CHILDHOOD OBESITY
April 2024 | Volume 20, Number 3
© Mary Ann Liebert, Inc.
DOI: 10.1089/chi.2022.0227

Prenatal Dietary Patterns and Associations With Weight-Related Pregnancy Outcomes in Hispanic Women With Low Incomes

Lauren T. Berube, PhD, MS, RDN,[1] Andrea L. Deierlein, PhD, MPH,[2]
Kathleen Woolf, PhD, RDN,[3] Mary Jo Messito, MD,[4] and Rachel S. Gross, MD, MS[1,4]

Abstract

Background: Dietary patterns during pregnancy may contribute to gestational weight gain (GWG) and birthweight, but there is limited research studying these associations in racial and ethnic minority groups. The objective of this study was to evaluate associations between prenatal dietary patterns and measures of GWG and birthweight in a cohort of culturally diverse Hispanic women with low incomes.

Methods: Data were analyzed from 500 mother–infant dyads enrolled in the Starting Early Program, a childhood obesity prevention trial. Diet over the previous year was assessed in the third trimester of pregnancy using an interviewer-administered food frequency questionnaire. Dietary patterns were constructed using the Healthy Eating Index-2015 (HEI-2015) and principal components analysis (PCA) and analyzed as tertiles. GWG and birthweight outcomes were abstracted from medical records. Associations between dietary pattern tertiles and outcomes were assessed by multivariable linear and multinomial logistic regression analyses.

Results: Dietary patterns were not associated with measures of GWG or adequacy for gestational age. Greater adherence to the HEI-2015 and a PCA-derived dietary pattern characterized by nutrient-dense foods were associated with higher birthweight z-scores [β: 0.2; 95% confidence interval (CI): 0.04 to 0.4 and β: 0.3; 95% CI: 0.1 to 0.5, respectively], but in sex-specific analyses, these associations were only evident in male infants (β: 0.4; 95% CI: 0.03 to 0.7 and β: 0.3; 95% CI: 0.03 to 0.6, respectively).

Conclusions: Among a cohort of culturally diverse Hispanic women, adherence to healthy dietary patterns during pregnancy was modestly positively associated with increased birthweight, with sex-specific associations evident only in male infants.

Keywords: birthweight; dietary patterns; gestational weight gain; Hispanic Americans; pregnancy

Introduction

Suboptimal gestational weight gain (GWG) and infant birthweight are early life risk factors associated with childhood obesity.[1,2] Dietary intake before and during pregnancy is a modifiable means of improving GWG and birthweight and may be an important target for childhood obesity prevention,[3] particularly in Hispanic families with low incomes who experience high rates of obesity.[4] However, research examining associations between dietary patterns and weight-related pregnancy outcomes in this population is limited.[5,6]

Studies use *a priori* and *a posteriori* methods to understand how prenatal diet is related to weight-related pregnancy outcomes,[7,8] but the best approach to assess dietary patterns in culturally diverse populations is uncertain.

[1]Department of Population Health; [4]Division of General Pediatrics, Department of Pediatrics; New York University Grossman School of Medicine, New York, NY, USA.
[2]Department of Epidemiology, New York University College of Global Public Health, New York, NY, USA.
[3]Department of Nutrition and Food Studies, New York University Steinhardt, New York, NY, USA.

A priori methods use indices that are based on evidence-based associations between diet and health.[9] The indices are scored by the presence or absence of specific dietary components, and the total score describes alignment to dietary recommendations. However, *a priori* measures do not capture different dimensions of food consumption patterns that may be important to assess in culturally diverse populations. *A posteriori* methods use available dietary data to derive population-specific dietary patterns without assumptions of their contribution to health.[10] As *a posteriori* methods generate more than one dietary pattern, these exploratory methods may identify heterogeneity in food consumption patterns of culturally diverse populations.[11]

In a previous study from our group, prenatal diet quality of Hispanic women, measured using the Healthy Eating Index-2015 (HEI-2015, an *a priori* approach), was strongly correlated with country of birth.[12] These findings suggest that dietary patterns of this population are unique to cultural preferences and warrant investigation using *a posteriori* methods. Understanding how prenatal dietary intake aligns with evidence-based recommendations while also capturing culturally specific dietary patterns may be important when evaluating associations with weight-related pregnancy outcomes.

