



Published in final edited form as:

*J Community Health*. 2012 February ; 37(1): 253–264. doi:10.1007/s10900-011-9420-4.

## EXPLORING MEDIATORS OF FOOD INSECURITY AND OBESITY: A REVIEW OF RECENT LITERATURE

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### Abstract

One in seven American households experience food insecurity at times during the year, lack of money and other resources hinder their ability to maintain consistent access to nutritious foods. Low-income, ethnic minority, and female-headed households exhibit the greatest risk for food insecurity, which often results in higher prevalence of diet-related disease. The food insecurity-obesity paradox is one that researchers have explored to understand the factors that influence food insecurity and its impact on weight change. The aim of this inquiry was to explore new evidence in associations of food insecurity and obesity in youth, adult, and elderly populations. A literature search of publication databases was conducted, using various criteria to identify relevant articles. Among 65 results, 19 studies conducted since 2005 were selected for review. Overall, the review confirmed that food insecurity and obesity continue to be strongly and positively associated in women. Growing evidence of this association was found in adolescents; but among children, results remain mixed. Few studies supported a linear relationship between food insecurity and weight outcomes, as suggested by an earlier review. New mediators were revealed (gender, marital status, stressors, and food stamp participation) that alter the association; in fact, newer studies suggest that food stamp participation may exacerbate obesity outcomes. Continued examination through longitudinal studies, development of tools to distinguish acute and chronic food insecurity, and greater inclusion of food security measurement tools in regional and local studies are warranted.

### Keywords

food insecurity; obesity; children; women; mediators

## INTRODUCTION

Most U.S. households have consistent, dependable access to enough food for active, healthy living—they are food secure. But a growing number of American households experience food insecurity at times during the year, meaning that their access to adequate food is limited by a lack of money and other resources. [1] In 1995, when the U.S. Department of Agriculture (USDA) published its initial report on U.S. household food security, approximately 11.9% of households experienced food insecurity. [2] Current estimates have increased to 14.6%, as of 2008. In other words, after thirteen years of monitoring food

security, hardship has worsened from one in ten to one in seven households affected. These trends have led to increased research about the characteristics and consequences of food insecurity.

Several terms exist to identify food insecurity, including food hardship, food insufficiency, and hunger. [3] Numerous definitions have been proposed to classify these terms, but the most commonly referenced resource for definition and measurement is the USDA. It defines household food security as “access by all members at all times to enough food for an active, healthy life.” [1] At a minimum, nutritionally adequate and safe foods are readily available and can be acquired in socially acceptable ways (i.e. without stealing, accessing emergency food supplies, or relying on other coping strategies). Alternatively, food insecurity implies a “limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways.” As of 2006, four categories classify the continuum of food security: high, marginal, low, and very low, based on responses to the 18-item USDA Core Food Security Module (CFSM). The latter two categories were previously named food insecurity without hunger and food insecurity with hunger, respectively. The revision was made to reflect that hunger was a related, but distinctive, phenomenon that could not be defined or measured appropriately in the context of food insecurity.

Due to the enhanced use of the CFSM in national surveys, both the USDA and other leading researchers in the field have identified key populations most likely to experience this food insecurity. Numerous studies have named low-income, single-female headed households, minority race, lower education levels, and more children or other household members as characteristics associated with this form of hardship. [3–6] Other research suggests limited availability and accessibility to healthy food outlets as another contributor. [7, 8] These factors often provoke changes in dietary intake and food behaviors. For example, members of food insecure households tend to consume foods that are high in energy density but are nutritionally poor. In addition, in circumstances where food is limited, individuals report overeating or eating foods they dislike to compensate for periods of lack. These very behaviors underlie diet-related disorders, including obesity and diabetes, and other chronic and mental health issues. [9–11] Consequently, the costs of nutritional deprivation to individuals, communities, and society are enormous. A 2007 study led by Brown estimated annual costs associated with hunger (using the revised USDA food insecurity categories to define hunger) in the United States to exceed \$90 billion. [12] The authors concluded that increased investments in federal food assistance programs could greatly reduce this burden.

The first step in decreasing the burden of food insecurity is to gain a better understanding of its effects on health. To this end, an increasing number of studies have aimed to summarize the impacts of food insecurity on health outcomes in children and adults. Specifically, the food insecurity-obesity paradox has been examined in a literature review by Dinour. [13] In her review, she summarized fourteen studies published from 1999 to 2006 which lend consistent support to positive insecurity and obesity links among women, mixed results among youth, and little or no evidence among men. Specifically, several studies affirmed highest levels of overweight/obesity among persons reporting the most severe categories of insecurity. Studies examining race differences found significant relationships more often among non-Hispanic white and Hispanic groups than among non-Hispanic blacks. Moreover, the authors explored the potential impact of food stamp program participation on the food insecurity-obesity relationship. The findings from Dinour’s review provided a new basis for future evaluations.

The number of publications exploring the food insecurity-obesity paradox has increased significantly over the past few years. New research is examining additional factors that may

more accurately explain this relationship. Moreover, with the availability of validated measures of food security, overweight, and obesity, comparability across studies is enhanced (Table 1). For these reasons, an updated review of the literature was warranted. The aim of this review is to update the literature, comparing with the previous review to clarify associations of food insecurity and overweight/obesity across adult and youth populations. Finally, in light of new evidence, suggestions for future studies will be proposed.

