RESEARCH
Original Research

A Longitudinal Study of Food Insecurity on Obesity in Preschool Children

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ARTICLE INFORMATION

Article history:
Accepted 19 July 2012

Keywords:
Food insecurity
Child obesity
Low income preschool children

2212-2672/$36.00
doi: 10.1016/j.jand.2012.08.031

ABSTRACT

Background Obesity and its co-occurrence with household food insecurity among low-income families is a public health concern, particularly because both are associated with later adverse health consequences.

Objective Our aim was to examine the relationship between household food insecurity with and without hunger in infancy and later childhood with weight status at 2 to 5 years.

Design This longitudinal study uses household food-security status, weight, and height data collected at the first infancy and last child (2 to 5 years) Special Supplemental Nutrition Program for Women, Infants, and Children visits. Household food security was based on parent/caretaker responses to a four-question subscale of the 18-item Core Food Security Module. Obesity was defined as sex-specific body mass index for age ≥95th percentile.

Participants/setting A diverse (58.6% non-white) low-income sample of 28,353 children participating in the Massachusetts Special Supplemental Nutrition Program for Women, Infants, and Children (2001-2006); 24.9% of infants and 23.1% of children lived in food-insecure households and 17.1% were obese at their last child visit.

Statistical analysis Multivariate logistic regression analyses assessed the association between household food-security status during the infant and child visits, and risk of preschool obesity, while controlling for child race/Hispanic ethnicity, sex, child and household size, maternal age, education, and prepregnancy weight. Interactions between these covariates and household food-security status were also examined. In cases of multiple comparisons, a Bonferroni correction was applied.

Results Persistent household food insecurity without hunger was associated with 22% greater odds of child obesity (odds ratio=1.22; 95% CI 1.06 to 1.41) compared with those persistently food secure ($P<0.05$). Maternal prepregnancy weight status modified this association with children of underweight (adjusted odds ratio=3.22; 95% CI 1.70 to 6.11; $P=0.003$) or overweight/obese (adjusted odds ratio=1.34; 95% CI 1.11 to 1.62; $P=0.03$) mothers experiencing greater odds of child obesity with persistent household food insecurity without hunger compared with those with persistent household food security.

Conclusions These results suggest that persistent household food insecurity without hunger is prospectively related to child obesity, but that these associations depend on maternal weight status. Vulnerable groups should be targeted for early interventions to prevent overweight and obesity later in life.

J Acad Nutr Diet. 2012;112:1949-1958.

CHILDHOOD OVERWEIGHT AND OBESITY ARE important public health problems in the United States[1,2] and worldwide[3] because of their magnitude, concurrent and long-term health consequences,[4-7] and persistence into adulthood.[8,9] In the United States, the prevalence of childhood obesity has been steadily rising, even among preschool-aged children, increasing from 7.2% to 12.4% among 2- to 5-year-olds between the 1988-1994 and 2003-2006 National Health and Nutrition Examination Surveys.[1,2] In addition, preschool-aged low-income children might have a higher prevalence of obesity compared with the prevalence in the general population.[10] Based on the Centers for Disease Control and Prevention's Pediatric Nutrition Surveillance System, the prevalence of obesity in low-income 2- to 5-year-old children participating in publicly funded health and nutrition programs in 2007 was 14.9%, representing a relative increase of 34.5% since 1995.[10] Even more striking was the substantially higher combined overweight and obe-

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sity prevalence: 33% of low-income preschool-aged children were either overweight or obese[10] compared with 24% of US preschool-aged children in the general population.[2]

Food insecurity is defined as the lack of access to enough food for an active healthy life that results from limited or uncertain access to nutritionally adequate and safe foods in socially acceptable ways.[11] The US Department of Agriculture reported that, in 2010, 14% of all US households experienced food insecurity, with low-income households, particularly those with children, experiencing household food insecurity at much higher rates.[12] In 2010, 41% of low-income household with young children (ie, younger than 6 years) in the United States reported low or very low household food security (called *food insecurity* in this article*).[12] Furthermore, food insecurity is over-represented among racial and ethnic minorities, with 25.1% of black and 26.2% of Hispanic households experiencing household food insecurity as compared with 10.7% of non-Hispanic white households.[12]

