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Peri-Urban, but Not Urban, Residence in Bolivia Is Associated with Higher Odds of Co-Occurrence of Overweight and Anemia among Young Children, and of Households with an Overweight Woman and Stunted Child

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Abstract

Background: Urban populations have grown globally alongside emerging simultaneous burdens of undernutrition and obesity. Yet, how heterogeneous urban environments are associated with this nutritional double burden is poorly understood.

Objective: We aimed to determine: *1*) the prevalence of the nutritional double burden and its components in urban, peri-urban, and rural areas of Bolivia; and *2*) the association of residence in these areas with the nutritional double burden and its components.

Design: We surveyed 3946 randomly selected households from 2 metropolitan regions of Bolivia. Census data and remotely sensed imagery were used to define urban, peri-urban, and rural districts along a transect in each region. We defined 5 nutritional double burdens: concurrent overweight and anemia among women of reproductive age (15–49 y), and children (6–59 mo), respectively; concurrent overweight and stunting among children; and households with an overweight woman and, respectively, an anemic or stunted child. Capillary hemoglobin concentrations were measured to assess anemia (women: hemoglobin <120 g/L; children: hemoglobin <110 g/L), and overweight and stunting were calculated from height, weight, and age data.

Results: In multiple logistic regression models, peri-urban, but not urban residence, was associated with higher odds of concurrent overweight and anemia among children (OR: 1.8; 95% CI; 1.0, 3.2) and of households with an overweight woman and stunted child (1.8; 1.2, 2.7). Examining the components of the double burden, peri-urban women and children, respectively, had higher odds of overweight than rural residents [women (1.5; 1.2, 1.8); children (1.5; 1.0, 2.4)], and children from peri-urban regions had higher odds of stunting (1.5; 1.1, 2.2).

Conclusions: Peri-urban, but not urban, residence in Bolivia is associated with a higher risk of the nutritional double burden than rural areas. Understanding how heterogeneous urban environments influence nutrition outcomes could inform integrated policies that simultaneously address both undernutrition and obesity. *J Nutr* 2018;148:632–642.

Keywords: urbanization, double burden, stunting, obesity, anemia

Introduction

Nearly a decade ago, a critical threshold was crossed that saw more than half the global population living in urban areas for the first time in history (1). This urbanizing trend, driven by population growth and rural–urban migration in low- and middle-income countries (LMICs) (2), is no longer concentrated

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Abbreviations used: BMIZ, body mass index-for-age *z* score; ELCSA, Latin American and Caribbean Food Security Scale; HAZ, height-for-age *z* score; Hb, hemoglobin; LMIC, low- and middle-income country; MET, metabolic equivalent.

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in large urban centers (3). Growth rates in many large cities have decelerated and urban expansion is taking place in adjacent municipalities on the outskirts of cities (4). These peri-urban regions are heterogeneous both within and across countries, and as a result, the definition of peri-urban itself is commonly contested (5). Generally, peri-urban areas are defined as regions on the fringes of urban cores, and relative to urban areas, are characterized in part by lower population density, younger residents, poorer infrastructure, weak governance institutions, unregulated land use, unemployment, poor access to public services, and high levels of environmental degradation and vulnerability to natural disasters (6–8).

A parallel nutrition transition has accompanied the demographic shift that has sparked growth in peri-urban regions of LMICs. This nutrition transition, characterized by changes in physical activity and increased consumption of highly refined foods and vegetable oils, has contributed to a rising prevalence of overweight (9, 10). At the same time, undernutrition (e.g., micronutrient deficiencies, associated adverse health outcomes, and child stunting) remains an unresolved public health challenge in most LMICs (11). This nutritional "double burden" has emerged as a concern at national levels (12), but also manifests within households (e.g., with both overweight and undernourished members) (13) and within individuals (e.g., overweight co-occurring with anemia or poor linear growth) (14, 15).

The determinants of the nutritional double burden are rooted in the diverse social and environmental conditions that influence food access, patterns of physical activity, and food preferences and consumption (16). Urban gradients—spatial differences in the degree to which a geographic unit is urban (17)—are strongly tied to these conditions (18). Yet, the specific role of these gradients in shaping the nutritional double burden remains unclear. To the authors' knowledge, only 1 study has explicitly assessed how peri-urban environments may be associated with the nutritional double burden (19), and nearly all previous literature assessing the relation of urban gradients with the nutritional double burden has examined only dichotomous rural–urban differences (20). Such rural–urban characterizations oversimplify the heterogeneity within urban areas (21, 22), and lack specificity for predicting health outcomes associated with urban gradients (23). Furthermore, examining peri-urban areas, distinct from urban areas, is important for determining the underlying environmental drivers of malnutrition given: *1*) the rapid growth seen in peri-urban areas worldwide, often decoupled from economic development (7); and *2*) the distinctiveness of areas emerging on the edges of cities suggesting these locations may influence nutrition outcomes through unique pathways.

In this study, we examine the nutritional double burden in 2 transitioning metropolitan regions of Bolivia. We aimed to: *1*) determine the prevalence of the nutritional double burden in urban, peri-urban, and rural areas—hereafter defined as urban gradients—of these 2 regions, and *2*) determine the association of residence across urban gradients with the double burden and its components. We defined the following 5 double burdens: *1*) concurrent overweight and anemia among women aged 15–49 y; *2*) concurrent overweight and anemia among children aged 6–59 mo; *3*) concurrent overweight and stunting among children; *4*) households with an overweight woman and anemic child; and *5*) households with an overweight woman and stunted child. The "components" of the double burden refer to those individual outcomes that underlie each double burden (i.e., overweight among women, overweight among children, anemia among women, anemia among children, stunting among children). We hypothesized that urban gradients would be associated with differential odds of the nutritional double burden and its components.