In this study, we evaluated associations of prenatal dietary intake, using the HEI-2015 (*a priori*) and principal components analysis (PCA, *a posteriori*), with measures of GWG and birthweight among a culturally diverse cohort of pregnant Hispanic women with low incomes. Given the sexual dimorphic response to the maternal environment,[13,14] we examined sex-specific differences in birthweight. We hypothesized that we would identify culturally specific *a posteriori* dietary patterns and that greater adherence to healthy dietary patterns would be associated with optimal weight-related pregnancy outcomes.

Materials and Methods

Study Population

Data were obtained from women enrolled in the Starting Early Program (StEP) Trial, a randomized controlled trial of a primary care-based child obesity prevention program beginning in pregnancy and continuing until the child reaches 3 years,[15] from 2012 to 2014. At baseline (28–32 weeks of gestation), pregnant women were recruited by trained bilingual research assistants from prenatal clinics affiliated with an urban hospital in New York City. Eligible participants self-reported their ethnicity as Hispanic/Latina, were ≥18 years of age with a singleton uncomplicated pregnancy, spoke fluent English or Spanish, and planned to continue prenatal and pediatric care at the study site. This secondary analysis includes women with plausible energy intakes during pregnancy (600–6000 kcal/day)[16] and measurements for GWG and birthweight.

Women who delivered after 34 weeks of gestation were randomized to either intervention or standard care. The standard care group received prenatal primary care visits, and the intervention group received prenatal primary care visits plus one individual breastfeeding support counseling session before delivery. Due to the timing and content, this individual session was not expected to influence weight-related pregnancy outcomes. Bellevue Hospital Center, New York City Health+Hospitals, and the Institutional Review Board of New York University Grossman School of Medicine approved this study (Clinicaltrials.gov Identifier: NCT01541761).

Dietary Assessment and Creation of Dietary Patterns

At baseline, research assistants administered the Block Food Frequency Questionnaire (FFQ) 2005 bilingual version, which queries usual dietary intake (frequency of intake and portion size) of 118 food items during the previous year. Food items are based on national dietary recall data and those relevant to Hispanic populations.[17] The Block FFQ has been validated in pregnant women to measure intakes in the previous trimester.[18] FFQs were analyzed by NutritionQuest using the USDA Food and Nutrient Database for Dietary Studies, version 1.0.[19]

A priori *method: HEI-2015.* The HEI-2015, a validated diet quality index that assesses alignment to the 2015–2020 Dietary Guidelines for Americans,[20,21] was used as an *a priori* method. The HEI-2015 uses least-restrictive standards to score nine adequacy components (higher score indicates higher intake: total fruits, whole fruits, total vegetables, greens and beans, whole grains, dairy, total protein, seafood and plant protein, and fatty acids) and four moderation components (higher score indicates lower intake: refined grains, sodium, saturated fat, and added sugars). The total score is out of 100, with a higher score indicating better alignment with guidelines. Using My Pyramid Equivalents Database food groups from the Block FFQ, total scores were calculated following the HEI-2015 Statistical Analysis Software code.[22]

A posteriori *method: PCA.* PCA was utilized as an *a posteriori* method.[10] The components derived by PCA represent different dietary patterns, and the loadings on each component describe how the original food group variables correlate with the component. To prepare dietary variables for PCA, the frequency of intake was adjusted into eight weekly (times per week) categories: 0 (never, a few times a year), 0.25 (once per month), 0.5 (2–3 times per month), 1, 2, 3.5 (3–4 times per week), 5.5 (5–6 times per week), and 7 (every day). We assumed that women who had one ($n=49$) or two ($n=4$) missing food items did not consume those items, and the frequency of intake was replaced as 0. Food items were specified by type when available (*e.g.,* whole milk, reduced fat). Daily intake of each food item was calculated as weekly frequency of intake multiplied by the quantity consumed, divided by 7 days.

