



Trabajo Original

Pediatría

Factors associated with body mass index in Brazilian children: structural equation model

Factores asociados con el índice de masa corporal en niños brasileños: modelo de ecuaciones estructurales

Tatiane Géa-Horta¹, Rita de C. Ribeiro Silva², Rosemeire L. Fiaccone^{3,4}, Maurício L. Barreto⁴ and Gustavo Velásquez-Meléndez¹

¹Department Maternal Infant and Public Health. School of Nursing. Federal University of Minas Gerais. Belo Horizonte, Minas Gerais. Brazil. ²Nutrition Science Department. Nutrition School. Federal University of Bahia. Salvador, Bahia. Brazil. ³Department of Statistics. Institute of Mathematics. Federal University of Bahia. Salvador, Bahia. Brazil. ⁴Institute of Public Health. Federal University of Bahia. Salvador, Bahia. Brazil

Abstract

Introduction: Overweight and obesity in children is an important global problem. Its prevalence is increasing in developed and developing countries.

Objective: The aim of this study was to evaluate the association between socioeconomic conditions, maternal body mass index (BMI), food security, and intake of obesogenic foods on excess body weight in children.

Methods: A cross-sectional study was conducted, using the data of 3,676 children from the latest National Demographic and Health Survey in Brazil. The children's BMI was the study outcome. Socioeconomic condition, maternal BMI, food security, and intake of obesogenic foods were used as predictors. structural equation models were used for analysis.

Results: Socioeconomic conditions directly influenced the children's BMI ($\beta = 0.102$; $p = 0.02$), mediated by intake of obesogenic foods ($\beta = 0.018$; $p = 0.04$). A direct association was observed between maternal and child BMIs ($\beta = 0.169$; $p < 0.001$) and intake of obesogenic foods and child BMI ($\beta = 0.114$; $p < 0.001$).

Conclusions: Favorable socioeconomic conditions, increased maternal BMI, and intake of obesogenic foods contributed to increased child BMI.

Key words:

Risk factors.
Nutritional status.
Child. Structural equation modeling.
Brazil.

Resumen

Introducción: el sobrepeso y la obesidad en los niños es un importante problema de salud global, habiéndose verificado aumento de la prevalencia en las poblaciones de los países desarrollados y en desarrollo.

Objetivo: el objetivo de este estudio fue estimar la asociación entre las condiciones socioeconómicas, el consumo y el exceso de peso corporal en los niños.

Métodos: estudio transversal de una muestra probabilística representativa de la población brasileña que incluyó 3.676 niños provenientes de la última Encuesta Nacional de Demografía y Salud. El índice de masa corporal (IMC) de los niños fue la variable desenlace. El nivel socioeconómico, IMC materno, inseguridad a la hora de alimentarlos y el consumo de alimentos obesogénicos fueron consideradas variables independientes. Las ecuaciones estructurales fueron usadas como método de análisis.

Resultados: las condiciones socioeconómicas influyeron directamente el IMC de los niños ($\beta = 0,102$; $p = 0,02$), mediado por la ingesta de alimentos obesogénicos ($\beta = 0,018$; $p = 0,04$). Se observó asociación directa entre el IMC de la madre y del niño ($\beta = 0,169$; $p < 0,001$) y entre el consumo de alimentos obesogénicos y el IMC del niño ($\beta = 0,114$; $p < 0,001$).

Conclusiones: la condición socioeconómica favorable, el IMC materno y la ingesta de alimentos obesogénicos pueden potencialmente contribuir para el aumento del IMC del niño.