Methods

Data. We used data from a survey of 3946 households that was conducted as the baseline assessment of a longitudinal study examining secular changes in the diets and nutritional status of Bolivian communities across urban gradients. The survey was implemented from August to December 2015 in and around 2 cities: *1*) El Alto, a highland city located at 4150 meters above sea level (masl) in western Bolivia; and *2*) Montero, a satellite city of the larger metropolitan region of Santa Cruz located in the Amazonian region of eastern Bolivia (350 masl). Both of these regions have experienced tremendous growth in recent decades from urban migration that has contributed to increasing heterogeneity in the populations and environments that constitute the urban, peri-urban, and rural areas examined in this study (24, 25). Yet, despite their shared experiences of growth, these 2 regions of Bolivia have distinct agroecological, political, economic, and sociocultural environments—comparable differences to those reflected between the highlands and Amazonian basins of the larger Andean region—that strengthen the representativeness of the sample (26).

Similar to most LMICs, the Bolivian government makes no official distinction between urban and peri-urban zones of metropolitan areas (27). Studies that have attempted to define intra-urban variation have predominantly assessed differences in population density (28, 29). Therefore, to distinguish peri-urban from urban districts within each study region, population data from the 2012 Bolivian National Census of Population and Housing (NCPH 2012) for each urban district in the municipalities of El Alto and Montero were combined with data on the geographic extents of each district, assessed using Google Earth, to calculate district-level population densities. In both study regions, we observed threshold changes in population density such that moving radially outward from the most population-dense districts of the urban core, population densities decreased precipitously across specific landscape boundaries (e.g., roads, railways, rivers) rather than incrementally decreasing with movement away from the city center. The landscape boundaries also served as district boundaries. Therefore, there was clear spatial demarcation of urban districts with relatively high and low population densities. After assessing and mapping the population density of all relevant districts, the low population density urban districts on the distal side of landscape boundaries were defined as peri-urban and the high population density urban districts on the proximal side of these boundaries were defined as urban. In El Alto, the mean population density of districts defined as peri-urban was 5078 people/km^2 as compared to 13,270 people/km^2 for districts defined as urban. In Montero, the mean population density of the peri-urban districts was 3875 people/km^2 as compared to 11,515 people/km^2 for urban districts. In both regions, the population density of peri-urban areas was approximately one-third that of the urban areas (i.e., 38.3% in El Alto and 33.7% in Montero).

One urban district, 1 peri-urban district, and 2 nearby rural communities were purposely selected within each study region to establish a gradient of urban to rural environments. Census blocks within chosen districts and communities were randomly selected for participation in the survey, and an equal number of eligible households within each census block was randomly selected to participate. Selection of households within each census block was stratified such that equal numbers of households with and without children aged 6–59 mo were selected. This sampling approach was adopted to maximize the number of households in the sample with young children given that, according to the most recent census data (27), fewer than half of households in the study region had young children. Data were considered missing for households or individuals if incomplete after 3 follow-up visits with failed attempts to establish contact.

Households were eligible to participate in the survey if the female spouse of the male head of household, or female head of household was a woman of reproductive age (15–49 y). The inhabitants of the approached home or apartment also had to be the primary residents. Given the transience of peri-urban populations (30, 31) and the high expected loss-to-follow-up among these study participants, peri-urban districts were oversampled (i.e., a larger number of census blocks were selected and therefore a larger number of study households were recruited). Target household sample sizes for urban ($n = 558$), peri-urban ($n = 735$), and rural ($n = 608$) areas, calculated to achieve sufficient statistical power to detect differences across these areas in the examined nutritional outcomes, and taking into consideration expected loss-to-follow-up, were identical in both El Alto and Montero.

All interviews were conducted in-person by trained enumerators. Data were collected from the household member most knowledgeable on the survey module topic. We collected data on recent diet and health behaviors from an index woman in each household, identified as either the female spouse of the male head of household or the female head of household. Among households with young children, an index child was identified (i.e., the youngest child in the household aged 6 to 59 mo) for whom data on dietary intake and health status were collected. All interviews were conducted in Spanish.

Measurement of variables. The 5 nutritional double burdens defined previously and the components of these double burdens were the primary outcomes for this study. We measured capillary hemoglobin (Hb) concentrations of index women and children from finger pricks using portable HemoCue photometers (Hemocue, Inc., Brea, CA). Anemia was defined as an altitude-adjusted Hb concentration <120 g/L for women and <110 g/L for children (32, 33). Anthropometry was assessed among all women of reproductive age within households, and among all children aged 6–59 mo. Body weight was assessed using electronic mother/child scales with a precision of 100 g (Seca, Hamburg, Germany). Children unable to stand on their own were weighed in the arms of an adult caregiver after zeroing the weight of the adult. Standard stadiometers with a precision of 1 mm were used to assess recumbent length of children aged <24 mo and standing height of adults and children aged ≥24 mo (Seca, Hamburg, Germany). The BMI of adult participants was calculated from these measurements as kg/m^2. Overweight was defined according to WHO standards as BMI ≥25 (34). BMI-for-age *z* scores (BMIZ) and height-for-age *z* scores (HAZ) of children aged 6–59 mo were calculated using macros provided by the WHO based on data from the Multicentre Growth Reference Study (35). Child overweight and stunting were calculated as BMIZ >2 and HAZ <–2, respectively (36, 37).

The study was explicitly designed to examine differences across urban gradients. Therefore, location of household residence, the principal independent variable, was defined as a 3-level categorical variable differentiating urban, peri-urban, and rural areas according to the selection of study districts described previously.

Sociodemographic, health, and nutritional covariates were included in analyses to adjust for potential confounding influences. These covariates were selected a priori based on prior theory and evidence of known predictors of the examined components of the nutritional double burden (38–41). The following covariates were included in select models: the age of women and children, number of total household members, sex of household head, sex of child, highest achieved education level of household members, household access to improved water and sanitation (42), study region, parity of index women, as well as recent diarrhea (past 7 d) and breastfeeding status of index children. Quintiles of an asset-based index of household wealth were also included as covariates in all models. The index was developed using assigned asset weights generated from a principal components analysis that created standardized asset scores (43). We also used the Latin American and Caribbean Food Security Scale (ELCSA) to assess household food insecurity (44), as described elsewhere (45). Two descriptive indicators of household mobility, duration in current residence and birth in a rural area, were developed from household roster data on individual adult household members' location of birth and history of previous residence. The physical activity level of index women was assessed using the WHO's Global Physical Activity Questionnaire (GPAQ) (46). Metabolic Equivalent (MET) minutes per week were calculated as the total time spent in physical activity during a typical week weighted by the intensity of the physical activity. A number of MET-minutes ≥600 was the cutoff for achieving the WHO recommendations on physical activity for health (46). Given the upward shift of the Hb distribution curve observed among smokers (47), recent smoked tobacco use among index women was also included as a covariate in models of anemia among women.