## METHODS

A literature search was conducted to identify recent articles that examined associations between food insecurity and overweight/obesity. Several online databases were queried, including CINAHL, Scopus, Ovid, and Pubmed. The following terms were used individually and in combination to source articles for consideration: food insecurity, food hardship, food insufficiency, hunger, overweight, obesity, race, and minority. In addition, articles had to be published after 2005, to avoid overlap with those reviewed previously by Dinour and colleagues. Initial searches yielded approximately 67 results. The abstracts of these papers were reviewed by five researchers (BF, AJ, DL, JM, SP) to confirm applicability. After considering additional exclusion criteria (non-English language, studies conducted outside of the United States, manuscripts not available as full-text), 19 papers remained. Since the populations examined in these studies varied (i.e. adults, elders, children, and adolescents), articles were summarized then grouped into appropriate categories for this review.

## RESULTS

Characteristics of studies are summarized in Table 2.

### Food insecurity and overweight among youth

Six articles examined food insecurity and obesity in youth (ages 3 to 17); two of these studies were led by Gundersen[14–19]. The first study aimed to determine if significant associations between food insecurity, maternal stressors, and overweight exist among low-income children. [16] Specifically, the authors proposed that maternal stressors would strengthen these associations. A sample of 841 children ages 3 to 17 in households with incomes below 200% of the poverty line was derived from the 1999–2002 National Health and Nutrition Examination Survey (NHANES). The analysis concluded that no direct association between food insecurity or maternal stressors and overweight existed for children of any age group (3 to 10 years or 11 to 17 years). However, after accounting for the interaction of stressors and food security status, unique results developed. In the absence of stressors, children in food-insecure households were more likely to be overweight than those who were food secure. Conversely, as stressors increased, the relationship shifted. Food secure children exhibited higher likelihood of overweight as stressors increased compared to children in food insecure households. In other words, stress exhibited a protective effect on children in food insecure versus food secure households. These results were significant only among younger children (ages 3 to 10). A second study by Gundersen used data from 2001–2004 NHANES to ascertain associations between food insecurity and multiple measures of obesity. [15] This sample included 2,516 children ages 8 to 17 in low-income households. Nearly four in ten children were food insecure. The results of the study indicated food insecure children were no more likely to be obese than children in food secure households regardless of obesity measure. This relationship held, even after controlling for other factors and examining subpopulations based on race/ethnicity and/or gender.

Miller and associates examined the association of hunger and overweight among children of low-income families visiting a community pediatric clinic in Massachusetts. [19] Using

completed interview and medical record data from 122 families, the authors determined that children were going hungry in nearly half of the households surveyed. While hungry children did not differ from their counterparts demographically, they were significantly more likely to be obese and have more medical diagnoses. Results were similar for mental health assessments, with hungry children reporting worse scores than their counterparts. However, greater prevalence of overweight among hungry children (19% versus 9%) trended toward, but did not reach, statistical significance. Similar poor outcomes were assessed in parents of hungry children. They were significantly more likely to report poorer mental and physical health, to include poor family functioning and self-reported health. Weight data was not collected for parents. Another study by Casey and colleagues used data from 1999–2002 NHANES to clarify associations between food insecurity (both child-specific and household) and overweight in youth. [14] This study used a larger sample of youth ages 3 to 17 than Gunderson's study described previously and found reverse results. Overall, children from food-insecure households were significantly more likely to be at risk for overweight (ARO) or overweight (OW) compared to children from food-secure households. Specifically, food-insecure teens (ages 12 to 17) had significantly higher prevalence of ARO and OW, when measured at both the child and household levels, as did females. This trend was nearly replicated in the children from the poorest households and those of white race, with these populations having significantly greater prevalence of ARO (at both levels) and OW (only for child-specific food-security status). Martin and Ferris examined associations of food insecurity and overweight/obesity in a convenience sample of low-income parents and their children (ages 2–12). [17] Nearly one-third of the children in their sample were overweight; having an obese parent and female gender were both significantly associated with this finding. However, no direct association of food insecurity and overweight existed among the children. Lastly, Metallinos-Katsaras and associates used a sample of low-income children below age 5 participating in the Special Supplemental Nutrition Program for Women, Infants and Children to observe associations between household food insecurity (with and without hunger) and overweight. [18] After stratification by age (under 2 and 2 to 5) and sex, analyses yielded two significant findings. First, girls younger than age 2 in food-insecure households (with and without hunger) were significantly less likely to be overweight than food-secure counterparts. Second, and conversely, girls between the ages of 2 and 5 experiencing food insecurity with hunger were more likely to exhibit overweight compared to food-secure counterparts. No significant relationships were found among boys.

