Household food insecurity in Mexico is associated with the co-occurrence of overweight and anemia among women of reproductive age, but not adolescent girls

Andrew D. Jones[1], Verónica Mundo-Rosas[2], Alejandra Cantoral[3], Teresa Shamah Levy[2]

[1]School of Public Health, University of Michigan, Ann Arbor, MI, USA

[2]Center of Nutrition and Health Research, National Institute of Public Health, Mexico City, Mexico

[3]CONACYT Research Fellow, National Institute of Public Health, Mexico City, Mexico

Corresponding author: Andrew D. Jones; 3846 SPH I, 1415 Washington Heights, Ann Arbor, MI 48109; phone: 734.647.1881; fax: 734.647.5762; e-mail: jonesand@umich.edu

Running title: Food security and nutritional double burden

Abstract word count: 232

Main body text word count (excluding references and legends): 4,715

Number of references: 77

Numbers of tables: 5 (includes 1 Supplemental Table)

Number of figures: 1

Acknowledgements: None.

Source of funding: This research received no specific grant from any funding agency, commercial or not-for-profit sectors.

Conflict of interest statement: None.

Contributor statement: A.D.J. formulated the research question, analyzed the data, and wrote the first draft of the manuscript. T.S.L. provided the data set for the research. V.M.R. assisted with data analysis. V.M.R., A.C., and T.S.L. provided guidance on the development of the manuscript, and assisted with revisions to the manuscript. A.D.J. had primary responsibility for the final content. All authors read and approved the final manuscript.

Household food insecurity in Mexico is associated with the co-occurrence of overweight and anemia among women of reproductive age, but not adolescent girls

Andrew D. Jones[1], Verónica Mundo-Rosas[2], Alejandra Cantoral[3], Teresa Shamah Levy[2]

[1]School of Public Health, University of Michigan, Ann Arbor, MI, USA

[2]Center of Nutrition and Health Research, National Institute of Public Health, Mexico City, Mexico

[3]CONACYT Research Fellow, National Institute of Public Health, Mexico City, Mexico

Corresponding author: Andrew D. Jones; 3846 SPH I, 1415 Washington Heights, Ann Arbor, MI 48109; phone: 734.647.1881; fax: 734.647.5762; e-mail: jonesand@umich.edu

Running title: Food security and nutritional double burden

Abstract word count: 232

Main body text word count (excluding references and legends): 4,715

Number of references: 77

Numbers of tables: 5 (includes 1 Supplemental Table)

Number of figures: 1

Acknowledgements: None.

Source of funding: This research received no specific grant from any funding agency, commercial or not-for-profit sectors.

Conflict of interest statement: None.

Contributor statement: A.D.J. formulated the research question, analyzed the data, and wrote the first draft of the manuscript. T.S.L. provided the data set for the research. V.M.R. assisted with data analysis. V.M.R., A.C., and T.S.L. provided guidance on the development of the manuscript, and assisted with revisions to the manuscript. A.D.J. had primary responsibility for the final content. All authors read and approved the final manuscript.

Abstract

We aimed to determine the association between household food insecurity (HFI) and the co-occurrence of overweight and anemia among women of reproductive age in the Mexican population. We analyzed data on 4,039 non-pregnant adolescent girls (15-19 years) and 10,760 non-pregnant adult women of reproductive age (20-49 years) from the 2012 National Health and Nutrition Survey of Mexico. The survey uses a two-stage sampling design, stratified by rural and urban regions. The Latin American and Caribbean Food Security Scale (ELCSA) was used to assess HFI. We assessed overweight and obesity in women based on World Health Organization classifications for body mass index (BMI), and BMI-for-age Z-scores for adolescent girls, and defined anemia as an altitude-adjusted hemoglobin (Hb) concentration < 120 g/L based on measurement of capillary Hb concentrations. In multiple logistic regression models adjusting for potential confounding covariates, HFI was not associated with the co-occurrence of anemia and overweight among adolescent girls. The adjusted odds of women of reproductive age from mildly and moderately food-insecure households, respectively, experiencing concurrent anemia and overweight were 48% (OR: 1.48; 95% CI: 1.15, 1.91) and 49% (OR: 1.49; 95% CI: 1.08, 2.06) higher than among women from food-secure households. Severe HFI was not associated with concurrent overweight and anemia among adolescent girls or women. HFI may be a shared mechanism for dual forms of malnutrition within the same individual, simultaneously contributing to overconsumption and dietary inadequacy.

Keywords: food insecurity, double burden of malnutrition, overweight, obesity, anemia, Mexico

Introduction

Food insecurity, commonly defined as a "state characterized by limited or uncertain access to adequate food for an active, healthy life" (Coleman-Jensen et al. 2013), is a critical underlying determinant of malnutrition (UNICEF 1990). In low-income countries, household food insecurity (HFI) is commonly associated with poor health outcomes (Cook et al. 2006), inadequate diets (Armar-Klemesu et al. 1995), as well as growth faltering and poor cognitive development in young children (Smith & Haddad, 2000). In high-income countries, adults and children from food-insecure households are similarly more likely to have low dietary intakes of essential micronutrients, dietary fiber, antioxidants, and fruits and vegetables (Smith & Richards, 2008; Kirkpatrick & Tarasuk, 2008; Kendall et al. 1996). However, women in particular from these households are also consistently more likely to be obese compared to women from food-secure households (Townsend et al. 2001; Adams et al. 2003; Wilde & Peterman, 2006; Hanson et al. 2007; Pan et al. 2012). This relationship has been observed among children and adolescents as well, though not as consistently (Bhargava et al. 2008; Gundersen et al. 2008, Bronte-Tinkew et al. 2007; Smith & Richards 2008).

The fact that HFI may be associated not only with undernutrition, but also obesity, has been viewed by some as a paradox (Dietz 1995). Food insecurity intuitively reflects a food deficit, yet food-insecure households in some contexts often have excessive intakes of dietary energy. Some explanations for this phenomenon are that low-income individuals tend to consume low-cost, energy-dense foods with low nutrient densities (Drewnowski & Specter 2004), or that they overeat certain foods when they become available to compensate for periods of food scarcity (Dinour et al. 2007), thereby increasing their risk of obesity. Food insecurity in some contexts then may not reflect caloric deficits so much as poor quality diets that lack diversity and essential nutrients. In this way, it is plausible that food insecurity places certain families and individuals at risk of both undernutrition and obesity. This so-called “double burden” of malnutrition is well recognized in low- and middle-income countries (LMICs). It has been examined primarily at national levels (e.g., high prevalence of underweight and overweight within a single country) (Subramanian & Smith 2006; Corsi et al. 2011), but has also been assessed within households (e.g., obese adult and stunted child within the same household) (Doak et al. 2005; Garrett & Ruel 2005), and even within individuals (e.g., co-occurring iron deficiency anemia and obesity within an individual) (Nead et al. 2004; Zeba et al. 2012). Yet, despite the plausible linkages between HFI and malnutrition across the spectrum from undernutrition to obesity, very little research has been conducted outside of the United States or other high-income countries examining the potential role of HFI in shaping the double burden of malnutrition. Understanding these dynamics within LMICs is especially critical given the pronounced nutrition transition that many of these countries have experienced in recent decades. This transition, characterized by a population-wide convergence toward increased intakes of highly-processed, energy-dense foods as well as changes in patterns of physical activity toward more sedentary lifestyles, has contributed to a rapidly increasing prevalence of obesity and diet-related chronic disease in LMICs (Popkin et al. 2012). At the same time, many of these countries still struggle with a high prevalence of anemia among women, adolescent girls, and children, and other persistent manifestations of undernutrition (e.g., micronutrient deficiencies, child stunting) (Black et al. 2013).

In Mexico, a nutrition transition has been underway for at least three decades. In this time, the prevalence of overweight and obesity has increased dramatically across all demographic groups—perhaps most strikingly among adolescent girls and women of reproductive age. The prevalence of overweight increased by 41% among girls and women aged 12-49 y from 25% in 1988 to 35% in 2012, while the prevalence of obesity increased among these women by 270% from 9.5% in 1988 to 35% in 2012 (Kroker-Lobos et al. 2014). During this same period, the prevalence of underweight among women aged 20-49 years declined from 8.8% to 1.5% (Instituto Nacional de Salud Pública 2012). While Mexico has concurrently made important strides in reducing undernutrition, one in ten non-pregnant women of reproductive age are still anemic (Backstrand et al. 2002; Villalpando et al. 2003). Though it has multiple causes (including infection), most anemia is caused by nutritional deficiencies—especially iron deficiency (Kraemer & Zimmermann 2006). Adolescent girls and women of reproductive age are particularly susceptible to iron deficiency anemia (World Health Organization 2008). In Mexico, nearly one-third (29%) of non-pregnant women of reproductive age are iron deficient—a prevalence that has not declined in recent years, and may even be increasing (Shamah-Levy et al. 2015). Iron deficiency is among the leading causes of disability worldwide (Institute for Health Metrics and Evaluation 2013), and the health effects of anemia among adolescent girls and women may have intergenerational consequences as anemia during pregnancy is associated with low birth weight, preterm delivery, and can adversely impact fetal iron stores, as well as child neurocognitive, motor, and social-emotional development (Scholl et al. 1997; Lozoff 2007). Mexico also has a substantially higher prevalence of HFI as compared to countries with analogous prevalences of adult overweight and obesity. In 2012, nearly three quarters (70%) of Mexican households were food insecure, and among these households, 28% were moderately to severely food insecure (Mundo-Rosas et al. 2013). Therefore, Mexico provides a unique context for assessing the potential influence of HFI on both undernutrition and obesity—distinct manifestations of malnutrition with seemingly disparate, but potentially shared etiologies.