Women's frequency of consumption of 50 food items and food groups in the previous 30 d was assessed using a qualitative food-frequency questionnaire. In particular, frequent consumption of 3 food groups was included in analytic models given their ubiquity across Bolivian markets and retail vendors, and their association with excess energy intake (48–50): *1*) sugar-sweetened beverages; *2*) fried chicken; and *3*) other commonly available fried foods including, among others, fried empanadas, French fries, and pork cracklings. Frequent consumption was defined as consumption ≥2 times/wk. Dietary intake among children was assessed from multiple-pass, quantitative 24-h recall interviews with primary caregivers using standard serving dishes to assist respondent recall (51). A second interview on a nonconsecutive day was carried out among approximately one-fifth of households with young children ($n = 416$). Nutrient intakes for individuals with repeat data were calculated as the 2-d mean intake. Intakes of individuals with 1 d of dietary data were adjusted to estimate the distribution of usual intakes among the sample population based on variance partitioning using data from the subsample of individuals with repeat data (52). Data from the Bolivian Food Composition Table were used to identify the energy and nutrient content of each food item reported (53). Missing data for zinc and folate were imputed from the Peruvian Food Composition Table (54). We calculated energy intake (in megajoules) from complementary foods (i.e., excluding breast milk) as the sum of energy intakes across all food items consumed on the day prior to the interview. Mean Micronutrient Density Adequacy (MMDA) of children's diets was calculated as the average density adequacy scores of 9 micronutrients (calcium, iron, zinc, vitamin A, thiamine, riboflavin, niacin, vitamin C, and folate) capped at 100% (55). These scores were calculated by dividing the nutrient densities of each micronutrient by the recommended nutrient density which was calculated as the RDA for the nutrient (or Adequate Intake when RDA was not available) (56) divided by the age-specific energy requirement from complementary foods, assuming an average breast milk intake (for those children currently breastfeeding) (57).

Statistical analysis. All analyses were carried out using the Stata statistical software package version 14.2 (2017; StataCorp, College Station, TX). We calculated means and proportions of the double burden and its components and other characteristics of households, women, and children. Two-sided *t* statistics and Pearson's chi-squared test statistics were calculated to test for differences in means and proportions of these characteristics, respectively, across urban gradients, as well as across samples of women and children with missing compared to nonmissing anthropometry and Hb data. We also estimated the average predicted probability of each double burden, conditional on residing in an urban, peri-urban, or rural location, and examined pairwise comparisons of these predictive margins. The expected prevalence of each double burden was calculated using the multiplicative rule of probability (i.e., the product of the components of each double burden based on the sample of individuals or households for whom the double burden was calculated) and compared to the observed prevalences of the double burdens.

We used multiple logistic regression, adjusting for the covariates described previously, to model the association of urban gradient with the double burdens and their components. We further adjusted SEs and variance-covariance matrices of the estimators for intra-household correlations using the robust estimator of variance to allow for intragroup correlation. Variance inflation factors were below recommended cutoffs for identifying collinearity among covariates as a concern (58). The statistical significance of associations was identified at the $P < 0.1$, $P < 0.05$, and $P < 0.01$ levels.

Ethical approval. The study protocol was approved by the University of Michigan Health Sciences and Behavioral Sciences Institutional Review Board and the National Bioethics Committee of Bolivia (Comité Nacional de Bioética). Comprehensive written informed consent was obtained from all study participants ≥18 y old and written informed assent was obtained for individuals aged 15–17 y.

Results

The final analytic sample for assessing overweight among women included 4452 women from 3733 households, and for assessing anemia, 3655 women from 3655 households (**Supplemental Figure 1**). For children, the final analytic sample for assessing overweight included 2317 children from 1903 households, and for anemia, 1802 children from 1802 households (Supplemental Figure 1). The sample for assessing stunting among children was the same as for child overweight. Samples of women and children were analyzed separately with the exception of analyses of the 2 household-level double burden outcomes. For these analyses, all women and children with complete outcome data for relevant nutrition outcomes were included.

Across urban, peri-urban, and rural areas, more than half of adult women were overweight (**Table 1**). The prevalence of anemia among women was lowest in urban areas at 42.7% and highest in rural areas at 62.5%. The prevalence of anemia among children was higher than that among women with 62.4% of children anemic in urban areas, and approximately three-quarters of children anemic in both peri-urban and rural areas (Table 1). The prevalences of both stunting and overweight among children were highest in peri-urban areas at 20.5% stunted and 12.0% overweight.

Sociodemographic characteristics of households and individuals also varied across urban gradients. For example, compared to urban or rural households, a lower proportion of women from peri-urban areas was educated beyond primary school, and a larger proportion of peri-urban households were in the lowest 2 wealth quintiles (Table 1). As compared to urban or rural areas, a lower prevalence of peri-urban households (69.6%) had ≥1 adult household member that had lived in the household's current residence their entire life (Table 1). The proportion of adult household members born in a rural area was highest in rural areas (89.5%), though the proportion in peri-urban areas (28.6%) was more than double that in urban areas (14.1%) (Table 1). Energy intake from complementary foods was lowest among children from rural households, and the prevalence of recent diarrhea was highest among these children (Table 1). However, as compared to children from urban households, children from peri-urban households had lower energy intake from complementary foods and a higher prevalence of recent diarrhea.

