($p<0.001$), and residence in rural areas ($p=0.007$).

The logistic regression model for stunting in schoolchildren documented significant associations of this condition with maternal characteristics but not with HFI (data not shown).

Table 4. Logistic regression model for mother-schoolchild pairs: both mother and child with overweight/obesity: Overweight and obesity in schoolchildren

	AOR*	p-value	95% CI
Mild HFI	0.79	0.017	(0.6,0.9)
Moderate HFI	0.72	0.005	(0.57,0.90)
Severe HFI	0.67	0.004	(0.51,0.9)
Maternal Overweight	2.25	<0.001	(1.8,2.8)
Maternal Obesity	3.96	<0.001	(3.3,4.8)
Age of child	1.12	<0.001	(1.1,1.2)
Beneficiaries of food assistance programs	0.85	0.039	(0.7,0.9)
Urbanicity			
Rural	0.79	0.007	(0.7,0.9)
Maternal Education			
Primary school	0.87	0.342	(0.6,1.2)
Secondary school	1.11	0.484	(0.8,1.5)
Senior high school (*Preparatoria*)	1.12	0.485	(0.8,1.6)
Bachelor or higher	1.93	<0.001	(1.3,2.9)
Const	0.12	0.000	(0.1,0.2)

*Model included all independent variables listed in table.

Discussion

We sought to describe the nutritional status of <11-year-old-children and their mothers, and to explore the relationship between their nutritional status and HFI. One of the strengths of this study concerns the fact that our research sample was representative of the Mexican population.

Many countries are witnessing an increase in the prevalence of adult overweight while still struggling with childhood stunting. Our study found that moderate and severe HFI were associated with low height in children who were under five and lived with mothers with overweight or obesity. Similar results have been obtained by other studies on the double burden of malnutrition, where stunted children live with overweight mothers in the same, and particularly in poor, households [32-33]. The problem has been analyzed at the household and individual levels both globally and within a number of countries, Mexico among them [34].

Studies conducted in the Latin American and Arctic regions have demonstrated that FI households exhibit not only a reduced variety of available food, but also inadequate consumption of fruits and vegetables [35] and foods of animal origin [36-37]. These findings have been explained by insufficient local food availability as well as the presence of inferior-quality, high-cost foods, both of which favor the choice of widely available cheaper foods of low nutritional value [38]. It has been reported that FI in Mexico has similar effects to those observed in the rest of Latin America as regards dietary diversity and food availability. Mexican children under five are not receiving the recommended daily energy intake [39] and female heads of household show diminished dietary diversity [40].

Evidence from a study of < 5 children of Mexican origin living in immigrant communities in California and in Mexico itself underscores the fact that FI contributes not only to increased energy and fat intake as a result of consuming cheap and energy-rich foods such as snacks, sweets and fried foods, but also to increased consumption of meat, especially fried chicken. For children living in Mexico, FI was associated with low consumption of carbohydrates, dairy products and vitamin B6 [41].

The pathway through which FI can lead to an increase in body fat is based on the following factors: (1) Diets characterized by high quantities of fat and carbohydrates together with a limited variety of vegetables are associated with high energy intake and a subsequent increase in body fat [42,43]. (2) According to one hypothesis, involuntary restriction of food including episodic lack of access can lead to compulsive eating and to ignoring internal signs of satiety [44], as well as to physiological adaptations in response to the periodic scarcity of food [17].

Conversely, our study demonstrated an association between FI and stunting among Mexican preschool children. The way in which FI negatively affects the nutritional state of these children relates largely to insufficient consumption of highly nutritious foods (such as products of animal origin, fruits and vegetables) coupled with recurrent infections and unhealthy living conditions linked to poverty. These factors contribute to loss of appetite, an increase in metabolic requirements and a deficit of nutrients [45].

Our results agree with those of a previous study where children from HFI households weighed less than their peers from food-secure households. Their

average body weight was within the normal range, whereas their peers were at risk of becoming overweight.

Adequate growth is not the only indicator of nutritional well-being among children living with HFI [36]. Nutritional status is also influenced by the quality of foods consumed. It has been demonstrated that obesity is an expected consequence of HFI for some subpopulations and at certain ages. Moreover, it has been shown that children and adolescents are often affected by HFI through both nutritional and non-nutritional pathways despite parental intentions or beliefs to the contrary [46].

A recent analysis of 16 Latin American countries revealed that all of them were running programs aimed at preventing undernutrition, and most were in the process of implementing obesity prevention strategies as part of their policy agendas [47]. According to the literature, cash transfers and food distribution programs may be triggering increased energy intake at the household level [48,49] and exacerbating the HFI-obesity link in populations that do not need assistance programs focused on caloric intake. This has raised concerns about the possible contribution of these programs to obesity in populations who are not energy deficient, and highlights the need for countries with a double burden of malnutrition to include obesity prevention strategies as an essential component of their cash and food transfer programs.

The principal findings of our study are particularly relevant for countries undergoing nutritional transition. Mexico has been facing rapid epidemiological and demographic changes with nutritional and environmental components. The health

profile of the Mexican population indicates a shift from high rates of mortality and infectious diseases - typical of poor countries - to low rates of mortality and high rates of non-communicable diseases - the main cause of mortality in wealthy countries [50].

Our study was subject to several limitations. First, its cross-sectional design restricts the drawing of causal inferences. Additionally, its findings refer specifically to Mexican children, adolescents and similar population groups, and therefore cannot be generalized to others.

Nevertheless, our study also has a number of strengths. For instance, our findings contribute to the limited research available on the relationship between HFI and the nutritional status of mother-child pairs. In addition, this is one of the first studies in this field dealing specifically with the Mexican population. The large sample size of our study constitutes another strength. It allowed us to introduce possible confounders in the statistical models and to provide evidence useful at the national level.

In order to develop effective and integral nutritional strategies, policymakers need to recognize the apparently contradictory presence of adult overweight/obesity and childhood stunting in the same household and understand its association with HFI. For households at different HFI levels to experience an actual improvement in their nutritional status, efforts to abate overnutrition, undernutrition and inadequate dietary quality must be rooted in this knowledge.

