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Obesity

Food Insecurity During Pregnancy Leads to Stress, Disordered Eating, and Greater Postpartum Weight Among Overweight Women

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Objective: To investigate the influence of food insecurity on women's stress, disordered eating, dietary fat intake, and weight during the postpartum period.

Methods: The association between marginal food security and food insecurity—measured during pregnancy and postpartum—and stress, disordered eating, dietary fat intake, and weight at 3 and 12 months postpartum was estimated using multivariate linear regression, controlling for demographic and socioeconomic characteristics and health behaviors. Effect modification between level of food insecurity and prepregnancy weight status was assessed, hypothesizing a stronger association would be found among women who started pregnancy with overweight or obesity.

Results: Food insecurity status during pregnancy was strongly associated with higher levels of stress, disordered eating, and dietary fat intake at 3 and 12 months postpartum; during the postpartum period, food insecurity was associated with these measures at 12 months postpartum. A significant interaction was found between level of food insecurity and prepregnancy weight status; food insecurity was associated with greater weight and BMI at 12 months only among women with overweight or obesity.

Conclusions: In order to return to one's prepregnancy weight, women with overweight and obesity who face household food insecurity may need multipronged assistance that not only addresses having enough high-quality food, but also include stress reduction and eating behavior interventions.

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Introduction

Food insecurity is a multidimensional construct that captures anxiety associated with the uncertainty of being able to obtain enough food, material resources constraints, and compromised dietary intake because of the dependence on purchasing low-cost, calorie-dense foods and in some instances binge eating (1,2). Therefore, the household food insecurity scale can be viewed as a crude measure that captures psychosocial stress, poor diet quality, and economic hardship. In recent years there has been a concern about the observed co-existence of household food insecurity and obesity, especially among women (3-8). Evidence is inconsistent for the association between food insecurity and being overweight among women (3,4,6,7), with more studies finding no association with being overweight (3,4,7). Conversely, the association between either moderate or severe food insecurity and obesity is a more consistent finding (3-5), especially among women of color (5).

Food insecurity may influence weight gain through a number of mechanisms. First, women from food-insecure households may become economically dependent on low-cost, processed, high-calorie

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foods in order to stretch the household budget. Consuming processed, high-calorie foods over time may lead to weight gain (9). Food insecurity is also a stressful event; in many studies, food insecurity is associated with anxiety, depression, and perceived stress (10-12). Stress brought on by food insecurity may cause non-homeostatic eating and eating for reasons other than caloric need and may lead to the selection of "comfort" foods, or highly palatable foods that are rich in fat, sugar, and sodium (13-15) and have been found to physiologically reduce stress (16). Furthermore, eating high-fat foods under stressful conditions is associated with accumulation of visceral fat and weight gain in animals (17,18) as well as humans (15,19).

Pregnancy is a period when women are expected to gain weight for an optimal birth outcome. The Institute of Medicine (IOM) guidelines recommend a target range for weight gain given a woman's prepregnancy weight (20); however, upwards of 60% of women gain outside their weight gain range (20,21). Women who are overweight or obese are more likely to gain either above or below the guidelines of 7-11 kg and 5-9 kg, respectively (20). We previously found that food insecurity during pregnancy was associated with greater gestational weight gain, a greater observed-to-recommended weight gain ratio and increased risk for developing gestational diabetes mellitus (22). Research from both animal and human studies suggest that being worried or concerned about having enough food, therefore the uncertainty about one's ability to obtain food is associated with stress-related weight gain (3,23). Variable foraging protocol, alternating *ad lib* and hidden food every two weeks for 16 weeks, was found to cause increased anxiety, aggression, and decreased attentiveness toward offspring in mother Bonnet Macaque monkeys. Among the offspring, an increase in obesity, insulin resistance, and metabolic syndrome was found at 4 years, especially among females (17). Therefore, we hypothesize that even marginal food insecure is a condition for weight gain.

