Title
Food Insecurity and Unhealthy Weight Gain in Pregnant Women and Children

Author
Gamba, Ryan Joseph

Publication Date
2016

Peer reviewed|Thesis/dissertation

Food Insecurity and Unhealthy Weight Gain in Pregnant Women and Children

By

Ryan Joseph Gamba

A dissertation submitted in partial satisfaction of the

requirements for the degree of

Doctor of Philosophy

in

Epidemiology

in the

Graduate Division

of the

University of California, Berkeley

Committee in charge:

Professor Barbara Laraia, Chair
Professor Brenda Eskenazi
Professor Alan Hubbard
Professor Kristine Madsen

Fall 2016

Abstract

Food Insecurity and Unhealthy Weight Gain in Pregnant Women and Children

by

Ryan Joseph Gamba

Doctor of Philosophy in Epidemiology

University of California, Berkeley

Professor Barbara Laraia, Chair

Background: Food insecurity is the state of being without reliable access to enough food for an active, healthy life. While the relationship between food insecurity and weight gain has been inconsistent in children and men, food insecurity is consistently associated with chronic distress and higher weight status among women. The primary goal of this dissertation is to assess the associations between food insecurity and weight gain and obesity in low income Latino children, and food insecurity and unhealthy weight gain among a California representative sample of pregnant women. Seventeen percent of American children are obese, making childhood obesity one of the most prevalent health challenges American children face. Forty-eight percent of women in America gain weight in excess of the Institute of Medicine's (IOM) gestational weight gain guidelines; over 56% of obese women and 51% of white women gain in excess of the IOM guidelines, making these groups especially vulnerable. Three studies have found evidence that obesity may stem from early life exposure to food insecurity, although no study has examined if early exposure to food insecurity is associated with obesity in late childhood and early adolescence. Only one study has assessed if transitioning to and from food insecurity is associated with growth in children and they found that changing food security status may affect boys and girls differently. Additionally, only three studies have assessed the association between food insecurity and gestational weight gain among pregnant women and they have found positive and null associations. Identifying if there is an association between food insecurity and weight status among low income Latino children and pregnant women would inform programs such as the Special Supplemental Nutrition Program for Women, Infants, and Children that aim to alleviate food insecurity and promote healthy weight gain in these vulnerable populations.

Methods: The Center for the Health Assessment of Mothers and Children of Salinas (CHAMACOS) study collected information from Latino mother-child dyads from pregnancy to age 12. The first paper in this dissertation analyzes 243 mother-child dyads from CHAMACOS to assess longitudinal associations between exposure to food insecurity in the first years of life and changes in growth and obesity status from age 2 to 12 by implementing linear and logistic regression models. The second paper analyzes 204 children from CHAMACOS, and investigates the longitudinal associations between food security status, changing food security status, and persistency of food insecurity with changes in growth and obesity status by implementing generalized estimating equations. The third paper applies linear and multinomial logistic regression models to investigate the cross sectional association between food insecurity and gestational weight gain among 12,097 women from California's Maternal Infant Health Assessment (MIHA), a random sample survey of English- or Spanish-speaking women in California who recently had a live birth.

Conclusion: Early life exposure to food insecurity in the first two years of life was associated with growth in childhood differentially between boys and girls at different times, even up to ten years after the food insecurity was experienced. Household food insecurity was associated with decreased growth in childhood and transitioning to and from food insecurity was also negatively associated with growth. During pregnancy, food insecurity was significantly associated with increases in gestational weight gain among non-Hispanic African American women. However, these changes in weight status did not translate into changes in obesity status or gaining excessive weight during pregnancy according to the IOM gestational weight gain guidelines. The associations between food insecurity and growth in children were modified by age and gender while the associations between food insecurity and gestational weight gain were modified by race/ethnicity. Of the few studies that have previously examined the relationships between food insecurity and weight status among Latino children and pregnant women, very few tested for effect modification by age, sex, and race/ethnicity. Therefore more studies that consider differential influences of food insecurity on weight are needed before we can conclude food insecurity is not associated with obesity or excessive gestational weight gain in these vulnerable populations.

In dedication to my wife, Lyndsey Marie Marcelino, and the rest of my family for showing me the value of hard work.

TABLE OF CONTENTS

Acknowledgements

Thank you to my dissertation chair, Professor Barbara Laraia. Without you I would not have been successful in this program. You took a chance on a hardworking but unrefined student with lots to learn, and helped me direct my passion into research. I have appreciated all of your advice and mentorship throughout my academic career, and I will implement all you have taught me in my continued work to eliminate food insecurity. Thank you for an opportunity of a lifetime.

I would also like to acknowledge the other members of my committee, Dr. Brenda Eskenazi, Dr. Alan Hubbard, and Dr. Kristine Madsen and my colleagues at UCSF and CDPH. Your patience, guidance, and thoughtfulness have allowed me to greatly improve my scholarship. Thank you for helping me through this process, and pushing me to think critically about our research. I assure you I will publish our findings.

Thank you to the Center for the Health Assessment of Mothers and Children of Salinas staff for collecting data for over a decade to make this work possible and thank you to the families who participated in the study for sharing your time for the health of others. Thank you also to the women who participated in the Maternal Infant Health Assessment and those who collect and manage this data for making this research possible.

I am also thankful for the support of the DICE, the Diversity, Inclusion, Community and Equity community here at Berkeley, and my lab mates Chris Chau, Dr. Janelle Downing, Dr. Irene Headen, Bethany Hendrickson O'Connell, Dr. Tashara Leak, and Dr. Tara Zhang. In times of trepidation, your passion inspired me to keep moving forward, and reminded me that none of us is alone in the fight against inequality.

Finally, I would also like to thank M.S.G. Thank you for letting me be a part of your life and giving me perspective.

This research was supported by the following grants: RD 83171001 and RD 826709 from the U.S. Environmental Protection Agency (US EPA) and PO1 ES009605 and RO1 ES015572 from NIEHS. The contents of this publication are solely the authors' responsibility and do not necessarily represent the official views of the NIEHS, NIH, EPA or the Centers for Disease Control and Prevention. This work was also supported by the California Department of Public Health, Maternal, Child and Adolescent Health Program, with funding from the California Title V Maternal and Child Health Services Block Grant and the California Special Supplemental Nutritional Program for Women, Infants and Children (WIC).

Chapter 1: Background

The 1968 CBS documentary, “Hunger in America,” brought national attention to a hidden hunger in the United States that was thought to have been solved long ago (1). The film gave the public an unprecedented look at the then ten million American families who struggled with hunger and poverty.

Currently, the United States measures food insecurity, which is distinct from poverty and hunger. Food insecurity is defined (2) as, “whenever the availability of nutritionally adequate and safe foods or the ability to acquire acceptable foods in socially acceptable ways is limited or uncertain” (pp. 1575-1576), and 12.7% of American households were food insecure in 2015 (3). Food insecurity measures multiple constructs, including anxiety, food quality and quantity, hunger and weight loss (4). Domestically, food security status is often determined with the United States Department of Agriculture’s Standard Food Security module which includes 18 questions that range from asking about running out of food and not having enough money to purchase more, to whether or not there were children in the household that did not eat for a whole day because there was not enough money for food (4). A six-item scale is also widely used to assess food security status (4) and has been found to have excellent sensitivity and good specificity (5). Additionally, a newer two-item screener has been validated among low income households with children and has also demonstrated high sensitivity and specificity when assessing food security status (6).

This dissertation implements the life course perspective to analyze how food insecurity is associated with weight gain at different stages of life in vulnerable populations. The life course perspective suggests stressors at critical stages of life can have greater influences on current health, and health trajectories (7). Therefore, the association between food insecurity and weight gain was assessed in infancy, childhood and pregnancy. The life course approach also utilizes the concepts of allostasis and allostatic load. Allostasis is the process in which the body reacts to stressors to maintain physiological homeostasis (8). When chronic stressors are experienced, the regulatory mechanisms that are used to return the body to homeostasis can become impaired (9). Allostatic load refers to the wear and tear that is placed on the body by the consistent use of the regulatory mechanisms that are used to achieve homeostasis (9). Populations that face chronic stressors such as ethnic minorities and those with low socioeconomic status have been found to have grater allostatic loads (10, 11), and increased allostatic loads have been associated with poor health outcomes such as decreased education and cognitive performance (12). This dissertation will analyze the association between food insecurity and weight gain among low income Latino infants and children from a farm working community. Children from farm working households may have large allostatic loads because there are hardships associated with being Latino and living in a farm working household in America (13-16). Their large allostatic loads may diminish their ability to cope with food insecurity. We hypothesize early life exposure to food insecurity will contribute to allostatic load and lead to weight gain and obesity in childhood and that current food insecurity will be associated with reduced growth.

Latino farm workers are often discussed within the context of social justice because they work long hours at dangerous jobs to grow food for the country, yet they often live in poverty and disproportionately suffer from food insecurity and poor health outcomes (17). The prevalence of food insecurity in this population across the country has not been established, in part because the number of migrant farm workers changes frequently by the season and the demands of the agricultural industry (18). A review that focused on food insecurity in migrant farm working populations found food insecurity to almost always be significantly higher than what is observed in non-migrant populations, and estimates as high as 88% were found (19). Roughly 76% of mothers analyzed in this dissertation lived in a farm working household during pregnancy. The vast majority are immigrants from Mexico who now reside in the Salinas Valley. The Salinas Valley is located in Monterey County in Southern California. Monterey County is the 3rd highest grossing agricultural crop producing county in the United States, yet the county experiences more food insecurity than any other county in California (20). One report suggests 66% of the farm workers in the Salinas Valley are food insecure (20). The high rates of food insecurity are in part because farm workers may be undocumented citizens, which limits their ability to participate in government food assistance programs such as the Special Nutrition Assistance Programs (19). Studying the association between food insecurity and weight gain among infants and children of farm working households is important because this population faces additional barriers to accessing healthy foods, which may exacerbate any association between food insecurity and weight status.

This dissertation will also analyze a California representative sample of Non-Hispanic White, Hispanic, non-Hispanic African American, and Asian and Pacific Islander women who had a live birth in the previous 12 months to assess the extent to which food insecurity is associated with gestational weight gain. There are large racial disparities in gestational weight gain; Non-Hispanic White women are at greater risk of gaining weight in excess of the Institute of Medicine's (IOM) gestational weight gain guidelines compared to non-Hispanic African American and Hispanic women, however non-Hispanic African American and Hispanic women are at greater risk of gaining inadequate weight during pregnancy (21). These differences in gestational weight gain likely translate into disparities in birth outcomes (22). For example, African American women may experience disproportionately high rates of preterm birth compared to white women because they are more likely to gain weigh below the IOM guidelines (22, 23). A large representative sample of diverse women is needed to assess if food insecurity is associated with gestational weight gain, and if so, if the association is modified by race/ethnicity. If race/ethnicity does modify the food insecurity and gestational weight gain relationship, addressing the disparities in food insecurity experienced during pregnancy would subsequently reduce the disparities in birth outcomes.

The second chapter of this dissertation will examine how early life exposure to food insecurity is associated with changes in growth from age 2 to 12 and childhood obesity among a population of Latino children from the Center for the Health Assessment of Mothers and Children of Salinas (CHAMACOS) study. The third chapter will analyze the associations between household food insecurity and growth from age 5 to 12 among children form CHAMACOS. This chapter also analyzes how persistent food insecurity and transitioning to and from food insecurity is associated with growth. The fourth chapter will focus on the relationship between food insecurity during pregnancy and gestational weight gain in a state-representative sample of women who recently had a live birth from California's Maternal and Infant Health Assessment Study (24). This analysis will distinguish between low and very low levels of food insecurity, and also investigate the role race/ethnicity may have in modifying the association between food insecurity and gestational weight gain.

Although the relationship between food insecurity and weight status has been studied extensively, this dissertation adds to the literature by focusing on vulnerable populations during critical time periods. Low income Latino children suffer from high rates of obesity and many pregnant women are gaining weight in excess of the Institute of Medicine's Guidelines for weight gain during pregnancy (25-28). Understanding the relationship between food insecurity and weight status in these populations would inform programs such as the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) that aim to alleviate food insecurity and promote healthy weight gain (29). Potentially, WIC staff could greater prioritize efforts to improve food insecurity if there was strong evidence that doing so would also improve weight status.

Chapter 2. Early life exposure to food insecurity is associated with changes in BMI during childhood among Latino children from CHAMACOS

Introduction

Childhood obesity has been associated with morbidity and premature mortality (30). Seventeen percent of American children are obese, and 22% of Latino children are obese (31). While the prevalence of obesity among Latino children in farm working households is not well established, studies conducted in Latino farm working communities have found the prevalence of childhood obesity to range from 27% to 34% (25, 32). Farm working Latino families are at greater risk of obesity because of limited financial access to healthy food, and barriers including language, culture, and immigration status (20, 25). However in recent years, early life exposures have been identified as possible contributors to the development of obesity later in life (33-35). Food insecurity may be such an early life exposure that contributes to disparities in obesity prevalence.

Food insecurity is defined as, "the state of uncertain access to enough nutritionally adequate food for an active and healthy life" (2). Three studies found positive associations between early life exposure to food insecurity, defined as within the first two years of life, and obesity later in childhood (36-38). Bronte-Tinkew et al. first reported this association (37). They found food insecurity experienced at 9 months acted through parenting practices, infant feeding practices, and parental depression to increase risk of obesity at age 2. Expanding on their findings, Metallinos-Katsaras et al. (36) found that early life exposure to food insecurity was still positively associated with obesity up to four years later. Suglia et al. (38) also found evidence that early life exposure to food insecurity was associated with the onset of obesity, but only among girls. A main contribution of this collection of studies is the consistency of association between early life exposure to food insecurity and obesity up until five years. Research is still needed to identify if early life food insecurity is associated with weight status later in childhood, especially during critical periods of development.

Assessing the relationship between early life exposure to food insecurity and obesity in a population that largely consists of Latino farm working households is important because this population disproportionately suffers from food insecurity; the prevalence of household food insecurity is 19.2% among all U.S. households with children, 26.9% among Latino households with children (3), and recent evidence suggests it ranges from 39.0% to 63.8% in studies of Latino children who live in farm working households (19, 39). The effects of food insecurity on Latino farm working households may be exacerbated by living in food deserts and having limited access to food assistance programs and healthcare (20, 25). The Center for the Health Assessment of Mothers and Children of Salinas (CHAMACOS) study collected data from Latino mother-child dyads from predominantly farm working households for over twelve years. With these data we analyze the association between early life exposure to food insecurity and weight status among children from age 2 to 12. Our study has two aims: (1) to assess the association between early life food insecurity and change in BMI over five different time periods in childhood to identify periods when early life food insecurity may be more strongly associated with BMI; and, (2) to analyze the association between early life food insecurity and obesity status at seven points in childhood. We hypothesize early life food insecurity to be associated with greater increases in BMI and obesity from age 2 to 12, and that these associations will be strongest earlier in life when the exposure to food insecurity is influencing parenting practices. Based on previous findings (38, 40, 41), we also hypothesize that early life food insecurity will be associated with greater gains in BMI and a greater increased risk of obesity in girls compared to boys.

Methods

CHAMACOS is a longitudinal birth cohort study that was originally designed to study the effects of environmental exposures on the health of pregnant women and their children. Details of this study have been described previously (42, 43). To be eligible for CHAMACOS, women needed to be in their first half of pregnancy, ≥18 years of age, English or Spanish speaking, MediCal eligible, and planning to deliver at the county hospital. Women were recruited between October 1999 and October 2000 from prenatal care clinics. Study protocols were approved by the institutional review board at the University of California, Berkeley. Mothers provided informed consent at the study's onset, and children provided oral assent starting at age 7 and written assent at age 12.