Interestingly, our study found that, in preschool children, HFI severity increased the risk of stunting only if their mothers were not obese. This may be explained by the growth of urbanization resulting in higher household incomes and greater food availability, but only as regards quantity, not quality [51]. The foods available to poor urban households are likely to be energy-rich but nutrient-poor. The presence of non-obese mothers in FI households may indicate a dearth of adequate quality food for children redounding in micronutrient deficiencies and protein quality issues that hinder their growth - particularly in relation to height. By contrast, the presence of maternal obesity in FI households may indicate greater access to the calories and nutrients needed for adequate child development, and may also account for the lower prevalence of stunting in these homes. This may explain the relative lack of any relationship of stunting to HFI severity in households with obese mothers.

Conclusions

The double burden of malnutrition in Mexico occurs most notably among mother-child pairs living with HFI. Crafting a sound approach to combat malnutrition is complex because of its multi-dimensional nature [52]. These conditions hamper the implementation of effective measures capable of protecting vulnerable population groups and ensuring adequate livelihoods. Policies and programs must tackle chronic undernutrition and overnutrition according to the food and nutritional needs of each age group, rather than assuming that their needs will be met by targeting the household as a homogenous unit. Consistent with other studies, our work highlights the importance of monitoring household food security based on

experience-related scales such as ELCSA. These have proved highly useful for food security governance [53].

List of abbreviations

BMI - Body Mass Index

ELCSA - Latin American and Caribbean Food Security Scale

ENSANUT 2012 - Mexican National Health and Nutrition Survey in Latin American

HFI - Household Food Insecurity

WHO - World Health Organization

Declarations

Ethics approval and consent to participate

All study procedures involving human participants were approved by the Ethics Committee of the National Institute of Public Health in Mexico. Written informed consent was obtained from all survey participants, with parents serving as proxies of minors under seven years.

Availability of data and materials

https://drive.google.com/a/cimat.mx/folderview?id=0BzGYRm5Poz8OdWhGWUhadENBSDA&usp=sharing

Competing interests

The authors declared no conflict of interest.

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Authors' contributions

The responsibilities of the authors were distributed as follows: TSL and IMGH contributed to data analysis and interpretation. They drafted the manuscript based on the input and feedback of all the co-authors. VMR, LCN and MCMR contributed

to the study design and critical review of the manuscript. TSL and RPE contributed to the study design, interpretation of results and critical review of the manuscript. All the authors read and approved the final version of the manuscript.

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Figure 1. Effect of HFI-maternal obesity interaction on stunting among children <5 years

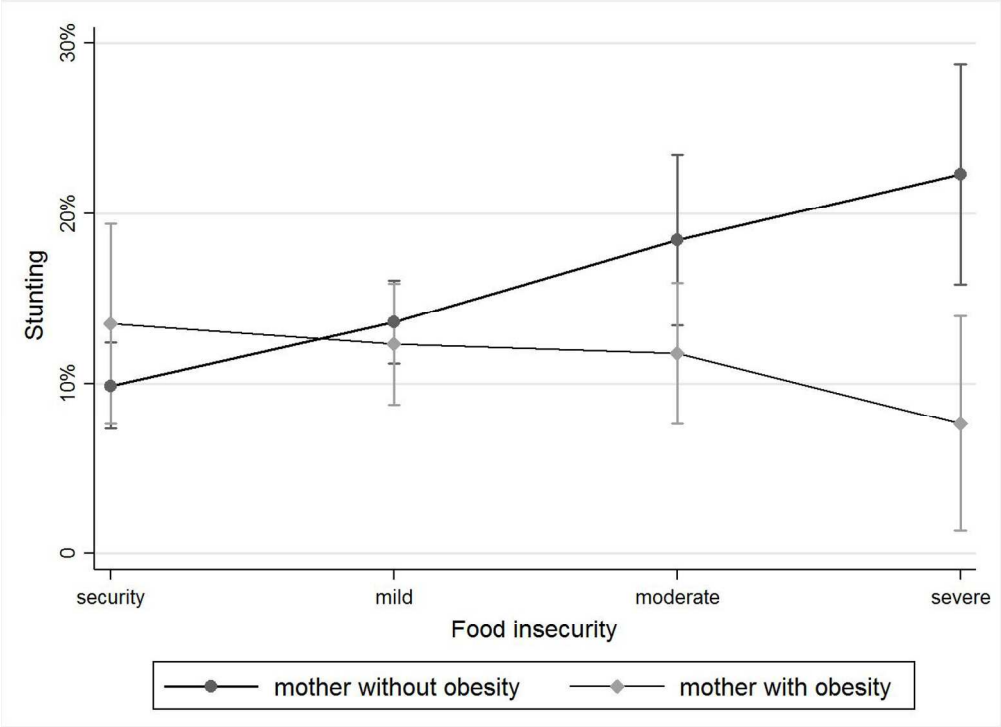

Figure 1. Effect of HFI-maternal obesity interaction on stunting among children <5 years

340x247mm (300 x 300 DPI)

Checklist of items that included in the manuscript: Food insecurity and the nutritional status of Mexican mother-child pairs

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Food insecurity and maternal-child nutritional status in Mexico: cross-sectional analysis of the National Health and Nutrition Survey 2012

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Abstract

Objective To examine the association between Household Food Insecurity (HFI) and risk of childhood stunting, and to determine whether this association is modified by maternal-child overweight/obesity.

Design Observational cross-sectional study.

Setting Data comes from the Mexican National Health and Nutrition Survey (*ENSANUT 2012* by its initials in Spanish), representative of rural and urban areas.

Participants Our study sample included 5,087 mother-preschool child pairs and 7,181 mother-schoolchild pairs. HFI was measured according to the Latin American and Caribbean Food Security Scale (*ELCSA* by its initials in Spanish). Weight and recumbent length or height measures were obtained from children. Overweight and obesity in women were determined according to the WHO Growth Reference charts. The following covariates were included: sex of the child, urbanicity (urban/rural), region of residence, and maternal education, benefiting from a food assistance programs and socioeconomic status (SES) index was included.