Pregnancy is a unique time for weight-related expectations for women. Not only are they expected to gain weight, they are expected to return to their prepregnancy weight at some point during the postpartum period; however, women who gain above the IOM recommendations are more likely to be heavier postpartum (21). In a small sample of pregnant women from rural upstate New York, prepregnancy obesity was associated with food insecurity at 2 years postpartum, when compared to food secure, normal-weight women. Furthermore, prepregnancy obesity combined with food insecurity was associated with greater risk for higher weight (>4.55 kg) from prepregnancy to 2 years postpartum (24), suggesting that food insecurity among women who are obese may drive additional weight gain.

In this study we investigate the relationships among food security status and perceived stress, disordered eating behavior, percentage of calories from fat, and postpartum weight status at 3 and 12 months. We hypothesize that any level of food insecurity experienced *during pregnancy* will be associated with higher levels of perceived stress, disordered eating, and percentage of calories from fat at 3 and 12 months. Any level of food insecurity experienced *during the postpartum period* would also be associated with higher levels of perceived stress, disordered eating, percentage of calories from fat at 12 months. In addition, we hypothesized effect modification between prepregnancy overweight or obesity and food insecurity with greater weight at 3 and 12 months postpartum.

Methods

This study included women from the Pregnancy, Infection, and Nutrition (PIN) Study cohort from 2000 to 2006 who provided information both during and after pregnancy regarding their food security status and other factors. In this analysis, we examined the association between food security status during and after pregnancy and psychosocial factors, dietary factors, and weight status.

Study population

The sample is from the PIN Postpartum Study ($n = 688$); a prospective longitudinal study of women in North Carolina enrolled during pregnancy and followed until 1 year after giving birth. Further details on recruitment and eligibility have been previously reported (12,25). This analysis includes the 550 women who enrolled in the postpartum study and completed the protocols through 12 months postpartum (25). Inclusion criteria were age > 16 years at time of conception, English speaking, plans to continue care or deliver at the study site, and a singleton pregnancy. Information on preconception and perinatal factors including sociodemographic characteristics and medical history was assessed by interviews, self-administered questionnaires, and information from medical records. Medical charts were abstracted to collect data on reproductive history, weight gain, pregnancy complications, and labor and delivery events. In the postpartum period (3 and 12 months) home visits were made to collect information on factors that potentially influence the mother's postpartum weight status including diet, physical activity, psychological factors, smoking, and breastfeeding. A total of 526 women were included in the final analyses ($n = 24$ were excluded because of missing information on food security status at 12 months postpartum). Few differences in SES characteristics were found among PIN participants who did not participate in the postpartum study, and among those who enrolled but did not complete the 12-month time point (25). The protocols for this study were approved by the UNC School of Medicine Institutional Review Board.

Food insecurity

Food insecurity during pregnancy was measured between 27 and 30 weeks' gestation with a telephone interview using the 18-item Core Food Security Module (CFSM) for families with children (26). At 12 months postpartum, the women were asked about food insecurity in the year since giving birth during a home visit using a six-item short form, which is a validated subset of the 18-item module (27). Household food security was defined as answering no to all questions. Marginally food secure households were defined as answering "yes" to two of 18-item scale during pregnancy and one of the six-item questions during the postpartum period, food insecure households were defined as answering "yes" to three or more of the 18-item questions and two or more of the six-item questions. The socioeconomic and demographic characteristics were not statistically significantly different between women from marginally secure and insecure households but were statistically significantly different compared to the food secure women, confirming that they should not be grouped with respondents from food secure households as previously identified (12,28).