The increased prevalence of overweight and its co-occurrence with household food insecurity among low-income families has raised the interesting question as to whether the relation between food security and overweight is causal. Dietz was the first to suggest that food insecurity might be one of the underlying contributors to pediatric obesity, and attributed this association to the possible inclusion of more high-fat energy-dense foods of poor nutritional quality in the diets of children in food-insecure households, or binge eating as an adaptive response to episodic food shortages.[14] Research on the association between household food insecurity and weight status in women has consistently shown that women who experience household food insecurity are at a significantly higher risk of overweight/obesity than women who live in food-secure households,[15,16] although findings vary depending on the instrument used to assess food insecurity.[17]

Cross-sectional and longitudinal studies of preschool and school-aged children that have examined associations between food insecurity and weight status have yielded mixed results[18-30]; six are cross-sectional[18-20,25,27,29,30] and six are longitudinal.[21-24,26,28] Inconsistencies in results of cross-sectional studies are likely a result of the inherent design limitations of cross-sectional studies, as well as differences in the childhood age group and socioeconomic status (ie, low-income or general population) studied. Of the seven longitudinal studies that have examined these relationships, four of which used the Early Childhood Longitudinal Study-Kindergarten cohort,[21-24,26,28,31] three found that food insecurity or insufficiency increased the risk of high weight status,[23,24,28] one found it decreased risk,[22] and three found no associations.[21,26,31] One recent study reported that high-risk children with a high cumulative social risk score at 1 and 3 years of age had a higher risk of obesity at age 5; this risk score included food insecurity.[31] A major limitation of even the well-designed longitudinal studies is that the samples were drawn from the general population rather than low-income populations, thus reducing the ability to detect associations between food insecurity and health outcomes given the low incidence of food insecurity among populations at higher income levels and unavoidable confounding by income. The purpose of the current analysis is to examine the relationship of household food insecurity with and without hunger in infancy and later childhood with weight status in a diverse low-income sample of 2- to 5-year-old children participating in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) program during a 5-year period (2001-2006).

It should be noted that the terms food insecure with hunger *and* food insecure without hunger *used in this article reflect accepted terminology at the time data were collected, rather than the current use of* low *and* very low *food security.*[13]

METHODS

Data for this study are derived from individuals who participated in the Massachusetts WIC program between September 2001 and August 2006. WIC is a federally funded nutrition program for low-income mothers and children. WIC sets income guidelines at <185% of the federal poverty threshold. WIC aims to improve the nutritional status of pregnant and lactating women and their children up to the age of 5 years by providing them vouchers for the purchase of nutritious foods to supplement their diet, breastfeeding support, nutrition counseling, and health care referrals. The Massachusetts WIC program data, captured by the WIC management information system, include anthropometric, food security, health-related, and sociodemographic information on mothers and children. The child's anthropometrics (height/length and weight) were either measured at WIC every 6 months at the participants' certification/recertification visit or were reported to WIC by the child's pediatrician. Household food-security information was also obtained at the certification visit every 6 months. Sociodemographic data and mother's health-related data were obtained once at the certification visits, which generally occurred during the mother's pregnancy. It should be noted that pregravid weight was self-reported rather than measured. Although clearly not optimal, several studies have evaluated the correlation between maternal self-reported pregravid weight and measured weight and found them to be well correlated.[32-34] In addition, most of the analyses we propose, weight gain is categorized. Under these circumstances, self-reported weight should provide a reasonable estimate, as the reporting error (1 to 2 kg) is a small percentage of total body weight.[35]

All these program data are reported to the Centers for Disease Control and Prevention (CDC) as part of the state's participation in the Pregnancy and Pediatric Nutrition Surveillance Systems. For this study, the data files of mothers and children were linked to provide relevant sociodemographic variables, such as maternal education, which is captured on the mother's file only.

All mothers and their children who were first certified into WIC between August 2001 and September 2006 and who met the following inclusion criteria were included in the analytic sample (n=28,353): mother received WIC during her pregnancy with that child and has complete data on covariates (ie, maternal education and age); infant age at certification ≤12 months; data are complete for household food-security status at child certification and last visit and on covariates (eg, birth weight, age, sex, race/ethnicity); child is non-Hispanic white, non-Hispanic black, Hispanic, or Asian; complete anthropometric data at first (infancy) and last (child) visit; and child's age 24 to 60 months at the last visit.

The study protocol was reviewed and approved by the Institutional Review Board for the Massachusetts Department of Public Health; it was also reviewed by the Simmons College Institutional Review Board and deemed exempt.