### **Food insecurity and overweight among adolescents**

Three studies among adolescent populations that studied food insecurity and overweight associations are summarized next. [20–22] Using data from the Three-City Study, Gunderson and coworkers examined the association between food insecurity and overweight among low-income adolescents ages 10 to 15. [20] While few children were food insecure (less than 8%), roughly half were overweight or were at risk for being overweight. Analysis concluded no greater likelihood of overweight or risk of overweight for food secure versus food insecure adolescents. A related study was led by Lohman, a colleague of Gunderson, to further examine independent relationships and interactions between food insecurity, various stressors and overweight/obesity using the same sample described previously. [21] The study maintained that no direct association existed, but did clarify the role of the interaction of food insecurity and maternal stressors. The analysis demonstrated that as the number of maternal stressors among food insecure adolescents increased, their likelihood of being overweight or obese increased by 35%. The third study was performed by Smith and colleagues to explore relationships between dietary intake, perceived insecurity, and obesity risk among homeless Minnesotan adolescents (ages 9 to 18). [22] Additionally, they explored adolescents' coping responses to food insecurity. Dietary examination revealed

under-consumption of fruits, vegetables, and dairy and, conversely, excessive servings of fats, oils, and sweets. About half of the sample was overweight or at risk for overweight. Moreover, half reported food insecurity, with one in four reported going to bed hungry. Forty-five percent reported inadequate food supply. Results of analyses revealed negative associations between body mass index (BMI) and “having enough food in the home” for both males and females. In other words, as this particular measure of food insecurity increased, the likelihood of overweight decreased. However, females who reported going to bed hungry were significantly more likely to be overweight.

### Food insecurity and overweight among adults

Six studies examined food insecurity and obesity in adults; one of these studies included children and has been summarized previously. [17, 23–27] Adult outcomes of this study are reported in this section. The first study, by Hanson et al, examined the relationship between food insecurity and body weight, and whether gender and marital status influenced that relationship. [23] A sample of 4,338 men and 4,172 women aged 20 and older was analyzed. This study revealed differential impacts of marital status on the food insecurity-obesity relationship. After controlling for demographic differences, divorced men were at significantly greater risk than never married men to live in a household with very low food security. Marginally food secure men had significantly higher mean BMI scores than food-secure counterparts and exhibited tendencies toward overweight and obesity, though the latter observations did not reach significance. However, males experiencing low food security were significantly less likely than food-secure others to be overweight or obese. Conversely, when compared with fully food-secure women, those with low food security were more likely to be obese. Additionally, marginal food security among women was significantly associated with overweight compared to food-secure counterparts. Lastly, a significant interaction between marital status and food insecurity among women revealed that food-insecure married, partnered, and widowed women were significantly more likely to be obese than food-secure never-married women. This interaction was not significant among men. Another study, led by Sullivan, used data from four Boston-area hospitals to ascertain food insecurity and related medical conditions and expenditures among adult emergency department (ED) patients (ages 18 and older). [25] Food insecurity was significantly associated with higher mean BMI and likelihood of obesity. However, when stratified by gender, higher mean BMI remained significant only among women. Food-insecure patients were also more likely than food-secure counterparts to report chronic disease and mental health problems (i.e. insomnia, chronic pain, and stress disorders) and to make choices between purchasing food and medications. Webb and colleagues used a sample of low-income adults to explore food insecurity and participation in government-sponsored food programs—two factors purported to contribute to BMI. [26] Food-insecure participants reported significantly higher BMI than those who were food secure, and a significantly higher percentage of them were obese. However, after controlling for demographic factors and food stamp program (FSP) participation, these findings lost significance. In contrast, FSP participation or previous year participation in any government-sponsored food program was significantly associated with higher BMI, even after controlling for food security status and other factors. Among current FSP participants, enrollment for six months or more was significantly associated with lower BMI when compared to those who had participated for a shorter period.

Data from the 1999–2002 NHANES were used by Wilde and Peterman to explore weight change in response to household food security status in about 10,000 adults. [27] Differential impacts of food security status and weight change were seen by gender. Among women, all levels of food insecurity were significantly associated with higher BMI and overweight when compared to full food security. Moreover, women experiencing marginal

food security or food insecurity without hunger were significantly more likely to be obese than food-secure counterparts. In fact, multivariate analysis confirmed that women experiencing food insecurity with hunger were 67% more likely to be overweight and women in marginally food secure and food insecure without hunger categories were 58% and 76% more likely, respectively, to be obese, when compared to the reference group (fully secure). In men, food insecurity without hunger was significantly associated with lower BMI and smaller proportion of overweight and obesity when compared to full food security. However, in multivariate analysis, men experiencing marginal food security were 1.43 times more likely to be obese than fully-secure counterparts. Analysis of weight change only yielded significant findings in women. Those experiencing marginal food security were 56% more likely to gain five pounds and 68% more to gain ten pounds compared to fully-secure women. Women with food insecurity without hunger had 43% increased likelihood of five-pound weight gain. A fifth study, conducted by Holben and Pheley, assessed the relationship of food security to various chronic health indicators among rural residents of Appalachian Ohio. [24] Survey and clinical examination data from 808 participants were used in the analysis. Food insecurity was significantly associated with higher BMI and higher proportions of obesity; however, no differences were found in diastolic blood pressure, total cholesterol, and random blood glucose. Among women, the results were more pronounced. BMI and HbA1c levels were significantly higher in food insecure versus fully secure women. Lastly, Martin and Ferris, as aforementioned, used a convenience sample of 200 low-income parents to examine the relationship between food insecurity and obesity. [17] Nearly two-thirds of adults were obese, seven in ten were single parents, and over half reported household food insecurity. Unlike the children in the sample, food insecure adults were nearly 2.5 times more likely to be obese than food secure counterparts. Education level was significantly and positively associated with overweight among adults.