Maternal outcomes

Maternal outcomes investigated in this study included psychological factors, dietary factors, and weight status. Perceived stress, a

TABLE 1 Maternal characteristics by food security status, expressed as mean ± sd or as number (percentage) of participants in the Pregnancy, Infection, and Nutrition Study ($n = 526$)

	During pregnancy			During postpartum		
	Food insecure ($n = 467$)	Marginally food secure ($n = 34$)	Food insecure ($n = 25$)	Food secure ($n = 468$)	Marginally food secure ($n = 24$)	Food insecure ($n = 34$)
Socioeconomic & demographics						
Race, number (%)						
White and other	427 (91.83)	21 (61.76)	13 (52.00)	423 (88.78)	16 (66.67)	25 (73.53)
Black	38 (8.17)	13 (38.24)*	12 (48.00)*	55 (11.22)	8 (33.33)*	9 (26.47)*
Marital status, number (%)						
Married	414 (89.61)	19 (55.88)*	15 (60.00)*	427 (87.68)	11 (45.83)*	22 (64.71)
Single	48 (10.39)	15 (44.12)*	10 (40.00)*	60 (12.32)	13 (54.17)*	12 (35.29)*
Prepregnancy age, years, mean ±sd	30.45±5.08	25.97±6.14*	28.26±6.22	30.30±5.27	26.46±5.84**	26.44±5.32*
Prepregnancy children, mean ±sd	0.72±0.83	1.0±1.0	1.4±1.41*	0.75±0.85	1.04±1.12	1.12±1.08
Maternal education, years, mean ±sd	16.48±2.44	14.0±2.55*	13.0±2.31*	16.28±2.59	14.2±2.6*	13.44±2.52*
≤ High school, number (%)	50 (10.73)	14 (42.42)*	13 (52.00)*	63 (12.86)	11 (45.83)*	20 (58.82)*
≥Some college, number (%)	416 (89.27)	19 (57.58)*	12 (48.00)*	427 (87.14)	13 (54.17)*	14 (41.18)*
Mean poverty index, mean ±sd						
Prepregnancy	475.6±199.7	196.8±153.9*	158.4±137.4*	461.6±208.4	214.1±150.8*	191.1±146.0*
Postpartum	340.4± 152.7	146.3± 83.9*	121.3± 124.2*	330.2± 158.4	168.0± 125.9*	127.5±85.35*
Health indicators						
Prepregnancy physical activity, total MET, mean ±sd	24.96±25.96	36.48±43.00	31.76±36.47	25.0±26.0	36.5±43.0	31.8±36.5
Smoking at 12 months postpartum, mean ±sd among smokers	10.16±5.81	11.62±6.01	7.33±5.09	10.87±6.03	8.29±4.19	8.18±4.29
Yes, number (%)	25 (5.35)	14 (23.73)*	14 (23.73)*	31 (6.30)	7 (29.17)*	11 (32.35)*
No, number (%)	461 (93.70)	17 (70.83)*	23 (67.65)*	461 (93.70)	17 (70.83)*	23 (67.65)*
Breastfeeding duration, weeks, mean ±sd						
3 months postpartum	9.97±4.00	8.07±4.55**	5.59±5.12*	9.81±4.07	6.24±5.28*	7.92±5.16**
12 months postpartum	33.95±21.06	22.68±21.88**	9.42±13.15*	33.15±21.29	15.42±19.29*	20.79±21.51**

Significantly different from referent group (food secure) at P-value < 0.001* or < 0.05**; chi2 for categorical, t-test for continuous variables.

psychological factor, was determined at three time points: 27-30 weeks gestation, 3 months postpartum, and 12 months postpartum. It was measured using a 10-item Perceived Stress Scale (29,30). Cohen's Perceived Stress has been used and validated with pregnant women (31). This scale is used to evaluate the respondent's perception of how threatening or demanding a stressful event was. This measure of the "degree to which situations in one's life are appraised as stressful" has been assessed for internal consistency. The 10-item scale provides a stable index of chronic stress or strain, and coping with these stresses. Each item is rated on a five-point scale ranging from never to almost always totaling 40 points. Another psychological factor, eating attitudes and behaviors, was evaluated at 3 and 12 months postpartum. This was performed using the 26-item Eating Attitude Test (EAT) that measures disordered eating (32). Questions ask about avoidant food behaviors, binge eating, dieting, guilt about eating, preoccupation with food and weight, and vomiting. The 26-items are scored on a six-point Likert scale, collapsing "never", "rarely", and "sometimes" to a 0 value, and a point each for responses of "often", "usually", and "always", and summed for a possible total of 78 points. Scores ≤10 are considered normal, 11-20 moderate eating disturbance, and ≥21 abnormal eating.