Palabras clave:

Factores de riesgo.
Estado nutricional.
Niños. Modelos de ecuaciones estructurales.
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Correspondence:

Gustavo Velásquez-Meléndez. Department Maternal Infant and Public Health. School of Nursing. Federal University of Minas Gerais. Belo Horizonte, Minas Gerais. Brazil
e-mail: jguveme@gmail.com

INTRODUCTION

Overweight and obesity is an important global problem. Its prevalence is increasing in developed and developing countries (1,2), not only in adults, but also in children. This has been observed in North American (3), European (4), and Latin American (5) populations, including in Brazil (6). Its persistence throughout life can lead to several comorbidities (7) such as postural impairment, psychosocial problems (8), and metabolic disorders (dyslipidemia, arterial hypertension, insulin resistance, hyperinsulinemia, and diabetes) (9).

Genetic and postnatal factors (such as social, economic, cultural, psychosocial, and behavioral factors) are related to excess weight, making this a complex and multifaceted condition (8,10). The association between socioeconomic conditions and weight outcomes in children is controversial (2,11). Income and education are associated with food choices and food availability (12,13). Less economically privileged families are more susceptible to food and nutritional insecurity (12). Families with food insecurity adopt compensatory eating practices such as an increased consumption of low-cost, high-calorie, low-nutrient foods (14). Although several studies have indicated a positive association between food insecurity and excess weight (15,16), other studies found no such association (17,18).

Several studies have also indicated that parental, particularly maternal, overweight/obesity status influences excess weight in children, owing to genetic and family-behavioral components and life habits, including food intake and the unrestricted availability of high-calorie, low-nutrient foods at home (19,20).

Determinants of body weight gain in childhood have been investigated through models in which linear regression analysis, logistic analysis, and meta-analysis are commonly performed. However, few studies have applied structural equation modeling (SEM), which limits the simultaneous analysis of explanatory relationships between multiple variables, whether latent or observed.

In this context, the aim of this study was to evaluate the association between socioeconomic conditions, maternal body mass index (BMI), food security, and intake of obesogenic foods on excess body weight in children and how these interrelate to trigger this nutritional outcome. To evaluate these correlations, we used a theoretical model and consulted other studies as references (21).

For the present study, the following hypotheses were established *a priori*: a) increased child BMI is directly associated with unfavorable socioeconomic conditions, mediated by increased maternal BMI, food insecurity, and intake of obesogenic foods by the child, which are, in turn, directly associated with increased child BMI; b) increased child BMI is directly associated with increase in maternal BMI, mediated by the intake of obesogenic foods by the child; and c) increased child BMI is directly associated with food insecurity, mediated by the child's intake of obesogenic foods. Thus, we expected to obtain information that might support preventive and control programs against this nutritional phenomenon, particularly in children.

MATERIALS AND METHODS

This cross-sectional study analyzed data from the latest National Demographic and Health Survey of Children and Women conducted between 2006 and 2007 in Brazil (PNDS) (22). The PNDS was designed to provide estimates representative of the Brazilian population living in private households (including slums), who were selected in 10 sampling strata that comprised a combination of all five major geographical Brazilian regions and both urban and rural areas. The sampling units were selected in two stages as follows: the primary units were composed of census tracts, and the secondary units were composed of households (22). Detailed sampling plans, data collection information and data quality assurance are available in the PNDS/DHS 2006 survey final reports at <http://bvsm.s.saude.gov.br/bvs/pnds/index.php>.

Anthropometric measurements of the mothers and children were performed according to internationally standardized procedures (23), where two measures were obtained for each anthropometric indicator (weight and height) and the mean value was used. Mothers whose children were alive and living with them at the date of the interview were included in this analysis. If the mother had more than one child (approximately 22% of participants), the eldest child was chosen for this study. This choice was due to older children having had a longer duration of exposure to excess weight (24). The final number of child observations was 3,676. No statistically significant differences in socioeconomic and demographic characteristics were observed between the excluded and included children (data not shown). In addition, the amount of missing data was minimal (maternal education level, $n = 44$; maternal BMI, $n = 16$; household condition, $n = 124$; food insecurity, $n = 109$). Substitution of mean variable values was used for imputation of missing data (25).