Food items were aggregated into 31 food groups based on nutrient content similarity, theorized relationship with weight-related outcomes, and foods traditional to Hispanic cuisine (Supplementary Table S1). Food groups were standardized to account for the differing number of food items aggregated into each food group. A scree plot (Supplementary Fig. S1) and the interpretability of components were used to determine the number of components to select. Orthogonal varimax rotation was performed to enhance the interpretability of selected components and food group loadings. A food group loading of ≥0.25 (absolute value) was considered a strong loading, and components were labeled based on the loadings. A component score was calculated for each participant, with a higher score indicating that the pattern was more likely to be present in the diet.

Pregnancy Outcomes

Gestational weight gain. Prepregnancy weight (defined as first measured weight at ≤12 weeks of gestation) and height were abstracted from medical records. If the first measured weight was taken at >12 weeks of gestation, self-reported prepregnancy weight was used ($n = 102$, 20.4%). Prepregnancy BMI (kg/m^2) was calculated using prepregnancy weight and height. GWG was calculated by subtracting prepregnancy weight from weight at delivery (abstracted from medical records). GWG was examined as a continuous variable (kilograms, kg) and categorized according to the 2009 Institute of Medicine guidelines based on women's prepregnancy BMI status[23]: inadequate, adequate, or excessive.

Birthweight. Infant birthweight, gestational age, and sex were abstracted from medical records and used to calculate birthweight z-score based on Fenton growth curves.[24] Birthweight z-score was examined continuously and categorically as adequacy for gestational age[24]: small for gestational age (SGA; birthweight z-score ≤10th percentile), adequate for gestational age (AGA; 10th–90th percentiles), or large for gestational age (LGA; ≥90th percentile).

Covariates

Sociodemographic, cultural, and lifestyle variables were collected at baseline, including maternal age, marital status, employment, parity, highest level of education completed, and country of birth. Physical activity questions were modified from the 2011 Behavioral Risk Factor Surveillance System.[25]

Statistical Analyses

Statistical analyses were performed using Stata Version 16.1 (StataCorp LLC, College Station, TX),[26] and statistical significance was set at $p \leq 0.05$. *A priori* and *a posteriori* dietary pattern scores were categorized into tertiles based on score distribution. Associations between dietary pattern tertiles and maternal and dietary characteristics were assessed using one-way analysis of variance (ANOVA) tests and chi-squared analyses.

Bivariate relationships between *a priori* and *a posteriori* dietary pattern tertiles and measures of GWG and birthweight z-score were examined using one-way ANOVAs and chi-squared analyses. Multivariable linear regression estimated associations between *a priori* and *a posteriori* dietary pattern tertiles and GWG and birthweight z-score. Birthweight z-score was analyzed overall and stratified by infant sex. Multinomial logistic regression models estimated associations between dietary patterns and GWG adequacy and adequacy for gestational age, with the lowest dietary pattern tertile as the reference. All models were adjusted for maternal age, parity, marital status, education, prepregnancy BMI, physical activity, and total energy. Sensitivity analyses were conducted excluding women with underweight prepregnancy BMI ($n = 7$) or who delivered preterm (<37 weeks of gestation, $n = 15$), and there were no differences in statistical significance, direction, or magnitude of regression results (Supplementary Tables S2 and S3). Analyses with the full analytic sample are presented.

Results

Of the 541 women who completed the Block FFQ, 500 (92.4%) had plausible energy intakes and GWG and birthweight measurements.

Dietary Patterns

The mean total HEI-2015 score was 69.0 ± 9.4. Two distinct *a posteriori* dietary patterns were identified (Table 1) and explained 32.5% of the variation in food items consumed. The Western pattern was characterized by high positive loadings for cakes, pies, and cookies, processed meat, American mixed dishes, candy, salty snacks, and sweetened beverages. The Fruits and Vegetables pattern was characterized by high positive loadings for nonstarchy vegetables, starchy vegetables, beans and peas, meat and vegetable soups, and whole fresh fruit.