Women completed the validated NCI-Block Food Frequency Questionnaire (FFQ), modified and validated for our population, at 24-29 weeks of gestation, 3 months postpartum, and 12 months postpartum and were told to consider their diet during the 3 months prior (33). Change in calories from fat was calculated by subtracting energy-adjusted fat intake during pregnancy from energy-adjusted fat intake at 3 and 12 months postpartum.

Weight prior to pregnancy was ascertained by self-report and checked against measured weight if a value was available before 15 weeks' gestation. An imputed weight for 3% ($n = 16$) was used when self-reported weight was missing or considered implausible; women gained more than 2.3 kg or lost more than 1.1 kg per week between prepregnancy and first clinical measured weight (34). Imputed weight was created by using the measured weight prior to 15 weeks minus the recommended amount of weight for that time period defined by the Institute of Medicine (20). Height and weight

TABLE 2 Maternal outcomes by food security status, expressed as mean (sd) of participants in the Pregnancy, Infection, and Nutrition Study ($n = 526$)

	During pregnancy			During postpartum		
	Food secure ($n = 467$)	Marginally food secure ($n = 34$)	Food insecure ($n = 25$)	Food secure ($n = 468$)	Marginally food secure ($n = 24$)	Food insecure ($n = 34$)
Psychosocial factors						
Mean PSS 3 months postpartum	12.59±5.52	18.21±6.15*	17.8±6.7*	12.79±5.66	16.92±6.02**	18.97±6.44*
Mean PSS 12 months postpartum	12.76±5.85	19.03±6.15*	17.9±7.4*	12.81±5.88	18.58±6.21*	19.94±6.94*
Mean EAT 3 months postpartum	4.32±4.56	7.15±7.05**	7.8±6.0**	4.29±4.36	8.33±9.76*	9.35±6.99*
Mean EAT 12 months postpartum	4.53±4.59	7.41±6.44**	6.92±5.48**	4.50±4.36	10.92±10.20*	7.15±5.20**
Calories from fat						
Percentage of calories from fat prepregnancy	34.09±5.53	34.26±6.81	34.09±8.18	34.22±5.53	31.21±6.86	34.14±7.80
Δ% of calories from fat 3 months postpartum–pregnancy	−0.79±5.93	0.68±9.83	1.80±8.20	−0.88±6.17	2.11±7.39	1.08±6.75
Δ% of calories from fat 12 months postpartum–pregnancy	−0.90±5.89	−1.21±10.47	2.83±9.65**	−1.10±6.06	2.73±10.01	1.52±8.18
Weight status						
BMI prepregnancy	24.47±6.04	27.45±7.73**	33.73±9.45*	24.81±6.39	26.62±8.39	29.11±7.96*
ΔBMI 3 months postpartum – prepregnancy	1.92±1.94	2.28±2.63	4.00±2.83*	1.89±1.93	3.23±2.81**	3.72±2.65*
ΔBMI 12 months postpartum – prepregnancy	1.12±2.19	2.45±3.25**	4.01±3.35*	1.18±2.24	3.32±3.17*	2.93±3.46*
Weight (pounds) prepregnancy	147.28±37.65	162.13±47.39	208.11±63.34*	149.25±39.78	161.17±53.28	179.05±56.70*
ΔWeight 3 months postpartum – prepregnancy	8.92±10.72	11.80±14.15	16.26±15.01**	8.75±10.67	15.37±14.83**	17.40±13.67*
ΔWeight 12 months postpartum – prepregnancy	4.53±12.01	12.86±18.13*	16.18±17.91*	4.73±12.31	16.17±15.22*	12.62±19.23**

Significantly different from referent group (food secure) at P-value < 0.001* or < 0.05**; t-test for continuous variables.
PSS, Cohen's Perceived Social Stress; EAT, Eating Attitude Test; BMI, body mass index.