BMI in children was expressed as a z-score in a continuous form and was considered the outcome variable. It was calculated as the weight (kg) divided by the square of the height (m^2). The category excess weight, including overweight and obesity, measured by the z-score of the body mass index/age (BMIz) indicator was greater and equal than 1 z-scores. BMI z-scores were calculated using the standardized reference curves of the World Health Organization (26).

For the analysis via the SEM from the defined conceptual model, the latent variables considered and represented by an ellipse were as follows:

A. Intake of obesogenic foods by the child (foodobes): latent variable composed of the observed variables (represented by a rectangle): A.1. Intake of fried foods (fried food); A.2. Snacks (pretzels); and A.3. Sweets within the week preceding the interview. These three foods best represented the obesogenic foods. The frequency questionnaire of food consumption used to assess dietary intake of children consisted of a list of twenty foods, food groups, or preparations. The frequency of consumption was in reference to the seven days prior to the interview, and the following answers could be chosen: not consumed, consumed on one day, consumed on two or three days, consumed on four to six

days, consumed every day, and do not know (27). To transform the categories of weekly frequencies into daily intake, a weight (S_n) was assigned to each food, in accordance with the intake frequency category as follows: $S_n = (1/7)[(a + b)/2]$, where a and b correspond to the numbers of days of weekly intake frequency (27). A zero value was assigned to the “does not consume” or “rarely” frequency categories. The remaining categories of weekly frequency were the following: once, 2 or 3 times, 4-6 times, and daily (category to which a maximum weight of 1 was allocated).

B. Socioeconomic conditions(ses): latent variables composed of the following observed variables: B.1. Possession of household goods (hholdg), based on the economic classification criteria of Brazil of the Brazilian Association of Research Companies (28), considering the sum of goods, used as a continuous variable; B.2. Household conditions (housecon) and the presence (assigned the value of 0) or absence (assigned the value of 1) of piped water, linkage to a sewage network, electricity, and type of construction (masonry or other), were assessed. Then, a variable composed of the sum of the points of all items, ranging from zero (domicile that possessed all items) to three (domicile that had none of the items), was created; and B.3. Maternal education level (mateduc): years of study of the mother, used as a continuous variable.

The possible mediating observed variables were as follows:

A. Food insecurity (foodsec): assessed using the Brazilian Food Insecurity Scale, represented by scores (0: food security; 1: mild food insecurity; 2: moderate food insecurity; 3: severe food insecurity). This scale was adapted and validated for the non-institutionalized Brazilian population (29) and measures families' perceptions regarding food access. **B. Maternal BMI (matbmi):** calculated as weight (kg) over the square of height (m²), used as a continuous variable.

The SEM was used to assess the relationship between the study variables. Estimation of the direct and indirect effects of theoretical risk factors on child BMI provided more-realistic model tests and potentially greater statistical power than traditional multistep methods. In addition, under complex sampling, both point and variance estimators derived under independently and identically distributed observation assumptions are well known to potentially produce biased and inconsistent estimates. The model specified for SEM was built in Mplus 7.0 software by using robust maximum likelihood, where the strategy for replacing inverse Fisher information with a sandwich estimator of variance is useful for non-normality and non-independence of observations (30). To consider the complex survey design of the data, we used the “Type = Complex” statement, which included sampling weights and clustering of the PNDS data.

In relation of model fitness information, we choose to use relative (TLI- Tucker-Lewis Index) and the no centrality parameter (CFI- Bentler's Comparative Fit Index, RMSEA- Root Mean Square Error of Approximation) fit indices that are relatively unaffected by sample size. Values > 0.95 are suggested as cut-offs for these indices (31).

Regarding the ethical aspects, PNDS (2006) received the approval from the Ethics Research Committee (CEP) of the Center of Reference and Training DST/AIDS of the State Department of

Health (SP). All individuals who agreed to participate in the study signed the informed consent form.