Of the 601 pregnant women recruited to the study, 532 women gave birth to liveborn infants. One child from each of five twin dyads was randomly selected by a random number generator to be excluded from this study to maintain independence between children. Interviews were conducted in English or Spanish by bicultural research staff. Mothers were interviewed during pregnancy and when their children were 1, 2, 3.5, 5, 7, 9, 10.5 and 12 years old. This analysis was restricted to mother-child dyads with complete food insecurity information at age 1 and 2, and BMI information at age 2, 3.5, 5, 7, 9, 10.5, and 12. This allowed us to analyze the same group of children throughout childhood. The final analytic sample consisted of 243 mother-child dyads. A sensitivity analysis was conducted that included children with at least one pair of BMI measures across two consecutive time points to examine if associations were consistent when children with partial information were included.

Early life food security status: At years one and two, mothers were asked to select yes/no in response to the statement, "felt like not enough food to feed baby" in the past 12 months. Children whose mothers indicated "yes" to the statement at either year one or year two were classified as experiencing early life food insecurity.

Growth outcomes: Trained research staff measured weight and height of the children at each visit from age 2 to 12. A SECA brand stadiometer was used to measure barefoot standing height to the nearest 1 mm three times, and the three measures were averaged to determine the child's height. A Tanita Mother-Baby Scale Model 1582, Tanita Corp. digital scale was used to measure the children's standing weight to the nearest 0.1 kg until age 9. At age 9, children's standing weight was assessed with a Tanita TBF-300A Body Composition Analyzer, Tanita Corp. bioelectrical impedance scale. BMI was calculated as weight (kg)/height (meters)^2. The Center for Disease Control and Prevention's (CDC) growth charts were used to determine height z-scores, weight z-scores, and BMI z-scores (44). BMI is a more precise measure when assessing changes in adiposity over time in children as opposed to BMI z-scores because the variability of a child's z-score depends on their level of adiposity (45, 46). Therefore, the results discussed in this paper primarily focus on BMI. BMI z-scores were reported because they reflect age and sex-specific values of body fat. Height and weight z-scores were measured to determine if changes in BMI were primarily due to changes in fatness as opposed to changes in height. Obesity was defined as having a BMI > 95th percentile based on age and sex.

Covariates: Maternal age (18-24, 25-29, ≥30), maternal proportion of life spent in the United States (<50%, ≥50%), marital status (married or living together, single), maternal education (≤ 6^{th} grade, 7-12^{th} grade, ≥ high school graduate), parity (first child, 2-3, ≥4^{th}), and household income (≤100% of the Federal Poverty Level, >100% of the Federal Poverty Level) were collected during pregnancy and were considered *a priori* confounders based upon previous research (37, 47). In the year 2000, 100% of the Federal Poverty Level corresponded to an annual income of $17,050 for a family of four (48). Child's birthweight was categorized as low (<2,500 g), normal (≥2500g & ≤4,000 g) or high (>4,000 g). Child's birthweight and mother's pre-pregnancy BMI (underweight & normal weight, overweight, obese) were adjusted for to account for variability in children's BMI (49, 50). Women with underweight pre-pregnancy BMI's (n=2) were combined with women with normal BMI's and low birthweight babies (n=10) were combined with normal birthweight babies (n=197) to avoid small cells. Self-reported pre-pregnancy weight and measured height were used to calculate women's pre-pregnancy BMI. Considering previous research (41),we tested for effect modification of the early life food insecurity and BMI relationship by child's sex (male, female).

Statistical analysis: Children who were included in the study were more likely to have mothers who were older and who had lived less than half of their lives in the US when their children were born compared to children who were excluded from the study. To account for differences among those with complete case information and those not included in the study, the sample was inverse probability weighted to up-weight those who remained in the sample who were similar to those who did not remain in the sample (51).

To identify the extent to which early life food insecurity was associated with growth across different time periods throughout childhood, we analyzed the change in growth measures across six intervals; age 2 to 3.5, 3.5 to 5, 5 to 7, 7 to 9, 9 to 10.5 and 10.5 to 12. Changes in BMI, BMI z score, height z-score, weight z-score, and obesity status were analyzed as dependent variables. We also analyzed the association between early life food insecurity and obesity at age 2, 3.5, 5, 7, 9, 10.5 and 12.

To assess the associations between early life food insecurity and change in BMI across each time interval, we implemented linear regressions. We used Wald tests to test for effect modification by sex on all of the early life food insecurity and growth associations ($p<0.10$ was considered statistically significant). When effect modification was not observed, statistical models adjusted for sex in addition to all aforementioned confounders. When effect modification was observed, results were stratified by sex and the non-stratified results were not presented. Linear regression models also assessed associations between early life food insecurity and change in height z-scores, in weight z-scores, and in BMI z-scores.

Generalized log linear models with Poisson distributions and robust standard errors were implemented to assess the associations between early life food insecurity and obesity status at age 2, 3.5, 5, 7, 9, 10.5, and 12. To analyze change in obesity status across each time interval we also used generalized log linear models with Poisson distributions and robust standard errors because analyzing binary or categorical variables that represented the change in obesity status resulted in statistical models that would not converge. Therefore, we assessed the change in obesity status by identifying current obesity status as the dependent variable, while controlling for obesity status at the previous time point in addition to the aforementioned covariates. STATA (version 12.0, StataCorp, College Station, TX) software was used to conduct all statistical analyses.

Results

At pregnancy, 48% of the women had spent less than five years in the United States and more than 60% of mothers were living under the Federal Poverty Level (Table 1). Approximately 76% of women lived in households that contained at least one farm worker. Nearly 30% of children experienced food insecurity in the first two years of life and the prevalence of childhood obesity ranged from 28% at age 3.5, to 36% at age 12 (Table 2). Throughout childhood, BMI measurements from the same child were highly correlated as Pearson correlation coefficients ranged from 0.78 to 0.96. Including children who became obese and those who transitioned out of obesity, 7-10% of children changed obesity status from the previous time point. The mean BMI and weight z-score increased as children got older but the mean BMI z-score and height z-score fluctuated throughout childhood.

Experiencing early life food insecurity was associated with a 0.43 (0.01, 0.82) kg/m^2 decrease in BMI from age 2 to 3.5 after adjusting for maternal age, maternal percent of life spent in the U.S., marital status, maternal education, household income, maternal parity, maternal pre-pregnancy BMI , child sex, and child birth weight (Table 3). Early life food insecurity was also associated with decreases in weight and BMI z-scores from age 2 to 3.5. However, these associations no longer remained significant when we analyzed children with incomplete BMI information (Appendix Table A1). No significant interactions between food security status and sex were found before age 3.5.

When analyzing the change in BMI from age 3.5 to 5 and 5 to 7, the associations between early life food insecurity and change in BMI varied significantly by sex. Experiencing early life food insecurity was significantly associated with a 0.92 kg/m^2 (0.38, 1.46) increase in BMI among boys from age 3.5 to 5 and a non-significant decrease of 0.04 kg/m2 (-0.59, 0.51) in BMI among girls after adjusting for covariates (Table 3). Similar associations were found when assessing the changes in BMI and weight z-scores in boys and girls from age 3.5 to 5. During the interval from age 5 to 7, experiencing early life food insecurity was associated with a non-significant increase in BMI among boys of 0.30 kg/m2 (-0.35, 0.96) and a significant decrease in BMI of 0.68 kg/m^2 (0.22, 1.14) among girls after adjusting for covariates. Significant associations between early life food insecurity and growth from age 3.5 to 7 were robust in sensitivity analyses. Effect modification by sex was not observed for any other growth outcome when analyzing the change in growth from age 5 to 7.

No significant associations between early life food insecurity and growth were observed between the ages of 7 and 10.5. While early life food insecurity was not associated with changes in BMI from age 10.5 to 12, it was associated with a 0.10 (0.01, 0.19) increase in weight z-score and a 0.12 (0.01, 0.21) increase in BMI z-score. The increase in weight z-score remained significant in sensitivity analyses while the increase in BMI z-score did not. No significant associations between early life food insecurity and change in height z-score or obesity status were found (Appendix Table A2).

Children who experienced early life food insecurity were more likely to be obese at every time point compared to those who were food secure (Appendix Table A3), however at no age was the association between early life food insecurity and risk of obesity statistically significant. For example, at age 12, the prevalence of obesity among children who experienced early life food insecurity was 40.5% and the prevalence of obesity among children who did not experience early life food security was 34.6%.

Discussion

Our study aimed to assess the associations between early life food insecurity and change in BMI and obesity status from age 2 to 12 in a sample of Latino children from predominantly farm working households. Early life food insecurity was associated with changes in growth differentially between boys and girls at different times and both positive and negative associations were found. Early life food insecurity was not associated with obesity at any time in childhood. This was also the first paper to our knowledge to identify an association between early life food insecurity and changes in growth in children ten years after the food insecurity was experienced.

In contrast with past longitudinal studies that found largely positive associations between early life food insecurity and weight status (36, 38), in the present study significant negative associations were found between early life food insecurity and change in weight z-score, BMI and BMI z-score from age 2 to 3.5. These findings were attenuated and not significant when analyzing children who did not have growth measures across every time frame. This may have been because those who were missing visits had experienced less severe early life food insecurity and were more comfortable missing opportunities to meet with health professionals, or this may have been by chance as the associations were borderline statistically significant. However, the negative associations we observed are consistent with cross sectional studies that have analyzed Latino populations and found that food insecurity may lead to decreased caloric intakes (52, 53). Although these studies focused on current food security status, early life food insecurity may act through similar episodes of under consumption to affect children’s growth from age 2 to 3.5, given the temporal proximity of when early life food insecurity occurred.

Consistent with previous cross sectional (40, 54, 55) and longitudinal (38, 41) studies, we found effect modification of the food insecurity and BMI relationship by sex. More specifically, our results are consistent with past research that found early life food insecurity to be associated with an increase in BMI from age 3.5 to 5 among boys (41) and a decrease in BMI from age 5 to 7 among girls (40, 41). However, our findings are inconsistent with our hypothesis that early life food insecurity would be associated with greater gains in BMI in both boys and girls. Our hypothesis was supported by evidence that indicated early life exposure to food insecurity may cause obesity promoting changes to the stress response (56), and additional research that found early life exposure to food insecurity engendered changes in parenting and feeding practices that promoted obesity (37). According to this evidence, we would expect the early life food insecurity and weight gain relationship to be modified by sex if boys and girls have different stress responses to food insecurity, or if the parenting and feeding practices used by parents are dependent on the sex of their children. Two past studies that found food insecurity to differentially effect weight status by gender suggested the difference may be attributed to dissimilarities in how boys and girls respond to stress (40, 41). However, while research has identified sex differences in response to prenatal stress (57), we found no research that investigated if early life food insecurity leads to different stress responses in boys and girls. In contrast, a body of research has identified that parents feed their children differently according to their sex (58-61). For example, Mexican American parents have been found to encourage their sons to eat more than their daughters, and also to promote restrictive feeding practices more to their daughters than their sons (58). If boys are taught feeding practices that promote greater consumption while girls are taught practices that promote less consumption in response to early life food insecurity, this would support our findings that early life food insecurity was associated with greater growth in boys and less growth in girls from age 3.5 to 7.

Early life food insecurity was not associated with BMI after age 7, although it was positively associated with BMI z-score in early adolescence. Early life food insecurity may not have been associated with BMI after age 7 because the effects of parental feeding practices may diminish as children get older (58). Children also may change their eating behaviors when they begin eating with peers outside of the household, which would likely occur more often as they get older (62, 63). However, it is difficult to explain how early life food insecurity could act through parenting or feeding practices to influence BMI z-scores in early adolescence, and not in later childhood. This association is better explained by implementing the life course perspective, which suggests that stressors experienced in critical time periods can have lasting adverse effects on health (7). Although not analyzed in this study, early life exposure to food insecurity has been associated with hormonal changes in infants that affect their growth later in life. Evidence from animal models suggests that low availability of food in the postnatal period can influence the expression of hormones to delay puberty (64-66). If early life exposure to food insecurity made it more likely for children to experience pubertal growth between age 10.5 and 12, this could explain the increase in BMI z-score we observed across this time period (67).

We found no significant association between early life food insecurity and increased risk for obesity, although the associations were consistently positive. These findings are inconsistent with three previous studies that found positive associations between early life food insecurity and obesity at ages that ranged from 2-5 (36-38). Our findings may have not reached statistical significance because we studied a smaller sample of children than past studies. It should also be noted that although early life food insecurity was not associated with changes in BMI categorization, that the changes in BMI recorded in this study were consistent in size with changes in BMI that have been associated with elevated blood pressure and lipid levels later in life (68, 69).

The prevalence of early life food insecurity and obesity in this study were both larger than the national average (70), which contributes to greater statistical power for the analyses (71). The longitudinal nature of the CHAMACOS dataset allowed us to analyze the association between early life food insecurity and weight status at seven time points across ten years. Analyzing a population that faces unique health barriers likely reduced the generalizability of the results, but the similar characteristics shared by this population may have reduced unmeasured confounding. This study would have been strengthened by assessing early life food insecurity with the United States Department of Agriculture's Food Security Core Module (72) because this would have allowed us to distinguish the severity of food insecurity experienced in the first years of life.

Farm working households face many barriers to health, and this study found that children from predominantly farm working households were often exposed to food insecurity in their first years of life. Programs and policies that focus on improving the food security status of farm working households with babies and infants need to be strengthened or created to protect these children from the long lasting effects of experiencing food insecurity during this critical time. This study highlighted how sex and age modify the association between early life exposure to food insecurity and weight. Future mechanistic studies are needed to explain why early life exposure to food insecurity may affect boys and girls differently.

Table 1: Characteristics of mothers and their children in the CHAMACOS study at baseline

Characteristic	Food Secure n=169 (70.5%) n (%)[1]	Food Insecure n=74 (29.5%) n (%)	Total Population n=243 (100%) n (%)
Maternal age			
18-24	74 (50.4)	22 (36.4)	96 (46.3)
25-29	54 (29.9)	31 (39.7)	85 (32.8)
≥30	41 (19.7)	21 (23.9)	62 (20.9)
Maternal % of life spent in the U.S.			
<50%	143 (80.8)	66 (85.8)	209 (82.3)
≥50%	26 (19.2)	8 (14.2)	34 (17.7)
Marital Status			
Married or living as married	142 (81.6)	61 (81.9)	203 (81.9)
Single	27 (18.4)	13 (18.1)	40 (18.1)
Maternal education			
≤ 6th Grade	70 (40.5)	38 (48.2)	108 (42.8)
7-12th Grade	62 (36.0)	25 (36.5)	87 (36.1)
≥ High school graduate	37 (23.5)	11 (15.3)	48 (21.1)
Maternal Parity			
First child	51 (33.7)	21 (31.7)	72 (33.1)
2-3	95 (53.2)	38 (49.7)	133 (52.2)
≥4th	23 (13.1)	15 (18.6)	38 (14.7)
Maternal Pre-pregnancy body mass index			
Underweight & Normal	63 (41.4)	22 (33.2)	85 (39.0)
Overweight	63 (36.1)	33 (43.5)	96 (38.3)
Obese	43 (22.5)	19 (23.3)	62 (22.7)
Household income			

≤100% of the Federal Poverty Level	105 (58.6)	54 (68.4)	159 (61.5)
>100% of the Federal Poverty Level	64 (41.4)	20 (31.6)	84 (38.5)
Child sex			
Female	95 (52.2)	35 (45.7)	130 (49.7)
Male	74 (47.8)	39 (54.3)	113 (50.3)
Child birth weight			
Low or normal weight	144 (86.2)	63 (86.4)	207 (86.2)
High	25 (13.8)	11 (13.6)	36 (13.8)

[1] Unweighted n's and weighted percentages.