Maternal and Dietary Characteristics

Mean maternal age was 28 ± 6 years and mean prepregnancy BMI was 27.5 ± 5.5 kg/m^2 (Table 2). Around one-third of women had less than high school education, were not married, and were nulliparous, and almost 20% of women reported no physical activity. Most women were not employed and born outside of the United States, with nearly half of women born in Mexico and one-third born in other Latin American countries.

Greater adherence to the HEI-2015 *a priori* pattern and the Fruits and Vegetables *a posteriori* pattern was associated with being older and born outside the United States, while greater adherence to the Western *a posteriori* pattern was associated with being younger and US born. Greater adherence to the HEI-2015 *a priori* pattern and the Fruits and Vegetables *a posteriori* pattern was also associated with greater fiber intake, a greater percentage of

Table 1. Dietary Patterns Derived from Principal Component Analysis and Corresponding Coefficients in the Starting Early Trial, 2012–2014

Food groups	Western	Fruits and vegetables
Nonstarchy vegetables	–0.10	**0.40**
Avocado and guacamole	0.02	0.18
Starchy vegetables	0.05	**0.30**
Beans and peas	–0.03	**0.34**
Meat/vegetable soups	–0.03	**0.35**
Nuts	0.01	0.22
Whole fresh fruit	–0.04	**0.35**
Fruit/vegetable juice and canned fruit	0.17	0.11
Breads	0.23	0.03
Rice and rice dishes	0.17	0.04
Cereals	0.04	0.21
Biscuits, muffins, and breakfast grains	0.23	0.05
Cakes, pies, and cookies	**0.32**	–0.03
Pasta dishes	0.16	0.15
Red meats	0.24	0.13
Organ meats	0.08	0.15
Poultry and eggs	0.15	0.14
Seafood	0.01	0.23
Processed meats	**0.31**	–0.05
Tortillas and tortilla dishes	0.04	0.04
American dishes	**0.33**	–0.03
Plant substitutes	–0.01	0.07
Whole milk	0.15	–0.04
Reduced fat milk	–0.15	0.20
Cheese	0.09	0.11
Sweetened dairy	0.20	0.12
Bars and dieting products	0.11	0.13
Candy	**0.31**	–0.10
Unsweetened beverages	0.09	0.01
Sweetened beverages	**0.29**	–0.09
Salty snacks	**0.32**	–0.04
Explained variance, %	23.6	8.9
Cumulative variance explained, %	—	32.5

Text in bold depicts food groups that have a coefficient ≥0.25 and characterize the dietary pattern.

energy from protein, and a lower percentage of energy from added sugars, while greater adherence to the Western *a posteriori* pattern was associated with lower fiber intake, a greater percentage of energy from added sugars and saturated fat, and a lower percentage of energy from protein.

Associations With Weight-Related Pregnancy Outcomes

Mean GWG was 9.9 ± 5.4 kg; 37.6% of women had inadequate GWG and 27.0% had excessive GWG (Table 3). Mean birthweight z-score was –0.02 ± 0.9. Most infants were born AGA, with 7.0% and 7.4% born SGA or LGA, respectively. In adjusted models, there were no associations between *a priori* or *a posteriori* dietary patterns and GWG (Table 4). Women with the greatest adherence to the HEI-2015 *a priori* pattern and Fruits and Vegetables *a posteriori* pattern had infants with higher birthweight z-scores than women in the lowest tertile, but in sex-specific analyses, these associations were only evident in male infants (Table 5). In analyses of HEI-2015 individual component scores and birthweight z-score, total vegetables, greens and beans, and whole grains explained this association (Supplementary Table S4).

Discussion

Among Hispanic women with low incomes, adherence to healthy prenatal dietary patterns, HEI-2015 *a priori* pattern and Fruits and Vegetables *a posteriori* pattern was modestly positively associated with higher birthweight z-score, specifically in male infants. *A priori* and *a posteriori* dietary patterns were not associated with GWG or adequacy for gestational age. *A posteriori* patterns were related to country of birth; being born outside the United States was associated with lower adherence to the Western pattern and higher adherence to the Fruits and Vegetables pattern.