Table 1. Time-integrated food-security variable used in a study examining the relationship between household food insecurity and obesity in preschool children

	Household Food-Security Status during Childhood		
Household food security during infancy	**Food secure**	**Food insecure without hunger**	**Food insecure with hunger**
Food secure	Persistent food security (n=16,777)	Late food insecurity, without hunger (n=3,478)	Late food insecurity with hunger (n=880)
Food insecure without hunger	Early food insecurity, without hunger (n=3,789)	Persistent food insecurity without hunger (n=1,378)	Persistent food insecurity with late hunger (n=253)
Food insecure with hunger	Early food insecurity with hunger (n=1,063)	Persistent food insecurity, with early hunger (n=369)	Persistent food insecurity with hunger (n=166)

Food-Security Measures

Food-security measures were added to the WIC information system in Massachusetts in 1998 as part of a demonstration site project to assess the feasibility and usefulness of their inclusion in the Pediatric Nutrition Surveillance System. Household food-security status was based on parent/caretaker responses to a four-question subscale[36] of the 18-item Core Food Security Module. The individual items and coding scheme for the four-item subscale have been provided in detail elsewhere.[25] Briefly, the four items in the subscale address the following aspects of household food-security status: not having enough money to buy food for a balanced meal, adults cutting the size of or skipping meals, adult frequency of cutting or skipping meals, and adults not eating for a whole day. Household food-security status was defined by the number of positive (yes or frequently true) responses to the questions.[37] This subscale has been validated in households with children with incomes <185% of the poverty level[36] and specific results have been published.[25] Based on the responses to the food-security questions, household food-security status was categorized as food secure, food insecure without hunger, or food insecure with hunger.

Household food-security status at the first infancy (hereafter called *infancy visit*) and last (when child was 2 to 5 years of age) child visits (hereafter called *child visit*) were used for these analyses. A third measure of food-security status was created by combining the two measures into a single time-integrated variable that reflected status at both time points as a measure of chronicity. The time-integrated measure of food-security variable includes nine different combinations of the three levels of food-security status at the infancy and child visits, as shown by the 3×3 table (Table 1), which illustrates the intersection of household food security at the infancy and child visits.

Because the sample sizes for the combinations that included food insecurity with hunger were small (n=166 for those whose households were food insecure with hunger at both time points), they were omitted from any stratified analyses that were conducted, although they were retained in the main effects analyses.

Weight Status Measures

Weights and heights were taken using standard procedures briefly described here.[37] At WIC, standing height was measured (to the nearest 1/8 in) using a Stadiometer, without shoes, hats or hair accessories, and weight was measured (to the nearest 1/4 lb) using a beam balance scale or a good-quality digital scale after the removal of shoes, sweaters, and heavy jackets (for children) and clothing (for infants) except undergarments. Height and weight were measured once at each visit.

Body mass index (BMI) was derived from directly measured height and weight. Child age was calculated as the difference between the last WIC measurement date and birth date. The age- and sex-specific BMI *z* score and percentile relative to the 2000 CDC growth reference[38] was determined using the child's measured height and weight. Anthropometric values that were not within the biologically plausible range based on CDC criteria were excluded.[39] For our analyses, BMI *z* score was analyzed as a continuous measure. We also used the sex-specific BMI-for-age to define obesity (BMI-for-age *z* score >95th percentile) based on CDC reference data, as recommended.[40,41]

Other Covariates

The choice of covariates was based on both the literature supporting their relationship to food-security status and their availability in the program data. The following covariates were included: maternal weight status based on prepregnancy BMI (categorized as underweight: BMI <18.5; healthy weight: BMI 18.5 to 25; or overweight/obese: BMI >25), maternal age in years, maternal education (categorized as <12 years, 12 years, or >12 years), household size (defined as number of people living in the household), child's age at the last visit in months, race/ethnicity (coded as non-Hispanic white, non-Hispanic black, Hispanic, or Asian) and birth weight. Because food insecurity has been shown to increase risk of overweight and obesity in women, inclusion of maternal weight status might partial out some of the effects of household food insecurity on child weight status.[42] On the other hand, maternal weight can be an indicator of both familial predisposition as well as feeding behaviors that can affect child's risk of overweight, thereby being an intermediary marker of such behaviors.[43] For these reasons, in our examination of the associations between household food-security and weight status, we considered models with and without maternal weight status.