Table 2: Height z-score, weight z-score, BMI z-score, BMI and obesity status of children in CHAMACOS from age 3.5 to 12 (n=243)

Age	Height z-score $\bar{x}$ (95% CI)	Weight z-score $\bar{x}$ (95% CI)	BMI z-score $\bar{x}$ (95% CI)	BMI $\bar{x}$ (95% CI)	Correlation with BMI from previous time point[1]	% Obese	% Changed obesity status from previous time point[1]
3.5	0.18 (0.06, 0.31)	0.84 (0.70, 0.99)	1.12 (0.97, 1.27)	17.5 (17.2, 17.8)	0.78	28	18
5	0.30 (0.18, 0.42)	0.87 (0.73, 1.02)	1.15 (1.02, 1.29)	17.7 (17.3, 18.1)	0.91	31	10
7	0.12 (0.00, 0.24)	0.91 (0.77, 1.05)	1.10 (0.98, 1.22)	18.7 (18.3, 19.2)	0.91	33	7
9	0.20 (0.08, 0.32)	0.96 (0.82, 1.11)	1.07 (0.94, 1.20)	20.5 (19.9, 21.1)	0.94	36	7
10.5	0.31 (0.19, 0.42)	0.98 (0.84, 1.12)	1.10 (0.98, 1.23)	22.1 (21.4, 22.7)	0.95	36	8
12	0.23 (0.13, 0.34)	0.98 (0.83, 1.12)	1.08 (0.95, 1.21)	23.3 (22.6, 24.0)	0.96	36	8

[1] Measurements from the previous time point at age 3.5 refer to measurements from age 2.

Table 3: Early life exposure to food insecurity and associated changes in growth among children in CHAMACOS, stratified by sex (n=243)[1, 2]

		Weight z-score			BMI			BMI z -score		
	Time Interval	All ß (95% CI)	Male ß (95% CI)	Female ß (95% CI)	All ß (95% CI)	Male ß (95% CI)	Female ß (95% CI)	All ß (95% CI)	Male ß (95% CI)	Female ß (95% CI)
Food Secure	2 - 3.5	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Food Insecure		-0.19 (-0.37, -0.02)*	-	-	-0.43 (-0.82, -0.04)*	-	-	-0.28 (-0.49, -0.07)**	-	-
Food Secure	3.5 - 5	-	Ref	Ref	-	Ref	Ref	-	Ref	Ref
Food Insecure			0.36 (0.16, 0.57)**	-0.06 (-0.21, 0.10)		0.92 (0.38, 1.46)**	-0.04 (-0.59, 0.51)		0.55 (0.27, 0.83)***	-0.06 (-0.25, 0.12)
Food Secure	5 - 7	Ref	Ref	Ref	-	Ref	Ref	Ref	Ref	Ref
Food Insecure		-0.10 (-0.22, 0.02)	-	-		0.30 (-0.35, 0.96)	-0.68 (-1.14, -0.22)**	-0.13 (-0.27, 0.0)	-	-
Food Secure	7 - 9	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Food		0.05	-	-	0.40	-	-	0.06	-	-

Insecure		(-0.05, 0.14)			(-0.00, 0.79)			(-0.04, 0.17)		
Food Secure	9 - 10.5	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Food Insecure		-0.05 (-0.13, 0.04)	-	-	-0.03 (-0.49, 0.42)	-	-	-0.05 (-0.15, 0.04)	-	-
Food Secure	10.5 - 12	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Food Insecure		0.10 (0.01, 0.19)*	-	-	0.30 (-0.20, 0.79)	-	-	0.12 (0.01, 0.21)*	-	-

[1] When effect modification by sex was observed ($p < 0.10$), the ß associated with early life food insecurity among all children was not reported as stratified estimates should be considered

[2] Non-stratified linear models were adjusted for maternal age, maternal proportion of life spent in the United States, marital status, maternal education, maternal parity, maternal pre-pregnancy body mass index, household income, child sex, and child birth weight. Stratified models adjusted for the same confounder set but excluded sex.

*p <0.05, ** p<0.01, *** p<0.001

Chapter 3. Household food insecurity is associated with decreased weight and body mass index z-scores among Latino children from CHAMACOS

Introduction

Household food insecurity is present "whenever the availability of nutritionally adequate and safe food, or the ability to acquire acceptable food in socially acceptable ways, is limited or uncertain" (2). Household food insecurity disproportionately affects U.S. households with children; 16.6% compared to 10.9% of households without children in 2015 (3). The prevalence of household food insecurity among Latino families is almost two times that for non-Hispanic white households and 21.9% of children in Latino households are exposed to food insecurity compared to 13.1% of non-Hispanic white households (3). Compared to non-Hispanic white children, Latino children disproportionately live in food deserts which may exacerbate any negative effects of food insecurity (73). Food insecurity and limited access to healthy foods have been hypothesized to influence children's weight (74-77).

Three review articles that assessed the association between household food insecurity and weight status in children concluded that studies had largely mixed findings (74-76). However, only three studies (41, 78, 79) focused on the association between household food insecurity and changes in BMI over time and two of these studies found positive associations (41, 79). Associations between household food insecurity and continuous BMI are important because a food insecurity induced increase in BMI during childhood that does not cause a child to become obese may still influence a child's risk of asthma, blood pressure and cardiovascular disease in adulthood (80-82). Additionally, observing changes in BMI throughout childhood could help identify periods when children are most susceptible to household food insecurity. Only two studies that assess the food insecurity and weight relationship focus on Latino populations, and both found food insecurity to be negatively associated with BMI (52, 53). Matheson et al. analyzed 124 Latino children in the 5th grade and found that food insecurity was associated with lower caloric intakes and BMI's in the days leading up to payday (52). They suggested the decrease in caloric intake resulted from there not being enough money for food.

Persistent food insecurity is defined as being food insecure over multiple measures in a longitudinal study (83, 84). The prevalence of persistent food insecurity has been reported to be low in nationally representative samples (83, 84). Among a nationally representative sample of kindergartners, Ryu et al. found that 3.2% of households were food insecure for three years and 1.2% of households were food insecure for four years when the average annual prevalence of food insecurity was 9% (83). Persistent food insecurity may have a greater adverse effect on children's health outcomes than experiencing food insecurity for a shorter duration (83, 85). Among children, Kirkpatrick et al. found experiencing hunger once in a ten year period was not associated with self-reported health while experiencing hunger two or more times was adversely associated with self-reported health (85). Although persistent food insecurity may have a greater adverse effect on children's health than experiencing shorter durations of food insecurity, no studies were identified that targeted low income children and followed them throughout childhood to determine how persistent food insecurity may be associated with growth. One study by Jyoti et al. (41) also provides evidence that changing food security status over time may influence weight status. Among 11,400 children, living in a household that transitioned from food security to food insecurity over a four year period was significantly associated with increases in weight and BMI gains among boys (1.2 kg and 0.43 kg/m^2 respectively), but was not significantly associated with decreases in weight and BMI gains among girls (-0.81 kg and -0.45 kg/m^2 respectively).

Our study attempts to build on existing research by examining the extent to which changing food security status across two time points is associated with subsequent changes in BMI over an eight-year period from age 5 to 12 in a sample of low income Latino children. We also assess how living in a persistently food insecure household across three time points is associated with changes in BMI. Informed by past research (41, 52, 53), we hypothesize that household food insecurity will be associated with decreased gains in BMI during the same time period. We also hypothesis that transitioning from a food insecure household to a food secure household will result in increased gains in BMI over the two time points because of the greater availability of food in the household. Lastly, the decreased gains in BMI brought on by household food insecurity are anticipated to be larger among boys, as girls may be more likely than boys to overconsume food after having to restrict their eating (36, 41, 59).

Methods

Study procedures and methods of the Center for the Health Assessment of Mothers and Children of Salinas (CHAMACOS) longitudinal birth cohort have been described elsewhere (42, 43). The primary aim of CHAMACOS was to explore how environmental exposures affected pregnant women and their children. The recruitment of pregnant women took place at prenatal clinics between October 1999 and October 2000, and follow-up is ongoing. Eligibility criteria included being in the first half of pregnancy, MediCal eligible, English or Spanish speaking, ≥18 years of age, and planning to deliver at the county hospital. All study protocols were approved by the University of California Berkeley institutional review board. Maternal consent was obtained at the beginning of follow-up and children provided oral assent at age seven and written assent at age 12.

Five hundred and thirty-two women had liveborn infants of the 601 pregnant women who participated in the study. A random number generator was used to exclude one child from each of five twin dyads to ensure independence between children. Demographic, socioeconomic and acculturation information was collected from mothers during pregnancy and when their child was 5, 7, 9, 10.5 and 12 years old. Child characteristics and behaviors were also collected at age 5, 7, 9, 10.5 and 12. Mothers were interviewed by bicultural interviewers in either English or Spanish at each child visit. Only the 204 mother-child dyads with complete household food security status, height z-score, weight z-score, body mass index (BMI) and BMI z-score data across all time points were included in this study. The study population was inverse probability weighted to the original sample to account for the differences between those who were included and excluded in the study (51). For sensitivity analyses, all statistical modeling was also performed on an imputed dataset that contained an additional 44 children who had incomplete data for one or more independent variables (86). The imputation model included all variables in the dataset and five imputations with chained equations were conducted.

Household food security status was assessed with the United States Department of Agriculture's (USDA) six-item Food Security Survey Model (87). Households were considered food insecure if the respondent answered one or more of the food insecurity questions affirmatively and food secure if they did not respond affirmatively to any question. Questions and affirmative responses are shown in Figure 1. Household food security status was characterized in three ways: household food security status at the time point prior to change in weight status, an indicator variable capturing status over two time points and an indicator variable capturing status over three time points. Household security status across two time points was categorized as transitioned to food security, transitioned to food insecurity, remained food secure across two time points, or remained food insecure across two time points. Household food security status across three time points was categorized as persistently food secure, persistently food insecure, or changed food security status at least once across the three time points. Additionally, based on previous research early life exposure to food insecurity was considered a confounder *a priori* (56). A child was considered to have experienced early life food insecurity if at age 1 or 2 their mother felt like she did not have enough food to feed their baby in the last 12 months.

Changes in height z-score, weight z-score, BMI, BMI z-score and obesity were assessed as outcomes. Weight and height were measured by trained research staff at age 5, 7, 9, 10.5 and 12. Standing height was measured to the nearest 1mm with a SECA brand stadiometer three times and then averaged. At age 5 and 7, weight was measured with a Tanita Mother-Baby Scale Model 1582, Tanita Corp. digital scale and was rounded to the nearest 0.1 kg. At age 9, children's standing weight was assessed with a bioelectrical impedance scale (Tanita TBF-300A Body Composition Analyzer, Tanita Corp.) and rounded to the nearest 0.1 kg. BMI was calculated as weight (kg)/height (meters)^2 and obesity was defined by having a BMI >95th percentile. Height z-scores, weight z-scores, and BMI z-scores were generated in accordance with the Center for Disease Control and Prevention's (CDC) growth charts (44). Change in BMI is the primary dependent variable because it is a more precise measure of changes in adiposity in childhood compared to change in BMI z-score because the variability of a child's BMI does not depend on their adiposity (45, 46). However, change in BMI z-score was also presented to provide gender and age specific measures of adiposity. Changes in height and weight z-scores were assessed to determine if changes in BMI were driven more by changes in height or weight.

The following demographic variables were retained for all models: Maternal age (18-24, 25-29, ≥30), marital status (married or living as married, single) and parity (1, >1). We also included socioeconomic and acculturation factors (41, 78, 79) as measured by the following: household income (≤100% of the Federal Poverty Level, >100% of the Federal Poverty Level); maternal percent of life spent in the United States (<50%, ≥50%); and maternal education (≤ 6th grade, 7-12th grade, ≥ high school graduate). The following child characteristics and behaviors were controlled for to reduce variability in the growth measures: child's birthweight (low <2,500g, normal birthweight ≥2500g & ≤4,000g and high birth weight >4,000g), hours spent watching television (<1 hour/day, 1-2 hours/day, 3+ hours/day), hours spent playing outside (<1 hour/day, 1-2 hours/day, 3+ hours/day), and puberty status (prepubescent, pubescent). A girl was considered pubescent if she achieved Tanner stage 2 for breast development, and a boy was considered pubescent if he had pubic hair or genitalia at stage 2. Normal birthweight babies were combined with low birthweight babies (n=6) to avoid positivity violations.

Linear regressions were applied when analyzing the associations between household food security status and change in height z-score, change in weight z-score, in BMI and in BMI z-score across each time interval. The household food security status exposure variable was lagged in statistical models, meaning when we assessed the association between household food security status and change in BMI from age 5 to 7, we analyzed household food security status at age 5. Wald tests ($p<0.10$) were implemented to test for effect modification of the household food insecurity and BMI relationship by pre-pregnancy BMI (underweight & normal weight, overweight, obese) and child's gender (girl, boy) (36, 41). The one woman with a pre-pregnancy BMI that indicated she was underweight was grouped with women with normal pre-pregnancy BMIs to avoid positivity violations from analyzing an unbalanced categorical variable.

Generalized log linear models with Poisson distributions and robust standard errors were used to analyze the associations between household food security status and change in obesity status across each time interval. To assess change in obesity status we identified current obesity status as the outcome in the statistical models and adjusted for obesity status from the previous time point, in addition to the aforementioned covariates.

Generalized estimating equations were not implemented to obtain a pooled estimate of the association between household food insecurity and BMI from age 5 - 12, as the association between household food insecurity and BMI was related to both increases and decreases in BMI depending on the age of the child. However, generalized estimating equations were implemented to identify how changing household food security status over two time points and the persistence of household food insecurity across three time points were associated with changes in growth. An unstructured correlation matrix was assigned to the generalized estimating equations due to unequal spacing in the data, and to allow the correlation of BMI from different time points to vary. Huber-White sandwich estimators were implemented to produce robust standard errors (88). STATA (version 12.0, StataCorp, College Station, TX) was implemented for all statistical analysis.

Results

At the time of pregnancy, mothers had lived in the United States an average of 7.5 years (Table 1) and 76% lived in households that contained at least one farm worker. At age 5, 15.9% of mothers were single and 78% had not graduated from high school. Over half of the mother-child dyads lived below the poverty level. As expected, during this time of growth and development the average BMI increased as children got older (Table 2). The prevalence of obesity increased from 30.1% at age 5 to 36.5% at age 12. The prevalence of household food insecurity decreased from 46.1% at age 5 to 36.9% at age 12 (Table 2) and 17% of households were food insecure across all five time points (data not shown). The proportion of children who transitioned to become food secure or transitioned to become food insecure over two time points decreased as children got older, ranging from 26% at age 7 to 19% at age 12.

Before age 9 there was no evidence of an association between household food security status and growth (Table 3, Appendix A4). Experiencing household food insecurity at age 9 was associated with a significant decrease in weight z-score of 0.15 (0.07, 0.23) and a significant decrease in BMI z-score of 0.18 (0.09, 0.26) between age 9 to 10.5 compared to experiencing household food security, after adjusting for maternal age, maternal proportion of life spent in the U.S., marital status, maternal education, household income, early life exposure to food insecurity, maternal parity, maternal pre-pregnancy BMI, child gender, child birth weight, hours the child plays outside, hours the child watches T.V., and child puberty status (Table 3). These findings remained significant when analyzing the imputed dataset that included the children with incomplete confounder information. The association between household food insecurity at age 10.5 and weight and BMI z-score from age 10.5 to 12 remained negative, although the results were no longer statistically significant. Household food insecurity was not associated with height or BMI at age 9 or after.