The overall prevalence of each nutritional double burden was as follows: overweight and anemic women: 32.9%; overweight and anemic children: 6.6%; overweight and stunted children: 2.3%; overweight woman and anemic child in the same household: 48.2%; overweight woman and stunted child in the same household: 12.5%. The prevalence of 4 of the 5 examined nutritional double burdens was highest in peri-urban areas (**Figure 1**). Households with an overweight woman and anemic child represented the most prevalent double burden across all areas, with nearly half of households demonstrating this condition, whereas child-level double burdens were less prevalent (e.g., 4.8%, 8.5%, and 5.4% of children in urban, peri-urban, and rural areas, respectively, were concurrently overweight and anemic while 1.8%, 2.7%, and 2.2% of children in urban, peri-urban, and rural areas, respectively, were concurrently overweight and stunted). The prevalence of concurrent overweight and stunting among children did not differ across urban gradients. The expected prevalences of the double burdens exceeded the observed prevalences for overweight and anemia among women and children, respectively, across all urban gradients, but were lower than the observed prevalences for the other 3 double burdens for nearly all urban gradients (Figure 1).

In multiple logistic regression models examining the components of the nutritional double burden and adjusting for differences in sociodemographic and health characteristics, women in both urban and peri-urban areas had higher odds of being overweight as compared to rural areas (OR (95% CIs): urban: 1.7 (1.3, 2.1); peri-urban: 1.5 (1.2, 1.8)) and lower odds of being anemic (urban: 0.48 (0.39, 0.58); peri-urban: 0.72 (0.61, 0.85)) (**Supplemental Table 1**). Children residing in peri-urban, but not urban regions, had higher odds of stunting (1.5 (1.1, 2.2)) and overweight (1.5 (1.0, 2.4)), respectively, as compared to rural areas. Children residing in urban areas had lower odds of being anemic (0.45 (0.31, 0.68)) and stunted (0.67 (0.42, 1.0)), respectively, than children living in rural areas.

The odds of experiencing all 5 nutritional double burdens was lower among urban residents as compared to rural residents; however, these associations were consistent with random variability ($P > 0.1$). Peri-urban residence was associated with higher odds of concurrent overweight and anemia among children (1.8 (1.0, 3.2)) and of households with an overweight woman and stunted child (1.8 (1.2, 2.7)) (**Table 2**).

Discussion

Using data from a large observational study across urban gradients in 2 distinct regions of Bolivia, we observed that the prevalence of overweight among adult women, and of anemia among both women and preschool-aged children, was high in urban, peri-urban, and rural locations. More than half of adult women were overweight or anemic in nearly all locations with similar findings for anemia among children. The prevalence of stunting and overweight, respectively, among children was more modest, but was highest in peri-urban areas where 1 in 5 and 1 in 10 children were stunted and overweight, respectively. We found the same trend in analyses adjusting for household wealth, educational attainment, dietary intake, and numerous other determinants wherein peri-urban, but not urban, locations were associated with higher odds of: stunting among children; overweight among children; and 2 double burdens including: (1) concurrent overweight and anemia among children; and (2) households with an overweight woman and stunted child.

A recent synthesis of studies from 9 Latin American countries (that did not include Bolivia) concluded that the coexistence of undernutrition and obesity was common throughout many countries in Latin America (59). Two-thirds or more of women in the countries included in the synthesis were overweight, while the prevalences of anemia and stunting were moderately high to very high in most countries. Though the current study was not nationally representative like those included in this synthesis, the findings here on the high prevalence of both undernutrition and overweight are aligned with those from other countries in the region. Yet, it is challenging to compare our findings to those from other studies given the dearth of analyses examining nutrition outcomes in peri-urban environments. One previous study that used country-level population density data to examine how urban gradients are associated with the nutritional double burden in sub-Saharan Africa similarly found that moderately urbanized regions were associated with higher odds of overweight among women, stunting among children

TABLE 1 Sociodemographic characteristics and health and nutrition indicators for the study sample population, by urban gradient[1]

				Urban gradient			
	n	Urban	*n*	Peri-urban	*n*	Rural	F-statistic or χ^2
Households	1138		1647		1161		
Region, %							3.7
El Alto	578	50.8	894	54.3	601	51.8	
Montero	560	49.2	753	45.7	560	48.2	
Household size	1138	4.8 ± 1.9[2]	1647	4.6 ± 1.6	1161	4.7 ± 1.7	5.4***
Sex of head of household, %							68.9***
Female	384	34.7	397	24.3	229	19.9	
Male	722	65.3	1240	75.8	923	80.1	
Age of head of household, y	1103	40.7 ± 12.7	1637	36.7 ± 10.3	1151	39.5 ± 11.9	45.7***
Highest attained education level (head of household), %							209***
No education	4	0.37	29	1.8	39	3.6	
Some primary (incomplete)	42	3.9	76	4.7	61	5.6	
Complete primary	322	29.7	706	44.0	499	45.7	
Complete secondary	465	42.9	659	41.1	393	36.0	
Education beyond secondary	250	23.1	134	8.4	100	9.2	
Access to improved water, %							275***
Yes	1136	99.8	1638	99.4	1032	88.9	
No	2	0.2	9	0.6	129	11.1	
Access to improved sanitation, %							17.2***
Yes	522	45.9	660	40.1	437	37.6	
No	616	54.1	987	59.9	724	62.4	
Wealth quintiles, %							223***
Lowest	155	13.6	417	25.3	214	18.4	
Low	166	14.6	389	23.6	235	20.2	
Middle	203	17.8	318	19.3	268	23.1	
High	240	21.1	304	18.5	245	21.1	
Highest	374	32.9	219	13.3	199	17.1	
Household food insecurity, %							14.8**
Food secure	420	36.9	654	39.9	428	37.0	
Mildly food insecure	408	35.9	499	30.5	419	36.2	
Moderately food insecure	206	18.1	332	20.3	220	19.0	
Severely food insecure	104	9.1	153	9.3	90	7.8	
≥1 adult household member lived in the residence their entire life, %							60.1***
Yes	862	75.8	1144	69.5	955	82.3	
No	275	24.2	503	30.5	206	17.7	
Proportion of adult household members born in a rural area	1138	14.1 ± 21.7	1647	28.6 ± 29.5	1161	89.5 ± 22.1	2953***
Women (15–49 y)	1657		2079		1563		
Age of women, y	1657	29.1 ± 9.4	2079	28.9 ± 9.5	1563	29.0 ± 10.0	0.27
Highest attained education level, %							324***
No education	5	0.31	22	1.1	29	1.9	
Some primary (incomplete)	31	1.9	98	4.9	66	4.4	
Complete primary	466	28.6	973	48.2	640	42.2	
Complete secondary	767	47.1	777	38.5	649	42.8	
Education beyond secondary	359	22.1	148	7.3	134	8.8	
Overweight (BMI ≥ 25), %							18.0***
Yes	828	60.6	1108	62.5	723	55.1	
No	538	39.4	665	37.5	590	44.9	
Anemia (Hb < 120 g/L),[3] %							84.4***
Yes	455	42.7	800	53.1	677	62.5	
No	610	57.3	707	46.9	406	37.5	
Achieved WHO recommendations for physical activity,[4] %							23.7***
Yes	841	72.7	1116	70.9	889	79.0	
No	316	27.3	459	29.1	236	21.0	
Parity	1157	2.2 ± 1.8	1575	2.6 ± 1.9	1125	2.5 ± 2.0	12.9***
Smoked tobacco in past 30 d, %							15.8***
Yes	77	6.7	53	3.4	58	5.2	
No	1069	93.3	1506	96.6	1057	94.8	