Main outcome measures Differences in the prevalence (95%. CI) of each HFI category by socioeconomic characteristic and maternal-child nutritional status was estimated. A logistic regression model was conducted for stunting and overweight among preschool children and for stunting and overweight/obesity among schoolchildren, adjusting for pertinent covariates. Results were expressed as Adjusted Odds Ratios (AORs).

Results Stunting proved more prevalent in preschool children with moderate or severe HFI (16.2% and16.8%, respectively) (p=0.036 and p=0.007, respectively) than in their counterparts with mild or no HFI (13.2% and 10.7%, respectively). Furthermore, the interaction between HFI and maternal obesity had a significant impact on stunting in preschool children (p<0.05). Severe HFI increased risk of stunting in children with non-obese mothers but not in those with obese mothers.

Conclusion We have discovered a new relationship between HFI and maternal obesity on the one hand and risk of childhood stunting on the other. This may reflect a shared mechanism involving dual forms of malnutrition.

Strengths and limitations of this study

- The cross-sectional study design restricts the drawing of causal inferences, and our results cannot be generalized, as they refer specifically to children, adolescents and similar population groups in Mexico.
- The findings of the study provide a significant contribution to the limited research available on the relationship between HFI and the nutritional status of mother-child pairs.
- This study is a pioneering study in the field, dealing specifically with the Mexican population.
- The large sample size of the study allowed us to introduce possible confounding variables in our statistical models and draw conclusions at the national level.

Introduction

Background

Food security "exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life, and is supported by an environment of adequate sanitation, health services and care" [1, 2].

The term hunger refers both to a feeling of discomfort from not eating and to the state of undernutrition, particularly within the context of food insecurity (FI) [3]. Experience-based indices can serve to assess hunger directly at the household level [4].

Household Food Insecurity (HFI) has been defined as "limited or uncertain availability of nutritionally adequate and safe food and also as limited and uncertain ability to acquire adequate food in socially acceptable ways" [5].

FI is a growing concern worldwide. It is estimated that over one billion people suffer from insufficient availability of dietary energy, and at least twice that number suffer from micronutrient deficiency [6].

FI in Mexico has evolved within a complex and contrasting environment where undernutrition and overweight/obesity, together, form part of an advanced nutritional transition characterized by widespread HFI. One out of three Mexican households suffers from moderate or severe FI. This condition heightens not only

the risk of malnutrition in children, but also the incidence of diabetes, overweight and obesity in adults, principally among women [7].

Recent studies have suggested a link between HFI and obesity [8], especially in adult women [9-11]. For instance, it has been documented that women with FI are more likely to suffer from obesity than women without FI [12]. It has also been reported that racial/ethnic minority communities and low-income households are the population groups most severely affected by HFI [13].

Generally viewed as separate public health problems, there is growing concern that FI and obesity may be related. FI can lead to weight gain because high-fat, high-calorie and energy-dense foods offer the least expensive option for obtaining calories [14], and these products, available at lower prices than healthful foods [15], have been identified as risk factors for child and adult obesity [16]. Furthermore, HFI can trigger disorderly eating patterns characterized by binging and restricted eating, depending on the availability of supplies, thus negatively affecting the body's metabolism [17].

Recent decades have witnessed alarming increases in prevalence of overweight/obesity among Mexican children: from 7.8% in 1988 to 9.7% in 2012 for children under five; from 26.9% in1999 to 34.4% in 2012 for 5-11-year olds; and from 11.1% in1988 to 35.8% in 2012 for female adolescents aged 12-19 years. In the adult population aged 20 and older, prevalence jumped from 61.8% to 71.3% in twelve years [18].

In 2012, children under five living in severe-FI households indicated 42% higher risk of stunting or chronic malnutrition than did their counterparts living in food secure households [19]. That same year women aged 20 to 59 had an average BMI of 28.9. More specifically, those living in mild, moderate and severe HFI had BMIs of 28.3, 29.3 and 29.4, respectively ($p<0.001$, $p=0.011$ and $p=0.007$, respectively) [11].

The double burden of malnutrition can occur not only within the same country, city or household (mother-child pairs), but also within the same individual at different stages of his or her life [20]. The fact that HFI may be associated with both undernutrition and obesity has been documented [17].

The twofold purpose of this article is to examine the association between HFI and risk of childhood stunting, and to determine whether this association is modified by maternal-child overweight/obesity.

Methods

Study population

Data were drawn from *ENSANUT 2012*, a cross-sectional, probabilistic and cluster survey with national, regional, urban-rural and state-level representativity. Oversampling was directed to Mexican households of lower socioeconomic status. A sample of 50,528 households of an estimated 29,429,252 households nationwide was obtained between October 2011 and May 2012. Details of sample size and design have been described elsewhere [21].

Our study consisted of a secondary analysis based on *ENSANUT 2012*. A total of 5,087 preschool children (1-4y), 8,401 schoolchildren (5-11y) and 9,581 mothers were included in the survey. We used a matching process to identify mother-preschool child and mother-schoolchild pairs, and included a total of 5,087 mother-preschool child pairs in our analysis. None of the mothers in this group had more than one child. A total of 7,181 mother-schoolchild pairs were included, with 2,432 mothers having more than one schoolchild, in which cases only one schoolchild was used in the matching process. Finally, the 2,677 mothers in the sample who had preschool children and schoolchildren were included in both pair groups.

Our analytical sample included 5,087 mother-preschool child pairs and 7,181 mother-schoolchild pairs with complete data. Where mothers had more than one schoolchild meeting the study criteria, analysis considered all their children.

Informed consent was obtained from all respondents – or their parents/guardians in cases of children under seven years – prior to their participation in the study. The survey protocol was approved by the Ethics Committee of the National Institute of Public Health in Mexico.