In this study we examine the individual-level double burden of obesity and anemia among adolescent girls and women of reproductive age in Mexico given: 1) the limited attention the individual-level double burden has received in empirical research studies, 2) the persistently high vulnerability to anemia that adolescent girls and women of reproductive age face across socioeconomic strata (Shamah-Levy et al. 2013; Bentley & Griffiths 2003), and, in LMICs, their increasingly high risk of developing obesity and diet-related chronic illness (OECD 2014), and 3) the hypothesized potential for HFI to influence diet-related determinants of both obesity and anemia among these girls and women.

The objectives of this study were to 1) identify the extent to which overweight and anemia co-occur among non-pregnant adolescent girls (15-19 years) and adult women of reproductive age (20-49 years) in the Mexican population, and 2) determine the association between HFI and the co-occurrence of these dual forms of malnutrition among this population. We hypothesized that HFI would be associated with increased odds of the co-occurrence of overweight and anemia among both adolescent girls and women of reproductive age.

Participants and methods

We analyzed data from the 2012 National Health and Nutrition Survey (ENSANUT 2012) of Mexico, a probabilistic survey of the Mexican population that is representative at national and state levels (Instituto Nacional de Salud Publica 2012). The survey uses a two-stage sampling design, stratified by rural and urban regions, wherein primary sampling units were first selected based on probability proportional to size according to the total number of households in the area, and then in a second stage, households were selected within those units. Data were collected from 50,528 households across 32 federal districts between October 2011 and May 2012. A complete description of the ENSANUT 2012 survey design has been published previously (Romero-Martínez et al. 2013).

Adolescent girls (15-19 y) and adult women of reproductive age (20-49 years) were eligible for inclusion in the analytic sample. To achieve conservative prevalence estimates, and to ensure a consistent interpretation of findings, we excluded from our sample pregnant adolescents and women given their increased risk of anemia during pregnancy (World Health Organization 2008). We further excluded instances of multiple adolescent girls or women from the same household to limit potential bias from intra-household correlation. In total, 8.2% of individuals in the sample were members of the same household as another individual in the sample. For such households, the youngest eligible woman or adolescent girl was retained for analyses.

Variables and measurement

We used the Latin American and Caribbean Food Security Scale (ELCSA) to assess HFI (Comite Cientifico ELCSA 2012). The ELCSA has been validated in several contexts throughout the Latin American and Caribbean region (Álvarez et al. 2006; Hackett et al. 2008a; Hackett et al. 2008b, Pérez-Escamilla & Segall-Correa 2008). In Mexico, it includes 15 questions addressed to the main household meal preparer that assess household experiences of inadequate food access in the previous three months resulting from a lack of resources to purchase or otherwise acquire food. Eight questions pertain to the experiences of adults in the household, and seven questions are focused on the experiences of children and adolescents under 18 years of age. Response options are dichotomous (i.e., yes or no) and answers were coded “1” for “yes” and “0” for “no”. The sum of these codes for the 15 questions were used to generate a continuous ELCSA score from which a categorical assessment of HFI was calculated using established cut-off values of the continuous score (Comite Cientifico ELCSA 2012). Households with children or adolescents under 18 years of age and those without such individuals, respectively, were considered to have “mild food insecurity” with ELCSA scores of 1-5 and 1-3, “moderate food insecurity” with scores of 6-10 and 4-6, and “severe food insecurity” with scores of 11-15 and 7-8. All households with an ELCSA score of 0 were considered “food secure”. Confirmation of the predictive and convergence validity of the ELCSA in Mexican populations has been reported previously (Mundo-Rosas et al. 2013; Cuevas-Nasu et al. 2014).

Body weight was assessed using electronic scales with a precision of 100 g and height was measured using standard stadiometers with a precision of 1 mm. These measures were used to calculate the body mass index (BMI) of participants (kg m^{-2}). BMI classifications according to World Health Organization standards were used to assess underweight (BMI $<$ 18.5), normal weight (18.5 $\leq$ BMI $<$ 25), overweight (25 $\leq$ BMI $<$ 30), and obesity (BMI $\geq$ 30) among adult women (World Health Organization, 2000). BMI-for-age Z-scores were calculated for adolescent girls according to World Health Organization standards (de Onis et al. 2007) using the WHO Anthro PLUS software (v.

10.4). Adolescents with Z-scores less than 2 standard deviations above the median but greater than 1 standard deviation were classified as overweight, and those with Z-scores greater than 2 were classified as obese. Abdominal obesity among non-adolescent women was also assessed based on waist circumference ($\geq$ 80 cm) measured by non-stretch metallic tape (Lean et al. 1995).

Capillary hemoglobin concentrations from finger pricks were assessed using portable HemoCue photometers (Hemocue, Inc., Brea, CA). Anemia was defined as an altitude-adjusted Hb concentration < 120 g/L (World Health Organization 1992; Cohen & Haas 1999). We defined the individual-level double burden in two different ways: the co-occurrence of anemia with 1) overweight or obesity according to BMI, or 2) abdominal obesity (among adult women only).

Several sociodemographic variables were also used in analyses to adjust for potential confounding influences. These variables included the age and parity (i.e., total number of live and still births) of the adolescent girl or woman, a six-level categorical variable describing the highest attained level of education of the individual, the current smoking status of the individual, the urban location and region of the household (i.e., urban or rural, and northern, central, southern, or Mexico City), the number of household members, and an indicator of household wealth status based on quintiles of an asset index created using principal components analysis (Gutierrez 2013).

Statistical analyses

Statistical analyses were carried out using Stata v. 13.1 (StataCorp, College Station, TX, USA). We calculated means and proportions of select sample characteristics using the *svy* command to estimate Taylor-linearized standard errors that adjust for the multistage sampling frame of the ENSANUT. The prevalence of each ELCSA component response, as well as the prevalence of mild, moderate and severe food insecurity were calculated. We further assessed the prevalence of anemia, overweight, abdominal obesity, and the co-occurrence of anemia with either overweight or abdominal obesity within an individual. We calculated the expected prevalence of these double burden conditions using the multiplicative rule of probability (i.e., the product of the proportion of individuals with anemia and either overweight/obesity or abdominal obesity).

Bivariate associations of the ELCSA component responses with overweight, anemia, and abdominal obesity were calculated using bivariate logistic regression models. In separate, age-specific multiple logistic regression models, we assessed the association of household-level food insecurity with overweight or obesity, anemia and the co-occurrence of anemia with overweight or obesity among adolescent girls and adult women, respectively. In sensitivity analyses, we also examined these associations among adult women by age groupings (i.e., 20-29, 30-39 and 40-49 years of age). Associations with abdominal obesity and its co-occurrence with anemia were also assessed for adult women only. HFI was included in models as a four-level categorical variable representing the four food security categorizations derived from the continuous ELCSA score. We adjusted models for age, parity, household size, the highest attained education level of the individual, household wealth status, urbanicity, and region. Models that included anemia as a dependent variable were also adjusted for current smoking status of the individual given the influence of smoking on hemoglobin concentrations (Leifert 2008). Results from unadjusted models are also presented. The *svy* command was similarly used for logistic regression models to account for the sampling weights, clustering, and stratification of the ENSANUT survey design. Multicollinearity was assessed, but observed not to be a concern among the covariates included in the models. Associations were considered statistically significant at $P<0.05$.

Ethical standards

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all 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.

Results

Height and weight measurements were available for 4,148 adolescent girls aged 15-19 years and 15,713 adult women aged 20-49 years. Data for anemia were available for 4,107 of these adolescent girls and 12,669 of the women. We excluded: 1) 191 observations for which no HFI data were available, 2) 459 pregnant women or adolescents, and 3) 1,327 individuals from households in which there were data for more than one adolescent girl or adult woman of reproductive age in the household (data for the youngest individual were retained). Nearly all individuals excluded according to this last criterion were adult women (n = 4 adolescent girls; n = 1,323 adult women). Therefore, the final sample used for analyses was 14,799: 4,039 adolescent girls and 10,760 adult women.

Sample characteristics

Nearly three-quarters of the households (73%) were food insecure (**Table 1**). In total, 62% of the women and adolescent girls were overweight or obese (i.e., BMI ≥25) and 80% of adult women were considered to have abdominal obesity (i.e., waist circumference ≥ 80 cm) (**Table 1**). The prevalence of obesity among women (36%) was approximately three times greater than that among adolescent girls (13%). Twelve percent of the sample was anemic (i.e., Hb < 120 g/L).

Nearly 10% of women were concurrently anemic and overweight or obese (9.2%), while just 1.8% of adolescent girls met this double burden criterion. The prevalence of these concurrent conditions in the sample was almost exactly the prevalence expected by assessing the statistical intersection of the two events in the sample (**Table 1**).

ELCSA component responses

Approximately two-thirds (63%) of households reported feeling anxiety that the household would run out of food because of a lack of money or other resources to obtain food (**Figure 1**). Other food insecurity conditions were less commonly reported. However, with the exception of one condition, one-fifth or more of households reported experiencing the household-level conditions in the ELCSA. Similarly, with the exception of one condition, 10% or more of households reported experiencing the child-level conditions in the ELCSA with 37% of households reporting that a child under the age of 18 in the household had consumed just a few types of foods in the previous three months because of a lack of resources.