### **Food insecurity and overweight among women**

Four studies addressed food insecurity and obesity in female populations. [28–31] The aim of the first study, by Laraia and colleagues, was to identify whether an independent association existed between household food insecurity and pregnancy-related complications, including weight change. [29] The analysis revealed a significant relationship between household food insecurity and pregravid severe obesity. After adjusting for covariates, food insecure women were three times more likely to be severely obese before pregnancy than those who were food secure. Contrarily, weight change and prevalence of excessive weight gain, though significantly higher among food-insecure women, did not maintain significance in regression analysis. Another conclusion drawn from the study was that food insecure women were more than twice as likely to experience gestational diabetes mellitus during pregnancy. Another study led by Olson followed 622 healthy adult women from early pregnancy to two years postpartum, to analyze impacts of food insecurity on weight at and between both time points. [30] The authors discovered a significant, positive relationship between food insecurity and obesity at two years postpartum, but not at pregnancy. However, obesity in early pregnancy was significantly and positively associated with food insecurity at two years postpartum. Women who were both obese and food insecure in early pregnancy were significantly more likely to maintain this status in the postpartum period. A third study by Whitaker and colleagues followed over 1,700 mothers of preschool children for two years to assess the impact of baseline food security status on weight change. [31] Women were categorized into four groups: food secure at both periods, food secure at baseline but not at follow-up, food insecure at both periods, and food insecure at baseline but not at follow-up. The authors found significant positive associations between baseline food insecurity and obesity at baseline and follow-up. However, these associations lost significance after controlling for demographic variables. Other analysis demonstrated no significant differences in weight change based on either baseline food security status or

change in food security status. A final study by Jones and Frongillo found that persistent food insecurity was significantly associated with weight loss of nearly 7 kilograms over a two-year period. [28] Analyses were based on a sample of 5,303 women ages 18 to 74. No significant associations between change in food insecurity status and weight change existed. Moreover, after testing the interaction of FSP participation, one of the two models demonstrated it was significantly associated with greater positive weight change among persistently food-insecure women.

### Food insecurity and overweight among elders

One study, by Kim et al, examined the effect of food security and participation in food assistance programs on overweight and depression among elders and their spouses. [32] The authors compared two datasets, Health and Retirement Study (HRS) and Asset and Health Dynamics Among the Oldest (AHEAD). Significant associations between food insecurity and weight variables were found in the AHEAD sample, but not HRS. Specifically, food-insecure elders at follow-up had significantly higher BMI, and those who were food-insecure at baseline experienced greater increases in BMI than food-secure counterparts. Additionally, as food-secure elders became insecure, BMI increased. Current food-insecure elders had significantly higher depression scores than food-secure others in both samples. Participation in food assistance programs as a modifier of food insecurity was associated with significant decreases on BMI in the AHEAD sample, except in one model. Analysis of the HRS sample demonstrated some evidence of decreasing depression among food-insecure elders participating in food assistance programs.

## DISCUSSION

Nineteen studies examining food insecurity and obesity outcomes have been published since Dinour's review, indicating the growing magnitude of this issue. Overall, the studies reviewed maintained mixed evidence of positive associations between food insecurity and obesity across age and gender groups. Food insecurity-obesity links among women remained consistent, with growing evidence among adolescents, mixed evidence among children, and sparse evidence among men (one study). Two studies demonstrated a linear association between food insecurity and obesity levels. [24, 29] Conversely, other studies revealed a U-shaped pattern, where obesity increased as food security declined to intermediate levels. [23, 26, 27] They noted that persons experiencing the most severe level of food insecurity tended to have lower BMIs than food secure counterparts.

Some theories about the food insecurity-obesity link continue to hold true; others lack support. The sacrifice theory has been heavily documented to explain inconsistent links in children and strong links among women. Mothers are thought to sacrifice their food supply to ensure that children remain food secure. This theory is supported by evidence that only half of food-insecure households with children are also child food-insecure. [1] Differences by gender may also be explained by differential physiological composition. [33] In addition, results of current studies continue to support theories related to consumption of low-cost, poor-quality foods when finances are limited or cyclical eating patterns. However, an earlier theory suggesting adolescents' ability to supplement food sources to protect against food insecurity was not supported by findings from Smith. [22]

Studies summarized in this review revealed new factors that may influence the food insecurity-obesity relationship. Maternal stressors demonstrated significant, but mixed, impacts on youth and adolescents. [16, 21] Marital status was identified as a risk factor for obesity among food insecure women in relationships with partners. [23] Lastly, three studies explored the interaction of participation in food assistance programs and food insecurity on weight outcomes. [26, 28, 32] Two studies supported a positive link between food stamp

participation and heavier weight; the other yielded opposite results. These factors deserve continued investigation. An updated review of the role of food assistance programs in explaining this paradox was recently published. [34]