HFI measurement

HFI was measured using a version of the Latin American and Caribbean Food Security Scale (*ELCSA* by its initials in Spanish). The scale included 15 questions targeting the head of the family or the woman in charge of preparing meals. Eight questions referred directly to HFI either in the household or specifically in the adults within the household; the remaining seven referred to HFI in minors (<18y).

The reference time frame was three months prior to survey administration. Based on the number of positive responses, and depending on whether or not households included people under 18, they were grouped into the following categories: households with no HFI (0 positive responses), mild HFI (1 to 3), moderate HFI (4 to 6), and severe HFI (7 to 8); and households with adults and minors under 18: no HFI (0 positive responses), mild HFI (1 to 5), moderate HFI (6 to 10), and severe HFI (11 to 15)[22]. The ELCSA has been validated in populations in the United States as well as in Mexico and other Latin American countries [23-25].

Anthropometric measurements

Weight and recumbent length measures were obtained from children < 2 and standing height measures from children aged 2 to < 5 following standard recommended procedures [26,27].

The anthropometric measures together with the age and sex of the children were used to calculate the weight-for-age, height-for-age, and weight-for-height z-scores according to the WHO growth standards [28]. Prevalence of undernutrition in its different forms (underweight, wasting and stunting) was calculated using the < -2 z-score cut-off point using the WHO growth standards.

Overweight and obesity were determined according to the WHO Growth Reference charts [29], with BMI (kg/m^2) z-scores adjusted for age: values between -5.0 and +5.0 were considered outside this range and regarded as implausible. There were no implausible values for BMI z-scores in children. For adults, the WHO standard BMI cut-off points were used to classify mothers into the following categories:

underweight (<18.5 kg/m^2), normal weight (18.5 to 24.9 kg/m^2), overweight (25-29.9 kg/m^2) and obese (≥ 30 kg/m^2) [30]. Only BMI values between 10 and 58 were considered; no BMI values were regarded as implausible.

Covariates

The following covariates were included in our statistical analyses: sex of the child, urbanicity (urban/rural), region of residence (northern, central, southern and Mexico City), and maternal education: none, primary, secondary, high school (*preparatoria* according to its Spanish equivalent) and university (bachelor's degree and beyond). Benefiting from a food assistance program was also included.

Socioeconomic Index

We used a standard socioeconomic status (SES) index developed in Mexico on the basis of various household characteristics: type of floor, wall and ceiling materials; the ratio of number of rooms used for sleeping to number of persons residing in the household; basic service infrastructure including water source and water disposal; and possession of domestic appliances such as a refrigerator, washing machine, microwave oven, stove, boiler, radio, television, cable television signal, telephone and computer. This SES index was selected to facilitate comparison with previous surveys in Mexico [31].

Ethical considerations

All study procedures involving human participants were approved by the Ethics Committee of the National Institute of Public Health in Mexico. Written informed

consent was obtained from all survey participants. Parents/guardians served as proxies for minors < 7 years.

Statistical analyses

We calculated the prevalence (95% CI) of each HFI category by socioeconomic characteristic and maternal-child nutritional status. We then conducted logistic regression models for stunting and overweight among preschool children and for stunting and overweight/obesity among schoolchildren, adjusting for pertinent covariates. The cluster effect for mothers with more than one schoolchild was tested and proved non-significant. No mothers had more than one preschool child. Results were expressed as Adjusted Odds Ratios (AORs) with their corresponding 95% confidence intervals. Prevalence estimates and logistic regression models considered clustered sample effects and sampling weights using STATA 13 SVY procedures for complex surveys.

Results

Our analytical sample included 5,087 pairs of mother-preschool children and 7,181 mother-schoolchild pairs with complete data.

In the mother-preschool child pairs, moderate HFI was significantly more prevalent among those residing in the southern, as opposed to the northern or central, regions of Mexico. As expected, severe HFI was five and six times more prevalent in the low and very low quintiles, respectively, than in the top quintile. Moderate and severe HFI were more prevalent in households with mothers who had not

studied beyond junior high school, and with beneficiaries of government food-assistance programs (Table 1).

Similarly, in the mother-schoolchild pairs, general HFI was more prevalent among those living in southern Mexico than among those living in the north. In addition, HFI was higher in the low and very low socioeconomic quintiles. Prevalence of moderate and severe HFI was significantly higher among those pairs where the mothers had not studied beyond junior high school, benefited from government food-assistance programs and belonged to an indigenous population group (Table 1).

Table 1. FI level according to the socio-demographic characteristics of the mother-preschool child and mother-schoolchild pairs

	Total	N* (thousands)	Food Insecurity Level in preschool children							
			Secure		Mild		Moderate		Severe	
	n	)	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Sex of child										
Female	2539	1452.9	24.2	(21.7,26.79)	43.8	(40.9,46.6)	21.6	(19.5,23.8)	10.5	(9.0,12.2)
Male	2548	1522.1	24.7	(22.3,27.13)	45.0	(42.4,47.7)	18.4	(16.5,20.6)	11.9	(10.3,13.8)
Urbanicity										
Urban	3142	2123.0	26.8	(24.6 ,29.1)	43.3	(40.9,45.8)	18.9	(17.1,20.9)	10.9	(9.4,12.6)
Rural	1945	851.9	18.5	(16.3,20.9)	47.0	(43.8,50.2)	22.4	(20.1,25.0)	12.0	(10.3,14.1)
Region										
Northern	1083	524.5	30.5	(27.2,34.0)	42.5	(38.9,46.2)	15.8	(13.3,18.6)	11.2	(9.2,13.5)
Central	1804	941.8	26.7	(24.0,29.6)	45.3	(42.2,48.4)	17.4	(15.1,20.0)	10.6	(8.8,12.6)
Mexico City	200	426.5	22.1	(15.6,30.4)	45.5	(37.9,53.4)	21.9	(16.3,28.8)	10.5	(6.3,16.9)
Southern	2000	1082.2	20.4	(18.1,22.8)	44.1	(41.1,47.1)	23.4	(21.2,25.9)	12.1	(10.3,14.2)
SES										
Very Low (Q1)	1319	666.0	12.4	(9.9,15.4)	45.8	(41.9,49.6)	23.8	(20.8,27.1)	18.0	(15.1,21.4)
Low (Q2)	1187	629.8	17.6	(15.0,20.6)	43.4	(39.3,47.7)	25.1	(21.5,29.2)	13.8	(11.2,16.9)
Medium (Q3)	1028	584.5	20.0	(17.1,23.4)	48.4	(44.8,52.1)	20.3	(17.3,23.8)	11.1	(8.7,14.2)
High (Q4)	879	575.7	29.1	(25.1,33.5)	44.2	(39.7,48.7)	18.5	(15.1,22.4)	8.2	(6.2,10.8)
Very High (Q5)	674	519.0	47.7	(42.3,53.2)	39.5	(34.4,44.7)	10.0	(7.2,13.6)	2.8	(1.8,4.6)
Maternal Education										
None	349	196.4	10.0	(6.8,14.4)	40.6	(34.2,47.4)	24.7	(19.4,30.9)	24.7	(18.9,31.5)