In bivariate logistic regression models for adolescent girls, the individual component responses of the ELCSA were not consistently associated with overweight or obesity, or anemia (i.e., the underlying components of the nutritional double burden) (**Table 2**). However, each of the first five food insecurity conditions described in the ELCSA was consistently associated with greater odds of overweight or obesity, anemia, and abdominal obesity among women of reproductive age (**Table 2**). Odds ratios ranged from 1.20 (95% CI: 1.05, 1.38) to 1.52 (1.30, 1.77) (*P*<0.05).

Household food insecurity and the individual-level double burden of malnutrition

In multiple logistic regression models adjusting for potential confounding covariates, HFI was not associated with overweight or obesity, anemia, or the co-occurrence of these conditions among adolescent girls (**Table 3**). However, among adult women of reproductive age there was a consistent positive association of HFI with overweight, anemia, and the co-occurrence of anemia and overweight or obesity (**Table 4**). Compared to food-secure households, the adjusted odds of experiencing concurrent anemia and overweight or obesity, or anemia and abdominal obesity were 48% (OR: 1.48; 95% CI: 1.15, 1.91) and 41% (OR: 1.41; 95% CI: 1.10, 1.81) higher, respectively, among women living in mildly food insecure households (*P*<0.05). The odds were even higher for women living in moderately food insecure households (i.e., 49% (OR: 1.49; 95% CI: 1.08, 2.06) and 64% (OR: 1.64; 95% CI: 1.21, 2.23) (*P*<0.05). Severe HFI was not associated with concurrent anemia and overweight or obesity, and was only modestly associated with concurrent anemia and abdominal obesity (OR: 1.32; 95% CI: 0.95, 1.84) (*P*<0.1). In sensitivity analyses examining subgroups of adult women, these associations of household food insecurity with concurrent anemia and overweight or obesity, or anemia and abdominal obesity were apparent only among women aged 30-39 years of age, and not among women aged 20-29 or 40-49 years (**Supplemental Table 1**).

Discussion

In this nationally-representative sample of non-pregnant adolescent girls (15-19 y) and adult women of reproductive age (20-49 y) from Mexico, less than 2% of adolescent girls (1.8%) and nearly one in ten adult women of reproductive age (9.2%) were concurrently overweight and anemic. We observed a strong and consistent positive association between mild or moderate HFI and the individual-level double burden of malnutrition (i.e., concurrent anemia and obesity), as well as its component conditions (i.e., anemia and obesity, respectively), among women, but not adolescent girls. Severe HFI was not associated with obesity, anemia or the co-occurrence of obesity and anemia among women or adolescent girls.

The actual prevalence of concurrent anemia and overweight or obesity among girls and women in this sample did not exceed the expected prevalence, assuming independence of the distributions of each component condition. This has been observed previously for the household-level double burden globally (i.e., a stunted child and overweight mother in the same household) (Dieffenbach & Stein 2012), as well as for both individual- and household-level double burden manifestations in Mexico (Kroker-Lobos et al. 2014).

Therefore, the co-occurrence of anemia and overweight within an individual in this population is a function of the prevalence of each individual condition. Given the higher prevalence of both overweight and anemia among women as compared to adolescent girls, it is not surprising that the prevalence of the individual-level double burden among women far exceeded that of adolescent girls. Despite the fact that the odds of anemia and overweight appear to be independent of one another in this population, the high prevalence of their co-occurrence among women of reproductive age—analogous to other regions with a high prevalence of the individual-level double burden of malnutrition (Gartner et al. 2014; Jones et al. 2016)—suggests the need for policy and programmatic responses that address both forms of malnutrition in this demographic group.

Women from mild to moderately food-insecure households had greater odds of anemia, overweight or obesity and the co-occurrence of anemia and overweight or obesity, independent of education and wealth. HFI, therefore, may serve as a common determinant of both undernutrition and overweight or obesity in this context. However, food security interventions that predominantly focus on increasing food availability may fall short of addressing those aspects of HFI that are likely influencing both of these outcomes. Such interventions could in fact exacerbate overweight and obesity. Severe HFI, characterized by household members experiencing hunger or children needing to reduce food intake, was associated neither with anemia nor obesity among girls or women. In fact, two of the ELCSA component responses related to child-level experiences of food insecurity characteristic of severe HFI were associated with lower odds of overweight and obesity among adolescent girls (i.e., a child in the household consumed less than they should; a child in the household did not receive a nutritious and varied diet). In contrast, those ELCSA component responses associated with poor diet quality were consistently associated with higher odds of anemia and obesity among women (e.g., the household lacked resources to obtain a nutritious and varied diet, or consumed a diet that lacked variety). Therefore, severe HFI seems to more consistently reflect household food insufficiency, while mild to moderate HFI —a condition that is much more common among households in Mexico and that is consistently associated with the individual-level double burden of malnutrition—likely reflects to an equal or even greater extent limited access to a diverse and nutritious diet.

Studies in Mexico and elsewhere (primarily the United States) have similarly observed positive associations between mild HFI and obesity among adult women (Townsend et al. 2001; Sarlio-Lähteenkorva & Lahelma 2001; Adams et al. 2003, Velasquez-Melendez et al. 2011; Morales-Ruan et al. 2014). At the same time, mild to severe HFI has been shown to be associated with anemia among adult women (Fischer et al. 2014), adolescents (Eicher-Miller et al. 2009), and children (Park et al. 2009). These studies have hypothesized that overconsumption of energy-dense, nutrient-poor foods among food insecure households—foods that are also commonly more affordable (Drewnowski & Specter 2004; Melgar-Quinonez et al. 2009)—may contribute to obesity, while inadequate intakes of essential micronutrients, or increased intakes of dietary components that inhibit mineral absorption (e.g., phytic acid) contribute to anemia. Our results build from and add to these findings, indicating that HFI, independent of household socioeconomic status, may serve as a shared mechanism for dual forms of malnutrition within the same individual, simultaneously contributing to overconsumption and dietary inadequacy.

We did not observe an association between HFI and anemia, obesity, or their co-occurrence among adolescent girls. Previous research has shown that adolescents are often shielded by parents from the deleterious consequences of HFI (Hadley et al. 2008; Dixon et al. 2001; Nord 2013). However, this mechanism may not fully explain differential associations of HFI with nutrition and health outcomes across age groups as children and adolescents experience food insecurity differently than adults in some contexts (Fram et al. 2011; Bernal et al. 2012). In a recent study in Brazil, moderate HFI was associated with obesity among adult women, but severe HFI was associated with excess weight among female adolescents (Schlussel et al. 2013). The authors posit that adolescents may be more resistant to accumulating body fat as compared to adult women, and therefore are less susceptible to the obesogenic influence of a food-insecure household environment. The differing stages of the nutrition transition in Mexico and Brazil may help to explain the divergent findings in our study. In Mexico, perhaps different from Brazil, HFI may not influence obesity risk in a monotonic fashion because of complex differences in the relationship between food access, the food environment, and experiences of food insecurity (Coates et al. 2006). The anxiety, deprivation and changes in social interactions associated with HFI (Frongillo 2013) seem to also have different nutritional consequences for adolescents as compared to adult women across these two contexts. Buffering by adults of the negative effects of HFI on adolescents may in part account for this, though we are not able to confirm this hypothesis with the available data. Regardless of the mechanism, examining heterogeneity in the influence of HFI on nutritional status by lifestage should remain a central focus of future analyses.

Though we adjust for several potential confounding variables in our analyses, it is possible that unobserved, non-nutritional determinants such as infection, environmental enteropathy, or genetic factors may have contributed to anemia among adolescent girls and women in the sample, or that failure to include other unmeasured determinants of overweight and obesity, including diet and physical activity (assessed only in a small subsample of participants for the ENSANUT 2012), could have biased our findings. The cross-sectional nature of this study further limits our ability to confirm the directionality of the hypothesized relationship between HFI and the individual-level double burden of malnutrition. Finally, though there were no differences with respect to the highest attained education of individuals in the 191 households that were removed because of missing data on HFI, these households did tend to have lower wealth status than those households for which data were not missing for HFI (i.e., 34% in lowest wealth quintile for households with missing food security data compared to 15% for households with non-missing data). Given that these missing data constituted 1.3% of the overall sample, it is unlikely, though possible, that their exclusion biased the observed results.