RESULTS

The mean age of the children was 2 years (standard deviation [SD] = 0.03), with similar frequency between sexes. The mean maternal age was 27 years (SD = 0.21), maternal BMI was 25 kg/m² (SD = 0.16), and number of years of schooling was 8 years (SD = 0.11). Among the study children, 54.4% (95% confidence interval [CI] 0.51-0.58) lived in excellent housing conditions, 34.1% (95% CI 0.30-0.38) were among those whose possessions were within the first third of household goods, 6.4% (95% CI 0.05-0.08) had severe food insecurity, 4.9% (95% CI 0.04-0.06) consumed fried foods, 16.8% (95% CI 0.01-0.03) consumed snacks and 19.7% (95% CI 0.17-0.23) consumed sweets daily. The prevalence of excess weight, including overweight and obesity, was 7.3% (95% CI 0.06-0.09): 4.1% (95% CI 0.03-0.05) among boys and 3.2% (95% CI 0.03-0.04) among girls (data not shown).

Significant correlations were observed between certain variables and child BMI, such as maternal education ($r = 0.05$; $p < 0.001$), household goods ($r = 0.11$; $p < 0.001$), intake of fried foods ($r = 0.05$; $p = 0.04$), intake of sweets ($r = 0.07$; $p = 0.01$), and maternal BMI ($r = 0.18$; $p < 0.001$). Other correlations are shown in table I.

The factorial loads (FL) for the latent variable socioeconomic conditions ranged from -0.05 to 0.80, with the possession of household goods being the component that contributed most in this model of measurement (FL = 0.80), followed by maternal education (FL = 0.59; Fig. 1). The latent variable intake of obesogenic foods by the child (foodobes) was represented by the indicators of intakes of fried foods, snacks, and sweets within the week preceding the interview. The factorial loads ranged from 0.27 to 0.67, with the intake of snacks (FL = 0.67; Fig. 1) contributing most to this model, followed by the intake of sweets (FL = 0.59; Fig. 1).

The direct and indirect effects (with their respective estimates) of socioeconomic conditions on child BMI, via maternal BMI, food security, and intake of obesogenic foods and how these variables are interrelated in triggering the outcome, are presented in table II and figure 1. We noted a direct association between socioeconomic conditions and child BMI ($\beta = 0.102$; $p = 0.02$) and an indirect effect mediated by the intake of obesogenic foods ($\beta = 0.018$; $p = 0.04$). This association was not mediated by maternal BMI ($\beta = 0.006$; $p = 0.37$) or food security ($\beta = -0.030$; $p = 0.84$). A direct positive association between socioeconomic conditions and intake of obesogenic foods was observed ($\beta = 0.155$; $p = 0.02$), along with an inverse association with food security ($\beta = -0.544$; $p < 0.001$). The data also indicated a direct association between maternal and child BMI ($\beta = 0.169$; $p < 0.001$) and intake of obesogenic foods ($\beta = 0.114$; $p < 0.001$). No other associations were statistically significant. The results of the SEM analysis attained acceptable values for adjustment indexes of the models (Table III).

Table I. Mean, standard deviation, and correlation coefficient of each study variable (Brazil, National Demographic and Health Survey of Children and Women, 2006-2007)

Variable	1	2	3	4	5	6	7	8	9
Mean (SD)	7.9 (0.12)	13.8 (0.26)	0.4 (0.02)	0.1 (0.01)	0.4 (0.01)	0.4 (0.01)	25.0 (0.17)	0.7 (0.03)	0.45 (0.03)
1. Maternal education	1.00								
2. Possession of household goods	0.48*	1.00							
3. Housing conditions	-0.04*	-0.02*	1.00						
4. Intake of fried foods	-0.02	0.03*	0.01	1.00					
5. Intake of sweets	0.02*	0.11*	-0.02*	0.17*	1.00				
6. Intake of snacks	-0.01	0.12*	-0.03**	0.18*	0.39*	1.00			
7. Maternal BMI	-0.04*	0.06	-0.04	0.02	0.03**	0.05	1.00		
8. Food security	-0.33*	-0.43*	0.08*	-0.01	0.07*	-0.09*	-0.03	1.00	
9. BMI in children (z-score)	0.05*	0.11*	-0.04	0.05**	0.07**	0.10	0.18*	-0.07	1.00

* $p < 0.001$; ** $p < 0.05$; BMI: body mass index; SD: standard deviation.