Primary and/or secondary school	3568	1951.6	19.1	(17.4,20.9)	46.1	(43.7,48.5)	21.5	(19.6,23.6)	13.3	(11.8,15.1)
Beyond secondary school	1165	823.0	40.4	(36.4,44.6)	41.4	(37.6,45.3)	15.1	(12.5,18.1)	3.0	(2.0,4.6)
Beneficiaries of Food Assistance Programs										
Beneficiaries	2246	1187.1	15.7	(13.6,18.1)	45.8	(42.7,48.8)	24.5	(22.1,27.1)	14.0	(12.0,16.3)
Non-beneficiaries	2400	1520.1	30.2	(27.6,33.0)	43.8	(41.1,46.6)	16.9	(14.9,19.1)	9.0	(7.6,10.8)
Indigenous										
Yes	101	1150.9	20.3	(11.7,32.8)	38.3	(27.8,50.1)	29.5	(20.1,40.9)	12.0	(6.4,21.2)
No	1906	41.9	23.5	(21.2,25.9)	44.1	(41.2,47.1)	20.3	(18.0,22.9)	12.0	(9.9,14.3)
		N*	**Food Insecurity Level in schoolchildren**							
	Total n	**(thousands)**	**Secure %**	**Secure 95% CI**	**Mild %**	**Mild 95% CI**	**Moderate %**	**Moderate 95% CI**	**Severe %**	**Severe 95% CI**
Sex of child										
Female	4269	2413.0	23.1	(21.3,25.1)	42.3	(40.4,44.3)	20.1	(18.4,22.0)	14.4	(12.9,15.9)
Male	4132	2337.1	24.0	(21.9,26.2)	43.6	(41.3,45.9)	19.8	(18.1,21.6)	12.6	(11.1,14.2)
Urbanicity										
Urban	5267	3444.7	26.2	(24.3,28.1)	42.0	(39.9,43.9)	18.4	(16.8,20.1)	13.5	(12.1,15.1)
Rural	3134	1306.3	16.7	(14.8,18.8)	45.8	(43.2,48.3)	24.2	(22.1,26.4)	13.4	(11.8,15.3)
Region										
Northern	1796	884.6	29.5	(26.4,32.8)	42.3	(39.2,45.4)	16.2	(13.9,18.8)	12.0	(10.2,14.2)
Central	2928	1446.1	25.8	(23.2,28.5)	45.1	(42.3,47.9)	16.8	(14.8,19.0)	12.3	(10.6,14.2)
Mexico City	353	717.3	25.6	(20.4,31.7)	36.2	(30.4,42.4)	21.6	(16.7,27.5)	16.6	(12.0,22.3)
Southern	3324	1738.9	18.0	(16.2,19.9)	44.2	(42.1,46.5)	23.8	(21.8,25.9)	14.0	(12.4,15.7)
SES										
Very Low (Q1)	1977	980.7	9.6	(7.9,11.6)	42.5	(39.1,46.1)	26.2	(23.3,29.4)	21.7	(18.7,25.1)
Low (Q2)	1874	947.06	15.0	(12.9,17.5)	39.6	(36.3,42.9)	25.5	(22.4,28.9)	19.9	(17.1,22.9)
Medium (Q3)	1717	914.6	16.0	(13.6,18.7)	50.5	(46.8,54.2)	19.7	(17.1,22.6)	13.9	(11.5,16.6)
High (Q4)	1583	995.9	29.8	(26.4,33.4)	43.8	(40.4,47.2)	17.4	(14.7,20.5)	9.05	(7.3,11.1)
Very High (Q5)	1250	912.7	48.2	(43.8,52.7)	38.5	(34.7,42.4)	10.7	(8.0,14.1)	2.6	(1.6,4.4)
Maternal Education										
None	651	339.1	13.4	(10.0,17.7)	40.9	(35.8,46.2)	21.6	(17.6,26.1)	24.1	(19.5,29.5)
Primary and/or secondary school	5970	3212.5	18.7	(17.2,20.3)	44.0	(41.9,45.9)	22.0	(20.4,23.7)	15.4	(13.9,16.9)
Beyond secondary school	1780	1199.4	39.5	(35.9,43.1)	41.0	(37.8,44.4)	14.1	(11.8,16.8)	5.4	(4.2,6.9)
Beneficiaries of Food Assistance Programs										
Beneficiaries	4527	2362.1	16.5	(14.9,18.2)	44.9	(42.5,47.3)	22.2	(20.5,24.1)	16.4	(14.6,18.4)
Non-beneficiaries	3299	2032.0	30.8	(28.2,33.4)	41.6	(39.1,44.1)	17.4	(15.4,19.6)	10.2	(8.8,11.9)
Indigenous										
Yes	595	228.1	10.8	(8.0,14.3)	44.4	(39.2,49.8)	26.1	(21.8,30.9)	18.7	(14.7,23.5)
No	7806	4522.9	24.2	(22.7,25.8)	42.9	(41.2,44.5)	19.7	(18.3,21.1)	13.2	(12.1,14.5)

* N refers to the sample population size.