The underlying review has several strengths. First, the studies reviewed here are more comparable than those reviewed by Dinour, due to greater consistency in definition and measurement of food security and weight status. This was a limitation mentioned in the previous review. Our studies also provide more information about other factors that potentially mediate the food insecurity-obesity relationship, including stressors, marital status, and participation in food assistance programs. Additionally, the use of longitudinal analyses provides greater insight about the impact of food insecurity over time on weight status. Among longitudinal studies reviewed, none supported a food insecurity-obesity link. [28, 30, 31]

Still, enhanced measurement and continued investigation of food security are warranted. Current tools do not distinguish acute and chronic food insecurity. Moreover, few longitudinal surveys evaluate food insecurity and weight status at various time points. Given the accessibility of the CFSM, food security evaluation can also be incorporated easily into local and regional studies. Other analyses might incorporate evaluations of food choices and/or behavior during periods of insecurity versus security. Lastly, future studies should explore factors influencing differential weight outcomes among groups at greatest risk for food insecurity (e.g. low-income, minority race, single marital status, female, and less than high-school education).

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**Table 1**

Definitions for food security and weight status measures used in studies

Variable	Source	Measure	Category	Definition
Food security	USDA [CFSM (18 items); Short form (6 items); Youth Module (12 years and older) (9 items)]	Food secure	High food security	Households had no problems, or anxiety about, consistently accessing adequate food
			Marginal food security	Households had problems at times, or anxiety about, accessing adequate food, but the quality, variety, and quantity of their food intake were not substantially reduced.
		Food insecure	Low food security	Households reduced the quality, variety, and desirability of their diets, but the quantity of food intake and normal eating patterns were not substantially disrupted.
			Very low food security	At times during the year, eating patterns of one or more household members were disrupted and food intake reduced because the household lacked money and other resources for food.
Weight status	CDC (children)	BMI	Normal	BMI between the 5th and 85th percentiles
			Overweight	BMI between the 85th and 95th percentiles
			Obese	BMI greater than or equal to the 95th percentile
	IOTF (children)	BMI	Normal	Age and sex specific values that are back-extrapolated to align to adult BMI between 18.5 and 24.9
			Overweight	Age and sex specific values that are back-extrapolated to align to adult BMI between 25 and 29.9
			Obese	Age and sex specific values that are back-extrapolated to align to adult BMI greater than or equal to 30
	CDC (adults)	BMI	Normal	BMI between 18.5 and 24.9
			Overweight	BMI between 25 and 29.9
			Obese	BMI greater than or equal to 30

Abbreviations: BMI: body mass index (ratio of height and weight, kg/m<sup>2</sup>), CDC: Centers for Disease Control and Prevention, CFSM: Core Food Security Module, IOTF: International Obesity Task Force, USDA: United States Department of Agriculture.

Notes: 1) CFSM (18 items) comprises the household level (w/or w/o children), adult-level (8-items) and child-level questions. Short form (6 items) and youth adaptations (for ages 12 and older, 9 items) of the CFSM are also available. Food security categories are scaled differently based on level of analysis (household level w/children, household level w/o children (equivalent to adult-level), child-level, short form, or youth module). First two categories considered food secure; latter food security categories considered food insecure. 2) Children's BMI is mapped into percentiles using gender and age-adjusted reference values in the CDC growth charts. 3) Underweight was excluded from the chart because most studies exclude underweight participants.

**Table 2**

Summary of studies reviewing food insecurity and weight outcomes

Population	Reference	Population (Setting)	Food insecurity measure	Weight measure(s)	Selected Significant Findings
Youth (6 studies)	Gundersen et al. (2008a)	841 children ages 3–17 and mothers w/HH income below 200% poverty line (NHANES 1999–2002)	<ul style="list-style-type: none"> <li>CFSM (HH, child)</li> <li>HH food insecure (3 or more positive responses)</li> <li>Child food insecure (2 or more positive responses to child level questions)</li> </ul>	<ul style="list-style-type: none"> <li>BMI= 5<sup>th</sup>–84<sup>th</sup> percentile (normal)</li> <li>BMI &gt;= 85<sup>th</sup> percentile (overweight/obese)</li> </ul>	<ul style="list-style-type: none"> <li>No direct association between food insecurity or maternal stressors, and overweight/obesity.</li> <li>In the absence of stressors, children in food-insecure households more likely to be overweight.</li> </ul>
	Gundersen et al. (2009)	2,516 children ages 8–17 w/HH income below 200% poverty line (NHANES 2001–2004)	<ul style="list-style-type: none"> <li>CFSM (HH)</li> <li>Food insecure (3 or more positive responses)</li> </ul>	<ul style="list-style-type: none"> <li>BMI= 5<sup>th</sup>–94<sup>th</sup> percentile (non-obese)</li> <li>BMI &gt;= 95<sup>th</sup> percentile (obese)</li> <li>WC &lt; 90<sup>th</sup> percentile (non-obese)</li> <li>WC &gt;= 90<sup>th</sup> percentile (obese)</li> <li>TSF thickness &lt; 95<sup>th</sup> percentile (non-obese)</li> <li>TSF thickness &gt;= 95<sup>th</sup> percentile (obese)</li> </ul>	<ul style="list-style-type: none"> <li>No direct association between food security and obesity (across all weight measures)</li> </ul>
	Miller et al. (2008)	122 low-income families (pediatric clinic in Massachusetts)	<ul style="list-style-type: none"> <li>CFSM (HH)</li> <li>Hungry (equivalent to criteria for very low food security)</li> </ul>	<ul style="list-style-type: none"> <li>BMI= 85<sup>th</sup>–94<sup>th</sup> percentile (overweight)</li> <li>BMI &gt;= 95<sup>th</sup> percentile (obese)</li> </ul>	<ul style="list-style-type: none"> <li>Children from hungry families were more likely to be obese and more likely to report poor health than food secure counterparts</li> </ul>
	Casey et al. (2006)	Children 3–17 years (NHANES 1999–2002)	<ul style="list-style-type: none"> <li>CFSM (HH, child)</li> <li>HH food insecure (3 or more positive responses)</li> <li>Child food insecure (2 or more positive responses to child level questions)</li> </ul>	<ul style="list-style-type: none"> <li>BMI= 5<sup>th</sup>–84<sup>th</sup> percentile (normal)</li> <li>BMI= 85<sup>th</sup>–94<sup>th</sup> percentile (at risk for overweight (ARO))</li> <li>BMI &gt;= 95<sup>th</sup> percentile (overweight)</li> </ul>	<ul style="list-style-type: none"> <li>HH food insecurity associated with being ARO or greater for groups: ages 12–17, girls, total sample, HHs with PI &gt; 4</li> <li>Child food insecurity associated with being ARO or greater for: above groups, and ages 3–5, Mexican American, and white</li> <li>After controlling for covariates, significant association between</li> </ul>