(*Continued*)

TABLE 1 *Continued*

	Urban gradient						
	n	Urban	*n*	Peri-urban	*n*	Rural	F-statistic or χ^2
Frequent consumption of SSBs (≥2 times/wk), %							15.6***
Yes	1011	61.0	1283	61.7	1049	67.1	
No	646	39.0	796	38.3	514	32.9	
Frequent consumption of fried chicken (≥2 times/wk), %							36.4***
Yes	662	40.0	820	39.4	483	30.9	
No	995	60.0	1259	60.6	1080	69.1	
Frequent consumption of other fried foods (≥2 times/wk), %							9.8***
Yes	466	28.1	551	26.5	365	23.4	
No	1191	71.9	1528	73.5	1198	76.7	
Children (6–59 mo)	776		1154		733		
Age of children, mo	776	32.8 ± 15.8	1153	33.7 ± 16.2	733	33.4 ± 16.2	0.86
Sex of children, %							1.0
Female	397	51.2	563	48.8	362	49.4	
Male	379	48.8	590	51.2	371	50.6	
Highest attained education level of mother of child, %							137***
No education	5	0.66	15	1.4	19	2.8	
Some primary (incomplete)	35	4.6	68	6.2	39	5.6	
Complete primary	250	32.9	578	52.3	319	46.1	
Complete secondary	334	44.0	385	34.8	262	37.9	
Education beyond secondary	136	17.9	60	5.4	53	7.7	
Stunted (HAZ < −2), %							26.3***
Yes	66	10.8	211	20.5	108	16.1	
No	548	89.3	821	79.6	563	83.9	
Overweight (BMIZ > 2), %							6.3**
Yes	64	10.4	124	12.0	55	8.2	
No	550	89.6	908	88.0	616	91.8	
Anemia (Hb < 110 g/L), %							25.6***
Yes	304	62.4	594	74.1	386	75.2	
No	183	37.6	208	25.9	127	24.8	
Currently breastfeeding, %							2.4
Yes	301	38.8	427	37.0	256	34.9	
No	475	61.2	727	63.0	477	65.1	
Energy intake from complementary foods (excluding BM), MJ/d	530	4.8 ± 3.4	817	3.8 ± 2.5	570	3.2 ± 2.3	48.1***
Mean Micronutrient Density Adequacy, %	414	73.2 ± 16.4	660	73.0 ± 14.0	456	72.4 ± 15.6	0.36
Recent diarrhea (past 7 d), %							20.1***
Yes	101	13.4	199	17.7	159	22.4	
No	652	86.6	926	82.3	552	77.6	

[1] F-statistics and Pearson's chi-squared test statistics shown for differences in means and proportions, respectively, for characteristics across urban gradients. Physical activity, parity, smoking, dietary intake, and anemia among women were assessed for only 1 index woman/household. Similarly, breastfeeding status, recent diarrhea, dietary intake, and anemia among children were assessed for only 1 index child/household. $^{**}P < 0.05$; $^{***}P < 0.01$. BM, breast milk; BMIZ, body mass index-for-age *z* score; HAZ, height-for-age *z* score; Hb, hemoglobin; MET, metabolic equivalent; SSB, sugar-sweetened beverage.

[2] Mean ± SD (all such values).

[3] Hb concentrations were adjusted for altitude.

[4] WHO recommendations for physical activity are ≥600 MET-min/wk based on data from the Global Physical Activity Questionnaire.

(whereas urban areas demonstrated evidence of lower risk), co-occurring overweight and anemia among women, and the coexistence of a stunted child and overweight mother in the same household (19). Approximately half of the studies that have examined dichotomous urban–rural differences in the nutritional double burden at the household level have found that urban residence is positively associated with an overweight adult living in the same household with a stunted, underweight, or wasted child (20). However, nearly all other studies that have examined this relation have found no association. In some cases, evidence that rural residents may be more vulnerable to various manifestations of the nutritional double burden has also been observed (60, 61).