Table 2 describes the nutritional status of the population by household food security/insecurity level. Stunting in preschool children was more prevalent in households with severe/moderate HFI (over 16% respectively) than in those with mild (13.2%) or no HFI (10.7%). Likewise, wasting was more prevalent in households with severe (3.7%) than in those with mild (1.7%), moderate (1.9%) or no HFI (2.2%).

Preschool children presented no significant differences in prevalence of overweight by HFI level.

While prevalence of stunting among schoolchildren was 10% in households with severe HFI, prevalence of overweight/obesity was markedly higher in households with food security (40%) as compared to households with mild (34.5%), moderate (32.1%) or severe (28.6%) HFI. Prevalence of maternal obesity was high regardless of HFI status: > 70% overall and 77% in mild HFI households.

Table 2. Prevalence of nutritional status by level of food insecurity

Nutritional status	Food Security			Food Insecurity in Preschool-Age Children								
				Mild			Moderate			Severe		
	N (thousands)	%	(95% IC)	N (thousands)	%	(95% IC)	N (thousands)	%	(95% IC)	N (thousands)	%	(95% IC)
Underweight	8.3	1.1	(0.6,2.1)	40.6	3.0	(2.3,4.1)	18.8	3.1	(2.2,4.6)	15.8	4.7	(2.7,8.1)
Stunting	77.6	10.7	(8.6,13.2)	175.4	13.2	(11.4,15.4)	96.2	16.2	(13.1,19.8)	56.0	16.8	(12.8,21.6)
Wasting	15.8	2.2	(1.1,4.1)	23.1	1.7	(1.0,2.8)	11.1	1.9	(1.1,3.1)	12.5	3.7	(2.0,6.9)
Overweight	75.9	11.0	(8.8,13.5)	120.7	9.7	(8.2,11.5)	47.6	8.3	(6.1,11.2)	31.5	9.6	(6.8,13.3)
Nutritional status	**Food Security**			**Food Insecurity in Schoolers**								
				Mild			**Moderate**			**Severe**		
	N (thousands)	**%**	**(95% IC)**	**N (thousands)**	**%**	**(95% IC)**	**N (thousands)**	**%**	**(95% IC)**	**N (thousands)**	**%**	**(95% IC)**
Stunting	48.4	4.4	(3.3,5.8)	128.7	6.4	(5.4,7.4)	75.8	8.0	(6.3,10.3)	64.2	10.10.1	(7.9,12.7)
Overweight	250.4	23.0	(20.4,25.7)	377.2	18.9	(17.2,20.8)	161.3	17.4	(15.1,19.9)	112.5	17.8	(14.9,21.0)
Obesity	190.6	17.5	(15.1,20.2)	310.8	15.6	(14.0,17.3)	136.4	14.7	(12.5,17.3)	68.6	10.8	(8.3,14.0)
Overweight and Obesity	441.0	40.4	(37.3,43.7)	688.0	34.5	(32.3,36.8)	297.7	32.1	(28.9,35.5)	181.1	28.6	(24.8,32.6)
Nutritional status	**Food Security**			**Food Insecurity in Women**								
				Mild			**Moderate**			**Severe**		

	N (thousands)	%	(95% IC)	N (thousands)	%	(95% IC)	N (thousands)	%	(95% IC)	N (thousands)	%	(95% IC)
Underweight	20.9	1.2	(0.6,2.1)	22.7	0.69	(0.5,0.9)	19.1	1.2	(0.6,2.5)	12.9	1.3	(0.8,2.3)
Overweight	683.5	37.9	(35.1,40.7)	1301.7	39.8	(37.7,41.9)	563.9	37.2	(33.9,40.8)	344.7	35.6	(31.9,39.5)
Obesity	589.9	32.7	(29.9,35.5)	1206.9	36.9	(34.9,38.9)	584.1	38.6	(35.3,41.9)	365.7	37.8	(33.6,42.3)
Overweight and Obesity	1273.4	70.5	(67.7,73.3)	2508.7	76.7	(74.8,78.6)	1148.0	75.9	(73.1,78.4)	710.4	73.5	(69.8,76.8)

* N refers to the sample population size.

(1) Z-score cut-off point of <-2 standard deviations to classify low weight-for-age, WHO
(2) Z-score cut-off point of <-2 standard deviations to classify low height-for-age, WHO
(3) Z-score cut-off point of <-2 standard deviations to classify low weight-for-height-, WHO
(4) Z-score cut-off point of >+2 standard deviations to classify body mass index (BMI)-for-age, WHO
(5) Z-score cut-off point of >+1 and ≤+2 standard deviations to classify body mass index (BMI)-for-age, WHO
(6) BMI <18.5 kg/m2
(7) BMI 25-29.9 kg/m2
(8) BMI ≥ 30 kg/m2

In the logistic regression model for preschool children, prevalence of stunting was significantly higher (AOR>1, p<0.05) in households with moderate or severe HFI as opposed to mild HFI (Table 3).

Table 3. Logistic regression model for mother-preschool child pairs: Stunting in children < 5 years old

	AOR*	p-value	95% CI
Mild HFI	1.26	0.232	(0.9,1.8)
Moderate HFI	1.66	0.036	(1.0, 2.7)
Severe HFI	1.99	0.007	(1.2,3.3)
Maternal obesity	1.40	0.266	(0.8,2.5)
Mild HFI and maternal obesity	0.62	0.207	(0.3,1.3)
Moderate HFI and maternal obesity	0.46	0.069	(0.2,1.1)
Severe HFI and maternal obesity	0.23	0.011	(0.1,0.7)
Age of children	0.89	0.007	(0.8,0.9)
Beneficiaries of food assistance programs	1.24	0.119	(0.9,1.6)
Urbanicity			
Rural	1.42	0.006	(1.1,1.8)
Maternal Education			
Primary school	0.53	<0.001	(0.4,0.8)
Secondary school	0.46	0.001	(0.3,0.7)
Senior high school (*Preparatoria*)	0.34	<0.001	(0.2,0.6)
Bachelor or higher	0.48	0.042	(0.2,0.9)
Const	0.26	<0.001	(0.2,0.4)

*Model included all independent variables listed in the table.