Population	Reference	Population (Setting)	Food insecurity measure	Weight measure(s)	Selected Significant Findings
	Martin and Ferris (2007)	212 children ages 2–12 (community settings in Connecticut)	<ul style="list-style-type: none"> <li>CFSM (HH)</li> <li>HH food insecure (3 or more positive responses)</li> </ul>	<ul style="list-style-type: none"> <li>BMI= 5<sup>th</sup>–84<sup>th</sup> percentile (normal)</li> <li>BMI= 85<sup>th</sup>–94<sup>th</sup> percentile (overweight)</li> <li>BMI <math>\geq</math> 95<sup>th</sup> percentile (obese)</li> </ul>	<ul style="list-style-type: none"> <li>No association between food insecurity and overweight</li> </ul>
	Metallinos-Katsaras et al. (2009)	8,493 children 5 years (SSNP/WIC clinics, Massachusetts)	<ul style="list-style-type: none"> <li>4-item subscale of CFSM (HH)</li> <li>HH food secure (No positive responses)</li> <li>HH food insecure w/o hunger (1–2 positive responses)</li> <li>HH food insecure w/ hunger (3–4 positive responses)</li> </ul>	<ul style="list-style-type: none"> <li>BMI= 5<sup>th</sup>–94<sup>th</sup> percentile (normal)</li> <li>BMI <math>\geq</math> 95<sup>th</sup> percentile (overweight)</li> </ul>	<ul style="list-style-type: none"> <li>HH food insecurity associated with less likelihood of overweight in girls under 2</li> <li>HH food insecurity with hunger associated with greater likelihood of overweight in girls 2–5 years</li> </ul>
Adolescents (3 studies)	Gundersen et al. (2008b)	1,031 low-income children ages 10–15 (Three-City Study)	<ul style="list-style-type: none"> <li>3-item subscale of CFSM (child)</li> <li>Child food secure (No positive responses)</li> <li>Child food insecure (any positive responses)</li> </ul>	<ul style="list-style-type: none"> <li>BMI= 5<sup>th</sup>–84<sup>th</sup> percentile (normal)</li> <li>BMI= 85<sup>th</sup>–94<sup>th</sup> percentile (ARO)</li> <li>BMI <math>\geq</math> 95<sup>th</sup> percentile (overweight) (IOTF cut-offs also used)</li> </ul>	<ul style="list-style-type: none"> <li>No association between child food insecurity and ARO or greater.</li> </ul>
	Lohman et al. (2009)	1,011 adolescents ages 10–15 (Three-City Study, wave 1)	<ul style="list-style-type: none"> <li>3-item subscale of CFSM (child)</li> <li>Child food secure (No positive responses)</li> <li>Child food insecure (any positive responses)</li> </ul>	<ul style="list-style-type: none"> <li>BMI= 5<sup>th</sup>–84<sup>th</sup> percentile (normal)</li> <li>BMI <math>\geq</math> 85<sup>th</sup> percentile (overweight/obese) (IOTF cut-offs also used)</li> </ul>	<ul style="list-style-type: none"> <li>Significant interaction of food insecurity and maternal stressors</li> <li>As maternal stressors increase, greater likelihood of overweight or obesity exists among food insecure</li> </ul>
	Smith and Richards (2008)	202 homeless youths ages 9–18 (Minnesota)	<ul style="list-style-type: none"> <li>4-item subscale of CFSM (child)</li> <li>Child food secure (“Never true” or “don’t know” response)</li> </ul>	<ul style="list-style-type: none"> <li>BMI= 5<sup>th</sup>–84<sup>th</sup> percentile (normal)</li> <li>BMI <math>\geq</math> 85<sup>th</sup> percentile (overweight/obese)</li> </ul>	<ul style="list-style-type: none"> <li>Significant association between “I do not get enough to eat at home” and overweight/obesity among females ages 9–13</li> <li>Significant correlation between “I go to bed hungry at night” and</li> </ul>