Conclusions

The nutrition transition in Mexico has advanced into a mature stage four pattern (Popkin 2006) characterized by food and physical activity environments that are contributing to broad-based vulnerability to malnutrition—both unresolved undernutrition such as nutritional anemia, as well as obesity. Food insecurity may provide an especially effective target for policy interventions that seek to ameliorate malnutrition across the spectrum. Government-sponsored efforts to eradicate food insecurity such as the National Crusade Against Hunger (Cruzada Nacional Contra el Hambre (CNCH)) are laudable (Social Development Secretariat, 2013). However, increasing food production and removing post-harvest losses throughout the food supply chain, two of the objectives of the CNCH program, will likely not be sufficient to address the concurrent burden of undernutrition and obesity observed both nationally in Mexico and within a troublingly high proportion of individuals, especially women of reproductive age. Rather, to effectively reduce undernutrition while simultaneously preventing obesity, policies must adopt a conceptualization of food insecurity that encompasses not only availability, but also physical and economic access to healthy, diverse diets (Jones et al. 2013), especially for low-income and marginalized communities. Agricultural production has an important role to play in achieving these goals, though interventions throughout the entire food supply chain, centered on promoting healthy diets overall, are needed that incentivize nutrition-sensitive value addition and processing (Gelli et al. 2015), strengthen access to diverse markets, and leverage consumer purchasing power to increase demand for healthy foods (Global Panel on Agriculture and Food Systems for Nutrition 2014). Cash transfer and food distribution programs aimed at ameliorating undernutrition may similarly need to adopt a more holistic approach centered on promotion of healthy diets more broadly. These programs have been shown to increase energy intakes among some untargeted subgroups, thus potentially exacerbating excessive weight gain (Leroy et al. 2010). The "Prospera" conditional cash transfer program in Mexico (previously "Oportunidades"), the country's primary initiative to prevent undernutrition, alongside efforts to prevent undernutrition, is scaling up a strategy to prevent excessive weight gain in children and adults through individual counseling, and reducing the energy content of food supplements (Kroker-Lobos et al. 2014). These important programmatic changes would also likely benefit from complementary policy efforts to reshape food systems (Rivera et al. 2014). The World Cancer Research Fund's NOURISHING framework provides guidance for a set of policy actions that are aimed at promoting healthy diets and addressing both undernutrition and obesity through food systems approaches (Hawkes et al. 2013). Polices based on this framework, including nutrition labeling, soda taxes, restricted food advertising, and "home-grown" school feeding programs have been implemented in Mexico and elsewhere throughout the globe (Hodge et al. 2016). Rigorous evidence is still needed to understand the impacts of these programs on food insecurity and related nutrition outcomes across the spectrum from deficiencies to excess. Yet, developing food systems-based food security policies that wield integrated strategies to mutually confront both undernutrition and obesity will no doubt help to bolster efforts to transform the unhealthy food environments that underlie the double burden of malnutrition in LMICs.

Key messages

1. Women of reproductive age from mildly and moderately food-insecure households, respectively, were more likely to experience concurrent anemia and overweight than were women from food-secure households.

2. Household food insecurity may be a shared mechanism for dual forms of malnutrition within the same individual, simultaneously contributing to overconsumption and dietary inadequacy.

3. Food insecurity may provide an especially effective target for policy interventions that seek to ameliorate malnutrition across the spectrum from undernutrition to obesity.

References

Adams E.J., Grummer-Strawn L., Chavez G. (2003) Food insecurity is associated with increased risk of obesity in California women. Journal of Nutrition **133**, 1070-4.

Álvarez M.C., Estrada A., Montoya E.C., Melgar-Quiñónez H. (2006) Validación de escala de la seguridad alimentaria doméstica en Antioquia, Colombia. Salud Pública de México **48**, 474-81.

Armar-Klemesu M., Rikimaru T., Kennedy D.O., Harrison E., Kido Y., Takyi E.E.K. (1995) Household food security, food consumption patterns, and the quality of children's diet in a rural northern Ghana community. Food & Nutrition Bulletin **16**, 27-33.

Backstrand J.R., Allen L.H., Black A.K., de Mata M., Pelto G.H. (2002) Diet and iron status of nonpregnant women in rural Central Mexico. American Journal of Clinical Nutrition **76**, 156-64.

Bentley M.E. & Griffiths P.L. (2003) The burden of anemia among women in India. European Journal of Clinical Nutrition **57**, 52-60.

Bernal J., Frongillo E.A., Herrera H., Rivera J. (2012) Children live, feel, and respond to experiences of food insecurity that compromise their development and weight status in peri-urban Venezuela. Journal of Nutrition **142**, 1343-9.

Bhargava A., Jolliffe D., Howard L.L. (2008) Socio-economic, behavioural and environmental factors predicted body weights and household food insecurity scores in the Early Childhood Longitudinal Study-Kindergarten. British Journal of Nutrition **100**, 438-44.

Black R.E., Victora C.G., Walker S.P., Bhutta Z.A., Christian P., de Onis M., et al. (2013) Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet **382**, 427-51.

Bronte-Tinkew J., Zaslow M., Capps R., Horowitz A., McNamara M. (2007) Food insecurity works through depression, parenting, and infant feeding to influence overweight and health in toddlers. Journal of Nutrition **137**, 2160-5.

Coates J., Frongillo E.A., Rogers B.L., Webb P., Wilde P.E., Houser R. (2006) Commonalities in the Experience of Household Food Insecurity across Cultures: What Are Measures Missing? Journal of Nutrition **136**, 1438S-48S.

Cohen J.H. & Haas J.D. (1999) Hemoglobin correction factors for estimating the prevalence of iron deficiency anemia in pregnant women residing at high altitudes in Bolivia. Revista Panamericana de Salud Pública **6**, 392–9.

Coleman-Jensen A., Nord M., Singh A. (2013) Household food security in the United States in 2012. Washington, DC: U.S. Department of Agriculture, Economic Research Service.

Comité Científico ELCSA (2012) Escala Latinoamericana y Caribeña de Seguridad Alimentaria (ELCSA): Manual de uso y aplicación. Santiago, Chile: Food and Agriculture Organization.

Cook J.T., Frank D.A., Levenson S.M., Neault N.B., Heeren T.C., Black M.M., et al. (2006) Child food insecurity increases risks posed by household food insecurity to young children's health. Journal of Nutrition **136**, 1073-6.

Corsi D.J., Finlay J.E., Subramanian S.V. (2011) Global burden of double malnutrition: has anyone seen it? PLoS One **6**, e25120.

Cuevas-Nasu L., Rivera-Dommarco J.A., Shamah-Levy T., Mundo-Rosas V., Méndez-Gómez-Humarán I. (2014) Food insecurity and nutritional status of preschool children in Mexico. Salud Pública de México **56**, S47–53.

de Onis M., Onyango A.W., Borghi E., Siyam A., Nishida C., Siekmann J. (2007) Development of a WHO growth reference for school-aged children and adolescents. Bulletin of the World Health Organization **85**, 660-7.

Dieffenbach S. & Stein A.D. (2012) Stunted child/overweight mother pairs represent a statistical artifact, not a distinct entity. Journal of Nutrition **142**, 771-3.

Dietz W.H. (1995) Does Hunger Cause Obesity? Pediatrics **95**, 766-7.

Dinour L.M., Bergen D., Yeh M.C. (2007) The food insecurity-obesity paradox: a review of the literature and the role food stamps may play. Journal of the American Dietetic Association **107**, 1952-61.

Dixon L.B., Winkleby M.A., Radimer K.L. (2001) Dietary intakes and serum nutrients differ between adults from food-insufficient and food-sufficient families: Third National Health and Nutrition Examination Survey, 1988-1994. Journal of Nutrition **131**, 1232-46.

Doak C.M., Adair L.S., Bentley M., Monteiro C., Popkin B.M. (2005) The dual burden household and the nutrition transition paradox. International Journal of Obesity **29**, 129-36.

Drewnowski A. & Specter S.E. (2004) Poverty and obesity: the role of energy density and energy costs. American Journal of Clinical Nutrition **79**, 6-16.

Fischer N.C., Shamah-Levy T., Mundo-Rosas V., Méndez-Gómez-Humarán I, Pérez-Escamilla R. (2014) Household Food Insecurity Is Associated with Anemia in Adult Mexican Women of Reproductive Age. Journal of Nutrition **144**, 2066–72.

Fram M.S., Frongillo E.A., Jones S.J., Williams R.C., Burke M.P., DeLoach K.P., Blake C.E. (2011) Children are aware of food insecurity and take responsibility for managing food resources. Journal of Nutrition **141**, 1114-9.

Frongillo E.A. (2013) Confronting myths about household food insecurity and excess weight. Cadernos de Saude Publica **29**, 229-30.

Garrett J.L. & Ruel M.T. (2005) Stunted child-overweight mother pairs: prevalence and association with economic development and urbanization. Food & Nutrition Bulletin **26**, 209-21.

Gartner A., El Ati J., Traissac P., Bour A., Berger J., Landais E., et al. (2014) A double burden of overall or central adiposity and anemia or iron deficiency is prevalent but with little socioeconomic patterning among Moroccan and Tunisian urban women. Journal of Nutrition **144**, 87-97.

Gelli A., Hawkes C., Donovan J., Harris J., Allen S., de Brauw A., Henson S., Johnson N., Garrett J., Ryckembusch D. (2015) Value Chains and Nutrition: A Framework to Support the Identification, Design, and Evaluation of Interventions. Washington, DC: International Food Policy Research Institute.

Global Panel on Agriculture and Food Systems for Nutrition. (2014) How Can Agriculture and Food System Policies Improve Nutrition? Technical Brief. London, UK: Global Panel on Agriculture and Food Systems for Nutrition.

Gundersen C., Lohman B.J., Eisenmann J.C., Garasky S., Steward S.D. (2008) Child-specific food insecurity and overweight are not associated in a sample of 10- to 15-year-old low-income youth. Journal of Nutrition **138**, 371-8.

Gutierrez J.P. (2013) Clasificación socioeconómica de los hogares en la ENSANUT 2012. Salud Pública de México **55**, S341–6.

Hackett M., Melgar-Quiñónez H., Perez-Escamilla R., Segall-Correa A.M. (2008a) Gender of respondent does not affect the psychometric properties of the Brazilian Household Food Security Scale. International Journal of Epidemiology **37**, 766-74.