Compared to children in households that remained food secure across two time points, children who lived in households that remained food insecure across two time points had decreased gains in height z-score, weight z-score, and BMI z-score but no decreased gains in absolute BMI (Table 4). Children in households that changed from being food secure to food insecure had decreased weight, BMI z-scores, and absolute BMI but not height z-score relative to children who lived in food secure households across both time points. No association was found among children in households that became food secure. Findings regarding changes in weight and BMI z-score were robust across sensitivity analyses.

Living in a persistently food insecure household or a household that changed food security status over three time points was associated with decreased gains in growth compared to children who lived in persistently food secure households, although these results were not statistically significant. Similarly, the adjusted log linear Poisson models showed no association between any of the household food security exposures and obesity (Appendix Table A5). Child gender and maternal pre-pregnancy BMI were only found to modify the relationship ($p<0.10$) between household food security status and change in growth in very few instances and never produced significant results. Therefore stratified estimates are not presented.

Discussion

Consistent with previous research (3, 31), the prevalence of household food insecurity (19.2%) and childhood obesity (16.9%) in this sample of low income Latino children consistently exceeded National prevalence estimates (3, 31). The extremely high prevalence of household food insecurity and persistent food insecurity in this study suggest that household food insecurity may be an enduring problem in low income Latino communities.

Unexpectedly, household food insecurity was only significantly associated with a decrease in growth from age 9 to 10.5. Although not analyzed in this study, finding an association between household food insecurity and decreased growth only from age 9 to 10.5 may be because household food insecurity is associated with delayed pubertal onset (89, 90). The children's average height z-score, weight z-score, BMI, and BMI z-score were all highest at age 10, which is possibly indicative of children having pubertal growth spurts from age 9 to 10.5. Although we adjusted for puberty at age 9, if children in food insecure households were more likely to begin puberty at the end of the 1.5 year interval, they may have been less likely to experience a large pubertal growth spurt over that time. This may explain why children living in food insecure households had relatively less growth over this time compared to children living in food secure households. However, with known differences in pubertal onset between boys and girls, we would have anticipated observing differences in growth by gender.

While some longitudinal studies have not found an association between household food insecurity and weight (78, 91), many have found positive associations and suggest the food insecurity and weight association is mediated by poor diet quality (36-38, 41, 92). Our results likely differed from previous studies because of two reasons. First, past studies (36-38, 41, 91, 92) largely focused on children of younger ages who may be better insulated from the harmful effects of household food insecurity; parents have been shown to buffer their children from the harmful effects of food insecurity by reducing their dietary intakes to insure the children have enough to eat (93, 94). Second, we analyzed a highly marginalized population of Latino children in the Salinas Valley. The majority of households contained at least one farm worker when mothers were pregnant with the children in this study, and Latino farm workers face barriers to accessing food assistance programs (15, 16). It is possible limited access to these programs exacerbated the effects of food insecurity and forced children to experience episodes of caloric restriction (52, 53, 55, 95, 96).

Inconsistent with our hypothesis, living in a household that transitioned from being food insecure to food secure did not result in increased weight gain. This hypothesis was based upon research that suggests food insecure individuals may overconsume when ample food becomes available (36, 41, 59), however because household food security status was assessed every one and a half to two years, the duration of overconsumption may have been relatively short and not contributed largely to growth. While persistent food insecurity was associated with decreased gains in growth, these associations were not statistically significant. Assessing change in growth over three time points as opposed to two reduced the number of observations analyzed, and the subsequent loss of power may explain why we did not observe statistically significant findings.

These results differ from Jyoti et al. (41) who found changing household food security status was significantly associated with greater weight gain and BMI among boys. Differences in our studies may be due to the varying length of time intervals examined, as Jyoti et al. analyzed the effect of changing household food security status on weight and BMI over a four year time period, while we measured the average association between change in household food security status and growth over four time intervals that were much shorter — one and a half or two years long. We may not have observed effect modification by gender because we analyzed older children and differences in parent feeding practices and how children respond to them may dissipate with age (58).

Four important points should be made regarding the measures and point estimates reported in this study and their potential impact on the childhood obesity epidemic. First, we observed more significant findings when analyzing weight and BMI z-scores as opposed to BMI. This may be because small changes in absolute BMI may reflect large changes in gender and age specific BMI z-scores in children. Second, large changes in height z-score were not observed, which suggests that changes in BMI were primarily caused by changes in weight. Third, although a large proportion of study participants were obese and household food insecurity was associated with decreased growth across all intervals after age 7, household food insecurity is not a beneficial experience for children as it has been associated with an array of negative health consequences (76, 97). Lastly, while household food insecurity was associated with statistically significant changes in growth, these changes might not be clinically meaningful, which in one instance has been defined as a change in BMI z-score > 0.5 (98). This may explain why the significant changes in BMI z-score did not translate to changes in obesity status in this study. However, the small changes in growth observed in this study may still affect health later in life

(68, 69, 81), and may have large effects on the U.S. population given the high prevalence of children who live in food insecure households (3).

Findings derived from the implementation of generalized estimating equations should be interpreted with caution as they estimated averaged associations across different consecutive time points, and we found that age modifies the association between household food security status and changes in growth. For example, when implementing generalized estimating equations to estimate the association between persistent food insecurity and growth, estimates associated with living in a persistently food insecure household from age 5 to 10.5 were averaged with estimates associated with living in a persistently food insecure household form age 7 to 12 to produce an estimated average effect. Therefore, the extrapolation of these results to children across a different age range should be avoided.

The key strength of this study was having five measurements of household food security status across eight years. This long duration allowed us to show that the association between household food security status and change in growth is modified by children's age. This study also benefited from studying Latino children from an agricultural community who may share many characteristics. Similarities in this population may have decreased unmeasured confounding, but also reduced the generalizability of our results.

The low income Latino children experienced high rates of household food insecurity, and household food insecurity was associated with decreases in childhood growth. The results of this study are consistent with previous work that suggested Latino children may decrease their caloric intakes because there is not enough money to buy food (52, 53). Household food insecurity is a dynamic condition, and identifying the developmental periods when children are most susceptible to the negative consequence of food insecurity will help programs that aim to alleviate food insecurity target vulnerable groups.

Figure 1: Description of the United States Department of Agriculture's six item scale to assess household food security status (87)

Question	**Affirmative response**
"The food that I bought just didn't last, and I didn't have money to get more." During the last 12 months, was that often, sometimes, or never true for you?	Often or sometimes
"I couldn't afford to eat balanced meals." During the last 12 months, was that often, sometimes, or never true for you?	Often or sometimes
During the last 12 months, did you ever cut the size of your meals or skip meals because there wasn't enough money for food?	Yes
During the last 12 months, did you ever eat less than you felt you should because there wasn't enough money to buy food?	Yes
How often did this [cut size or skip meals] happen?	Almost every month or Some months but not almost every month
During the last 12 months, were you ever hungry but didn't eat because you couldn't afford enough food?	Yes
Assessing Food Security Status 0 Affirmative responses – Food secure ≥1 Affirmative response – Food insecure	

Table 1: Characteristics of mothers and their children in the CHAMACOS study at age 5[1]

Characteristics	Food Secure n=109 (54.8%) n (%)	Food Insecure n=95 (45.2%) n (%)	Total Population n=204 (100%) n (%)
Maternal age			
18-24	45 (49.9)	34 (40.7)	79 (45.7)
25-29	33 (26.9)	39 (41.3)	72 (33.4)
≥30	31 (23.2)	22 (23.9)	53 (20.9)
Maternal % of life spent in the U.S.			
<50%	92 (78.1)	86 (87.8)	178 (82.5)
≥50%	17 (21.9)	9 (12.2)	26 (17.5)
Maternal education			
≤ 6th Grade	44 (40.5)	46 (47.9)	90 (43.8)
7-12th Grade	34 (30.0)	37 (39.0)	71 (34.1)
≥ High school graduate	31 (29.5)	12 (13.1)	43 (22.1)
Maternal Pre-pregnancy body mass index			
Underweight & normal	44 (47.8)	24 (29.4)	68 (39.5)
Overweight	40 (34.1)	41 (43.3)	81 (38.3)
Obese	25 (18.2)	30 (27.3)	55 (22.3)
Early life food insecurity			
Food Secure	92 (86.0)	55 (57.8)	147 (73.2)
Food insecure	17 (14.1)	40 (42.2)	57 (26.8)
Child gender			
Female	62 (51.9)	48 (46.3)	110 (49.4)
Male	47 (48.1)	47 (53.7)	94 (50.6)
Child birth weight			
Low or normal weight	92 (86.0)	81 (86.5)	173 (86.2)

Macrosomic	17 (14.0)	14 (13.5)	31 (13.8)
Time varying characteristics			
Marital status			
Married or living as married	94 (84.1)	86 (90.1)	180 (86.8)
Single	15 (15.9)	9 (10.0)	24 (13.2)
Maternal parity			
1	58 (57.1)	32 (36.3)	90 (47.7)
>1	51 (42.9)	63 (63.7)	114 (52.3)
Household income			
≤100% of the Federal Poverty Level	57 (51.9)	73 (77.7)	130 (63.6)
>100% of the Federal Poverty Level	52 (48.1)	22 (22.3)	74 (36.4)
Child T.V. status			
<1 hour/day	27 (24.7)	28 (28.6)	55 (26.4)
1-2 hours/day	33 (32.2)	32 (32.4)	65 (32.3)
3+ hours/day	49 (43.1)	35 (39.1)	84 (41.3)
Child physical activity status			
<1 hour/day	15 (13.6)	15 (14.2)	30 (13.8)
1-2 hours/day	55 (46.6)	48 (50.9)	103 (48.5)
3+ hours/day	39 (39.8)	32 (35.0)	71 (37.6)
Child puberty status			
Prepubescent	109 (100)	95 (100)	204 (100)
Pubescent	0 (0)	0 (0)	0 (0)

[1] Unweighted n's and weighted percentages

Table 2: Height z-score, weight z-score, BMI z-score, BMI, obesity and food security status and change in food security status of children in CHAMACOS from age 5 to 12 (n=204)

Age	Height z-score $\bar{x}$ (95% CI)	Weight z-score $\bar{x}$ (95% CI)	BMI z-score $\bar{x}$ (95% CI)	BMI $\bar{x}$ (95% CI)	% Obese	% Food insecure	% Changed food security status from previous time point[1]
5	0.28 (0.15, 0.42)	0.85 (0.69, 1.00)	1.14 (1.00, 1.29)	17.6 (17.3, 18.0)	30.1	45.2	-
7	0.11 (-0.02, 0.25)	0.91 (0.75, 1.06)	1.11 (0.98, 1.23)	18.7 (18.2, 19.2)	32.1	46.1	26.0
9	0.17 (0.04, 0.31)	0.95 (0.80, 1.11)	1.07 (0.93, 1.22)	20.5 (19.8, 21.1)	35.7	42.0	22.9
10.5	0.27 (0.14, 0.41)	0.96 (0.80, 1.11)	1.09 (0.95, 1.23)	22.0 (21.2, 22.7)	36.5	39.5	20.2
12	0.20 (0.08, 0.32)	0.95 (0.80, 1.10)	1.07 (0.92, 1.21)	23.2 (22.4, 24.0)	36.3	36.9	19.0

Table 3: Food security status and associated changes in height z-score, weight z-score, BMI, and BMI z-score among children in CHAMACOS from age 5 to 12 (n=204)[1]

	Time Interval	Δ in height z-score ß (95% CI)	Δ in weight z-score ß (95% CI)	Δ in BMI ß (95% CI)	Δ in BMI z-score ß (95% CI)
Food Secure	5 - 7	Reference Group	Ref	Ref	Ref
Food Insecure		-0.02 (-0.12, 0.08)	0.03 (-0.10, 0.15)	0.33 (-0.11, 0.77)	0.03 (-0.11, 0.18)
Food Secure	7 - 9	Ref	Ref	Ref	Ref
Food Insecure		0.00 (-0.10, 0.11)	-0.01 (-0.13, 0.12)	-0.13 (-0.59, 0.33)	0.02 (-0.11, 0.15)
Food Secure	9 - 10.5	Ref	Ref	Ref	Ref
Food Insecure		-0.05 (-0.13, 0.03)	-0.15 (-0.23, -0.07)***[a]	-0.43 (-0.89, 0.03)	-0.18 (-0.26, -0.09)***[a]
Food Secure	10.5 - 12	Ref	Ref	Ref	Ref
Food Insecure		-0.07 (-0.16, 0.02)	-0.06 (-0.15, 0.04)	-0.18 (-0.71, 0.36)	-0.04 (-0.15, 0.06)

[1]Models were adjusted for maternal age, maternal proportion of life spent in the U.S., maternal education, maternal pre-pregnancy body mass index, early life food insecurity, child gender, and child birth weight. Models were also adjusted for marital status, maternal parity, household income, hours the child watches T.V., hours the child plays outside, and child's puberty status as measured at the beginning of the time interval. Food security was assessed at the beginning of the time interval and outcomes were assessed at the end of the time interval.

*** $p<0.001$

[a] Significant in sensitivity analysis with imputed dataset.

Table 4: Changes in food security status and associated changes in height z-score, weight z-score, BMI, and BMI z-score among children in CHAMACOS from age 5 to 12[1]

	n	Δ in height z-score ß (95% CI)	Δ in weight z-score ß (95% CI)	Δ in BMI ß (95% CI)	Δ in BMI z-score ß (95% CI)
Food security status across 2 time points	816				
Food secure across interval		Reference Group	Ref	Ref	Ref
Food insecure across interval		-0.05 (-0.10, -0.00)*	-0.09 (-0.15, -0.03)**[a]	-0.26 (-0.56, 0.05)	-0.09 (-0.16, -0.02)**[a]
Δ from food insecure to food secure		-0.05 (-0.10, 0.01)	-0.04 (-0.11, 0.04)	-0.20 (-0.51, 0.12)	-0.03 (-0.11, 0.05)
Δ from food secure to food insecure		-0.06 (-0.14, 0.02)	-0.12 (-0.21, -0.03)**	-0.35 (-0.68, -0.02)*	-0.10 (-0.20, -0.01)*
Food security status across 3 time points	612				
Persistent food security		Ref	Ref	Ref	Ref
Persistent food insecurity		-0.06 (-0.15, 0.03)	-0.12 (-0.24, 0.01)	-0.26 (-0.85, 0.34)	-0.12 (-0.25, 0.01)
Any Δ in food security status		-0.07 (-0.15, 0.00)	-0.09 (-0.18, 0.00)	-0.31 (-0.76, 0.14)	-0.09 (-0.18, 0.00)

[1]Models were adjusted for maternal age, maternal proportion of life spent in the U.S., maternal education, maternal pre-pregnancy body mass index, early life food insecurity, child gender, and child birth weight. Models were also adjusted for marital status, maternal parity, household income, hours the child watches T.V., hours the child plays outside, and child's puberty status as measured at the beginning of the time interval.
[a] Significant in sensitivity analysis with imputed dataset.

Chapter 4. Food insecurity is not associated with excessive gestational weight gain in a California representative sample of pregnant women from the Maternal and Infant Health Assessment Survey 2010 – 2012

Introduction

Food insecurity is the state of uncertain access to enough nutritionally adequate food for an active and healthy life (2). Household food insecurity has been associated with elevated body mass index (BMI) and obesity in non-pregnant populations (97, 99-106), including women (100-102), women of child-bearing age (99, 103) and post-partum women (104-106). Although 18% of pregnant women in the United States experience household food insecurity (107), only two small studies have examined the association between food insecurity and weight gain during pregnancy (105, 108).