Population	Reference	Population (Setting)	Food insecurity measure	Weight measure(s)	Selected Significant Findings
Adults (6 studies)	Hanson et al. (2007)	4,338 men and 4,172 women 20 years (NHANES 1999–2002)	• Child food insecure (“Often true” or “sometimes” response)	<ul style="list-style-type: none"> <li>BMI= 18.5–24.9 (normal)</li> <li>BMI &gt;= 25 (overweight)</li> <li>BMI &gt;= 30 (obese)</li> </ul>	<ul style="list-style-type: none"> <li>After controlling for covariates, “not enough food in the house” associated with decreased likelihood of overweight/obesity for all females</li> </ul>
			• Each question analyzed separately		
			• CFISM (HH)		
			• Standard four- category measure (full, marginal, low, very low)		
			• HH food secure (fully food secure)		
			• HH food insecure (latter categories)		
Sullivan et al. (2010)	ED patients 18 years (Boston, Massachusetts)	• CFISM (HH)	<ul style="list-style-type: none"> <li>BMI= 18.5–29.9 (normal)</li> <li>BMI &gt;= 30 (obese)</li> </ul>	<ul style="list-style-type: none"> <li>Patients from food insecure households more likely to be obese; association remained significant in women only</li> <li>Patients from food insecure households reported more chronic and mental health problems</li> </ul>	
		• Three-category measure (food secure, food insecure w/o hunger, food insecure w/hunger)			
		• CFISM (HH)			
Webb et al. (2008)	435 adults from low- income neighborhoods (Massachusetts)	• CFISM (HH)	<ul style="list-style-type: none"> <li>BMI= 18.5–24.9 (normal)</li> <li>BMI &gt;= 25 (overweight)</li> <li>BMI &gt;= 30 (obese)</li> </ul>	<ul style="list-style-type: none"> <li>Food insecure adults more likely to be obese, report higher mean BMI</li> <li>After controlling for covariates, food insecurity and BMI not associated</li> <li>Participation in government funded programs for more than 6 months resulted in slightly lower BMI</li> </ul>	
		• HH food insecure (3 or more positive responses)			
		• Food insecure with hunger (5 or more [HH w/o children] or 7 or more [HH w/children] positive responses)			
Wilde and Peterman (2006)	4,618 men and 5,080 women 18 years (NHANES 1999–2002)	• CFISM (HH)	<ul style="list-style-type: none"> <li>BMI= 18.5–24.9 (normal)</li> <li>BMI &gt;= 25 (overweight)</li> </ul>	<ul style="list-style-type: none"> <li>Prevalence of obesity increased significantly with level of food insecurity</li> </ul>	
		• HH food secure (fully food secure)			

Population	Reference	Population (Setting)	Food insecurity measure	Weight measure(s)	Selected Significant Findings
			<ul style="list-style-type: none"> <li>• HH food insecure (marginal, food insecure w/o hunger)</li> </ul>	<ul style="list-style-type: none"> <li>• BMI <math>\geq</math> 30 (obese)</li> <li>• 5-lb weight change (1 yr)</li> <li>• 10-lb weight change (1 yr)</li> </ul>	<ul style="list-style-type: none"> <li>• Women who were marginally secure and insecure w/o hunger 58% and 76% more likely to be obese, respectively.</li> <li>• U-shaped curve for association between food insecurity and weight change categories for women</li> </ul>
	Holben and Pheley (2006)	2,580 adults (clinics in rural Appalachian Ohio)	<ul style="list-style-type: none"> <li>• CFSM (HH)</li> <li>• HH food secure (fully, marginally food secure)</li> <li>• HH food insecure (food insecure w/, w/o hunger)</li> </ul>	<ul style="list-style-type: none"> <li>• BMI= 18.5–24.9 (normal)</li> <li>• BMI= 25–29.9 (overweight)</li> <li>• BMI <math>\geq</math> 30 (obese)</li> </ul>	<ul style="list-style-type: none"> <li>• Greater prevalence of obesity, HbA1c <math>&gt;</math>7, and diabetes; higher BMI among food-insecure adults</li> <li>• Prevalence of obesity increased with food insecurity status</li> <li>• Greater prevalence of obesity, higher HbA1c remained significant for women only</li> </ul>
	Martin and Ferris (2007)	200 low-income parents (community settings in Connecticut)	<ul style="list-style-type: none"> <li>• CFSM (HH)</li> <li>• HH food insecure (3 or more positive responses)</li> </ul>	<ul style="list-style-type: none"> <li>• BMI= 18.5–24.9 (normal)</li> <li>• BMI= 25–29.9 (overweight)</li> <li>• BMI <math>\geq</math> 30 (obese)</li> </ul>	<ul style="list-style-type: none"> <li>• Food insecure adults 2.5 times more likely to be obese, after controlling for covariates</li> </ul>
Women (4 studies)	Laraia et al. (2010)	810 pregnant women (Pregnancy, Infection, and Nutrition cohort)	<ul style="list-style-type: none"> <li>• CFSM (HH)</li> <li>• HH food secure (No positive responses)</li> <li>• HH marginally secure (1–2 positive responses)</li> <li>• HH food insecure (3 or more positive responses)</li> </ul>	<ul style="list-style-type: none"> <li>• BMI= 19.8–25.9 (normal)</li> <li>• BMI= 26–28.9 (overweight)</li> <li>• BMI= 29–34.9 (obese)</li> <li>• BMI <math>\geq</math> 35 (severe obesity) (IOM cut-offs for women)</li> <li>• Gestational weight gain</li> </ul>	<ul style="list-style-type: none"> <li>• Food insecure women 3 times more likely to be severely obese (pre-pregnancy) after controlling for covariates</li> <li>• Food insecure women gained more weight during pregnancy, more likely to exceed expected weight gain than food secure counterparts, after controlling for covariates</li> <li>• Food insecure women twice as likely to have gestational diabetes</li> </ul>
	Olson and Strawderman (2008)	662 healthy adult women (Bassett Mothers Health Project)	<ul style="list-style-type: none"> <li>• IOM Nutrition Questionnaire (early pregnancy)</li> <li>• 3-item subscale of CFSM (post-partum)</li> <li>• Food secure (No positive responses)</li> </ul>	<ul style="list-style-type: none"> <li>• BMI= 18.5–24.9 (normal)</li> <li>• BMI= 25–29.9 (overweight)</li> <li>• BMI <math>\geq</math> 30 (obese)</li> </ul>	<ul style="list-style-type: none"> <li>• Food insecurity associated with increased risk of obesity at 2 years postpartum; association lost significance after controlling for covariates</li> </ul>