Statistical Analyses

We examined the association between household food-security status at the infancy and child WIC visits and children's weight

status using both multivariate linear and logistic regressions. Linear regression was used to examine the association between both infancy and child visits' measures of household food-security status and a continuous measure of children's weight status, as expressed by BMI-for-age *z* score; all three levels of household food-security status were included at each time point (ie, household food secure, household food insecure without hunger, and household food insecure with hunger). The interaction term (ie, infant food security by child food-security status) was also examined; this is comparable with examining a time-integrated variable as described previously.

Logistic regression analyses were used to examine the association between infancy and child household food-security measures and the likelihood of 2- to 5-year-old children being obese at their last child WIC visit. Household food-security status was examined in relation to child obesity by inclusion of the time-integrated household food-security variable (described previously), with persistent food security as the referent.

For models with child obesity status as the dependent variable, the outcome was obese vs BMI-for-age between the 5th and 95th percentile. Underweight (ie, BMI-for-age <5th percentile) children (3.3% of the sample) were excluded from these analyses because the key contrast of interest was between obese children and those with weight within the normal range. We wanted to have as pure a subgroup as possible, so restricted the comparison group to normal weight children.

The multivariate analyses were conducted including all of the covariates and child birth weight in the model. A second set of analyses additionally controlled for maternal prepregnancy weight status (ie, underweight, normal weight, or overweight/obese). Only preplanned comparisons that related to the questions under investigation were made.

Research suggests that child feeding can vary by food-security status,[31] race/ethnicity,[31] maternal education, and maternal weight status[44,45]; some of these differences have been shown to affect weight status in early childhood.[23,31] These potential differences imply that the effect of food insecurity on risk of child obesity can be different by differing levels of these variables. Therefore, in separate models, we also tested for two-way interactions between the household food-security status variables and the covariates: maternal education, maternal age, maternal prepregnancy weight status, child race/ethnicity, birth weight, and child sex. A P value of <0.05 was considered statistically significant for main effects and for interactions. Where interactions were statistically significant, stratified models are presented. All analyses were conducted using SAS version 9.2 (SAS Institute, Inc).

RESULTS

Overall, 28,353 children contributed data to these analyses; sample sizes for the analyses that included maternal prepregnancy weight status (n=28,152) were slightly lower due to missing values (<1% of the total sample). Sociodemographic characteristics are shown in Table 2. On average, at the child WIC visit, children were about 3 years old, and came from households with four members (including the child). Almost 60% of children were from non-Hispanic black, Hispanic, or Asian backgrounds, with the majority of Hispanic origin. About one third of mothers had <12 years of education, and about 21% had >12 years of education. At their infancy visit, about one quarter of infants lived in households with some food insecurity, with 5.7% living in households reporting food insecurity with hunger. At their child visit, 23% of children lived in households with some food insecurity, with 4.6% living in households reporting food insecurity with hunger. Approximately 17% of 2- to 5-year-old children were obese.

Household Food Security and Child BMI-for-Age *z* Scores

Household food-security status at the infancy and child visits were examined in relation to child visit BMI-for-age *z* score. Although the main effect of household food security at the infancy visit (controlling for the food-security status at the child visit) on child BMI-for-age *z* score was of borderline significance ($P<0.06$), the adjusted means show that household food-security status in infancy was prospectively associated with child BMI-for-age *z* score at 2 to 5 years (Table 3). Infants from households reporting food insecurity without hunger had a higher mean childhood BMI-for-age *z* score than infants whose households reported food insecurity with hunger (0.54 vs 0.47; $P<0.05$). A significant interaction was identified between infancy household food-security status and maternal prepregnancy weight status ($P<0.05$). The adjusted means from the analyses stratified by maternal prepregnancy weight status indicated that although there was no association between household food-security status and mean BMI-for-age *z* scores among children whose mother's prepregnancy weight status was normal or underweight, there was an association among those whose mothers were overweight or obese (Table 4). Among children whose mothers were overweight/obese prepregnancy, infants residing in households that reported food insecurity without hunger (ie, infancy visit) later had a significantly higher adjusted mean child BMI-for-age *z* scores than infants whose households were food secure (mean difference=0.06 *z* score units; $P=0.018$). There was no association between household food-security status at the child visit and child's mean BMI-for-age *z* score at their child visit ($P=0.22$).