Understanding if the association between food insecurity and weight gain persists into pregnancy is important. Gaining either inadequate or excessive gestational weight can lead to a host of negative outcomes for a mother and her offspring, including complications during pregnancy and birth, and a higher incidence of chronic disease later in life (109, 110). Unhealthy gestational weight gain is currently a major public health concern as approximately 20% of pregnant women do not gain an adequate amount of weight during gestation, and almost 50% exceed the Institute of Medicine's (IOM) guidelines for weight gain during pregnancy (26-28).

Food insecurity may be associated with both positive and negative gestational weight gain, depending on the severity of the food insecurity experienced. Studies finding positive associations between food insecurity and weight gain often theorize that it is due to an economic reliance on energy dense, nutrient poor foods (97, 100, 108). However, Dutch hunger studies have also shown that food insecurity can be associated with gaining less weight during pregnancy in extreme cases, where women do not consume enough calories (111). Distinguishing between low and very low levels of food insecurity may help explain why past analysis of the food insecurity and gestational weight gain relationship have produced mixed results.

Race has been found to modify associations between food insecurity and health outcomes (112, 113). Adams et al. found food insecurity to be associated with an increased risk of obesity among non-white women, but not among white women (22), and suggested the differences in weight gain may be due to people of different racial/ethnic backgrounds having different cultural attitudes towards body size and different coping mechanisms in response to food insecurity. Determining if the food insecurity and gestational weight gain association is modified by race/ethnicity may provide insight into the mechanism for which food insecurity influences gestational weight gain, and may help explain the large racial differences in gestational weight gain (114).

This study has two aims: 1) Analyze the influence of low and very low food security on gestational weight gain; and 2) Assess differential association of food insecurity on gestational weight gain by race/ethnicity. We hypothesize women who experience marginal and low food security will gain more gestational weight and women who experience very low food insecurity will gain less gestational weight than their food secure counterparts. Additionally, we hypothesize that any association between food insecurity and gestational weight gain will be attenuated among non-Hispanic white women compared to women of other racial/ethnic backgrounds.

Methods

California's Maternal and Infant Health Assessment (MIHA) is an annual stratified random sample survey of English- or Spanish-speaking women in California who recently had a live birth. MIHA has been conducted since 1999 and its methodology has been published elsewhere (24). Non-residents, women with multiple births greater than three, non-institutionalized women, and girls under age 15 years are excluded; its data are weighted to represent all California women with a live birth during each survey year. The Birth Statistical Master File produced by the Office of Vital Statistics identifies the target population for the weights (115). African American women are oversampled to ensure there are enough individuals from this group to report reliable estimates. Since its inception, MIHA has maintained an annual response rate of approximately 70% by contacting women through mail and telephone (115).

This analysis includes 12,097 of the 20,480 women who participated in MIHA from 2010 – 2012. Women with household incomes >400% of the Federal Poverty Guidelines (FPG, n=3,109) were excluded because food insecurity is rarely observed in houses with incomes greater than 400%. Women who had multiple births (n=212) and women <20 years of age (n=1,759) were excluded as gestational weight gain recommendations may be different for these groups (116, 117). Women who did not have a full-term birth (37-42 weeks) were also excluded (n=1,215), as were women with missing food security status (133), gestational weight gain (72), or covariate (1,845) information. Additionally, women who reported losing >30 pounds (n=16) or gaining >97 pounds (n=21) were excluded. After identifying this subpopulation from the weighted sample of pregnant women, one woman was the lone sampling unit in a stratum and was therefore excluded (118), which left a final sample of 12,097 women.

For sensitivity analysis, multiple imputations were conducted to predict household income values for women who were only missing household income information (n=671) because household income was the only variable that >5% of women had missing values for (5.3%). The ordered logistic regression imputation model determined if the household income was 0-100% the FPG, 101-200% the FPG, 201-300% FPG, or 301-400% FPG. Five imputations were conducted and all variables were included in the imputation model.

Food insecurity during pregnancy was assessed using the Food Security Module Six Item Short Form developed by the United States Department of Agriculture (4); it was modified to ask about the women's experiences during pregnancy as opposed to the household's experience during the previous 12 months (Table 1). Food security status was determined by the number of affirmative responses women gave to the 6 food security questions. Values were imputed for respondents with 1-2 missing questions (6% of the population, n=663). Imputation involves ordering the questions from least severe to most severe. Because some questions had more than two responses, an affirmative response (i.e. "yes") was determined for each question, as shown in Table 1. Missing values were imputed to "yes" if a) any more severe questions had an affirmative response and b) no less severe items had a negative response. Values otherwise were imputed to "no." After imputation, all women were categorized into one of four groups based on their responses: full food security (n=7,975), marginal food security (n=1,355), low food security (n=1,917), or very low food security (n=850).

Birth certificate data on gestational weight gain was analyzed (95% of the population, n=11,310) unless this information was missing, in which case data from the MIHA survey was analyzed (5% of the population, n=787). Weight gain data from birth certificates was given precedence over the weight gain from the MIHA survey because it was gathered closer to conception. Gestational weight gain was analyzed continuously as pounds gained, and categorically – inadequate, adequate, and excessive—relative to the IOM guidelines. The IOM guidelines for weight gain during pregnancy are dependent on pre-pregnancy BMI. Underweight women (BMI <18.5) are encouraged to gain 28-40 lbs., normal weight women (BMI 18.5 – 24.9) 25-35 lbs., overweight women (BMI 25-29.9) 15-25 lbs., and obese women (BMI ≥30) 11-20 lbs. (116). Birth certificate data on pre-pregnancy BMI measures were analyzed (96% of the population, n=11,364) unless this information was missing, in which case data from the MIHA survey was analyzed (4% of the population, n=733). For sensitivity analyses, gestational weight gain was also measured as an age standardized z-score (119). For gestational age standardization, women were compared to a cohort of non-Hispanic white and non-Hispanic African American women in the United States with uncomplicated singleton pregnancies (119).

Survey year (2010, 2011, 2012), nativity (born in the U.S., foreign born), language spoken at home (English, Spanish, other language - including both English and Spanish equally), age (20-24, 25-29, 30-34,>35), number of live births (1 indicating this was their first pregnancy, 2, 3-5, ≥6), marital status (married, living with someone, single – including divorced, widowed and separated), educational attainment (< high school, high school or General Education Diploma, some college experience, college degree or more), household income (≤100% of the FPG, 101 - 200%, 201% - 300%, >301% - 400%), health insurance during pregnancy (Medi-Cal, private, uninsured, other), smoking during pregnancy (smoked, did not smoke), and gestational age (continuous), were considered a priori to be included as confounders in the regression models that analyzed associations between food insecurity and gestational weight gain.

Survey weighted chi-square tests were conducted to assess bivariate associations between potential confounders and food security status. Linear regressions were implemented to assess the food insecurity and gestational weight gain relationship when gestational weight gain was assessed continuously. Multinomial logistic regressions were implemented to assess the relationship between food insecurity and gaining inadequate or excessive weight during pregnancy, as determined by the IOM guidelines. The reference group was women who gained the appropriate amount of weight according to the IOM guidelines. Linear and multinomial logistic regressions were conducted on women with complete case information who had full-term births (37-42 weeks).

Consistent with past research (19, 20), Wald tests of independence with a p-value of 0.2 as a cut point for significance were implemented to assess effect modification of the food security and weight gain relationship by pregravid BMI (normal, overweight, and obese) and race/ethnicity (non-Hispanic White, Hispanic, non-Hispanic African American, Asian/Pacific Islander).

Results
Sixty-six percent of the women were food secure during pregnancy, 11% were marginally food secure, 16% experienced low food security and 7% experienced very-low food security (Table 2). Non-Hispanic African American and Hispanic women experienced more food insecurity overall and more very low food insecurity than non-Hispanic white and Asian/Pacific Islander women. Food insecurity was associated with many indicators of poor health, including low educational attainment, being obese before pregnancy, lower income, not being married, lack of health insurance, and smoking during pregnancy.

On average, pregnant women gained 29 ± 14 pounds during pregnancy. According to the IOM guidelines, 21% gained inadequate weight, 33% gained adequate weight, and 46% gained weight in excess (Table 3). In unadjusted analysis, race/ethnicity was significantly associated with gestational weight gain ($p<0.001$), as non-Hispanic African American and non-Hispanic white women gained the most weight during pregnancy and were the most likely to gain excessive gestational weight.

Food insecurity was not associated with gestational weight gain after adjusting for age, education, household income, marital status, nativity, race/ethnicity, language spoken at home, health insurance, parity, pre-pregnancy BMI, smoking during pregnancy, gestational age, and year of survey (Table 4). However, Wald tests identified race/ethnicity ($p=0.12$) as an effect modifier of the food insecurity and gestational weight gain association. Pre-pregnancy BMI was not found to significantly modify the association ($p=0.64$, data not shown). Adjusted regression models were therefore presented stratified by race/ethnicity.

The racial/ethnic stratified analysis found non-Hispanic African American women who had full-term births and experienced low-food security during pregnancy gained 7.3 (95% CI: 1.2, 13.5) more pounds than their food secure counterparts, adjusting for age, education, household income, marital status, nativity, language spoken at home, health insurance, parity, pre-pregnancy BMI, smoking during pregnancy, gestational age, and year of survey. This association was not statistically significant in sensitivity analyses when multiple imputations were implemented to address missing household income data or when the gestational weight gain z-score was analyzed as the outcome. All other associations between food insecurity and continuous gestational weight gain were not statistically significant.

Multinomial logistic regressions found non-Hispanic white women who experienced low food security had a decreased risk [RRR: 0.5, 95% CI: (0.3, 0.9)] of gaining inadequate weight compared to non-Hispanic white women who were food secure, after adjusting for covariates. This association remained significant after missing income data was imputed. No other statistically significant relationships were found.

Discussion
Overall, few of the associations between food insecurity and gestational weight gain were statistically significant and in no instance was food insecurity associated with excessive gestational weight gain. These findings are largely consistent with a study by Olson et al. who found no association between food insecurity and gestational weight gain among 311 pregnant women in upstate New York (105). Laraia et al. found a positive association between food

insecurity and gestational weight gain among 810 pregnant women from the Pregnancy, Infection, and Nutrition prospective cohort study (108); however this positive association did not translate into an increased risk for excessive gestational weight gain. Our results contrast with further analysis conducted by Laraia et al. (2013) in the same sample that found women who experienced past dietary restraint and current marginal food security gained approximately 10 more pounds and had an increased risk of gaining excessive gestational weight gain compared to food secure women who did not experience past dietary restraint (120). It is possible that our findings were not entirely consistent with past research because past analyses did not analyze a representative sample of pregnant women, stratify by race/ethnicity, or distinguish between low and very low food security.

We observed low and very low food security to be differentially associated with gestational weight gain among Non-Hispanic African American and Non-Hispanic White women. However, in contrast to our hypothesis, no consistent patterns showed marginal or low food security to be associated with greater gestational weight gain or very low food security to be associated with lower gestational weight gain. Although not analyzed in this study, we may have found largely null results because pregnant women are buffered from the harmful effects of food insecurity by other household members. Analogous to food insecure households with children, non-pregnant members of a food insecure household may decrease their dietary intakes to ensure a pregnant household member does not have to decrease her intake (93). It is also possible that very low food security was not associated with a greater risk of inadequate gestational weight gain because the very low food security experienced in this study did not reflect the severe level of food insecurity experienced by those who gained inadequate weight in other studies, such as the women during the Dutch famine.

Race/ethnicity was found to modify the food security status and gestational weight gain association. Although stratification by race/ethnicity did not produce many statistically significant findings, the magnitude and direction of the food insecurity and gestational weight gain associations varied widely by race/ethnicity. Past research suggests the association between food security status and weight gain might vary because of cultural differences in how women respond to food insecurity, and how women from different cultures have different attitudes about body size (112). In this study, according to IOM guidelines, non-Hispanic white women were the most likely to gain excessive weight in pregnancy (55%) and non-Hispanic white women who experienced low food security as opposed to food security had a lower risk of gaining inadequate weight during pregnancy. Among non-Hispanic white women, those who experience low food security may have a lower risk of gaining inadequate weight than those who are food secure because they may rely on cheap, low-nutrient, and calorie dense foods (97, 100, 108) that promote weight gain. However it is unclear why this association only existed in non-Hispanic white women. Although our results suggest low food security status reduces the risk of inadequate weight gain among non-Hispanic white women, the abundance of research illustrating the ill effects of experiencing food insecurity during pregnancy outweigh this potential benefit (108, 121-123).

The public health implications derived from this research stem from the high prevalence of California women with household incomes ≤400% of the FPG who experience food insecurity (33%), and gain weight outside of the IOM guidelines (67%). Food insecurity and unhealthy gestational weight gain are both largely associated with social determinants of health, including race/ethnicity, education and income, (107, 114, 124) and are often experienced by the most vulnerable pregnant women. The prenatal period is a critical time period for health (125), and also when many women access health services. Therefore, the prenatal period represents a great opportunity for providers to screen families for household food insecurity and to discuss the importance of gaining the recommended weight during pregnancy. Given the prevalence of food insecurity and unhealthy weight gain, pregnant women should be referred to programs such as The Special Supplemental Nutrition Program for Women, Infants and Children that aim to improve weight gain in pregnancy and food security status (29).

The cross sectional nature of this study prevented determining causality, which is a concern as some evidence suggests obesity may lead to food insecurity (105). The inability to test for effect modification by past dietary restraint is also a concern given previous work, but was not the primary goal of this analysis (120). Despite these limitations, this study was the first to analyze a population based sample representative of the state of California. California contributes to about 13% of all births in the United States, and the state's racial diversity allowed for stratification by race/ethnicity (126). Additionally, the large sample size provided an opportunity to distinguish the associations of low and very low food security with gestational weight gain.

This study did not find consistent associations between food insecurity and gestational weight gain across different race/ethnicities and levels of food insecurity. Results did suggest that both race/ethnicity and level of food insecurity should be considered when analyzing the food insecurity and gestational weight gain relationship. This study supports the promotion and use of programs that aim to ameliorate food insecurity and unhealthy weight gain during pregnancy.