Far fewer studies have assessed how urban gradients influence individual-level double burdens, and these studies have not produced consistent findings. In China, for example, the co-occurrence of anemia and metabolic syndrome among adult men, but not women, was found to be more prevalent in urban compared to rural areas (62). In India, this same double burden among both men and women was similarly associated with increasing urbanization (63). In another study from China, moderately urbanized regions (i.e., those with lower population density) were associated with a higher risk of concurrent stunting and overweight among children <18 y of age whereas high levels of urbanization were associated with a lower risk (64). Similarly, the coexistence of obesity and anemia among older

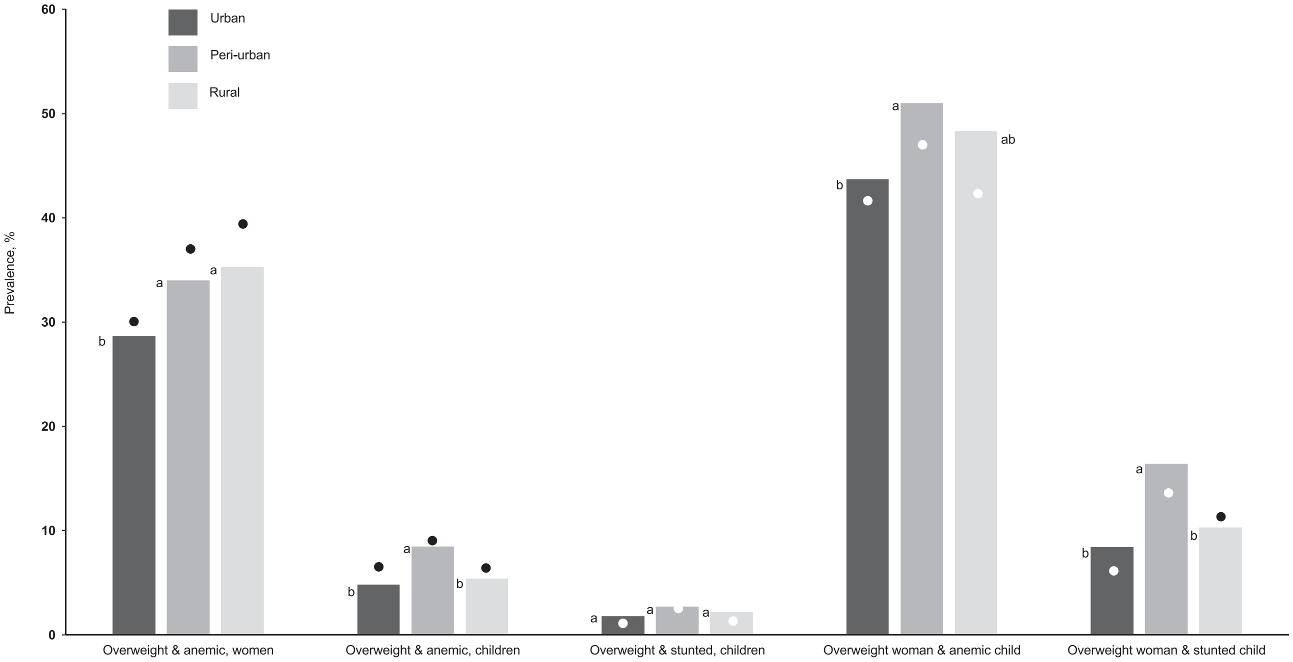

FIGURE 1 Observed and expected prevalences of the nutritional double burdens. Bars show the observed prevalence of each double burden by urban, peri-urban, and rural location. Dots above or within bars indicate the expected prevalence of each double burden calculated as the product of the components of each double burden based on the sample of individuals or households for whom the double burden was calculated. Labeled percentages without a common letter are different, $P < 0.05$. These differences were assessed based on examining pairwise comparisons of the average predicted probability of each double burden conditional on residing in an urban, peri-urban, or rural location. Anemia among women and children was defined as an altitude-adjusted hemoglobin concentration of <120 and <110 g/L, respectively. Overweight among women was defined as a BMI ≥25. Overweight and stunting among children were defined as a BMI-for-age z score >2 and a height-for-age z score <–2, respectively. Sample sizes by double burden and urban, peri-urban, and rural locations are: overweight and anemic women—urban, $n = 999$; peri-urban, $n = 1434$; rural, $n = 1013$; overweight and anemic children—urban, $n = 462$; peri-urban, $n = 779$; rural, $n = 502$; overweight and stunted children—urban, $n = 614$; peri-urban, $n = 1032$; rural, $n = 671$; overweight woman and anemic child—urban, $n = 497$; peri-urban, $n = 792$; rural, $n = 509$; overweight woman and stunted child—urban, $n = 514$; peri-urban, $n = 830$; rural, $n = 544$.

adults was most common among medium-sized communities in Mexico relative to more population-dense metropolitan locations or rural areas (65). Though these latter 2 studies did not explicitly examine peri-urban areas, it is noteworthy that intermediate levels of population density, akin to what is observed in many peri-urban settings, were observed to be most strongly associated with the nutritional double burden. In the case of the study from China (64), this association was in the opposite direction to that observed in highly urbanized, more population-dense areas.

The inconsistent evidence for the association of urban gradients with the nutritional double burden may be due in part to insufficient disaggregation of urban environments. As described previously, the sociodemographic characteristics of peri-urban areas are often markedly different from urban areas in ways that may lead to differential nutritional risk. Data from our study confirm that such differences are apparent in 2 distinct regions of Bolivia. For example, as compared to both urban and rural areas, fewer women from peri-urban areas were educated beyond primary school, and a larger proportion of peri-urban households was of lower wealth status. Differences in food access and food environments across urban and peri-urban areas may also underlie geographic differences in the risk of diverse forms of malnutrition. Migrants to peri-urban areas, for example, may be at a high risk of food insecurity (66), which is associated with both undernutrition and overweight (67–69). In our study, the proportion of adult household members born in a rural area was more than twice as high among peri-urban compared to urban households, suggesting higher rates of rural–urban migration among peri-urban residents. Furthermore, the proportion of moderately and severely food insecure households was highest among peri-urban households, and children in households from peri-urban areas had lower consumption of energy from complementary foods than urban children. Rural migrants may also be dislocated from food production activities and become more reliant on purchased foods (70), especially highly processed foods that contribute to excessive energy intakes (71). Indeed, women in peri-urban areas in our study consumed highly processed foods with similar frequency to women in urban areas, and were also less likely to meet the WHO recommendations for physical activity. Transience related to job insecurity and associated diminishment of social connectedness among peri-urban residents (72, 73) could also contribute to poor health behaviors, psychosocial stress, and loss of social support networks, all of which could adversely affect nutrition outcomes (74, 75). Peri-urban areas exhibited the lowest prevalence of households with ≥1 adult household member that had lived in the household's current residence their entire life, suggesting greater transience among residents of these areas. Taken together, these data suggest that peri-urban and urban populations are distinct in important ways that may contribute to a convergence of risk of both undernutrition and overweight among peri-urban residents (76).