Hackett M., Melgar-Quiñónez H., Uribe M.C.A. (2008b) Internal validity of a household food security scale is consistent among diverse populations participating in a food supplement program in Colombia. BMC Public Health **8**, 175.

Hadley C., Lindstrom D., Tessema F., Belachew T. (2008) Gender Bias in the Food Insecurity Experience of Ethiopian Adolescents. Social Science & Medicine **66**, 427-38.

Hanson K.L., Sobal J., Frongillo E.A. (2007) Gender and marital status clarify associations between food insecurity and body weight. Journal of Nutrition **137**, 1460-5.

Hawkes C., Jewell J., Allen K. (2013) A food policy package for healthy diets and the prevention of obesity and diet-related non-communicable diseases: the NOURISHING framework. Obesity Reviews **14**, 159-68.

Hodge J., Verstraeten R., Ochoa-Avilés A. (2016) Malnutrition's New Frontier: The Challenge of Obesity. In: Nourishing Millions. Gillespie S., Hodge J., Yosef S., Pandya-Lorch R., eds. Washington, DC: International Food Policy Research Institute. pp. 81-88

Institute for Health Metrics and Evaluation. (2013) The global burden of disease: generating evidence, guiding policy. Seattle, WA: Institute for Health Metrics and Evaluation.

Instituto Nacional de Salud Publica (2012) Encuesta Nacional de Salud y Nutrición 2012: Resultados Nacionales. Cuernavaca, Mexico: Instituto Nacional de Salud Publica.

Jones A.D., Ngure F.M., Pelto G., Young S.L. (2013) What Are We Assessing When We Measure Food Security? A Compendium and Review of Current Metrics. Advances in Nutrition **4**, 481-505.

Jones A.D., Hayter A.K., Baker C.P., Prabhakaran P., Gupta V., Kulkarni B., et al. (2016) The co-occurrence of anemia and cardiometabolic disease risk demonstrates sex-specific sociodemographic patterning in an urbanizing rural region of southern India. European Journal of Clinical Nutrition **70**, 364-72.

Kendall A., Olson C.M., Frongillo E.A. (1996) Relationship of Hunger and Food Insecurity to Food Availability and Consumption. Journal of the American Dietetic Association **96**, 1019-24.

Kirkpatrick S.I. & Tarasuk V. (2008) Food Insecurity Is Associated with Nutrient Inadequacies among Canadian Adults and Adolescents. Journal of Nutrition **138**, 604-12.

Kraemer K., Zimmermann M.B., eds. (2007) Nutritional Anemia. Switzerland: Sight and Life Press.

Kroker-Lobos M.F., Pedroza-Tobias A., Pedraza L.S., Rivera J.A. (2014) The double burden of undernutrition and excess body weight in Mexico. American Journal of Clinical Nutrition **100**, 1652s-8s.

Lean M.E., Han T.S., Morrison C.E. (1995) Waist circumference as a measure for indicating need for weight management. British Medical Journal **311**, 158-61.

Leifert J.A. (2008) Anaemia and cigarette smoking. International Journal of Laboratory Hematology **30**, 177-84.

Leroy J.L., Gadsden P., Rodríguez-Ramírez S., González de Cossío T. (2010) Cash and in-kind transfers in poor rural communities in Mexico increase household fruit, vegetable, and micronutrient consumption but also lead to excess energy consumption. Journal of Nutrition **140**, 612–7.

Lozoff B. (2007) Iron deficiency and child development. Food and Nutrition Bulletin **28**, S560-71.

Melgar-Quiñonez H., Ye Q., Zubieta A.C., Remley D., Long C., Angell D., Mims S. (2009) Assessing the Monthly Food Abundance-Shortage Cycle in Food Insecure Overweight Women. Journal of Nutrition Education and Behavior **41**, S4.

Morales-Ruan M.C., Mendez-Gomez H.I., Shamah-Levy T., Valderrame-Alvarez Z., Melgar-Quiñónez H. (2014) La inseguridad alimentaria está asociada con obesidad en mujeres adultas de México. Salud Pública de México **56**, S54-S61.

Mundo-Rosas V., Shamah-Levy T., Rivera-Dommarco J.A. (2013) Epidemiología de la inseguridad alimentaria en México. Salud Pública de México **55**, S206-S13.

Nead K.G., Halterman J.S., Kaczorowski J.M., Auinger P., Weitzman M. (2004) Overweight children and adolescents: a risk group for iron deficiency. Pediatrics **114**, 104-8.

Nord M. (2013) Youth Are Less Likely to be Food Insecure than Adults in the Same Household. Journal of Hunger & Environmental Nutrition **8**, 146-63.

OECD. (2014) OECD Health Statistics 2014. Paris, France: Organisation for Economic Co-operation and Development.

Pan L., Sherry B., Njai R., Blanck H.M. (2012) Food insecurity is associated with obesity among US adults in 12 states. Journal of the Academy of Nutrition & Dietetics **112**, 1403-9.

Pérez-Escamilla R. & Segall-Correa A.M. (2008). Food insecurity measurement and indicators. Revista Nutrição Campinas **21**, 15s-26s.

Popkin B.M. (2006) Global nutrition dynamics: the world is shifting rapidly toward a diet linked with noncommunicable diseases. American Journal of Clinical Nutrition **84**, 289-98.

Popkin B.M., Adair L.S., Ng S.W. (2012) Global nutrition transition and the pandemic of obesity in developing countries. Nutrition Reviews **70**, 3-21.

Rivera J.A., Pedraza L.S., Martorell R., Gil A. (2014) Introduction to the double burden of undernutrition and excess weight in Latin America. American Journal of Clinical Nutrition **100**, 1613s-6s.

Romero-Martínez M., Shamah-Levy T., Franco-Núñez A., Villalpando S., Cuevas-Nasu L., Gutiérrez J.P., et al. (2013) Encuesta Nacional de Salud y Nutrición 2012: Diseño y Cobertura. Salud Pública de México **55**, S332-S40.

Sarlio-Lähteenkorva S. & Lahelma E. (2001) Food Insecurity Is Associated with Past and Present Economic Disadvantage and Body Mass Index. Journal of Nutrition **131**, 2880-4.

Schlussel M.M., Silva A.A., Perez-Escamilla R., Kac G. (2013) Household food insecurity and excess weight/obesity among Brazilian women and children: a life-course approach. Cadernos de Saude Publica **29**, 219-26.

Scholl T.O., Hediger M.L., Bendich A., Schall J.I., Smith W.K., Krueger P.M. (1997) Use of multivitamin/mineral prenatal supplements: influence on the outcome of pregnancy. American Journal of Epidemiology **146**, 134-41.

Shamah-Levy T., Villalpando S., Mundo-Rosas V., Cruz-Góngora V.D.L., Mejía-Rodríguez F., Gómez-Humarán I.M. (2013) Prevalencia de anemia en mujeres mexicanas en edad reproductiva, 1999-2012. Salud Pública de México **55**, S190-S8.

Shamah-Levy T., Villalpando S., Mejia-Rodriguez F., Cuevas-Nasu L., Gaona-Pineda E.B., Rangel-Baltazar E., et al. (2015) Prevalence of iron, folate, and vitamin B12 deficiencies in 20 to 49 years old women: Ensanut 2012. Salud Pública de México **57**, 385-93.

Smith L. & Haddad L. (2000) Explaining Child Malnutrition in Developing Countries: A Cross-country Analysis. Washington, DC: International Food Policy Research Institute.

Smith C. & Richards R. (2008) Dietary intake, overweight status, and perceptions of food insecurity among homeless Minnesotan youth. American Journal of Human Biology **20**, 550-63.

Social Development Secretariat. (2013) Functioning and organization guidelines of the National Board of the Crusade Against Hunger (in Spanish). Mexico City, Mexico: Secretaria de Desarrollo Social.

Subramanian S.V. & Smith G.D. (2006) Patterns, distribution, and determinants of under- and overnutrition: a population-based study of women in India. American Journal of Clinical Nutrition **84**, 633-40.

Townsend M.S., Peerson J., Love B., Achterberg C., Murphy S.P. (2001) Food insecurity is positively related to overweight in women. Journal of Nutrition **131**, 1738-45.

UNICEF. (1990) Strategy for Improved Nutrition of Children and Women in Developing Countries. New York, NY: United Nations Children's Fund (UNICEF).

Velasquez-Melendez G., Schlussel M.M., Brito A.S., Silva A.A., Lopes-Filho J.D., Kac G. (2011) Mild but not light or severe food insecurity is associated with obesity among Brazilian women. Journal of Nutrition **141**, 898-902.

Villalpando S., Montalvo-Velarde I., Zambrano N., García-Guerra A., Ramírez-Silva C.I., Shamah-Levy T., et al. (2003) Vitamins A, and C and folate status in Mexican children under 12 years and women 12-49 years: a probabilistic national survey. Salud Pública de México **45**, S508-19.

Wilde P.E. & Peterman J.N. (2006) Individual weight change is associated with household food security status. Journal of Nutrition **136**, 1395-400.

World Health Organization. (1992) The prevalence of anemia in women: a tabulation of available information, 2nd ed. Geneva, Switzerland: World Health Organization.

World Health Organization. (2000) Obesity: Preventing and Managing the Global Epidemic, Report of a WHO Consultation on Obesity. Geneva, Switzerland: World Health Organization.

World Health Organization. (2008) Worldwide prevalence of anaemia, 1993–2005. Geneva, Switzerland: World Health Organization.