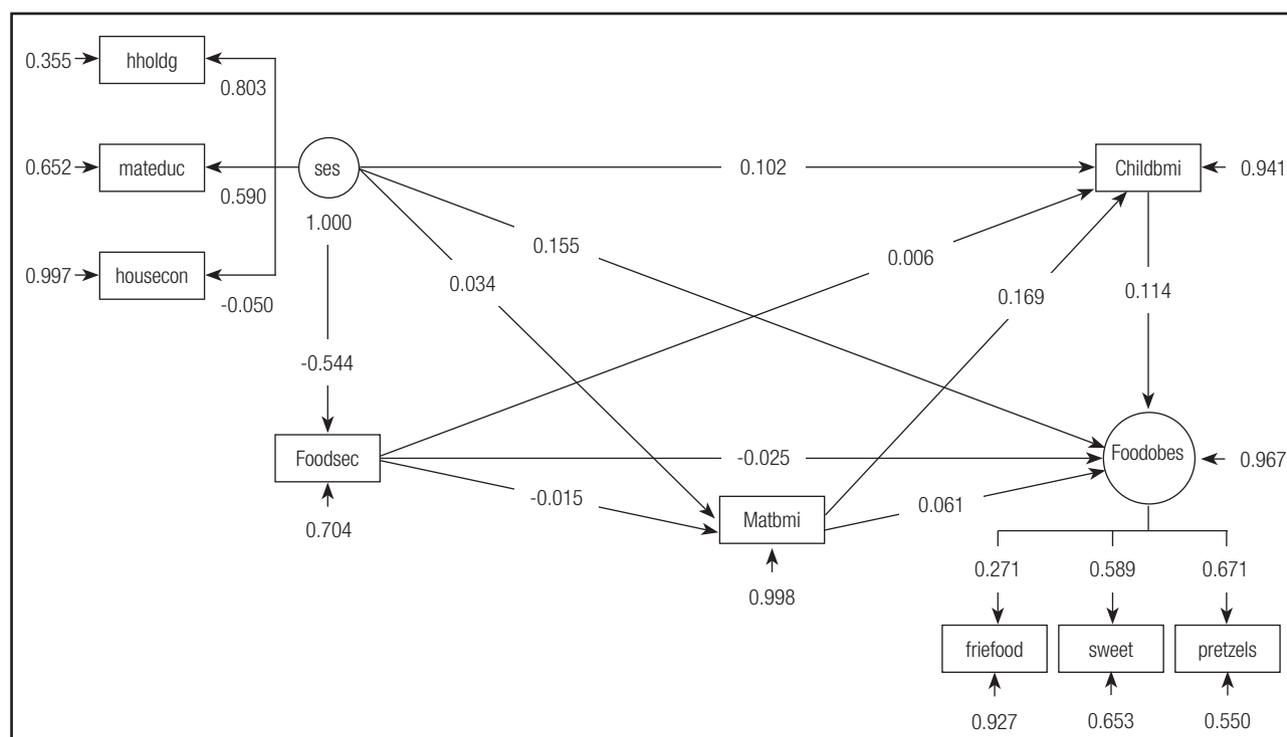


Figure 1.

Standardized estimates from structural equations modeling: measurement model and analysis of direct and indirect effects (note: hholdg: possession of household goods; mateduc: maternal education level; housecon: household conditions; ses: socioeconomic conditions; foodsec: food insecurity; matbmi: maternal body mass index; foodobes: intake of obesogenic foods by the child; childbmi: body mass index of child; friefood: intakes of fried foods).