Table 1: Description of how food security status was assessed during pregnancy in the Maternal Infant Health Assessment Survey 2010 - 2012

Question	**Affirmative response**
"The food that I bought just didn't last, and I didn't have money to get more." During your most recent pregnancy, was that often, sometimes, or never true for you?	Often or sometimes
"I couldn't afford to eat balanced meals." During your most recent pregnancy, was that often, sometimes, or never true for you?	Often or sometimes
During your pregnancy, did you ever cut the size of your meals or skip meals because there wasn't enough money for food?	Yes
During your pregnancy, did you ever eat less than you felt you should because there wasn't enough money to buy food?	Yes
How often did this [cut size or skip meals] happen?	Almost every month or Some months but not almost every month
During your pregnancy, were you ever hungry but didn't eat because you couldn't afford enough food?	Yes
Assessing Food Security Status 0 Affirmative responses – Food secure 1 Affirmative response – Marginally Food Secure 2-4 Affirmative responses – Low food security 5-6 Affirmative responses – Very low food security	

Table 2: Characteristics of women with full-term births in California with incomes ≤400% of the Federal Poverty Guidelines in the Maternal and Infant Health Assessment, 2010-12 (n=12,097)

Characteristic[1,2]	Whole Population 100% (n=12,097) % (n)	Food Secure 66% (n=7,975) Row % (n)	Marginally Food Secure 11% (n=1,355) Row % (n)	Low Food Security 16% (n=1,917) Row % (n)	Very Low Food Security 7% (n=850) Row % (n)
Race/Ethnicity***					
Non-Hispanic white	24.9 (3,538)	75.7 (2,561)	8.4 (350)	10.2 (396)	5.6 (231)
Hispanic	58.2 (6,415)	61.3 (3,964)	12.6 (765)	18.4 (1,207)	7.8 (479)
Non-Hispanic African American	6.3 (1,054)	65.1 (695)	11.1 (125)	15.8 (157)	7.9 (77)
Asian/Pacific Islander	10.6 (1,090)	72.5 (755)	9.9 (115)	12.4 (157)	5.4 (63)
Nativity***					
Born in the United States	56.2 (7,270)	70.2 (5,010)	10.8 (795)	12.3 (937)	6.8 (528)
Foreign born	43.8 (4,827)	61.3 (2,965)	11.7 (560)	19.7 (980)	7.3 (322)
Language Spoken at Home***					
English	50.4 (6,765)	70.8 (4,682)	9.8 (715)	12.4 (885)	6.9 (483)
Spanish	27.8 (3,094)	57.3 (1,786)	12.7 (382)	22.5 (693)	7.5 (233)
Other (including both English and Spanish equally)	21.9 (2,238)	67.3 (1,507)	12.3 (258)	13.9 (339)	6.6 (134)
Age*					
≥35	15.6 (1,749)	70.6 (1,199)	8.2 (165)	16.6 (277)	4.6 (108)

30 - 34	24.8 (2,862)	68.5 (1,957)	10.6 (298)	13.3 (416)	7.6 (191)
25-29	31.2 (3,935)	65.0 (2,602)	11.8 (460)	15.4 (602)	7.8 (271)
20-24	28.4 (3,551)	63.4 (2,217)	12.6 (432)	17.1 (622)	7.0 (280)
Pre-pregnancy BMI***					
Underweight	3.2 (403)	66.2 (272)	10.8 (49)	16.2 (56)	6.8 (26)
Healthy Weight	44.4 (5,229)	71.0 (3,668)	10.7 (523)	12.9 (746)	5.4 (292)
Overweight	27.7 (3,391)	63.3 (2,174)	11.5 (403)	18.0 (540)	7.2 (274)
Obese	24.7 (3,074)	61.3 (1,861)	11.8 (380)	17.3 (575)	9.6 (258)
Parity***					
1	31.5 (3,730)	69.8 (2,581)	11.0 (415)	13.3 (520)	5.9 (214)
2	33.5 (4,049)	69.9 (2,733)	10.5 (463)	13.8 (603)	5.7 (250)
3-5	32.4 (4,023)	60.5 (2,497)	12.0 (448)	18.3 (730)	9.3 (348)
≥6	2.6 (295)	49.3 (164)	11.5 (29)	30.2 (64)	9.0 (38)
Marital status***					
Married	53.4 (6,199)	72.5 (4,474)	9.5 (613)	13.2 (813)	4.7 (299)
Living with a partner	29.3 (3,594)	59.4 (2,143)	12.0 (426)	18.9 (686)	9.7 (339)
Single	17.3 (2,304)	58.7 (1,358)	14.7 (316)	17.0 (418)	9.6 (212)
Educational Level***					
College grad or more	19.7 (2,147)	84.0 (1,753)	5.6 (170)	7.5 (158)	3.0 (66)
Any college experience	35.2 (4,551)	67.3 (3,055)	11.4 (519)	14.3 (645)	7.0 (332)
High School or GED	23.7 (2,928)	61.9 (1,810)	13.8 (359)	16.8 (547)	7.6 (212)
< High School	21.4 (2,471)	53.3 (1,357)	13.0 (307)	23.7 (567)	10.1 (240)
Household Income: % of Federal Poverty Guidelines***					
301 ≤ 400%	9.8 (998)	90.5 (921)	6.2 (46)	3.1 (26)	0.2 (5)
201 ≤ 300%	12.5 (1,387)	85.9 (1,168)	6.8 (99)	5.7 (86)	1.7 (34)

101 ≤ 200%	25.7 (3,315)	70.8 (2,353)	11.1 (385)	13.5 (423)	4.6 (154)
0 ≤ 100%	52.0 (6,397)	54.8 (3,533)	13.2 (825)	21.3 (1,382)	10.7 (657)
Health Insurance***					
Medi-Cal	60.1 (8,348)	57.7 (5,030)	13.0 (1,025)	19.7 (1,582)	9.6 (711)
Private Insurance	32.4 (2,959)	80.6 (2,367)	8.1 (255)	8.7 (244)	2.6 (93)
Uninsured	2.5 (286)	55.6 (157)	12.4 (44)	21.2 (50)	10.8 (35)
Other	5.0 (504)	82.0 (421)	9.0 (31)	6.7 (41)	2.4 (11)
Smoked During Pregnancy***					
Smoked	8.5% (1,325)	52.0 (724)	14.0 (171)	18.6 (243)	15.3 (187)
Did Not Smoke	91.5% (10,772)	67.6 (7,251)	10.9 (1,184)	15.3 (1,674)	6.2 (663)

[1] Weighted percentages and unweighted n's
[2] P-values were generated from chi-square tests that measured the bivariate associations between food security status and the characteristics. P-values reflect the probability that the observed relationship between food insecurity and the characteristic are due to chance.
*p<0.05, ***p<0.001

Table 3: Food security status and race/ethnicity by gestational weight gain among women with full-term births in California with incomes ≤400% of the Federal Poverty Guidelines in the Maternal and Infant Health Assessment, 2010 – 2012 (n=12,097)

	Weight Gain According to IOM Guidelines				Weight Gain
Characteristics	Whole Population 100% (n=12,097) Column % (n)	Gained Adequate 33% (n=4,022) Row % (n)	Gained Excessive 46% (n=5,706) Row % (n)	Gained Inadequate 21% (n=2,369) Row % (n)	Lbs. n=12,097 Mean ± SD
Food Security Status					
Food Secure	66.3 (7,975)	33.0 (2,704)	46.1 (3,757)	20.8 (1,14)	29.6 ± 14.0
Marginally Food Secure	11.2 (1,355)	31.5 (416)	46.3 (656)	22.2 (283)	28.6 ± 14.7
Low Food Security	15.5 (1,917)	33.3 (640)	45.1 (868)	21.5 (409)	28.5 ± 15.3
Very Low Food Security	7.0 (850)	30.9 (262)	46.8 (425)	22.3 (163)	29.1 ± 14.7
Race/Ethnicity***					
Hispanic	58.2 (6,415)	43.6 (2,801)	43.6 (2,801)	23.7 (1,422)	27.4 ± 13.3
Non-Hispanic white	24.9 (3,538)	31.1 (1,108)	54.5 (1,939)	14.4 (491)	33.0 ± 16.2
Non-Hispanic African American	6.3 (1,054)	25.4 (283)	54.2 (562)	20.4 (209)	31.3 ± 19.2
Asian/Pacific Islander	10.6 (1,090)	41.0 (439)	34.9 (404)	24.0 (247)	29.9 ± 11.2

[1] Weighted percentages and unweighted n's
[2] P-values were generated from chi-square tests that measured the bivariate associations between race/ethnicity and the characteristics. P-values reflect the probability that the observed relationship between gestational weight gain and the characteristic are due to chance.
***p<0.001

Table 4: Food insecurity and weight gain by race/ethnicity among women with full-term births in California and incomes ≤400% of the Federal Poverty Guidelines in the Maternal and Infant Health Assessment, 2010-12 (n=12,097)[1]

Race/Ethnicity	n	Adjusted Weight Gain (Lbs.) ß (95% CI)	Relative Risk Ratio for gaining Excessive Weight RRR (95% CI)	Relative Risk Ratio for gaining Inadequate Weight RRR (95% CI)
Non-Hispanic white	n=3,538			
Food Secure		Ref	Ref	Ref
Marginal Food Secure		1.8 (-0.9, 4.4)	1.3 (0.8, 2.0)	1.0 (0.6, 1.7)
Low Food Security		2.1 (-0.7, 4.1)	1.1 (0.7, 1.6)	0.5 (0.3, 0.9)*
Very Low Food Security		0.3 (-2.8, 3.4)	0.9 (0.5, 1.5)	0.8 (0.4, 1.6)
Hispanic	n=6,415			
Food Secure		Ref	Ref	Ref
Marginal Food Secure		-0.2 (-1.8, 1.8)	0.9 (0.7, 1.3)	1.0 (0.6, 1.4)
Low Food Security		-0.5 (-2.0, 1.0)	0.8 (0.6, 1.1)	0.9 (0.7, 1.2)

Very Low Food Security		1.0 (-1.5, 3.5)	1.0 (0.7, 1.6)	1.1 (0.7, 1.8)
Non-Hispanic African American	n=1,054			
Food Secure		Ref	Ref	Ref
Marginal Food Secure		-2.9 (-8.1, 2.3)	2.1 (0.8, 5.5)	2.5 (0.7, 8.9)
Low Food Security		7.3 (1.2, 13.5)*	2.0 (0.8, 4.8)	1.5 (0.5, 3.9)
Very Low Food Security		-0.7 (-5.6, 6.2)	0.4 (0.2, 1.1)	0.9 (0.3, 3.0)
Asian/Pacific Islander	n=1,090			
Food Secure		Ref	Ref	Ref
Marginal Food Secure		-2.7 (-5.9, 0.6)	0.7 (0.3, 1.9)	1.0 (0.4, 2.5)
Low Food Security		-0.5 (-3.6, 2.6)	1.4 (0.7, 3.1)	1.3 (0.6, 3.0)
Very Low Food Security		4.4 (-1.3, 10.0)	2.0 (0.7, 6.3)	1.1 (0.3, 3.7)

[1]All adjusted models, including those analyzing relative risk ratios, were adjusted for year of survey, pre-pregnancy BMI, age, education, household income, marital status, nativity, household size, language spoken at home, health insurance, parity, smoking during pregnancy and gestational age. *$p<0.05$

CHAPTER 5. CONCLUSION

The primary goal of this dissertation was to assess the associations between food insecurity and weight status in pregnant women and children. This dissertation benefited greatly from having a large California representative sample of pregnant women, and a longitudinal dataset of low income Latino children that spanned over 12 years. These datasets provided unique opportunities to explore the relationships between food insecurity and weight status.

Three conclusions can be drawn across the studies. First, the prevalence of food insecurity was consistently high among Latino children in the first two years of life (30%), Latino children from age 5 to 12 (ranged from 37% to 46%), and among a California representative sample of women who just had a live birth (34%). Second, food insecurity was both positively and negatively associated with weight status in all three populations, but the associations varied by race/ethnicity, sex, and age. Third, although food insecurity was associated with weight status, food insecurity was not associated with childhood obesity or gaining weight in excess of the Institute of Medicine's guidelines.

The high prevalence of food insecurity experienced in these vulnerable populations underscores the potential improvement in health that could be observed by addressing food security status. However these improvements in health might not include reductions in excessive gestational weight gain or childhood obesity as these outcomes were largely not associated with food security status in this dissertation. Food security status appears to be a small, but significant factor in the complex relationship between diet and weight. While this dissertation did not link food insecurity to unhealthy weight status, it did identify subpopulations that may be more susceptible to food insecurity induced changes in weight status, including infants from age 0 to 2, children at age 9, and non-Hispanic African American pregnant women.

In addition to overarching themes, there were key findings from each study that represent significant contributions to the literature. The second chapter provided evidence that food insecurity experienced in the first years of life may predict weight status at age intervals upwards of 10 years later. The third chapter found that transitioning to a food insecure household from a food secure household was associated with lower weight gain among low income Latino households. Lastly, the fourth chapter found that the level of food insecurity experienced in pregnancy is important when assessing the relationship between gestational weight gain and food security status.

Food insecurity causes stress, sadness, sickness and suffering (76, 97, 127, 128), and is a known social determinant of health. Food insecurity is also recognized as a life course indicator, meaning it can alter an individual's health trajectory in addition to their immediate health (129). This dissertation illustrated the need to monitor food security status and the different levels of food insecurity experienced among low income Latino children and pregnant women. In particular, the relationship between severe food insecurity in marginalized children and poor growth should be continuously evaluated given the evidence that children's caloric intakes may be reduced in response to food insecurity. Although food insecurity was not associated with unhealthy growth or weight gain, the evidence presented in this dissertation is still alarming as it suggests the growth of vulnerable populations is significantly being affected by their food security status.

Evidence from this dissertation suggests future research should consider when food insecurity is being experienced in an individual’s life course and if they have experienced food insecurity previously during a critical period of development. Further, future research should consider age, sex, and severity of food insecurity to be potential effect modifiers of food insecurity and growth relationship. Mediation analyses that describe the mechanisms through which food insecurity leads to changes in weight are needed before the research presented in this dissertation can be translated into changes in health programs that serve pregnant women and low income Latino children.

References

1. CBS Reports: Hunger In America. CBS News, 1968.

2. Core indicators of nutritional state for difficult-to-sample populations. The Journal of nutrition 1990;120 Suppl 11:1559-600.

3. Alisha Coleman-Jensen, Matthew P. Rabbitt, Christian Gregory, and Anita Singh. Household Food Security in the United States in 2014, ERR-194, U.S. Department of Agriculture, Economic Research Service, September 2015.

4. Bickel G, Nord M, Price C, Hamilton W, Cook J. Guide to measuring household food security. Alexandria Department of Agriculture Food and Nutrition Service 2000.

5. Blumberg SJ, Bialostosky K, Hamilton WL, Briefel RR. The effectiveness of a short form of the Household Food Security Scale. American journal of public health 1999;89(8):1231-4.

6. Hager ER, Quigg AM, Black MM, Coleman SM, Heeren T, Rose-Jacobs R, Cook JT, de Cuba SAE, Casey PH, Chilton M. Development and validity of a 2-item screen to identify families at risk for food insecurity. Pediatrics 2010;126(1):e26-e32.

7. Alwin DF. Integrating varieties of life course concepts. The Journals of Gerontology Series B: Psychological Sciences and Social Sciences 2012:gbr146.

8. Offidani E, Tomba E, Linder M. Two key concepts in the life course approach in medicine: allostatic load and cumulative life course impairment. Edtion ed. Dermatological Diseases and Cumulative Life Course Impairment: Karger Publishers, 2013:17-32.

9. McEwen BS, Seeman T. Protective and damaging effects of mediators of stress: elaborating and testing the concepts of allostasis and allostatic load. Annals of the New York Academy of Sciences 1999;896(1):30-47.

10. Berger M, Sarnyai Z. “More than skin deep”: stress neurobiology and mental health consequences of racial discrimination. Stress 2015;18(1):1-10.

11. Lu MC, Halfon N. Racial and ethnic disparities in birth outcomes: a life-course perspective. Maternal and child health journal 2003;7(1):13-30.

12. Juster R-P, McEwen BS, Lupien SJ. Allostatic load biomarkers of chronic stress and impact on health and cognition. Neuroscience & Biobehavioral Reviews 2010;35(1):2-16.

13. Menjívar C. Fragmented ties: Salvadoran immigrant networks in America: Univ of California Press, 2000.

14. Sano Y, Garasky S, Greder KA, Cook CC, Browder DE. Understanding food insecurity among Latino immigrant families in rural America. Journal of Family and Economic Issues 2011;32(1):111-23.

15. Flores G, Abreu M, Olivar MA, Kastner B. Access barriers to health care for Latino children. Archives of pediatrics & adolescent medicine 1998;152(11):1119-25.

16. Chilton M, Black MM, Berkowitz C, Casey PH, Cook J, Cutts D, Jacobs RR, Heeren T, De Cuba SE, Coleman S. Food insecurity and risk of poor health among US-born children of immigrants. American journal of public health 2009;99(3):556-62.

17. Minkoff-Zern L-A. Hunger amidst plenty: farmworker food insecurity and coping strategies in California. Local Environment 2014;19(2):204-19.

18. Flocks JD. Environmental and Social Injustice of Farmworker Pesticide Exposure, The. Geo J on Poverty L & Pol'y 2012;19:255.