TABLE 3 Association between food insecurity status and perceived stress, Eating Attitude Test and change in percent energy intake from fat at 3 and 12 months among postpartum women in the Pregnancy, Infection, and Nutrition study

	3 months postpartum			12 months postpartum		
	Perceived stress[a] β (95% CI)	EAT score[b] β (95% CI)	Δ% Energy from fat[a] β (95% CI)	Perceived stress[a] β (95% CI)	EAT score[c] β (95% CI)	Δ% Energy from fat[c] β (95% CI)
Food security status during pregnancy	($n = 506$)	($n = 503$)	($n = 426$)	($n = 506$)	($n = 506$)	($n = 396$)
Marginally secure	4.30 (2.12, 6.49)	2.44 (0.58, 4.30)	2.40 (−0.59, 5.38)	5.86 (3.54, 8.19)	2.62 (0.77, 4.46)	−0.30 (−3.43, 2.84)
Food insecure	3.36 (0.79, 5.92)	1.95 (−0.25, 4.16)	3.17 (0.07, 6.28)	3.67 (0.94, 6.41)	0.77 (−1.42, 2.96)	4.86 (1.44, 8.27)
Constant	13.07 (8.50, 17.63)	3.58 (−0.47, 7.63)	−7.22 (−12.86, −1.57)	10.10 (5.24, 14.97)	2.46 (−1.55, 6.47)	−1.76 (−7.90, 4.38)
Food security status during postpartum period				($n = 526$)	($n = 526$)	($n = 406$)
Marginally secure				5.33 (2.72, 7.93)	5.79 (3.70, 7.88)	4.42 (1.09, 7.76)
Food insecure				6.12 (3.86, 8.38)	1.79 (−0.03, 3.62)	3.47 (0.64, 6.31)
Constant				9.27 (4.65, 13.89)	0.93 (−2.92, 4.78)	−3.80 (−9.78, 2.19)

[a]Adjusted for prepregnancy BMI, age, race, education, income, marital status, children.
[b]Adjusted for prepregnancy BMI, age, race, education, income, marital status, children, smoking at 3 months, and breastfeeding duration at 3 months.
[c]Adjusted for prepregnancy BMI, age, race, education, income, marital status, children, smoking at 12 months, and breastfeeding duration at 12 months.
Note: Sample size varies because of missing values of the outcome.

TABLE 4 Association between food insecurity status and 3 and 12 months weight status change from prepregnancy weight

	3 months postpartum[a]		12 months postpartum[b]	
	Weight (pounds) β (95% CI)	BMI β (95% CI)	Weight (pounds) β (95% CI)	BMI β (95% CI)
Food security status during pregnancy	($n = 505$)	($n = 505$)	($n = 492$)	($n = 492$)
Marginally secure	0.19 (−4.12, 4.51)	−0.25 (−1.03, 0.53)	2.91 (−1.89, 7.71)	0.28 (−0.59, 1.14)
Food insecure	6.36 (1.25, 11.47)	1.74 (0.81, 2.66)	5.00 (−0.69, 10.70)	1.65 (0.62, 2.68)
Constant	23.28 (13.91, 32.65)	4.28 (2.59, 5.97)	17.15 (6.69, 27.61)	3.52 (1.63, 5.40)
Food security status during postpartum			($n = 512$)	($n = 512$)
Marginally secure			4.47 (−1.00, 9.94)	0.84 (−0.15, 1.83)
Food insecure			3.97 (−0.82, 8.76)	0.93 (0.07, 1.80)
Constant			16.87 (6.75, 26.99)	3.32 (1.50, 5.15)