Zeba A.N., Delisle H.F., Renier G., Savadogo B., Baya B. (2012) The double burden of malnutrition and cardiometabolic risk widens the gender and socio-economic health gap: a study among adults in Burkina Faso (West Africa). Public Health Nutrition **15**, 2210-9.

Figure legend

Figure 1. Percentage of Mexican households reporting specific food insecurity conditions in the previous three months, 2012.

[a]ELCSA: Latin American and Caribbean Food Security Scale.

[b]See Table 2 for description of ELCSA component questions.

Tables

Table 1. Nutritional and sociodemographic characteristics of the sample, disaggregated by adolescent girls (15-19 years) and adult women of reproductive age (20-49 years).

Characteristic	Adolescents (15-19 years)		Adult women (20-49 years)		Total	
	n	mean (SD) or %	n	mean (SD) or %	n	mean (SD) or %
Age (y) (%)						
15-19	4,039	100	.	.	4,039	26
20-29		.	3,316	30	3,316	22
30-39		.	4,245	40	4,245	30
40-49		.	3,199	30	3,199	22
Parity[c]	3,643	0.18 (0.47)	10,396	2.4 (1.7)	14,039	1.8 (1.8)
Current smoking (%)	3,706	8.7	10,324	14	14,030	12
BMI (%)	4,039		10,705		14,744	

Underweight (<18.5)		0.99		1.6		1.3
Normal weight (≥18.5 & <25)		62		27		36
Overweight (≥25 & <30)		24		36		33
Obese (≥30)		13		36		30
Abdominal obesity (waist circumference ≥ 80 cm) (%)[d]	.	.	10,105	80	10,105	80
Anemia (hemoglobin < 120 g/L) (%)	3,373	7.4	10,760	13	14,133	12
ELCSA score	4,039	3.8 (4.2)	10,760	3.8 (4.2)	14,799	3.8 (4.2)
Food insecurity (%)	4,039		10,760		14,799	
Food secure		26		28		27
Mild food insecurity		44		43		43
Moderate food insecurity		19		18		18
Severe food insecurity		11		11		11
Household size	4,039	4.8 (1.8)	10,760	4.3 (1.8)	14,799	4.5 (1.8)
Highest level of education (%)	4,039		10,760		14,799	
No education or preschool only		0.58		3.3		2.6
Primary		8.2		27		22
Secondary		44		32		35
Post-secondary or technical college		44		23		29
Undergraduate degree		3.6		13		11
Graduate degree		0		.98		0.72
Urbanicity (%)	4,039		10,760		14,799	
Urban		77		79		78
Rural		23		21		22
Concurrent anemia & overweight/obesity (%)	3,786		10,755		14,541	
Sample prevalence		1.8		9.2		7.4
Expected prevalence		2.7		9.4		7.4

[a]ELCSA: Latin American and Caribbean Food Security Scale.

[b]Proportions and means are based on estimated samples and linearized standard errors adjusting for the multistage sampling frame of the 2012 ENSANUT.

[c]Parity refers to the total number live and still births.

[d]Data on waist circumference were not collected for adolescent girls in the 2012 ENSANUT.

Table 2. Bivariate associations of the Latin American and Caribbean Food Security Scale (ELCSA) component responses with overweight, anemia, and abdominal obesity among adolescent girls (15-19 years) and adult women of reproductive age (20-49 years).

ELCSA component response	Overweight/obesity		Anemia		Abdominal obesity[d]
	Adolescents OR (95% CI)	Adult women OR (95% CI)	Adolescents OR (95% CI)	Adult women OR (95% CI)	Adult women OR (95% CI)
Household-level experiences of food insecurity					
n	4,039	10,705	3,373	10,760	10,105
Q01: worried that household would run out of food	0.91 (0.80, 1.0)	1.4*** (1.2, 1.6)	0.93 (0.71, 1.2)	1.2[+] (0.99, 1.4)	1.5*** (1.3, 1.8)
Q02: household ran out of food	0.96 (0.83, 1.1)	1.2* (1.0, 1.4)	1.2 (0.87, 1.6)	1.2* (1.0, 1.5)	1.3** (1.1, 1.5)
Q03: household lacked resources to obtain a nutritious and varied diet	0.94 (0.83, 1.1)	1.2** (1.1, 1.4)	0.86 (0.67, 1.1)	1.4** (1.1, 1.6)	1.3** (1.1, 1.5)
Q04: adult in household consumed a diet that lacked variety	0.93 (0.82, 1.1)	1.2** (1.1, 1.4)	0.87 (0.68, 1.1)	1.3** (1.1, 1.6)	1.3** (1.1, 1.5)
Q05: adult in household did not eat breakfast, lunch, or dinner	0.99 (0.85, 1.2)	1.3** (1.1, 1.5)	1.2 (0.93, 1.7)	1.3** (1.1, 1.6)	1.2* (1.0, 1.5)
Q06: adult in household ate less than they thought they should	0.89[+] (0.77, 1.0)	1.1 (0.96, 1.3)	0.93 (0.71, 1.2)	1.3** (1.1, 1.6)	1.3** (1.1, 1.5)
Q07: adult in household felt hungry but could not eat because lacked resources to obtain food	1.0 (0.85, 1.2)	1.2[+] (0.97, 1.4)	1.2 (0.86, 1.6)	1.1 (0.90, 1.4)	1.3* (1.0, 1.5)
Q08: adult in household went without eating for a whole day	1.0 (0.85, 1.2)	1.2[+] (1.0, 1.4)	1.2 (0.87, 1.7)	1.2* (1.0, 1.5)	1.2[+] (0.99, 1.5)
Child-level experiences of food insecurity					
n	3,540	9,093	2,967	9,132	8,501
Q10: child in household did not receive a nutritious and varied diet	0.84* (0.72, 0.97)	1.1 (0.95, 1.3)	0.94 (0.71, 1.2)	1.1 (0.95, 1.4)	1.2[+] (0.99, 1.4)
Q11: child in household consumed just a few types of food	0.90 (0.79, 1.0)	1.1 (0.97, 1.3)	0.96 (0.73, 1.3)	1.3** (1.1, 1.6)	1.2[+] (1.0, 1.4)
Q12: child in household consumed less than they should	0.79* (0.65, 0.96)	1.0 (0.83, 1.3)	1.5* (1.1, 2.1)	1.1 (0.88, 1.4)	0.95 (0.75, 1.2)
Q13: served less food to a child	0.88 (0.74, 1.0)	1.1 (0.93, 1.3)	1.2 (0.86, 1.6)	1.1 (0.88, 1.4)	1.1 (0.88, 1.3)
Q14: child in household felt hungry but could not get more food	0.91 (0.77, 1.1)	1.1 (0.93, 1.3)	1.0 (0.77, 1.4)	1.2[+] (0.97, 1.4)	1.1 (0.94, 1.4)

Q15: child in household went to bed hungry	0.90 (0.72, 1.1)	1.0 (0.81, 1.3)	1.5* (1.0, 2.1)	0.99 (0.76, 1.3)	0.82 (0.64, 1.1)
Q16: child in household went without eating for an entire day	0.86 (0.68, 1.1)	0.90 (0.70, 1.2)	1.5* (1.0, 2.2)	1.2 (0.93, 1.6)	0.85 (0.65, 1.1)

[a]Odds ratios (OR) and 95% confidence intervals (CI) from bivariate logistic regression models are shown for separate regression models. *P*-values are for ORs for each regression analysis (*P<0.05, **P<0.01, ***P<0.001). Odds ratios use linearized standard errors adjusting for the multistage sampling frame of the 2012 ENSANUT.

[b]Overweight or obesity was defined as a body mass index (BMI) ≥ 25 kg m^{-2}; abdominal obesity was defined as a waist circumference ≥ 80 cm; anemia was defined as an altitude adjusted Hb concentration < 120 g/L.

[c]All questions ask about conditions experienced due to a lack of money or other resources to obtain food during the previous 3 months.

[d]Data on waist circumference to calculate abdominal obesity were not collected for adolescent girls in the 2012 ENSANUT.

Table 3. Unadjusted and adjusted logistic regression analyses of the association of household food insecurity with overweight, anemia and the co-occurrence of these conditions among adolescent girls (15-19 years).