Household Food Security and Risk of Childhood Obesity

The association between the time-integrated household food-security variable and preschool obesity showed that persistent household food insecurity without hunger was associated with 22% greater odds of obesity at the child visit (odds ratio=1.22; 95% CI 1.06 to 1.41; $P<0.01$) compared with those who were persistently food secure (Table 5). Other factors associated with an elevated risk of obesity included child age and black non-Hispanic or Hispanic origin (Table 5). Factors associated with a lower risk included being of Asian origin, and having a mother with >12 years of education (Table 5). Maternal prepregnancy weight status was also significantly associated with obesity at the child visit: maternal prepregnancy overweight/obesity was associated with a 65% (adjusted odds ratio [AOR]=1.65; 95% CI 1.54 to 1.77) greater risk, while maternal underweight was associated with a 45% (AOR=0.55; 95% CI 0.44 to 0.66) lower risk of childhood obesity at the child visit compared with children of healthy-weight mothers.

Tests for interaction revealed that the relationship between the time-integrated household food-security status variable and child weight status was modified by maternal prepregnancy weight status ($P<0.05$). In stratified models (Table 6), the association between the time integrated household food-security

Table 2. Description of sample used to assess the association between household food insecurity and weight status of 2- to 5-year-old children (N=28,353)[a]

	⟵ *mean±standard deviation* ⟶
Age (mo)	36.9±9.7
Birth weight (g)	3,264±606
Household size (no. of people)	4.12±1.46
Maternal age (y)	26.4±6.4
	⟵ % ⟶
Female	49.0
Maternal education (% of household)	
<12 y	33.3
12 y	46.0
>12 y	20.7
Maternal weight status (n=25,012)	
Underweight (BMI[b] <18.5)	6.1
Normal weight (BMI 18.5-25)	48.8
Overweight/obese (BMI >25)	45.1
Infancy visit household food-security status	
Food secure	75.1
Food insecure without hunger	19.2
Food insecure with hunger	5.7
Child visit household food-security status	
Food secure	76.9
Food insecure without hunger	18.5
Food insecure with hunger	4.6
Child race/ethnicity	
Non-Hispanic white	41.4
Non-Hispanic black	20.6
Hispanic	31.6
Asian	6.5
Weight status category of child at age 2 to 5 y	
Underweight (BMI-for-age <5th percentile)	3.3
Normal weight (BMI-for-age 5th to 85th percentile)	62.8
Child overweight (BMI-for-age 85th to 95th percentile)	16.8
Child obese (BMI-for-age >95th percentile)	17.1

[a]Includes 201 children for whom maternal prepregnancy weight is missing.
[b]BMI=body mass index.

variable, among those children whose mothers were either underweight or overweight/obese ($P<0.05$), was positive, but there was no association evident among children whose mothers had normal weight status. Specifically, compared with those whose households were persistently food secure, children of underweight mothers from households with persistent food insecurity without hunger (compared with those from persistently food-secure households) were more than three times as likely to be obese at 2 to 5 years of age (AOR=3.22; 95% CI 1.70 to 6.11). Similarly, children of overweight/obese mothers who came from households with persistent food insecurity without hunger (compared with children from food-secure households) were 34% more likely to be obese at 2 to 5 years of age (AOR=1.34; 95% CI 1.11 to 1.62).

Table 3. Adjusted[a] mean±standard error for BMI[b]-for-age *z* scores by household food-security status at infancy and child visits (main effects) in a study examining the relationship between household food insecurity and obesity in preschool children

	Infant visit	Child visit
Household food secure	0.50±0.01[yz]	0.52±0.01
Household food insecure without hunger	0.54±0.02[y]	0.52±0.02
Household food insecure with hunger	0.47±0.03[z]	0.46±0.03

[a]Controlling for age at child visit, sex, race/ethnicity, household size, birth weight, maternal age, maternal education, maternal weight status, household food-security status at the child visit and interaction term between maternal weight and food-security status at child Special Supplemental Nutrition Program for Women, Infants, and Children visit.

[b]BMI=body mass index.

[yz]Means without a common superscripts are different from each other; $P<0.05$.