[a]Controlling for prepregnancy BMI, age, race, education, income, marital status, children, smoking at 3 months, and breastfeeding duration at 3 months.
[b]Controlling for prepregnancy BMI, age, race, education, income, marital status, children, smoking at 12 months, and breastfeeding duration at 12 months.
Note: Sample size varies because of missing values of the outcome.

were measured at 3 and 12 months. This information was used to calculate change in weight (in pounds) at 3 and 12 months as well as change in BMI at 3 and 12 months.

Covariates and demographic information

Telephone interviews and self-administered questionnaires were used to obtain information on maternal race, age, marital status, education, parity, physical activity, smoking during pregnancy, and poverty level. In addition, information on smoking at 12 months postpartum, breastfeeding at 3 and 12 months postpartum, and poverty level were collected during in-person interviews.

Statistical analysis

Differences between maternal characteristics and outcome for women by food security status during pregnancy or postpartum were assessed using chi-square and *t*-tests. Associations between food security status and psychological factors, dietary factors, and weight status were performed using multivariate linear regression. All models were adjusted for demographic (age, maternal race, parity) and socioeconomic (poverty level during pregnancy, education, marital status) variables previously identified in the literature. We tested additional confounders of physical activity, smoking, breastfeeding, and poverty level at different timepoints; only breastfeeding and smoking were associated with food security status or the outcomes at $P < 0.15$ and retained for some models. Multiplicative interaction between food security status and prepregnancy weight status (overweight/obese vs. normal/underweight) was tested using likelihood ratio test. A Chi-squared with a P-value ≤ 0.15 indicated the interaction term contributed to the model (35). When the interaction term was significant, stratified models by prepregnancy weight status were used. Sensitivity analysis restricting the sample to $\leq$400% poverty were used to make sure that the results were robust to exclusion of women living at higher income levels as their exposure to

TABLE 5 Association between food insecurity status and 12 months weight status change from prepregnancy weight stratified by prepregnancy weight

	12 months weight (pounds)[a]		12 months BMI[a]	
	Normal weight β (95% CI)	Overweight/obese β (95% CI)	Normal weight β (95% CI)	Overweight/obese β (95% CI)
Food security status during pregnancy	($n = 320$)	($n = 172$)	($n = 320$)	($n = 172$)
Marginally secure	0.85 (−4.70, 6.39)	4.48 (−4.02, 12.98)	−0.11 (−1.15, 0.92)	0.60 (−0.90, 2.10)
Food insecure	−2.46 (−10.71, 5.78)	10.37 (0.89, 19.84)	−0.11 (−1.64, 1.43)	2.60 (0.92, 4.27)
Constant	11.56 (−2.54, 25.66)	30.55 (10.43, 50.68)	2.70 (0.06, 5.33)	6.00 (2.45, 9.56)
Food security status during postpartum	($n = 320$)	($n = 180$)	($n = 320$)	($n = 172$)
Marginally secure	3.36 (−2.78, 9.52)	6.80 (−3.55, 17.15)	0.28 (−0.87, 1.43)	1.50 (−0.34, 3.34)
Food insecure	−2.02 (−7.90, 3.88)	7.33 (−1.39, 16.05)	−030 (−1.40, 0.80)	1.59 (0.04, 3.14)
Constant	9.99 (−4.15, 24.12)	24.66 (4.41, 44.90)	2.55 (0.09, 5.19)	4.49 (0.89, 8.09)

[a]Controlling for prepregnancy BMI, age, race, education, income, marital status, children, smoking at 12 months, and breastfeeding duration at 12 months
Note: Sample size varies because of missing values of the outcome.

food insecurity is extremely low. All analyses were performed using STATA 10.1 and statistical significance noted at P-value <0.05 (36).