Though we analyzed a large, well-characterized sample of households and individuals from a study that was designed explicitly to examine differences in nutrition outcomes across urban gradients, this study did have several limitations. Our ability to draw causal inferences from the observed associations is

TABLE 2 Logistic regression analyses of the association of urban gradients with the nutritional double burdens[1]

	Nutritional double burdens				
	Overweight and anemia, women	Overweight and anemia, children	Overweight and stunted, children	Overweight woman and anemic child	Overweight woman and stunted child
Unadjusted analysis					
n	3446	1743	2317	1798	1888
Location of household residence					
Rural (reference)	—	—	—	—	—
Peri-urban	0.95 (0.80, 1.1)	1.6** (1.0, 2.6)	1.2 (0.65, 2.3)	1.1 (0.89, 1.4)	1.7*** (1.2, 2.4)
Urban	0.74*** (0.61, 0.89)	0.88 (0.49, 1.6)	0.80 (0.36, 1.8)	0.83 (0.65, 1.1)	0.80 (0.52, 1.2)
Adjusted analysis					
n	3285	1503	1341	1591	1412
Location of household residence					
Rural (reference)	—	—	—	—	—
Peri-urban	1.0 (0.85, 1.1)	1.8** (1.0, 3.2)	1.8 (0.69, 4.5)	1.1 (0.83, 1.4)	1.8*** (1.2, 2.7)
Urban	0.87 (0.70, 1.1)	0.73 (0.36, 1.5)	0.56 (0.16, 2.0)	0.80 (0.59, 1.1)	0.76 (0.44, 1.3)
Age of head of household, y	—	—	—	1.0** (1.0, 1.0)	0.98* (0.96, 1.0)
Age of women, y	1.0*** (1.0, 1.0)	—	—	—	—
Age of children, mo	—	0.97*** (0.95, 0.99)	0.96** (0.93, 0.99)	0.98*** (0.97, 0.99)	0.99 (0.98, 1.0)
Household size	1.1** (1.0, 1.1)	1.0 (0.89, 1.2)	0.98 (0.79, 1.2)	1.2*** (1.1, 1.3)	1.1* (0.99, 1.2)
Sex of child					
Male (reference)	—	—	—	—	—
Female	—	0.86 (0.56, 1.3)	0.92 (0.42, 2.0)	1.0 (0.85, 1.3)	1.0 (0.73, 1.4)
Sex of household head					
Male (reference)	—	—	—	—	—
Female	0.82** (0.69, 0.98)	1.3 (0.81, 2.2)	1.1 (0.43, 2.7)	0.68*** (0.52, 0.88)	0.68* (0.43, 1.1)
Education level of woman or mother					
No education (reference)	—	—	—	—	—
Some primary	1.5 (0.73, 3.1)	0.53 (0.13, 2.1)	—	1.6 (0.71, 3.8)	0.83 (0.28, 2.4)
Complete primary	1.4 (0.70, 2.6)	0.86 (0.40, 1.8)	0.54 (0.06, 4.6)	1.5 (0.70, 3.1)	0.46 (0.18, 1.2)
Complete secondary	1.3 (0.64, 2.5)	0.80 (0.40, 1.6)	0.47 (0.05, 4.4)	1.4 (0.68, 3.1)	0.36** (0.14, 0.95)
Education beyond secondary	1.0 (0.51, 2.1)	—	0.62 (0.05, 7.6)	1.5 (0.67, 3.4)	0.50 (0.17, 1.5)
Access to improved water					
No (reference)	—	—	—	—	—
Yes	0.67* (0.45, 1.0)	0.80 (0.27, 2.3)	0.79 (0.15, 4.3)	1.4 (0.77, 2.5)	1.5 (0.58, 4.0)
Access to improved sanitation					
No (reference)	—	—	—	—	—
Yes	0.88 (0.75, 1.0)	1.5* (0.94, 2.2)	1.2 (0.55, 2.8)	1.2 (0.95, 1.5)	1.2 (0.83, 1.7)
Wealth quintiles					
Lowest (reference)	—	—	—	—	—
Low	1.0 (0.81, 1.3)	1.1 (0.56, 2.3)	0.41 (0.10, 1.6)	1.3* (0.96, 1.8)	0.93 (0.57, 1.5)
Middle	0.99 (0.78, 1.3)	1.3 (0.63, 2.5)	1.2 (0.46, 3.3)	0.93 (0.67, 1.3)	1.1 (0.67, 1.8)
High	1.1 (0.84, 1.4)	1.7 (0.84, 3.4)	1.0 (0.33, 3.3)	0.91 (0.65, 1.3)	1.1 (0.64, 1.8)
Highest	0.97 (0.75, 1.3)	1.5 (0.69, 3.2)	0.63 (0.16, 2.6)	0.83 (0.56, 1.2)	1.1 (0.61, 2.0)
Household food insecurity					
Food secure (reference)	—	—	—	—	—
Mildly food insecure	0.84* (0.70, 1.0)	0.69 (0.43, 1.1)	0.92 (0.37, 2.3)	0.90 (0.70, 1.1)	1.1 (0.75, 1.7)
Moderately food insecure	1.0 (0.82, 1.3)	0.67 (0.37, 1.2)	1.8 (0.71, 4.6)	0.95 (0.70, 1.3)	1.6 (1.0, 2.6)**
Severely food insecure	0.96 (0.72, 1.3)	0.89 (0.37, 2.1)	0.95 (0.20, 4.4)	0.88 (0.58, 1.3)	1.5 (0.83, 2.8)
Achieved WHO recommendations for PA					
No (reference)	—	—	—	—	—
Yes	0.99 (0.83, 1.2)	—	—	0.84 (0.66, 1.1)	0.60** (0.40, 0.90)
Parity	1.0 (0.98, 1.1)	—	—	1.1** (1.0, 1.2)	1.2*** (1.1, 1.3)
Smoked tobacco in past 30 d					
No (reference)	—	—	—	—	—
Yes	1.2 (0.87, 1.7)	—	—	—	—
Consumption of SSBs ($\geq$2 times/wk)					
No (reference)	—	—	—	—	—
Yes	1.2* (0.98, 1.4)	—	—	1.1 (0.87, 1.4)	0.98 (0.69, 1.4)