DISCUSSION

The analysis of WIC program data on low-income mothers and children in Massachusetts (2001-2006) provides evidence of an association between household food security and child weight status that depends in part on maternal factors. Our results indicate that household food insecurity at the infancy visit was prospectively related to later child relative BMI. Our results also showed that a time-integrated indicator of household food insecurity both in infancy and childhood was related to child obesity, but that mother's prepregnancy weight modified these relationships. Among children whose mothers were overweight or obese before pregnancy, household food insecurity without hunger in infancy was associated with higher BMI-for-age *z* scores in childhood than those in food-secure households. Similarly, among children whose mothers were either overweight/obese or underweight prepregnancy, persistent food insecurity (without hunger) through infancy and childhood increased the odds of childhood obesity.

Factors associated with obesity in early life are important to identify, given the evidence that children who gain weight rapidly during the first few years of life are at increased obesity risk.[46] Moreover, the identification of significant interactions between household food-security status and maternal weight status suggest that failure to examine such interactions in relation to childhood weight and obesity might account at least in part for some of the conflicting findings found in the literature. Several other factors were also associated with obesity risk in this study. Some identified as protective against child obesity risk included being of Asian origin, having a mother with >12 years of education, and having an underweight mother, while maternal overweight/obesity elevated risk.

One interpretation of this study's findings is that in the presence of familial predisposition to overweight, food insecurity can interfere with healthy food choices. Food insecurity, particularly that without hunger, is characterized by not having enough money for balanced meals, which can impact the quality of food more than its quantity. This trade-off between quality and quantity among food-insecure households can lead to increased consumption of lower-quality foods that are typically higher in refined grains, fat, and sugar, and are less satiating and more likely to lead to weight gain.[47] In addition, some evidence suggests that food insecurity has an indirect effect on toddler overweight risk through parenting and infant feeding practices,[48] with less supportive parenting and infant feeding practices being observed in households with food insecurity.[48] In addition, a recent study shows that among girls, those in lower-income families are not only more likely to consume two or more sweetened beverages per day at age 5, but this higher consumption at age 5 is associated with higher weight status at 15 years of age.[49] Although food insecurity was not directly examined in the aforementioned study, poverty and food insecurity are highly correlated,[12] therefore making these findings relevant.

Previous prospective studies of these associations in this age group are few, and results are inconsistent. Of the six published longitudinal studies of the association between household food insecurity (either specifically or as part of a risk index) and offspring weight status among young children,[21-24,28] two found that food insecurity or insufficiency increased the risk of high weight gain[23] or high weight status,[24,28] one reported an indirect association that was mediated through parenting and infant feeding practices that were associated with child overweight, and one found that food insecurity as part of a high cumulative risk score was associated with obesity risk at age 5.[31] One of these studies reported that food insecurity was associated with a reduced risk of overweight[22] while another found no association.[21] The results of our study are consistent with four of these longitudinal studies, most of which examined this association in a general population sample.[23,24,28,31] Jyoti and colleagues[23] examined this question over a 3-year period (kindergarten to third grade) and, similar to our study, found that household food insecurity increased weight or BMI in girls and boys. Specifically, persistent household food insecurity (compared with persistent food security) was associated with significantly higher BMI change among girls. Among boys, becoming food insecure over the 3-year course of the study (compared with households that became food secure) was associated with greater weight and BMI gains[23]; in our study, the elevated risk of child obesity associated with persistent food insecurity without hunger did not vary by child sex, however. Our study is also consistent with a recent longitudinal study that examined food insecurity as one social risk factor of several, and reported that children with a high cumulative social risk score at 1 and 3 years of age were more likely to be obese at age 5.[31] The population studied in this article was a high-risk population with additional risk factors and, therefore, might be comparable with the study of cumulative risk mentioned previously.

A major limitation of even the well-designed longitudinal studies is that the samples were drawn from the general population. There are three major issues with use of the general population to address this question. First, household food insecurity is most relevant among low-income populations, given that it is much more prevalent in these populations.[12] Second, there are inherent socioeconomic differences between food-secure and food-insecure groups, given the virtually nonexistent food insecurity in higher-income groups; those that are food secure are not only higher income, but are less likely to be single mothers, have young children, and be people of color.[12] Examining this question in the general population involves accounting for these

Table 4. Adjusted[a] means±standard error for BMI[b]-for-age *z* scores by household food-security status at first infancy visit and maternal prepregnancy weight status in a study examining the relationship between household food insecurity and obesity in preschool children

	Maternal Prepregnancy Weight Status (n=28,152)		
Household food-security status	**Underweight (BMI <18.5)**	**Normal weight (BMI 18.5-25)**	**Overweight/obese (BMI >25)**
Food secure	0.09±0.03	0.42±0.02	0.69±0.02[x]
Food insecure without hunger	0.21±0.06	0.40±0.02	0.76±0.03[yz]
Food insecure with hunger	0.21±0.11	0.36±0.04	0.66±0.04[xz]

BMI=body mass index.