19. Kiehne E, Mendoza NS. Migrant and Seasonal Farmworker Food Insecurity: Prevalence, Impact, Risk Factors, and Coping Strategies. Social work in public health 2015;30(5):397-409.

20. Kresge L, Eastman C. Increasing food security among agricultural workers in California's Salinas Valley. California Institute for Rural Studies, Davis, CA 2010.

21. Liu J, Gallagher AE, Carta CM, Torres ME, Moran R, Wilcox S. Racial differences in gestational weight gain and pregnancy-related hypertension. Annals of epidemiology 2014;24(6):441-7.

22. Viswanathan M, Siega-Riz AM, Moos M-K, Deierlein A, Mumford S, Knaack J, Thieda P, Lux LJ, Lohr KN. Outcomes of maternal weight gain. 2008.

23. Schaaf JM, Liem SM, Mol BWJ, Abu-Hanna A, Ravelli AC. Ethnic and racial disparities in the risk of preterm birth: a systematic review and meta-analysis. American journal of perinatology 2013;30(06):433-50.

24. Heck KE, Braveman P, Cubbin C, Chávez GF, Kiely JL, Chárez GF. Socioeconomic status and breastfeeding initiation among California mothers. Public Health Reports 2006:51-9.

25. Rosado JI, Johnson SB, McGinnity KA, Cuevas JP. Obesity among Latino children within a migrant farmworker community. American Journal of Preventive Medicine 2013;44(3):S274-S81.

26. Chu SY, Callaghan WM, Bish CL, D'Angelo D. Gestational weight gain by body mass index among US women delivering live births, 2004-2005: fueling future obesity. American journal of obstetrics and gynecology 2009;200(3):271. e1-. e7.

27. Deputy NP, Sharma AJ, Kim SY. Gestational weight gain: United States, 2012 and 2013. MMWR Morbidity and mortality weekly report 2015;64:1215-20.

28. 2010 Pregnancy Nutrition Surveillance. Centers for Disease Control and Prevention. Table 1D. From https://idph.iowa.gov/Portals/1/Files/WIC/2010%20National%20PNSS%20tables.pdf.

29. Women, Infants and Children Supplemental Nutrition. California Department of Public Health. From http://www.cdph.ca.gov/PROGRAMS/CENTERFORFAMILYHEALTH/Pages/WICFactSheet.aspx (Accessed 4/15/2014).

30. Reilly JJ, Kelly J. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review. International Journal of Obesity 2011;35(7):891-8.

31. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011-2012. JAMA : the journal of the American Medical Association 2014;311(8):806-14.

32. Rosas LG, Guendelman S, Harley K, Fernald LC, Neufeld L, Mejia F, Eskenazi B. Factors associated with overweight and obesity among children of Mexican descent: results of a binational study. Journal of immigrant and minority health / Center for Minority Public Health 2011;13(1):169-80. doi: 10.1007/s10903-010-9332-x.

33. D'Onofrio BM, Class QA, Rickert ME, Sujan AC, Larsson H, Kuja-Halkola R, Sjölander A, Almqvist C, Lichtenstein P, Oberg AS. Translational epidemiologic approaches to understanding the consequences of early-life exposures. Behavior genetics 2016;46(3):315-28.

34. Kelishadi R, Poursafa P. A review on the genetic, environmental, and lifestyle aspects of the early-life origins of cardiovascular disease. Current problems in pediatric and adolescent health care 2014;44(3):54-72.

35. Moore V, Davies M. Early life influences on later health: the role of nutrition. Asia Pacific journal of clinical nutrition 2001;10(2):113-7.

36. Metallinos-Katsaras E, Must A, Gorman K. A longitudinal study of food insecurity on obesity in preschool children. Journal of the Academy of Nutrition and Dietetics 2012;112(12):1949-58.

37. Bronte-Tinkew J, Zaslow M, Capps R, Horowitz A, McNamara M. Food insecurity works through depression, parenting, and infant feeding to influence overweight and health in toddlers. The Journal of nutrition 2007;137(9):2160-5.

38. Suglia SF, Duarte CS, Chambers EC, Boynton-Jarrett R. Cumulative social risk and obesity in early childhood. Pediatrics 2012;129(5):e1173-9. doi: 10.1542/peds.2011-2456.

39. Rosas LG, Harley K, Fernald LC, Guendelman S, Mejia F, Neufeld LM, Eskenazi B. Dietary associations of household food insecurity among children of Mexican descent: results of a binational study. Journal of the American Dietetic Association 2009;109(12):2001-9.

40. Metallinos-Katsaras E, Sherry B, Kallio J. Food insecurity is associated with overweight in children younger than 5 years of age. Journal of the American Dietetic Association 2009;109(10):1790-4.

41. Jyoti DF, Frongillo EA, Jones SJ. Food insecurity affects school children's academic performance, weight gain, and social skills. The Journal of nutrition 2005;135(12):2831-9.

42. Eskenazi B, Gladstone EA, Berkowitz GS, Drew CH, Faustman EM, Holland NT, Lanphear B, Meisel SJ, Perera FP, Rauh VA. Methodologic and logistic issues in conducting longitudinal birth cohort studies: lessons learned from the Centers for Children's Environmental Health and Disease Prevention Research. Environmental health perspectives 2005:1419-29.

43. Eskenazi B, Harley K, Bradman A, Weltzien E, Jewell NP, Barr DB, Furlong CE, Holland NT. Association of in utero organophosphate pesticide exposure and fetal growth and length of gestation in an agricultural population. Environmental health perspectives 2004:1116-24.

44. Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, Flegal KM, Guo SS, Wei R, Mei Z, Curtin LR, Roche AF, Johnson CL. CDC growth charts: United States. Advance data 2000(314):1-27.

45. Berkey CS, Colditz GA. Adiposity in adolescents: change in actual BMI works better than change in BMI z score for longitudinal studies. Annals of epidemiology 2007;17(1):44-50.

46. Cole TJ, Faith M, Pietrobelli A, Heo M. What is the best measure of adiposity change in growing children: BMI, BMI%, BMI z-score or BMI centile? European journal of clinical nutrition 2005;59(3):419-25.

47. Smith TM, Colón-Ramos U, Pinard CA, Yaroch AL. Household food insecurity as a determinant of overweight and obesity among low-income Hispanic subgroups: Data from the 2011–2012 California Health Interview Survey. Appetite 2016;97:37-42.

48. Prior HHS poverty guidelines and Federal Register References. Retrieved September 23, 2016. US Department of Health and Human Services, 2008.

49. Reynolds R, Osmond C, Phillips D, Godfrey K. Maternal BMI, parity, and pregnancy weight gain: influences on offspring adiposity in young adulthood. The Journal of Clinical Endocrinology & Metabolism 2010;95(12):5365-9.

50. Salbe AD, Weyer C, Lindsay RS, Ravussin E, Tataranni PA. Assessing risk factors for obesity between childhood and adolescence: I. Birth weight, childhood adiposity, parental obesity, insulin, and leptin. Pediatrics 2002;110(2):299-306.

51. Hernán MA, Hernández-Díaz S, Robins JM. A structural approach to selection bias. Epidemiology (Cambridge, Mass) 2004;15(5):615-25.

52. Matheson DM, Varady J, Varady A, Killen JD. Household food security and nutritional status of Hispanic children in the fifth grade. The American journal of clinical nutrition 2002;76(1):210-7.

53. Buscemi J, Beech BM, Relyea G. Predictors of obesity in Latino children: acculturation as a moderator of the relationship between food insecurity and body mass index percentile. Journal of Immigrant and Minority Health 2011;13(1):149-54.

54. Casey PH, Simpson PM, Gossett JM, Bogle ML, Champagne CM, Connell C, Harsha D, McCabe-Sellers B, Robbins JM, Stuff JE, et al. The association of child and household food insecurity with childhood overweight status. Pediatrics 2006;118(5):e1406-13. doi: 10.1542/peds.2006-0097.

55. Alaimo K, Olson CM, Frongillo EA. Low family income and food insufficiency in relation to overweight in US children: is there a paradox? Archives of pediatrics & adolescent medicine 2001;155(10):1161-7.

56. Kaufman D, Banerji MA, Shorman I, Smith EL, Coplan JD, Rosenblum LA, Kral JG. Early-life stress and the development of obesity and insulin resistance in juvenile bonnet macaques. Diabetes 2007;56(5):1382-6.

57. Tibu F, Hill J, Sharp H, Marshall K, Glover V, Pickles A. Evidence for sex differences in fetal programming of physiological stress reactivity in infancy. Development and psychopathology 2014;26(4pt1):879-88.

58. Olvera-Ezzell N, Power TG, Cousins JH. Maternal Socialization of Children's Eating Habits: Strategies Used by Obese Mexican-American Mothers. Child development 1990;61(2):395-400.

59. Faith MS, Scanlon KS, Birch LL, Francis LA, Sherry B. Parent-child feeding strategies and their relationships to child eating and weight status. Obesity research 2004;12(11):1711-22.

60. Costanzo PR, Woody EZ. Domain-specific parenting styles and their impact on the child's development of particular deviance: the example of obesity proneness. Journal of social and clinical psychology 1985;3(4):425.

61. Fisher JO, Birch LL. Restricting access to palatable foods affects children's behavioral response, food selection, and intake. The American journal of clinical nutrition 1999;69(6):1264-72.

62. Salvy SJ, Kieffer E, Epstein LH. Effects of social context on overweight and normal-weight children's food selection. Eating behaviors 2008;9(2):190-6. doi: 10.1016/j.eatbeh.2007.08.001.

63. Salvy S-J, De La Haye K, Bowker JC, Hermans RC. Influence of peers and friends on children's and adolescents' eating and activity behaviors. Physiology & behavior 2012;106(3):369-78.

64. Castellano JM, Bentsen AH, Sánchez-Garrido MA, Ruiz-Pino F, Romero M, Garcia-Galiano D, Aguilar E, Pinilla L, Diéguez C, Mikkelsen JD. Early metabolic programming of puberty onset: impact of changes in postnatal feeding and rearing conditions on the timing of puberty and development of the hypothalamic kisspeptin system. Endocrinology 2011;152(9):3396-408.

65. Lie ME, Overgaard A, Mikkelsen JD. Effect of a postnatal high-fat diet exposure on puberty onset, estrous cycle regularity, and kisspeptin expression in female rats. Reproductive biology 2013;13(4):298-308.

66. Smith JT, Spencer SJ. Preweaning over-and underfeeding alters onset of puberty in the rat without affecting kisspeptin. Biology of reproduction 2012;86(5):145.

67. Rogol AD, Roemmich JN, Clark PA. Growth at puberty. Journal of adolescent health 2002;31(6):192-200.

68. Hardy R, Wadsworth ME, Langenberg C, Kuh D. Birthweight, childhood growth, and blood pressure at 43 years in a British birth cohort. International journal of epidemiology 2004;33(1):121-9.

69. Skidmore PM, Hardy RJ, Kuh DJ, Langenberg C, Wadsworth ME. Life course body size and lipid levels at 53 years in a British birth cohort. Journal of epidemiology and community health 2007;61(3):215-20.

70. Ogden CL, Carroll MD, Lawman HG, Fryar CD, Kruszon-Moran D, Kit BK, Flegal KM. Trends in Obesity Prevalence Among Children and Adolescents in the United States, 1988-1994 Through 2013-2014. JAMA : the journal of the American Medical Association 2016;315(21):2292-9.

71. Jewell NP. Statistics for epidemiology: CRC Press, 2003.

72. Opsomer JD, Jensen HH, Pan S. An evaluation of the U.S. Department of Agriculture food security measure with generalized linear mixed models. The Journal of nutrition 2003;133(2):421-7.

73. Hilmers A, Hilmers DC, Dave J. Neighborhood disparities in access to healthy foods and their effects on environmental justice. American journal of public health 2012;102(9):1644-54.

74. Larson NI, Story MT. Food insecurity and weight status among U.S. children and families: a review of the literature. Am J Prev Med 2011;40(2):166-73. doi: 10.1016/j.amepre.2010.10.028.

75. Dinour LM, Bergen D, Yeh M-C. The food insecurity–obesity paradox: a review of the literature and the role food stamps may play. Journal of the American Dietetic Association 2007;107(11):1952-61.

76. Ke J, Ford-Jones EL. Food insecurity and hunger: A review of the effects on children's health and behaviour. Paediatrics & child health 2015;20(2):89-91.

77. Powell LM, Auld MC, Chaloupka FJ, O'Malley PM, Johnston LD. Associations between access to food stores and adolescent body mass index. Am J Prev Med 2007;33(4 Suppl):S301-7. doi: 10.1016/j.amepre.2007.07.007.

78. Bhargava A, Jolliffe D, Howard LL. Socio-economic, behavioural and environmental factors predicted body weights and household food insecurity scores in the Early Childhood Longitudinal Study-Kindergarten. British Journal of Nutrition 2008;100(02):438-44.

79. Burke MP, Frongillo EA, Jones SJ, Bell BB, Hartline-Grafton H. Household Food Insecurity is Associated With Greater Growth in Body Mass Index Among Female Children from Kindergarten Through Eighth Grade. Journal of hunger & environmental nutrition 2016:1-15.

80. Ziyab AH, Karmaus W, Kurukulaaratchy RJ, Zhang H, Arshad SH. Developmental trajectories of Body Mass Index from infancy to 18 years of age: prenatal determinants and health consequences. Journal of epidemiology and community health 2014;68(10):934-41.

81. Nonnemaker JM, Morgan-Lopez AA, Pais JM, Finkelstein EA. Youth BMI trajectories: evidence from the NLSY97. Obesity 2009;17(6):1274-80.

82. Baker JL, Olsen LW, Sørensen TI. Childhood body-mass index and the risk of coronary heart disease in adulthood. New England Journal of Medicine 2007;357(23):2329-37.

83. Ryu J-H, Bartfeld JS. Household food insecurity during childhood and subsequent health status: the early childhood longitudinal study—kindergarten cohort. American journal of public health 2012;102(11):e50-e5.

84. Wilde PE, Nord M, Zager RE. In longitudinal data from the survey of program dynamics, 16.9% of the US population was exposed to household food insecurity in a 5-year period. Journal of hunger & environmental nutrition 2010;5(3):380-98.

85. Kirkpatrick SI, McIntyre L, Potestio ML. Child hunger and long-term adverse consequences for health. Archives of pediatrics & adolescent medicine 2010;164(8):754-62.

86. Azur MJ, Stuart EA, Frangakis C, Leaf PJ. Multiple imputation by chained equations: what is it and how does it work? International journal of methods in psychiatric research 2011;20(1):40-9.

87. Nord M, Andrews M. Six-item short form of the Food Security Survey Module. USDA Economic Research Service Briefing Room 1999:2007.

88. Williams RL. A note on robust variance estimation for cluster-correlated data. Biometrics 2000;56(2):645-6.

89. Belachew T, Hadley C, Lindstrom D, Getachew Y, Duchateau L, Kolsteren P. Food insecurity and age at menarche among adolescent girls in Jimma Zone Southwest Ethiopia: a longitudinal study. Reproductive Biology and Endocrinology 2011;9(1):1.

90. Jansen EC, Herrán OF, Villamor E. Trends and correlates of age at menarche in Colombia: Results from a nationally representative survey. Economics & Human Biology 2015;19:138-44.

91. Winicki J, Jemison K. Food insecurity and hunger in the kindergarten classroom: its effect on learning and growth. Contemporary Economic Policy 2003;21(2):145-57.

92. Dubois L, Farmer A, Girard M, Porcherie M. Family food insufficiency is related to overweight among preschoolers'. Social science & medicine 2006;63(6):1503-16.