Results

Among women in the analytical sample, approximately 7.8% reported marginal food security and 5.2% food insecurity during pregnancy, and 4.4% reported marginal food security and 6.2% food insecurity during postpartum. Almost 6% of women experienced some level of food insecurity at both time points and food security status at each time point was significantly associated ($\chi 2 = 176.90$, $P \leq 0.001$). Black women comprised a larger proportion of the less food secure groups (Table 1). Women experiencing any level of food insecurity were more likely to be single, younger, less educated, and had higher levels of poverty compared to women from food secure households. The mean number of children was also slightly higher among those from food insecure households during pregnancy. A greater proportion of women from marginally food secure or food insecure households smoked during the 12 months postpartum and breastfed for a shorter duration compared to women from food secure households.

Table 2 reports the psychological factors, dietary factors, and weight status by food security status. Overall, perceived stress and poor eating attitudes were higher for women from marginally food secure and food insecure compared to those from food secure households. Those from food insecure households during pregnancy had a greater change in the percentage of calories consumed from fat at 12 months postpartum. Prepregnancy BMI was higher among women reporting any level of food insecurity during pregnancy. In addition, women from any level of food insecurity gained and retained more weight postpartum at 3 and 12 months than women from food secure households.

In adjusted models, women exposed to either level of food insecurity during pregnancy had higher scores on the perceived stress scale at both 3 and 12 months postpartum (Table 3). Marginal food security was consistently associated with the EAT, and food insecurity was consistently associated with a higher percentage of calories from fat at 3 and 12 months postpartum, although 95% confidence intervals overlap between the groups. Women exposed to any level of food insecurity during the postpartum period also had higher scores on the perceived stress scale, the EAT, and a higher percentage of calories from fat at 12 months postpartum, compared to women from food secure households. Sensitivity analysis of these models (data not shown), restricting the sample to those at or below 400% of the income/poverty ratio (those most at risk of household food insecurity), resulted in very similar point estimates and remained statistically significant for perceived stress, eating attitudes, and for percentage of calories from fat, although less precise at 3 months.

Among women exposed to marginal food security during pregnancy or the postpartum period there were no significant associations with weight change and BMI after adjustment (Table 4). At 3 months postpartum, women exposed to food insecurity during pregnancy weighed 6.4 pound more and were 1.74 BMI unit higher, and at 12 months a significantly greater BMI (1.65) persisted, compared to women from food secure households. Exposure to food insecurity during the postpartum period was associated with approximately a 1 BMI unit increase at 12 months postpartum compared to women from food secure households. Sensitivity analysis restricting the dataset to women at 400% of the income/poverty ratio resulted in associations in the same direction and of similar magnitude but with wider confidence intervals (data not shown).

We found a significant interaction between food security status and prepregnancy weight status with BMI at 12 months (Table 5). Food insecurity among overweight/obese women was associated with 11 pounds and 2.6 BMI units greater if exposed to food insecurity during pregnancy, and 7.34 pounds and 1.6 BMI units greater if exposed to food insecurity during postpartum compared to overweight/obese food secure women. No postpartum weight differences were found by food security status among normal-weight women or among any women at 3 months postpartum.

Discussion

This study sought to understand the association of household food security status with stress, disordered eating behavior, dietary fat intake, and weight status as women transition from pregnancy to the postpartum period. We found in adjusted models, that food security status (at either time point) was associated with higher levels of perceived stress, disordered eating behavior and dietary fat intake above the recommended amount at 3 and 12 months postpartum. Sensitivity analysis were significant for stress, eating attitudes, and percentage of energy from fat suggesting that findings were robust to the exclusion of upper income women who have a very low risk of food insecurity. These findings are consistent with the notion that food insecurity is a multidimensional measure, and one that can alter eating behaviors and potentially influence metabolic processes and fat storage.