[a]Controlling for age at child visit, sex, race/ethnicity, household size, birth weight, maternal age, maternal education, maternal weight status, household food-security status at the child visit and interaction term between maternal weight and food-security status at child Special Supplemental Nutrition Program for Women, Infants, and Children visit.

[xyz]Means without a common superscripts are different from each other at $P=0.018$ with a Bonferroni correction; unadjusted $P=0.003$.

and other underlying factors associated with food-security status and child weight statistically. Statistical control for this myriad of factors is likely to be ineffective, given that one is really comparing different income categories when comparing food-secure and insecure groups.

It is noteworthy that both approaches to characterizing the effects of food security over time yielded findings that point to an important interaction between maternal weight status and child overweight risk. Importantly, the findings suggest that different mechanisms might be operating for mothers, depending on their own weight status. Low-income lean and overweight mothers might be actively limiting their own intakes (in different ways) in order to assure that their children have food,[50] although there is evidence that this food might be of lower quality because of economic constraints.[47] This would be consistent with findings that in food-insecure households mothers tend to go hungry in order to protect their children from hunger.[51] Among overweight mothers, changes in behavior to protect their children in the face of household food insecurity[50] can occur in conjunction with both a biological predisposition to overweight and ongoing food insecurity that limits access to nutritionally adequate food; these can jointly increase the risk for their children. In addition, there is some evidence that the effect of different types of feeding behaviors on children can vary, depending on maternal weight status. One study reported that overweight mothers' restriction of their 5-year-old daughters' food intake increased the child's eating in the absence of hunger at age 9. This was not found among daughters of normal-weight mothers who restricted food at age 5. In addition, among daughters of overweight mothers, higher eating in the absence of hunger at age 5 was associated with higher BMI change between 5 and 9 years of age.[52]

As noted previously, results from prospective studies on the association between food security and overweight have been inconsistent, and none of the previous studies have included measures of maternal weight. The findings presented here would argue for a more fully delineated model that considers maternal weight status as well as food-security status in predicting child weight.

Although current debates around food-security measures and nomenclature are beyond the scope of this article, the shift in terminology to *food security*, *low food security*, and *very low food security*,[53] rather than *food insecurity with and without hunger* implies a linear relation between food-security types and weight status, with very low food security being most severe; this implication belies the contention by experts at the US Department of Agriculture (USDA) that the measures are not linear.[54] Our study results are also consistent with a nonlinear relationship, given that the measure of food insecurity that was most highly related to child BMI was that of food insecurity without hunger, a "middle" category. This would argue for examining these distinct categories within food insecurity separately because their effects on diet likely differ with reduced dietary quality being the predominant feature of food insecurity without hunger and reduced quantity and quality being more common in food insecurity with hunger.[54] It has been shown that energy-dense food is less expensive than nutrient-dense food,[47] and that those with food insufficiency had a worse diet quality based on the Healthy Eating Index than those who were food sufficient.[55]

Our study had several strengths. This is the first longitudinal study of preschool weight status that examined this issue within a low-income, diverse population at high risk for both household food insecurity and obesity. The large sample conferred a level of statistical power to detect small effect sizes and enabled an examination of other factors that could modify the relationship between food insecurity and child obesity, as well as the ability to stratify analyses to understand their effects.

Several limitations to the current undertaking are noteworthy. The data used for this study are program data and generally have greater measurement error than data gathered specifically for research. For example, the heights and weights of mothers and children were collected with a single measurement, rather than in duplicate or triplicate. Also, household food-security status reflected adult (rather than child) status. Earlier studies suggest that adults might

Table 5. Predictors of obesity in 2- to 5-year-olds used in a study examining the relationship between household food insecurity and obesity in preschool children