Socioeconomic conditions were observed to play an important role, affecting child BMI both directly (82.9% of the total effect; not mediated by other variables) and indirectly through maternal BMI (4.9% of the total effect) and the intake of obesogenic foods (14.6% of the total effect). The direct effect

was 17 and 6 times greater than the indirect effect of maternal BMI and intake of obesogenic foods, respectively (Table IV). A similar effect was observed for maternal BMI (results not shown), although the indirect effect was not statistically significant.

Table II. Direct and indirect effects of factors associated with child BMI (Brazil, National Demographic and Health Survey of Children and Women, 2006-2007)

Effects	β	SD	p
<i>Socioeconomic conditions on child BMI</i>			
Direct	0.102	0.04	0.02
Via maternal BMI	0.006	0.01	0.37
Via food insecurity	-0.003	0.02	0.84
Via intake of obesogenic foods	0.018	0.01	0.04
<i>Socioeconomic conditions on maternal BMI</i>			
Direct	0.034	0.04	0.37
<i>Socioeconomic conditions on food insecurity</i>			
Direct	-0.544	0.03	< 0.001
<i>Socioeconomic conditions on intake of obesogenic foods</i>			
Direct	0.155	0.07	0.02
<i>Maternal BMI on child BMI</i>			
Direct	0.169	0.03	< 0.001
Via food intake	0.007	0.01	0.16
<i>Maternal BMI on intake of obesogenic foods</i>			
Direct	0.061	0.04	0.14
<i>Food security on child BMI</i>			
Direct	0.006	0.03	0.84
Via intake of obesogenic foods	-0.003	0.01	0.62
<i>Food security on maternal BMI</i>			
Direct	-0.015	0.03	0.67
<i>Food security on intake of obesogenic foods</i>			
Direct	-0.025	0.05	0.61
<i>Intake of obesogenic food on child BMI</i>			
Direct	0.114	0.04	< 0.001

BMI: body mass index; β : standardized beta coefficient; SD: standard deviation.

Table III. Adjustments of the final model for the factors associated with child BMI (Brazil, National Demographic and Health Survey of Children and Women, 2006-2007)

Tests	Values	Reference
Comparative fit index (CFI)	0.98	> 0.95
Tucker-Lewis index (TLI)	0.97	> 0.95
Root Mean Square Error of Approximation (RMSEA)	0.02	< 0.05

DISCUSSION

From a nationally representative survey, the interrelations (direct and indirect) of socioeconomic conditions, maternal BMI, food security, and intake of obesogenic foods with the BMI z-scores of Brazilian children were tested using SEM.

Socioeconomic conditions positively influenced the increase in child BMI z-scores; this direct relationship (82.9%) was the most important association observed. It was further noted that a part of this total effect (14.6%) was mediated by the intake of obesogenic foods, indicating that as the socioeconomic level increases, food choices can lead to increased intake of unhealthy foods, which are predictors of increasing child BMI (32).

The association between an improved socioeconomic situation and unhealthy intake patterns may be indication of the changes in the modern lifestyle experienced by Brazilian families in the last few decades. In today's hectic world, the demand for practical and easy foods such as industrialized/processed foods, has increased. This increasingly contributes to the introduction of unhealthy intake patterns in families, including children's eating habits (33).

Results contrary to those observed in the present study showed that higher socioeconomic levels are associated with the adoption of consuming adequate and healthy foods (34). Evidence shows that higher maternal schooling and higher family income contribute positively to healthy food choices for children, as they allow parents to assimilate messages of nutritional education programs and understand the importance of diet as a way to promote health, leading to a reduced risk of excess weight in this age group (14). Nonetheless, the overestimation of the registry of healthy food intake, which occurs mainly among individuals with higher education levels, must not be disregarded. Having greater knowledge about healthy foods can lead them to exaggerate their report on their food intakes, thus concealing their actual food intakes (35). Therefore, this controversial correlation still needs to be clarified.