Dependent variables	Overweight/obesity	Anemia	Anemia and overweight/obesity
	OR (95% CI)	OR (95% CI)	OR (95% CI)
Unadjusted analyses			
n	4,039	3,373	3,786
Household food insecurity			
Food secure (reference)	.	.	.
Mild food insecurity	0.95 (0.80, 1.1)	0.95 (0.69, 1.3)	0.98 (0.56, 1.7)
Moderate food insecurity	0.95 (0.78, 1.1)	1.1 (0.73, 1.6)	1.1 (0.56, 2.1)
Severe food insecurity	0.79* (0.63, 0.99)	1.2 (0.79, 1.8)	1.0 (0.47, 2.2)
Adjusted analyses			
n	3,643	3,188	3,466
Household food insecurity			
Food secure (reference)	.	.	.
Mild food insecurity	1.1 (0.89, 1.3)	0.89 (0.64, 1.3)	1.1 (0.58, 1.9)
Moderate food insecurity	1.1 (0.88, 1.3)	0.93 (0.62, 1.4)	1.2 (0.58, 2.4)
Severe food insecurity	0.99 (0.77, 1.3)	1.1 (0.71, 1.8)	1.3 (0.58, 3.0)
Age	1.1** (1.0, 1.2)	1.0 (0.92, 1.1)	1.1 (0.87, 1.3)
Parity	1.2* (1.0, 1.4)	1.5** (1.1, 1.9)	1.6* (1.0, 2.5)
Current smoking	.	0.55^{+} (0.28, 1.06)	1.3 (0.58, 2.9)
Household size	0.93*** (0.89, 0.96)	0.99 (0.93, 1.1)	0.95 (0.84, 1.1)
Highest level of education			
No education or preschool only (reference)	.	.	.
Primary	0.95 (0.40, 2.3)	0.53 (0.17, 1.7)	0.19^{+} (0.04, 1.0)
Secondary	0.77 (0.33, 1.8)	0.50 (0.16, 1.5)	0.18* (0.04, 0.85)
Post-secondary or technical college	0.68 (0.29, 1.6)	0.50 (0.16, 1.5)	0.25^{+} (0.05, 1.2)
Undergraduate degree	0.50 (0.19, 1.3)	0.44 (0.10, 1.9)	0.21 (0.02, 1.8)
Graduate degree	.	.	.
Wealth			
Very low	0.67** (0.53, 0.85)	1.3 (0.88, 2.1)	0.56 (0.25, 1.3)
Low	0.88 (0.71, 1.1)	1.1 (0.75, 1.7)	0.90 (0.45, 1.8)
Medium (reference)	.	.	.
High	0.95 (0.77, 1.2)	1.0 (0.67, 1.6)	1.0 (0.50, 2.0)
Very high	1.1 (0.85, 1.3)	0.88 (0.56, 1.4)	0.85 (0.40, 1.8)
Urbanicity			
Urban (reference)	.	.	.
Rural	0.79** (0.67, 0.93)	0.79 (0.58, 1.1)	0.93 (0.54, 1.6)
Region			
Northern (reference)	.	.	.
Central	0.79* (0.66, 0.95)	0.95 (0.66, 1.4)	0.44* (0.23, 0.86)
Mexico City	0.73^{+} (0.51, 1.0)	0.84 (0.41, 1.7)	0.36 (0.08, 1.6)
Southern	0.96 (0.79, 1.2)	1.4^{+} (0.97, 1.9)	1.1 (0.66, 2.0)

[a]Odds ratios (OR) and 95% confidence intervals (CI) from unadjusted and adjusted logistic regression models are shown for separate regression models. Odds ratios use linearized standard errors adjusting for the multistage sampling frame of the 2012 ENSANUT.

[b]*P*-values are for ORs for each regression analysis (^{+}P<0.10, *P<0.05, **P<0.01, ***P<0.001).

[c]Overweight or obesity was defined as a body mass index (BMI) ≥ 25 kg m^{-2}; anemia was defined as an altitude adjusted Hb concentration < 120 g/L.

Table 4. Unadjusted and adjusted logistic regression analyses of the association of household food insecurity with overweight, abdominal obesity, anemia and the co-occurrence of these conditions among adult women of reproductive age (20-49 years).

Dependent variables	Overweight/obesity	Anemia	Abdominal obesity	Anemia & overweight/obesity	Anemia & abdominal obesity
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Unadjusted analyses					
n	10,705	10,760	10,105	10,755	10,656
Household food insecurity					
Food secure (reference)	.	.	.	.	.
Mild food insecurity	1.5*** (1.3, 1.7)	1.4** (1.1, 1.7)	1.5*** (1.3, 1.8)	1.6*** (1.2, 2.0)	1.5*** (1.2, 1.9)
Moderate food insecurity	1.3** (1.1, 1.6)	1.6*** (1.3, 2.1)	1.6*** (1.2, 2.0)	1.7*** (1.3, 2.3)	1.9*** (1.4, 2.5)
Severe food insecurity	1.6*** (1.2, 2.0)	1.5** (1.1, 2.0)	1.6** (1.2, 2.0)	1.6** (1.2, 2.2)	1.6** (1.2, 2.2)
Adjusted analyses					
n	10,343	10,324	9,750	10,319	10,222
Household food insecurity					
Food secure (reference)	.	.	.	.	.
Mild food insecurity	1.2* (1.0, 1.4)	1.3* (1.1, 1.6)	1.2 (0.97, 1.4)	1.5** (1.2, 1.9)	1.4** (1.1, 1.8)
Moderate food insecurity	1.1 (0.88, 1.3)	1.5** (1.1, 1.9)	1.3^{+} (0.99, 1.6)	1.5* (1.1, 2.1)	1.6** (1.2, 2.2)
Severe food insecurity	1.1 (0.81, 1.4)	1.3^{+} (0.97, 1.8)	1.0 (0.74, 1.3)	1.3 (0.94, 1.9)	1.3^{+} (0.95, 1.8)
Age	1.1*** (1.1, 1.1)	1.0** (1.0, 1.0)	1.1*** (1.1, 1.1)	1.0** (1.0, 1.0)	1.0*** (1.0, 1.0)
Parity	1.1** (1.0, 1.1)	1.0* (0.99, 1.1)	1.1** (1.0, 1.2)	1.1* (1.0, 1.1)	1.1^{+} (1.0, 1.1)
Current smoking	.	0.68* (0.49, 0.93)	.	0.65* (0.46, 0.92)	0.67* (0.48, 0.93)
Household size	0.98 (0.94, 1.0)	1.0 (0.98, 1.1)	1.0 (0.96, 1.1)	1.0 (0.95, 1.1)	1.0 (0.96, 1.1)
Highest level of education					
No education or preschool only (reference)	.	.	.	.	.
Primary	1.7** (1.2, 2.3)	0.88 (0.59, 1.3)	1.4^{+} (0.95, 2.1)	0.92 (0.58, 1.5)	0.87 (0.56, 1.4)
Secondary	1.5* (1.1, 2.0)	1.0 (0.69, 1.6)	1.2 (0.80, 1.7)	1.0 (0.64, 1.7)	1.0 (0.63, 1.6)
Post-secondary or technical college	1.2 (0.85, 1.7)	0.95 (0.61, 1.5)	0.93 (0.61, 1.4)	0.89 (0.53, 1.5)	0.88 (0.53, 1.5)
Undergraduate degree	0.88 (0.61, 1.3)	0.94 (0.55, 1.6)	0.62* (0.40, 0.96)	0.74 (0.39, 1.4)	0.76 (0.41, 1.4)
Graduate degree	0.75 (0.38, 1.5)	0.61 (0.19, 1.9)	0.70 (0.32, 1.5)	0.53 (0.15, 2.0)	0.71 (0.22, 2.3)
Wealth					
Very low	0.77* (0.62, 0.96)	0.79^{+} (0.62, 1.0)	0.88 (0.67, 1.1)	0.64** (0.47, 0.87)	0.73* (0.55, 0.96)
Low	1.0 (0.83, 1.3)	1.0 (0.79, 1.3)	1.1 (0.87, 1.4)	0.94 (0.71, 1.3)	1.1 (0.85, 1.4)
Medium (reference)	.	.	.	.	.
High	1.1 (0.92, 1.4)	0.83 (0.63, 1.1)	1.2 (0.95, 1.5)	0.78 (0.57, 1.1)	0.89 (0.67, 1.2)
Very high	0.99 (0.79, 1.2)	0.80 (0.59, 1.1)	1.1 (0.85, 1.4)	0.88 (0.62, 1.3)	0.90 (0.64, 1.3)
Urbanicity					
Urban (reference)	.	.	.	.	.
Rural	0.86* (0.74, 0.99)	0.96 (0.80, 1.1)	0.90 (0.76, 1.1)	0.90 (0.73, 1.1)	0.83^{+} (0.67, 1.0)

Region					
Northern (reference)	.	.	.	.	.
Central	0.77** (0.66, 0.90)	1.0 (0.82, 1.2)	0.85 (0.71, 1.0)	0.89 (0.70, 1.1)	0.94 (0.75, 1.2)
Mexico City	0.90 (0.69, 1.2)	1.1 (0.81, 1.6)	0.85 (0.63, 1.1)	1.1 (0.74, 1.6)	1.0 (0.70, 1.4)
Southern	1.2[+] (0.99, 1.4)	1.3** (1.1, 1.6)	0.98 (0.81, 1.2)	1.4** (1.1, 1.8)	1.3* (1.0, 1.6)

[a]Odds ratios (OR) and 95% confidence intervals (CI) from unadjusted and adjusted logistic regression models are shown for separate regression models. Odds ratios use linearized standard errors adjusting for the multistage sampling frame of the 2012 ENSANUT.

[b]*P*-values are for ORs for each regression analysis ([+]$P<0.10$, *$P<0.05$, **$P<0.01$, ***$P<0.001$).

[c]Overweight or obesity was defined as a body mass index (BMI) ≥ 25 kg m^{-2}; abdominal obesity was defined as a waist circumference ≥ 80 cm; anemia was defined as an altitude adjusted Hb concentration < 120 g/L.

Supplemental Table 1. Unadjusted and adjusted logistic regression analyses of the association of household food insecurity with overweight, abdominal obesity, anemia and the co-occurrence of these conditions among adult women aged 20-29, 30-39, and 40-49 years.