We identified an interaction between HFI and maternal obesity. Estimated marginal prevalence rates and confidence intervals obtained from the logistic regression model are plotted in Figure 1. Severe HFI raises the risk of stunting in children with non-obese mothers but not in children with obese mothers. Preschool children showed no significant interaction between HFI, overweight and maternal characteristics.

For schoolchildren, the logistic regression model revealed a significantly lower prevalence of overweight and obesity among those with mild, moderate or severe HFI ($p<0.05$) (Table 4), mothers having higher levels of education (bachelor's and beyond) ($p<0.001$), and residence in rural areas ($p=0.007$).

The logistic regression model for stunting in schoolchildren documented significant associations of this condition with maternal characteristics but not with HFI (data not shown).

Table 4. Logistic regression model for mother-schoolchild pairs: both mother and child with overweight/obesity: Overweight and obesity in schoolchildren

	AOR*	p- value	95% CI
Mild HFI	0.79	0.017	(0.6,0.9)
Moderate HFI	0.72	0.005	(0.57,0.90)
Severe HFI	0.67	0.004	(0.51,0.9)
Maternal Overweight	2.25	<0.001	(1.8,2.8)
Maternal Obesity	3.96	<0.001	(3.3,4.8)
Age of child	1.12	<0.001	(1.1,1.2)
Beneficiaries of food assistance programs	0.85	0.039	(0.7,0.9)
Urbanicity			
Rural	0.79	0.007	(0.7,0.9)
Maternal Education			
Primary school	0.87	0.342	(0.6,1.2)
Secondary school	1.11	0.484	(0.8,1.5)
Senior high school (*Preparatoria*)	1.12	0.485	(0.8,1.6)
Bachelor or higher	1.93	<0.001	(1.3,2.9)
Const	0.12	<0.001	(0.1,0.2)

*Model included all independent variables listed in table.

Discussion

We sought to describe the nutritional status of <11-year-old-children and their mothers, and to explore the relationship between their nutritional status and HFI. One of the strengths of this study concerns the fact that our research sample was representative of the Mexican population.

Many countries are witnessing an increase in the prevalence of adult overweight while still struggling with childhood stunting. Our study found that moderate and severe HFI were associated with low height in children who were under five and lived with mothers with overweight or obesity. Similar results have been obtained by other studies on the double burden of malnutrition, where stunted children live with overweight mothers in the same, and particularly in poor, households [32-33]. The problem has been analyzed at the household and individual levels both globally and within a number of countries, Mexico among them [34].

Studies conducted in the Latin American and Arctic regions have demonstrated that FI households exhibit not only a reduced variety of available food, but also inadequate consumption of fruits and vegetables [35] and foods of animal origin [36-37]. These findings have been explained by insufficient local food availability as well as the presence of inferior-quality, high-cost foods, both of which favor the choice of widely available cheaper foods of low nutritional value [38]. It has been reported that FI in Mexico has similar effects to those observed in the rest of Latin America as regards dietary diversity and food availability. Mexican children under five are not receiving the recommended daily energy intake [39] and female heads of household show diminished dietary diversity [40].

Evidence from a study of < 5 children of Mexican origin living in immigrant communities in California and in Mexico itself underscores the fact that FI contributes not only to increased energy and fat intake as a result of consuming cheap and energy-rich foods such as snacks, sweets and fried foods, but also to increased consumption of meat, especially fried chicken. For children living in Mexico, FI was associated with low consumption of carbohydrates, dairy products and vitamin B6 [41].

The pathway through which FI can lead to an increase in body fat is based on the following factors: (1) Diets characterized by high quantities of fat and carbohydrates together with a limited variety of vegetables are associated with high energy intake and a subsequent increase in body fat [42,43]. (2) According to one hypothesis, involuntary restriction of food including episodic lack of access can lead to compulsive eating and to ignoring internal signs of satiety [44], as well as to physiological adaptations in response to the periodic scarcity of food [17].

Conversely, our study demonstrated an association between FI and stunting among Mexican preschool children. The way in which FI negatively affects the nutritional state of these children relates largely to insufficient consumption of highly nutritious foods (such as products of animal origin, fruits and vegetables) coupled with recurrent infections and unhealthy living conditions linked to poverty. These factors contribute to loss of appetite, an increase in metabolic requirements and a deficit of nutrients [45].

Our results agree with those of a previous study where children from HFI households weighed less than their peers from food-secure households. Their

average body weight was within the normal range, whereas their peers were at risk of becoming overweight.

Adequate growth is not the only indicator of nutritional well-being among children living with HFI [36]. Nutritional status is also influenced by the quality of foods consumed. It has been demonstrated that obesity is an expected consequence of HFI for some subpopulations and at certain ages. Moreover, it has been shown that children and adolescents are often affected by HFI through both nutritional and non-nutritional pathways despite parental intentions or beliefs to the contrary [46].

A recent analysis of 16 Latin American countries revealed that all of them were running programs aimed at preventing undernutrition, and most were in the process of implementing obesity prevention strategies as part of their policy agendas [47]. According to the literature, cash transfers and food distribution programs may be triggering increased energy intake at the household level [48,49] and exacerbating the HFI-obesity link in populations that do not need assistance programs focused on caloric intake. This has raised concerns about the possible contribution of these programs to obesity in populations who are not energy deficient, and highlights the need for countries with a double burden of malnutrition to include obesity prevention strategies as an essential component of their cash and food transfer programs.

The principal findings of our study are particularly relevant for countries undergoing nutritional transition. Mexico has been facing rapid epidemiological and demographic changes with nutritional and environmental components. The health

profile of the Mexican population indicates a shift from high rates of mortality and infectious diseases - typical of poor countries - to low rates of mortality and high rates of non-communicable diseases - the main cause of mortality in wealthy countries [50].