The findings of this study also revealed the direct and positive influence of obesogenic food intake on child BMI. Studies have analyzed the correlation between food intake patterns and excess weight, especially in children, and have shown that intake patterns based on junk food, characterized by a high intake of sweets, chocolate, ice cream, foods with added sugar, fried foods, and sugar-sweetened soft drinks, are related to excess weight. The effect of the intake of fatty foods on BMI gain is due to the high energy density associated with low levels of micronutrients that can result in an excessive passive intake, in which excess calories are unintentionally ingested (36,37). Most studies on this topic remain limited to cross-sectional studies, allowing investigation of the associations between variables only. However, several randomized and controlled intervention studies concluded that changes in eating practices to promote healthy eating positively influenced body weight reductions in all age groups (38).

Another important result of this study is the positive influence of maternal BMI on child BMI, reiterating findings from other studies that maternal obesity is one of the main predictors of excess weight in children (11,12). Although in the present study no direct positive association was observed between maternal BMI and the

Table IV. Proportion of direct and indirect effects contributing to the total effect of socioeconomic conditions on child BMI (Brazil, National Demographic and Health Survey of Children and Women, 2006-2007)

Socioeconomic conditions on child BMI	β	95% CI	Proportion of direct and indirect effects (%)
Total	0.123	-	-
Direct	0.102	0.018 - 0.187	82.9
Indirect - via maternal BMI	0.006	-0.007 - 0.018	4.9
Indirect - via food safety	-0.003	-0.036 - 0.029	-2.4
Indirect - via intake of obesogenic foods	0.018	0.001 - 0.035	14.6

BMI: body mass index; CI: confidence interval; β : standardized beta coefficient.

child's intake of obesogenic foods, the parents' influence on the development of their child's eating habits according to their preferences and attitudes toward diet could not be ignored, as it can interfere with the availability of food in households and can shape the child's nutritional status (22). One must also consider the role of genetics associated with obesity, which has been pointed out as an explanation for the occurrence of excess weight among individuals of the same family (10).

As expected, a reduction in food insecurity was directly associated with an increase in socioeconomic conditions. Despite the absence of statistical significance, food insecurity was negatively associated with child BMI, corroborating the results of another Brazilian study (17). However, our findings differ from those of studies in other underdeveloped and developing countries (39,40). In those studies, increased food insecurity was associated with increased body weight. According to the authors, the lack of financial resources often led families to adopt compensatory feeding practices, such as increasing the intake of high-calorie diets rather than foods with better nutritional quality. This may result in increased body weight in this segment of the population (16,17). These findings must be interpreted with caution, as socioeconomic status does not represent a direct or sufficient indicator of food security, because it does not take into account existing intra-family differences or specific problems such as maternal depression and parental dietary practices, which interfere with the food choices offered to the child (14).

As limitations, we highlight that the cross-sectional design of this study only allowed us to estimate associations between exposure and nutritional outcome; it cannot establish causal relationships. Another aspect that must be considered is that important factors associated with excess weight, such as children's physical activity level, hours of sleep, assisted use of television, and genetic factors were not considered in the models, as such information was not obtained by PNDS (2006-2007). On the other hand, the data from DHS are considered of high quality, as they follow strict standardization procedures and, in most cases, are the only sources of data on maternal and infant health to which several countries refer, especially those with developing or transitioning economies.

In conclusion, the results of this study confirm findings already reported in the literature, that favorable family socioeconomic con-

ditions, increased maternal BMI, and intake of obesogenic foods contribute positively to increased child BMI. These data confirm the complexity of the interrelations between variables involved in determining child BMI and the need to mobilize several sectors of society to promote healthy habits and maintain healthy body weights in children.

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