Dependent variables	Overweight/obesity	Anemia	Abdominal obesity	Anemia & overweight/obesity	Anemia & abdominal obesity
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Women aged 20-29 years					
Unadjusted analyses					
n	3,301	3,316	2,938	3,316	3,253
Household food insecurity					
Food secure (reference)	.	.	.	.	.
Mild food insecurity	1.2[+] (0.99, 1.4)	0.97 (0.74, 1.3)	1.3** (1.1, 1.6)	1.0 (0.72, 1.4)	0.96 (0.69, 1.3)
Moderate food insecurity	1.2 (0.95, 1.4)	1.2 (0.89, 1.7)	1.4* (1.1, 1.7)	0.94 (0.61, 1.4)	1.0 (0.68, 1.6)
Severe food insecurity	1.2 (0.91, 1.5)	1.5* (1.1, 2.2)	1.3[+] (0.98, 1.8)	1.5[+] (0.94, 2.4)	1.5[+] (0.96, 2.5)
Adjusted analyses					
n	3,171	3,118	2,813	3,107	3,057
Household food insecurity					
Food secure (reference)	.	.	.	.	.
Mild food insecurity	1.1 (0.91, 1.3)	0.93 (0.70, 1.2)	1.1 (0.93, 1.4)	0.94 (0.67, 1.3)	0.95 (0.67, 1.4)
Moderate food insecurity	1.0 (0.82, 1.3)	1.1 (0.74, 1.5)	1.2 (0.91, 1.5)	0.80 (0.51, 1.2)	0.98 (0.63, 1.5)
Severe food insecurity	0.92 (0.69, 1.2)	1.2 (0.82, 1.8)	0.98 (0.71, 1.4)	1.1 (0.66, 1.8)	1.3 (0.80, 2.2)
Women aged 30-39 years					
Unadjusted analyses					
n	4,227	4,245	4,003	4,243	4,212
Household food insecurity					
Food secure (reference)	.	.	.	.	.
Mild food insecurity	1.4*** (1.1, 1.6)	1.5** (1.2, 1.9)	1.3** (1.1, 1.7)	1.6** (1.2, 2.1)	1.5** (1.1, 2.0)
Moderate food insecurity	1.4** (1.1, 1.7)	1.5** (1.2, 2.0)	1.3* (1.0, 1.7)	1.6** (1.2, 2.2)	1.7** (1.2, 2.3)
Severe food insecurity	1.2 (0.94, 1.5)	2.0*** (1.5, 2.7)	1.3 (0.94, 1.7)	1.9*** (1.3, 2.7)	2.0*** (1.4, 2.8)
Adjusted analyses					
n	4,107	4,121	3,885	4,119	4,088
Household food insecurity					
Food secure (reference)	.	.	.	.	.

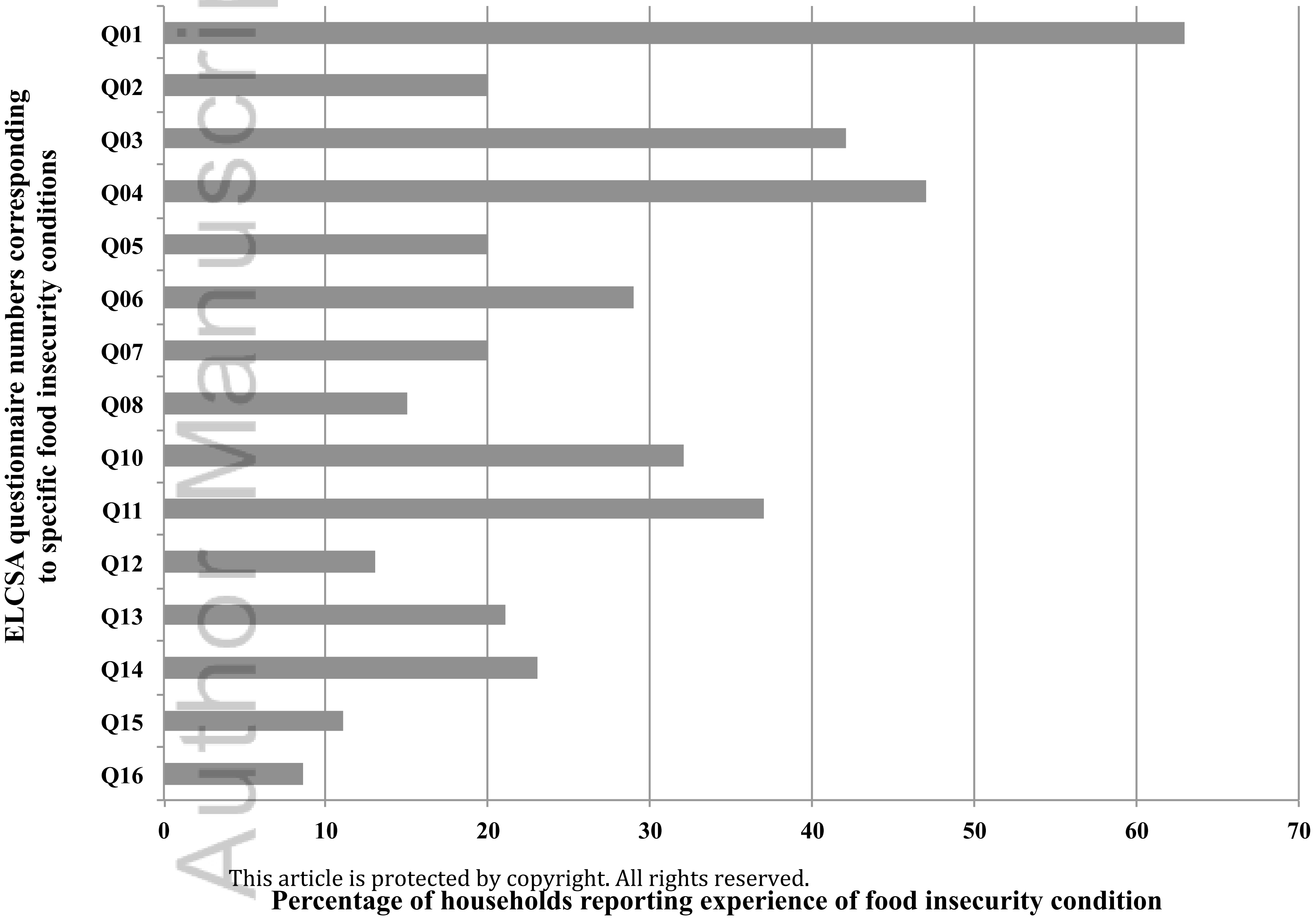
Mild food insecurity	1.2* (1.0, 1.5)	1.4** (1.1, 1.8)	1.1 (0.91, 1.4)	1.4* (1.1, 1.9)	1.3* (1.0, 1.8)
Moderate food insecurity	1.2^{+} (0.98, 1.6)	1.3* (1.0, 1.8)	1.1 (0.83, 1.4)	1.4^{+} (0.98, 1.9)	1.4* (1.0, 2.0)
Severe food insecurity	1.1 (0.81, 1.4)	1.7** (1.3, 2.4)	0.97 (0.70, 1.3)	1.6* (1.1, 2.3)	1.6* (1.1, 2.3)
Women aged 40-49 years					
Unadjusted analyses					
n	3,177	3,199	3,164	3,196	3,191
Household food insecurity					
Food secure (reference)	.	.	.	.	.
Mild food insecurity	1.1 (0.87, 1.4)	1.1 (0.83, 1.4)	1.2 (0.85, 1.6)	1.1 (0.80, 1.4)	1.1 (0.81, 1.4)
Moderate food insecurity	0.89 (0.67, 1.2)	1.1 (0.80, 1.4)	0.99 (0.70, 1.4)	0.97 (0.70, 1.3)	1.0 (0.73, 1.4)
Severe food insecurity	0.96 (0.70, 1.3)	1.0 (0.75, 1.5)	0.99 (0.67, 1.5)	1.2 (0.82, 1.7)	1.1 (0.80, 1.6)
Adjusted analyses					
n	3,065	3,085	3,052	3,082	3,077
Household food insecurity					
Food secure (reference)	.	.	.	.	.
Mild food insecurity	0.99 (0.76, 1.3)	1.0 (0.78, 1.3)	1.1 (0.79, 1.5)	0.98 (0.73, 1.3)	1.0 (0.76, 1.3)
Moderate food insecurity	0.77^{+} (0.57, 1.0)	1.0 (0.73, 1.4)	0.92 (0.62, 1.3)	0.89 (0.62, 1.3)	0.94 (0.67, 1.3)
Severe food insecurity	0.81 (0.57, 1.2)	0.94 (0.66, 1.4)	0.94 (0.61, 1.5)	1.0 (0.70, 1.5)	1.0 (0.70, 1.5)

[a]Odds ratios (OR) and 95% confidence intervals (CI) from unadjusted and adjusted logistic regression models are shown for separate regression models. Adjusted models control for age, parity, household size, the highest attained education level of the individual, household wealth status, urbanicity, and region. Models that included anemia in the response variable were also adjusted for current smoking status of the individual.

[b]*P*-values are for ORs for each regression analysis ($^{+}P<0.10$, $*P<0.05$, $**P<0.01$, $***P<0.001$).

[c]Overweight or obesity was defined as a body mass index (BMI) ≥ 25 kg m^{-2}; abdominal obesity was defined as a waist circumference ≥ 80 cm; anemia was defined as an altitude adjusted Hb concentration < 120 g/L.

Figure 1


ELCSA questionnaire numbers corresponding to specific food insecurity conditions
Q01
Q02
Q03
Q04
Q05
Q06
Q07
Q08
Q10
Q11
Q12
Q13
Q14
Q15
Q16
0
10
20
30
40
50
60
70
Percentage of households reporting experience of food insecurity condition