Population	Reference	Population (Setting)	Food insecurity measure	Weight measure(s)	Selected Significant Findings
			<ul style="list-style-type: none"> <li>Food insecure (any positive responses)</li> </ul>		
	Whitaker and Sarin (2007)	1,707 mothers with preschool children (Fragile Families and Child Wellbeing Study)	<ul style="list-style-type: none"> <li>CFSM (HH, adult)</li> <li>Food secure (No positive responses)</li> <li>Marginally secure (1-2 positive responses)</li> <li>Food insecure (3 or more positive responses)</li> <li>Not food secure (any positive response)</li> </ul>	<ul style="list-style-type: none"> <li>BMI= 18.5-29.9 (normal)</li> <li>BMI &gt;= 30 (obese)</li> </ul>	<ul style="list-style-type: none"> <li>Food insecurity significantly associated with obesity (at both periods); significance lost after controlling for covariates</li> </ul>
	Jones and Frongillo (2006)	5,303 women ages 18-74 (Panel Study of Income Dynamics)	<ul style="list-style-type: none"> <li>CFSM (HH, adult)</li> <li>Food secure (food secure category)</li> <li>Food insecure (food insecure w/o hunger, food insecure w/moderate hunger, food insecure w/severe hunger categories)</li> </ul>	<ul style="list-style-type: none"> <li>2-year weight change</li> </ul>	<ul style="list-style-type: none"> <li>Persistent food insecurity was associated with a smaller weight change in women</li> <li>Interaction of food insecurity and FSP participation associated with higher difference in weight change with \$2,000 increase in annual FSP benefits</li> </ul>
Elderly (1 study)	Kim and Frongillo (2007)	Elders ages 51-61 and their spouses (HRS); Elders 70 (AHEAD)	<ul style="list-style-type: none"> <li>2 items from CFISM</li> <li>Food secure (negative response to Q1 or positive response to Q2)</li> <li>Food insecure (positive response to Q1 or negative response to Q2)</li> </ul>	<ul style="list-style-type: none"> <li>BMI= 18.5-24.9 (non-overweight)</li> <li>BMI &gt;= 25 (overweight)</li> </ul>	<ul style="list-style-type: none"> <li>Previous food insecure elders had greater BMI change (AHEAD, lagged model)</li> <li>Current food insecure elders had higher BMI than current food secure elders (AHEAD, current model)</li> <li>Elders who became food insecure had larger BMI increase than those who remained food secure (AHEAD, difference model)</li> <li>Previous food insecure elders who were overweight had greater BMI change than overweight food secure counterparts (HRS, lagged)</li> <li>Trends remained consistent among FSP nonparticipants, but</li> </ul>



Population	Reference	Population (Setting)	Food insecurity measure	Weight measure(s)	Selected Significant Findings
					not participants (AHEAD, current and lagged models)

Abbreviations: AHEAD: Asset and Health Dynamics Among the Oldest Old; ARO: at risk for overweight; BMI: body mass index; CFSM: Core Food Security Module; FSP: Food Stamp Program; HH: household; HRS: Health and Retirement Study; IOM: Institute of Medicine; IOTF: International Obesity Task Force; lb: pounds (weight); NHANES: National Health and Nutrition Examination Survey; Q: question; SSNP/WC: Special Supplemental Nutrition Program for Women, Infants, and Children; TSF: triceps skinfold; w/: with; w/o: without; WC: waist circumference; yr: year.