Our study was subject to several limitations. First, its cross-sectional design restricts the drawing of causal inferences. Additionally, its findings refer specifically to Mexican children, adolescents and similar population groups, and therefore cannot be generalized to others.

Nevertheless, our study also has a number of strengths. For instance, our findings contribute to the limited research available on the relationship between HFI and the nutritional status of mother-child pairs. In addition, this is one of the first studies in this field dealing specifically with the Mexican population. The large sample size of our study constitutes another strength. It allowed us to introduce possible confounders in the statistical models and to provide evidence useful at the national level.

In order to develop effective and integral nutritional strategies, policymakers need to recognize the apparently contradictory presence of adult overweight/obesity and childhood stunting in the same household and understand its association with HFI. For households at different HFI levels to experience an actual improvement in their nutritional status, efforts to abate overnutrition, undernutrition and inadequate dietary quality must be rooted in this knowledge.

Interestingly, our study found that, in preschool children, HFI severity increased the risk of stunting only if their mothers were not obese. This may be explained by the growth of urbanization resulting in higher household incomes and greater food availability, but only as regards quantity, not quality [51]. The foods available to poor urban households are likely to be energy-rich but nutrient-poor. The presence of non-obese mothers in FI households may indicate a dearth of adequate quality food for children redounding in micronutrient deficiencies and protein quality issues that hinder their growth - particularly in relation to height. By contrast, the presence of maternal obesity in FI households may indicate greater access to the calories and nutrients needed for adequate child development, and may also account for the lower prevalence of stunting in these homes. This may explain the relative lack of any relationship of stunting to HFI severity in households with obese mothers.

Conclusions

The double burden of malnutrition in Mexico occurs most notably among mother-child pairs living with HFI. Crafting a sound approach to combat malnutrition is complex because of its multi-dimensional nature [52]. These conditions hamper the implementation of effective measures capable of protecting vulnerable population groups and ensuring adequate livelihoods. Policies and programs must tackle chronic undernutrition and overnutrition according to the food and nutritional needs of each age group, rather than assuming that their needs will be met by targeting the household as a homogenous unit. Consistent with other studies, our work highlights the importance of monitoring household food security based on

experience-related scales such as ELCSA. These have proved highly useful for food security governance [53].

List of abbreviations

BMI - Body Mass Index

ELCSA - Latin American and Caribbean Food Security Scale

ENSANUT 2012 - Mexican National Health and Nutrition Survey in Latin American

HFI - Household Food Insecurity

WHO - World Health Organization

Declarations

Ethics approval and consent to participate

All study procedures involving human participants were approved by the Ethics Committee of the National Institute of Public Health in Mexico. Written informed consent was obtained from all survey participants, with parents serving as proxies of minors under seven years.

Availability of data and materials

https://drive.google.com/a/cimat.mx/folderview?id=0BzGYRm5Poz8OdWhGWUhadENBSDA&usp=sharing

Competing interests

The authors declared no conflict of interest.

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Authors' contributions

The responsibilities of the authors were distributed as follows: TSL and IMGH contributed to data analysis and interpretation. They drafted the manuscript based on the input and feedback of all the co-authors. VMR, LCN and MCMR contributed to the study design and critical review of the manuscript. TSL and RPE contributed to the study design, interpretation of results and critical review of the manuscript. All the authors read and approved the final version of the manuscript.

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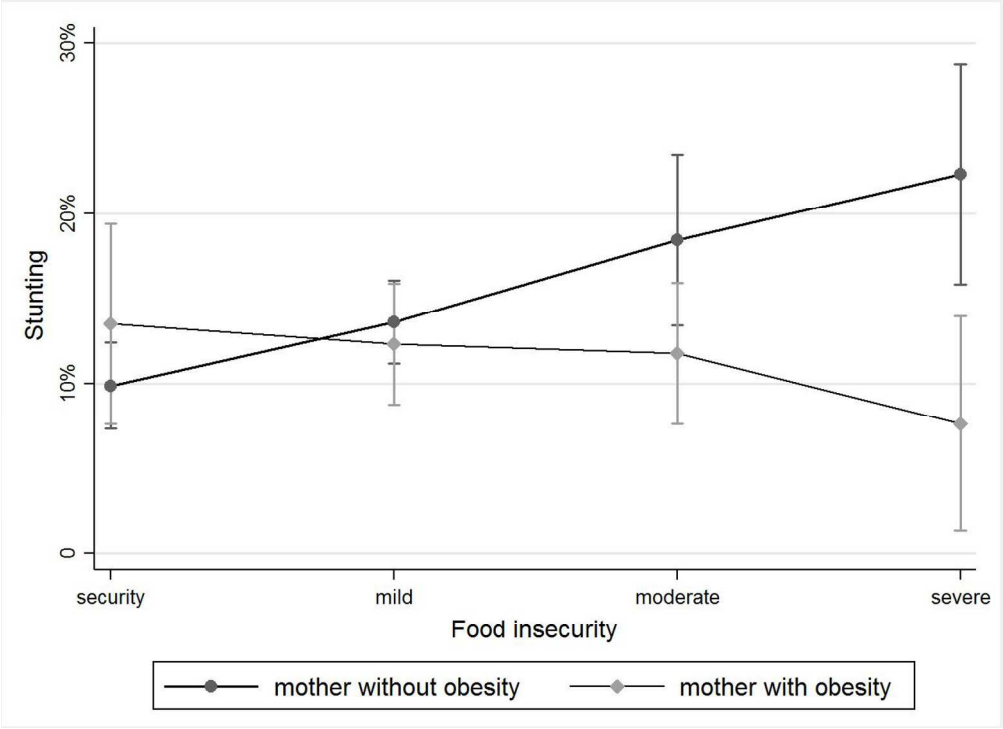

Figure 1. Effect of HFI-maternal obesity interaction on stunting among children <5 years

340x247mm (300 x 300 DPI)

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