93. McIntyre L, Glanville NT, Raine KD, Dayle JB, Anderson B, Battaglia N. Do low-income lone mothers compromise their nutrition to feed their children? CMAJ : Canadian Medical Association journal = journal de l'Association medicale canadienne 2003;168(6):686-91.

94. Campbell CC, Desjardins E. A model and research approach for studying the management of limited food resources by low income families. Journal of Nutrition Education 1989;21(4):162-71.

95. Rose D, Bodor JN. Household food insecurity and overweight status in young school children: results from the Early Childhood Longitudinal Study. Pediatrics 2006;117(2):464-73.

96. Jones SJ, Jahns L, Laraia BA, Haughton B. Lower risk of overweight in school-aged food insecure girls who participate in food assistance: results from the panel study of income dynamics child development supplement. Archives of pediatrics & adolescent medicine 2003;157(8):780-4.

97. Laraia BA. Food insecurity and chronic disease. Advances in nutrition (Bethesda, Md) 2013;4(2):203-12. doi: 10.3945/an.112.003277.

98. Reinehr T, Andler W. Changes in the atherogenic risk factor profile according to degree of weight loss. Archives of disease in childhood 2004;89(5):419-22.

99. Gooding HC, Walls CE, Richmond TK. Food Insecurity and Increased BMI in Young Adult Women. Obesity (Silver Spring) 2012;20(9):1896-901. doi: 10.1038/oby.2011.233.

100. Wilde PE, Peterman JN. Individual weight change is associated with household food security status. J Nutr 2006;136(5):1395-400.

101. Ivers LC, Cullen KA. Food insecurity: special considerations for women. The American journal of clinical nutrition 2011;94(6):1740S-4S. doi: 10.3945/ajcn.111.012617.

102. Townsend MS, Peerson J, Love B, Achterberg C, Murphy SP. Food insecurity is positively related to overweight in women. The Journal of nutrition 2001;131(6):1738-45.

103. Olson CM. Nutrition and health outcomes associated with food insecurity and hunger. The Journal of nutrition 1999;129(2):521S-4S.

104. Olson CM, Strawderman MS, Hinton PS, Pearson TA. Gestational weight gain and postpartum behaviors associated with weight change from early pregnancy to 1 y postpartum. International journal of obesity and related metabolic disorders : journal of the International Association for the Study of Obesity 2003;27(1):117-27. doi: 10.1038/sj.ijo.0802156.

105. Olson CM, Strawderman MS. The relationship between food insecurity and obesity in rural childbearing women. J Rural Health 2008;24(1):60-6. doi: 10.1111/j.1748-0361.2008.00138.x.

106. Laraia B, Vinikoor-Imler LC, Siega-Riz AM. Food insecurity during pregnancy leads to stress, disordered eating, and greater postpartum weight among overweight women. Obesity 2015;23(6):1303-11.

107. Braveman P, Marchi K, Egerter S, Kim S, Metzler M, Stancil T, Libet M. Poverty, near-poverty, and hardship around the time of pregnancy. Maternal and child health journal 2010;14(1):20-35. doi: 10.1007/s10995-008-0427-0.

108. Laraia BA, Siega-Riz AM, Gundersen C. Household food insecurity is associated with self-reported pregravid weight status, gestational weight gain, and pregnancy complications. Journal of the American Dietetic Association 2010;110(5):692-701. doi: 10.1016/j.jada.2010.02.014.

109. Stotland NE, Cheng YW, Hopkins LM, Caughey AB. Gestational weight gain and adverse neonatal outcome among term infants. Obstetrics & Gynecology 2006;108(3, Part 1):635-43.

110. Oken E, Rifas-Shiman S, Field A, Frazier A, Gillman M. Maternal Gestational Weight Gain and Offspring Weight in Adolescence. Obstetric Anesthesia Digest 2009;29(4):189-90.

111. Stein AD, Ravelli AC, Lumey LH. Famine, third-trimester pregnancy weight gain, and intrauterine growth: the Dutch Famine Birth Cohort Study. Human Biology 1995:135-50.

112. Adams EJ, Grummer-Strawn L, Chavez G. Food insecurity is associated with increased risk of obesity in California women. The Journal of nutrition 2003;133(4):1070-4.

113. Stuff JE, Casey PH, Szeto KL, Gossett JM, Robbins JM, Simpson PM, Connell C, Bogle ML. Household food insecurity is associated with adult health status. The Journal of nutrition 2004;134(9):2330-5.

114. Headen IE, Davis EM, Mujahid MS, Abrams B. Racial-ethnic differences in pregnancy-related weight. Advances in Nutrition: An International Review Journal 2012;3(1):83-94.

115. MIHA Methods. California Department of Public Health. From http://www.cdph.ca.gov/data/surveys/MIHA/Pages/mihamethods.asp. (Accessed 11/29/2016).

116. Rasmussen KM, Yaktine AL. Weight gain during pregnancy: reexamining the guidelines: National Academies Press, 2009.

117. Harper LM, Chang JJ, Macones GA. Adolescent pregnancy and gestational weight gain: do the Institute of Medicine recommendations apply? American journal of obstetrics and gynecology 2011;205(2):140. e1-. e8.

118. Statistical Computing Seminars. Applied Survey Data Analysis in Stata 9. UCLA Statistical Consulting Group. From http://www.ats.ucla.edu/stat/stata/seminars/applied_svy_stata9/ (Accessed 9/162016).

119. Hutcheon JA, Platt RW, Abrams B, Himes KP, Simhan HN, Bodnar LM. A weight-gain-for-gestational-age z score chart for the assessment of maternal weight gain in pregnancy. The American journal of clinical nutrition 2013;97(5):1062-7.

120. Laraia B, Epel E, Siega-Riz AM. Food insecurity with past experience of restrained eating is a recipe for increased gestational weight gain. Appetite 2013.

121. Carmichael SL, Yang W, Herring A, Abrams B, Shaw GM. Maternal food insecurity is associated with increased risk of certain birth defects. The Journal of nutrition 2007;137(9):2087-92.

122. Hromi-Fiedler A, Bermudez-Millan A, Segura-Perez S, Perez-Escamilla R. Household food insecurity is associated with depressive symptoms among low-income pregnant Latinas. Maternal & child nutrition 2011;7(4):421-30. doi: 10.1111/j.1740-8709.2010.00266.x.

123. Borders AE, Grobman WA, Amsden LB, Holl JL. Chronic stress and low birth weight neonates in a low-income population of women. Obstetrics and gynecology 2007;109(2 Pt 1):331-8. doi: 10.1097/01.AOG.0000250535.97920.b5.

124. Hickey CA. Sociocultural and behavioral influences on weight gain during pregnancy. The American journal of clinical nutrition 2000;71(5):1364s-70s.

125. Kuh D, Ben-Shlomo Y, Lynch J, Hallqvist J, Power C. Life course epidemiology. Journal of epidemiology and community health 2003;57(10):778.

126. Statewide birth statisical data tables. State of California, Department of Public Health, Birth Records. From http://www.cdph.ca.gov/data/statistics/pages/statewidebirthstatisticaldatatables.aspx (Accessed 5/31/2016).

127. Cook JT, Black M, Chilton M, Cutts D, de Cuba SE, Heeren TC, Rose-Jacobs R, Sandel M, Casey PH, Coleman S. Are food insecurity's health impacts underestimated in the US population? Marginal food security also predicts adverse health outcomes in young US children and mothers. Advances in Nutrition: An International Review Journal 2013;4(1):51-61.

128. Eisenmann JC, Gundersen C, Lohman BJ, Garasky S, Stewart SD. Is food insecurity related to overweight and obesity in children and adolescents? A summary of studies, 1995-2009. Obesity reviews : an official journal of the International Association for the Study of Obesity 2011;12(5):e73-83. doi: 10.1111/j.1467-789X.2010.00820.x.

129. Life Course Indicators Online Tool. Association of Maternal and Child Health Programs. From http://www.amchp.org/programsandtopics/data-assessment/Pages/LifeCourseIndicators.aspx. (Accessed 12/8/2016).

APPENDIX

Table A1: Early life exposure to food insecurity and associated changes in growth among children in CHAMACOS with at least two consecutive measures of BMI, stratified by sex (n=374)[1, 2]

		Weight z-score			BMI			BMI z -score		
	Time Interval	All ß (95% CI)	Male ß (95% CI)	Female ß (95% CI)	All ß (95% CI)	Male ß (95% CI)	Female ß (95% CI)	All ß (95% CI)	Male ß (95% CI)	Female ß (95% CI)
Food Secure	2 - 3.5	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Food Insecure		-0.10 (-0.26, 0.05)	-	-	-0.22 (-0.60, -0.16)	-	-	-0.18 (-0.37, 0.01)	-	-
Food Secure	3.5 - 5	-	Ref	Ref	-	Ref	Ref	-	Ref	Ref
Food Insecure			0.28 (0.08, 0.47)**	-0.06 (-0.20, 0.08)		0.63 (0.18, 1.10)**	-0.13 (-0.64, 0.38)		0.35 (0.09, 0.62)**	-0.10 (-0.27, 0.07)
Food Secure	5 - 7	Ref	Ref	Ref	-	Ref	Ref	Ref	Ref	Ref
Food Insecure		-0.07 (-0.17, 0.04)	-	-		0.32 (-0.25, 0.88)	-0.67 (-1.10, -0.24)**	-0.10 (-0.23, 0.02)	-	-
Food Secure	7 - 9	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref

Food Insecure		0.03 (-0.06, 0.12)	-	-	0.20 (-0.18, 0.58)	-	-	0.03 (-0.07, 0.13)	-	-
Food Secure	9 - 10.5	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Food Insecure		-0.05 (-0.13, 0.02)	-	-	0.01 (-0.40, 0.42)	-	-	-0.03 (-0.12, 0.05)	-	-
Food Secure	10.5 - 12	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Food Insecure		0.09 (0.00, 0.19)*	-	-	0.22 (-0.23, 0.68)	-	-	0.10 (-0.00, 0.20)	-	-

[1] When effect modification by sex was observed ($p < 0.10$), the ß associated with early food insecurity among all children was not reported as stratified estimates should be considered.
[2] Non-stratified linear models were adjusted for maternal age, maternal proportion of life spent in the United States, marital status, maternal education, maternal parity, maternal pre-pregnancy Body Mass Index, household income, child sex, and child birth weight. Stratified models adjusted for the same confounder set but excluded sex.
*$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A2: Early life exposure to food insecurity and associated changes in height z-score and obesity among children in CHAMACOS, stratified by sex (n=243)[1]

		Height z-score			Obesity		
	Time Interval	All ß (95% CI)	Male ß (95% CI)	Female ß (95% CI)	All ß (95% CI)	Male ß (95% CI)	Female ß (95% CI)
Food Secure	2 - 3.5	Reference Group	Ref	Ref	Ref	Ref	Ref
Food Insecure		-0.00 (-0.16, 0.16)	0.03 (-0.18, 0.23)	-0.11 (-0.37, 0.15)	1.02 (0.71, 1.15)	0.99 (0.63, 1.54)	1.05 (0.70, 1.60)
Food Secure	3.5 - 5	Ref	Ref	Ref	Ref	Ref	Ref
Food Insecure		-0.01 (-0.10, 0.07)	0.02 (-0.10, 0.14)	-0.04 (-0.17, 0.09)	1.03 (0.71, 1.49)	1.33 (0.77, 2.30)	0.71 (0.39, 1.27)
Food Secure	5 - 7	Ref	Ref	Ref	Ref	Ref	Ref
Food Insecure		-0.03 (-0.11, 0.05)	0.03 (-0.09, 0.14)	-0.09 (-0.21, 0.03)	1.19 (0.92, 1.53)	1.47 (0.99, 2.17)	0.81 (0.53, 1.24)
Food Secure	7 - 9	Ref	Ref	Ref	Ref	Ref	Ref
Food		0.01 (-0.08, 0.10)	-0.01 (-0.14, 0.12)	0.06 (-0.07, 0.19)	0.96 (0.79, 1.16)	0.99 (0.76, 1.30)	0.98 (0.69, 1.39)

Insecure							
Food Secure	9 - 10.5	Ref	Ref	Ref	Ref	Ref	Ref
Food Insecure		-0.00 (-0.08, 0.08)	0.02 (-0.07, 0.11)	-0.05 (-0.18, 0.08)	0.99 (0.82, 1.21)	0.96 (0.74, 1.24)	1.16 (0.81, 1.67)
Food Secure	10.5 - 12	Ref	Ref	Ref	Ref	Ref	Ref
Food Insecure		0.02 (-0.07, 0.11)	-0.02 (-0.14, 0.10)	0.08 (-0.05, 0.22)	1.00 (0.79, 1.25)	1.04 (0.77, 1.40)	0.94 (0.63, 1.39)

[1] Non-stratified linear models were adjusted for maternal age, maternal proportion of life spent in the United States, marital status, maternal education, maternal parity, maternal pre-pregnancy body mass index, household income, child sex, and child birth weight. Stratified models adjusted for the same confounder set but excluded sex.

Table A3: Percent obese by early life exposure to food insecurity from age 2 to 12 for children in CHAMACOS (n=243)

	Age 2	Age 3.5	Age 5	Age 7	Age 9	Age 10.5	Age 12
	% (n) Obese[1]	% (n) Obese	% (n) Obese	% (n) Obese	% (n) Obese	% (n) Obese	% (n) Obese
Food Secure	13.6 (24)	26.3 (47)	29.2 (53)	29.8 (55)	33.7 (61)	34.5 (62)	34.6 (62)
Food Insecure	19.2 (14)	31.3 (24)	34.0 (25)	39.0 (29)	41.6 (31)	40.3 (30)	40.5 (30)

[1] Unweighted n's and weighted percentages.

Table A4: Food security status and associated changes in obesity status among children in CHAMACOS from age 5 to 12 (n=204)[1]

	Time Interval	Δ in Obesity status Incident Rate Ratio (95% CI)
Food Secure	5-7	Ref
Food Insecure		1.22 (0.93, 1.61)
Food Secure	7 - 9	Ref
Food Insecure		0.94 (0.75, 1.20)
Food Secure	9 - 10.5	Ref
Food Insecure		0.84 (0.61, 1.17)
Food Secure	10.5 - 12	Ref
Food Insecure		0.99 (0.74, 1.32)

[1]Models were adjusted for maternal age, maternal proportion of life spent in the U.S., maternal education, maternal pre-pregnancy body mass index, early food insecurity, child sex, and child birth weight. Models were also adjusted for marital status, maternal parity, household income, hours the child watches T.V., hours the child plays outside, child's puberty status and obesity status as measured at the beginning of the time interval. Food security was assessed at the beginning of the time interval and outcomes were assessed at the end of the time interval.

Table A5: The associations between change-in and persistency of food security status and change in obesity status among children in CHAMACOS from age 5 to 12[1]

	n	Obesity[2] Odds Ratio (95% CI)
Food security status across 2 time points	816	
Food secure across interval		Reference Group
Food insecure across interval		0.81 (0.40, 1.65)
Δ from food insecure to food secure		1.02 (0.49, 2.10)
Δ from food secure to food insecure		0.83 (0.30, 2.26)
Food security status across 3 time points	612	
Persistent food security		Ref
Persistent food insecurity		0.46 (0.19, 1.09)
Any Δ in food security status		0.73 (0.28, 1.88)

[1]Models were adjusted for maternal age, maternal proportion of life spent in the U.S., maternal education, maternal pre-pregnancy body mass index, early food insecurity, child sex, and child birth weight. Models were also adjusted for obesity status, marital status, maternal parity, household income, hours the child watches T.V., hours the child plays outside, and child's puberty status as measured at the beginning of the time interval.
[2] Obesity status was identified as the outcome in the models however the models were adjusted for obesity status at the previous time point in an attempt to approximate the associations between change-in and duration of food security status and change in obesity status.