Our findings are consistent with results from animal studies that find stress is associated with weight gain, gestational weight gain, and postpartum weight. More specifically, stress, and stress-induced eating is associated with the accumulation of visceral fat, with and without added weight (37,38). The accumulation of visceral fat is thought to be brought about because stress that is perceived as a threat will invoke the hypothalamus–pituitary–adrenal axis setting off a cascade of hormones such as cortisol, insulin and leptin as well as neuropeptide Y that directly influence central fat storage (37). Exposure to food insecurity has been hypothesized as this type of threat to one's wellbeing and survival, even in an environment with sufficient calories (17). Both animal and human studies find that stress is associated with dysregulated eating patterns and consumption of highly palatable foods (13-17,19,37).

A significant interaction between food security status and prepregnancy weight status was found; among overweight/obese women, food insecurity was associated with a higher BMI at 12 months postpartum compared to overweight/obese women from food secure households. This finding is consistent with our hypothesis that overweight and obese women who experience food insecurity are more likely to retain additional weight. This finding supports the previous research conducted by Olson and Strawderman (24) that found women who were obese during pregnancy and who experienced food insecurity retained or gained significant weight at 2 years after pregnancy.

Although food insecurity was associated with postpartum weight status, we were not able to explore other weight measures, especially the accumulation of central adiposity or visceral fat. It is possible that using visceral fat or waist-to-hip circumference as a measure of the more metabolic fat pad associated with stress-induced eating instead of the more general body mass index or weight gain that we used here, may better capture shifts in metabolic processes brought on by stress. Another important effect modifier may be the synergistic relationship of being exposed to food insecurity at both time points. Because of sample size we were not able to assess the association of persistent food insecurity on health behaviors and weight. We would hypothesize that women exposed to food insecurity at both time points would result in greater risk of negative behaviors and higher weight.

Although we cannot substantiate causality, the temporal sequence of the data is a major improvement over cross-sectional studies. We had a measure of household food insecurity at two time points and we were able to assess the association of food insecurity at each time point with subsequent stress, disordered eating behavior, dietary fat intake, and weight status. For example, food insecurity status reported during pregnancy was associated with meaningful higher scores on perceived stress and disordered eating after controlling for a number of important covariates. Furthermore, we hypothesized that the exposure of household food insecurity during and after pregnancy would impact a woman's level of stress and her eating behavior, dietary fat intake, and ability to return to her prepregnancy weight; although household food insecurity was associated with these outcomes, we cannot be certain that additional intervening factors also did not influence these outcomes. Intervening factors such as postpartum depression, a lack of social support, poor access to resources and a subsequent pregnancy may all influence weight status at 12 months. There was a very low prevalence of food insecurity in this sample. Future studies are needed that have an adequate sample size of women who are the most at-risk for food insecurity, that can assess the severity of food insecurity, and distinguish the influence of persistent versus intermittent food insecurity during pregnancy and the postpartum period. Additionally, future studies are needed to assess how these associations differ by race/ethnicity and by socioeconomic status. Finally, self-reported weight was used to calculate pregravid BMI, which may not be as accurate as weight measured during the study. There are several studies that suggest self-report correlates well with actual weight. All weights in this study were checked for biologic plausibility of the self-reported weight against the first prenatal visit measured weight if it occurred before 15 weeks and were corrected if deemed implausible. However, adequacy of the gestational weight gain was based on pregravid BMI, which may be a less accurate variable.

These findings support the hypothesis that household food insecurity is a multifactorial insult on women's health by potentially increasing stress, promoting disordered eating behavior, and promoting increased fat intake during the postpartum period; all of which have been associated with increased weight status. Food insecurity experienced either during pregnancy or the postpartum period was associated with negative health outcomes. Furthermore, among women who are susceptible to gaining weight; those who began pregnancy overweight or obese, the strong association between household food insecurity and increased weight at 12 months underscore the importance of the emerging field examining the extent to which household food insecurity plays a large role in weight gain and obesity. O

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