(*Continued*)

TABLE 2 *Continued*

	Nutritional double burdens				
	Overweight and anemia, women	Overweight and anemia, children	Overweight and stunted, children	Overweight woman and anemic child	Overweight woman and stunted child
Consumption of fried chicken (≥2 times/wk)					
No (reference)	—	—	—	—	—
Yes	0.86* (0.72, 1.0)	—	—	1.1 (0.84, 1.3)	0.93 (0.64, 1.4)
Consumption of other fried foods (≥2 times/wk)					
No (reference)	—	—	—	—	—
Yes	0.83** (0.69, 0.99)	—	—	0.88 (0.69, 1.1)	0.79 (0.51, 1.2)
Currently breastfeeding					
No (reference)	—	—	—	—	—
Yes	—	0.63* (0.38, 1.1)	0.59 (0.23, 1.5)	0.81 (0.61, 1.1)	0.78 (0.50, 1.2)
Energy intake from complementary foods, MJ	—	0.98 (0.91, 1.1)	0.94 (0.81, 1.1)	0.97 (0.93, 1.0)	0.96 (0.89, 1.0)
Mean Micronutrient Density Adequacy	—	—	1.0 (0.98, 1.0)	—	0.99 (0.99, 1.0)
Recent diarrhea (past 7 d)					
No (reference)	—	—	—	—	—
Yes	—	0.70 (0.37, 1.3)	0.68 (0.23, 2.0)	0.95 (0.72, 1.3)	0.80 (0.49, 1.3)
Region					
Montero (reference)	—	—	—	—	—
El Alto	1.0 (0.84, 1.2)	2.0*** (1.3, 3.2)	1.5 (0.67, 3.5)	2.1*** (1.6, 2.7)	1.9*** (1.2, 2.8)

[1] Values are ORs (95% CIs) from logistic regression models. Adjusted models are multiple logistic regression models that control for all covariates shown. Where covariate information is missing, the relevant variable was not included in the model. Education level of the mother of children was included as a covariate in models of child outcomes, and the education level of the relevant woman was included in models of women's outcomes. SEs and variance-covariance matrices of the estimators are adjusted for intra-household correlations using the robust estimator of variance. Anemia among women and children was defined as an altitude-adjusted hemoglobin concentration of <120 g/L and <110 g/L, respectively. Overweight among women was defined as a BMI ≥25. Overweight and stunting among children were defined as a BMI-for-age *z* score >2 and a height-for-age *z* score <–2, respectively. Wealth quintiles were calculated from an asset-based wealth index using assigned asset weights from a principal components analysis to create standardized asset scores (43). Categorizations of food insecurity were defined based on the Latin American and Caribbean Food Security Scale (ELCSA) (44). The number of MET-min/wk for each woman, calculated as time spent in physical activity during a typical week weighted by the intensity of the physical activity, was used to calculate the WHO's recommendations for physical activity for health (i.e., MET-min ≥600) (46). Mean Micronutrient Density Adequacy was calculated as the average density adequacy scores of 9 micronutrients (calcium, iron, zinc, vitamin A, thiamine, riboflavin, niacin, vitamin C, and folate) capped at 100% (55). $^{*}P < 0.1$; $^{**}P < 0.05$; $^{***}P < 0.01$. MET, metabolic equivalent; PA, physical activity; SSB, sugar-sweetened beverage.

limited. Some authors have suggested that shifting cultural norms, attitudes, or household dynamics associated with urbanization, and not urbanization itself (i.e., changes in physical environments), may be responsible for the differences in dietary patterns observed between urban and rural areas (77). Others have posited that differences in economic development underlie the observed associations between urban gradients and the nutritional double burden (78). It also possible that unmeasured biological characteristics of individuals could have contributed to the observed associations. Though our findings are independent of wealth, education, and a broad set of confounders that were hypothesized to be associated with the specified outcomes, we cannot rule out residual confounding as an explanation for our findings. Though we implemented standardized protocols for diet assessment and assessed foods consumed outside the home, underreporting of dietary intake data by women for their own diet or by caregivers reporting on children's diets is another potential limitation of the study (51). We were also not able to assess our primary outcomes among all eligible participants (Supplemental Figure 1). The proportion of households with missing or incomplete data for anthropometric outcomes and anemia was higher in El Alto as compared to Montero, and in rural areas as compared to urban or peri-urban areas (**Supplemental Tables 2** and 3). However, we observed no consistent differences in the sociodemographic characteristics of households with missing or incomplete outcome data compared to households with complete data (Supplemental Tables 2 and 3). We therefore expect that missingness did not significantly influence the observed findings of the study.

In conclusion, the nutritional double burden is conspicuous in Bolivia, suggesting that integrated policies are needed that simultaneously attend to the full spectrum of malnutrition. This is a daunting challenge, to be certain. Social welfare programs have had contradictory impacts on malnutrition (79). Perhaps because of the complexity of the task, few countries have attempted to design integrated policies to address both undernutrition and obesity (59, 80). Bolivia is no exception, despite laudable and successful government efforts to reduce undernutrition (81, 82). Our results demonstrate that the extent of the nutritional double burden varies across areas that are defined homogeneously as urban in Bolivian national census data—a phenomenon seen in national census data globally—and in nearly all empirical research to date that has examined how urban environments may affect nutrition outcomes. These novel findings, particularly the divergence of nutritional risk between urban and peri-urban areas, suggest that examining how distinct urban forms differently impact nutrition outcomes is important for understanding the underlying environmental drivers of malnutrition, for informing evidence-based policies that address the nutritional double burden, and for targeting investments to confront this problem where it is most prevalent. Indeed, adopting a place-based understanding of nutrition and health risks (83) is needed for constructing effective, integrated policies to address the multiple nutritional challenges now facing LMICs.

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to the writing and revision of the manuscript, and read and approved the final manuscript.

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