Predictor in the model (n=27,426)	Obese (BMI[a] ≥95) vs normal weight, adjusted[b] odds ratio (95% CI)
Child age at last visit (mo)	
Each additional month	1.02[c] (1.01-1.02)
Child sex	
Female vs male	0.95 (0.89-1.01)
Child's birth weight (g)	1.00[c] (1.00-1.001)
Child's race/ethnicity	
Black non-Hispanic vs white non-Hispanic	1.12[c] (1.02-1.22)
Hispanic vs white non-Hispanic	1.51[c] (1.40-1.62)
Asian vs white non-Hispanic	0.77[c] (0.66-0.90)
Household size	
One additional member	0.96[c] (0.94-0.98)
Maternal age (y)	1.01[c] (1.01-1.02)
Maternal education	
12 y vs <12 y	0.94 (0.87-1.01)
>12 y vs <12 y	0.82[c] (0.75-0.90)
Food security (time-integrated variable)	
Early food insecurity, no hunger vs persistent food security	1.00 (0.91-1.10)
Late food insecurity, no hunger vs persistent food security	1.01 (0.91-1.11)
Persistent food insecurity, no hunger vs persistent food security	1.22[d] (1.06-1.41)
Early food insecurity with hunger vs persistent food security	1.00 (0.85-1.18)
Late food insecurity with hunger vs persistent food security	0.84 (0.69-1.02)
Persistent food insecurity, with early hunger vs persistent food security	0.97 (0.73-1.29)
Persistent food insecurity, with late hunger vs persistent food security	0.96 (0.69-1.34)
Persistent food insecurity with hunger vs persistent food security	0.85 (0.55-1.32)

[a]BMI=body mass index.
[b]Controlling for age at last visit, sex, race/ethnicity, household size, birth weight, and maternal education and maternal age.
[c]$P<0.05$.
[d]$P=0.04$ after a Bonferroni correction; unadjusted $P=0.005$.

deprive themselves in order to buffer effects of household food insecurity on their children.[51] To the extent that household food-acquisition strategies can be modified by household food insecurity without hunger, the quality of food available to the child might represent an underlying contributor to higher *z* scores.

CONCLUSIONS

The results of this study point to a significant association between persistent household food insecurity without hunger, young children's weight status, and risk of childhood obesity. It is noteworthy, however, that the associations depend on mater-

Table 6. Association between longitudinal measures of household food-security status (hunger excluded) and obesity risk of children at 2 to 5 years, stratified by maternal weight status

Time integrated household food-security status[a]	Maternal Weight Status (N=24,613)		
	BMI[b] <18.5 (n=1,466)	BMI 18.5 to <25 (n=12,013)	BMI ≥25 (n=11,134)
	← *adjusted[c] odds ratio (95% CI)* →		
Early food insecurity no hunger vs persistently food secure	1.09 (0.62-1.92)	0.87 (0.75-1.02)	1.12 (0.98-1.27)
Late food insecurity no hunger vs persistently food secure	1.53 (0.85-2.73)	0.98 (0.78-1.24)	1.01 (0.88-1.15)
Persistent food insecurity, no hunger vs persistently food secure	3.22 (1.70-6.11)[d]	0.98 (0.78-1.24)	1.34 (1.11-1.62)[e]

[a]Excluding those with food insecurity with hunger (n=166).
[b]BMI=body mass index.
[c]Controlling for age at last visit, sex, race/ethnicity, household size, birth weight, maternal age, and maternal education.
[d]P =0.0027 after a Bonferroni correction for multiple comparisons (unadjusted P=0.0003).
[e]P=0.027 after a Bonferroni correction for multiple comparisons (unadjusted P=0.003).

nal weight status. Given that results imply that specific groups of children are particularly vulnerable to adverse effects of household food insecurity, targeting these groups might be necessary.

Future studies should examine effects of household food insecurity on child weight, while not only controlling for maternal weight status, but also assessing whether this or other factors modify how food insecurity is associated with child weight; this appears to be a complex relationship and should be examined as such.

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

FUNDING/SUPPORT

This research was funded through a Research Innovation and Development Grants in Economics (RIDGE) Grant from the Economic Research Service of the USDA.

ACKNOWLEDGEMENTS

We would like to gratefully acknowledge the Economic Research Service of the USDA for providing the funding for this research and the following individuals for their contribution to this project: Lucia Kaiser and Tammy McMurdo, UC Davis RIDGE; Jan Kallio, former director of Nutrition Services, Massachusetts WIC; Joshua Nyambose, Data management and cleaning; Mark Nord, ERS USDA; Bettylou Sherry, CDC; Mary Kassler, Massachusetts WIC Director, and WIC program staff.