Despite suboptimal diet quality reflected by the HEI-2015, the mean HEI score was higher than what has been reported from a US national sample of pregnant women.[27] Other research using *a priori* methods found that non-White women have similar or higher prenatal diet quality than White women, which may be related to cultural factors that influence diet.[28,29] Studies using *a posteriori* methods to analyze population-specific diet in pregnancy generally reported healthy patterns, characterized by nutrient-dense foods, and unhealthy patterns, characterized by foods high in saturated fats and sugars.[7,8] Similar dietary patterns were identified in our study and were associated with country of birth, which agrees with research showing that Hispanic adults born outside the United States had greater adherence to traditional dietary patterns high in fruits, vegetables, and fiber,[30] while those born in the United States were more likely to adopt a Western dietary pattern.[31]

Table 2. Maternal and Dietary Characteristics of the Starting Early Cohort by Tertiles of Principal Component Analysis-Derived and Healthy Eating Index-2015 Adherence Scores, Starting Early Trial, 2012–2014 (N = 500)

		PCA-derived scores					
		Western[a,b]		Fruits and Vegetables[a,c]		HEI-2015[a]	
	Overall	T1	T3	T1	T3	T1	T3
n		167	166	167	166	167	166
Score	—	−1.8 ± 0.4	1.9 ± 1.5	−1.8 ± 0.5	2.2 ± 1.7	58.4 ± 4.9	79.2 ± 4.5
Maternal characteristics							
Age, years	28 ± 6	30 ± 6	27 ± 5***	27 ± 6	29 ± 6*	27 ± 6	30 ± 6***
Education							
Less than high school	168 (33.6)	67 (40.1)	49 (29.5)	70 (41.9)	47 (28.3)*	53 (31.7)	52 (31.3)
High school or greater	332 (66.4)	100 (59.9)	117 (70.5)	97 (58.1)	119 (71.7)	114 (68.3)	114 (68.7)
Employed	124 (24.8)	33 (19.8)	44 (26.5)	44 (26.3)	37 (22.3)	39 (23.4)	40 (24.1)
Marital status							
Single/separated/divorced	142 (28.4)	45 (27.0)	58 (34.9)	48 (28.7)	37 (22.3)	49 (29.3)	45 (27.1)
Legally/living as married	358 (71.6)	122 (73.1)	108 (65.1)	119 (71.3)	129 (77.7)	118 (70.7)	121 (72.9)
Country of birth							
United States	99 (19.8)	18 (10.8)	53 (31.9)***	42 (25.2)	21 (12.7)*	57 (34.1)	18 (10.8)***
Mexico	236 (47.2)	86 (51.5)	58 (34.9)	79 (47.3)	85 (51.2)	77 (46.1)	71 (42.8)
Other Latin American countries	165 (33.0)	63 (37.7)	55 (33.1)	46 (27.5)	60 (36.1)	33 (19.8)	77 (46.4)
Prepregnancy BMI, kg/m^2	27.5 ± 5.5	27.6 ± 4.8	26.9 ± 5.7	27.9 ± 5.4	27.4 ± 5.8	27.2 ± 5.5	27.9 ± 5.2
Physical activity							
None	96 (19.2)	30 (18.0)	40 (24.1)	39 (23.4)	27 (16.3)	44 (26.4)	17 (10.2)***
Yes	404 (80.8)	137 (82.0)	126 (75.9)	128 (76.7)	139 (83.7)	123 (73.7)	149 (89.8)
Nulliparous	185 (37.0)	56 (33.5)	68 (41.0)	65 (38.9)	59 (35.5)	64 (38.3)	66 (39.8)
Male infant	242 (48.4)	89 (53.3)	82 (49.4)	81 (48.5)	81 (48.8)	83 (49.7)	82 (49.4)
Dietary characteristics							
Daily total energy, kcal/day	2193 ± 973	1361 ± 389	3195 ± 894***	1606 ± 632	2935 ± 1014***	2527 ± 1069	1933 ± 761***
Carbohydrates, % energy	50.2 ± 6.1	50.9 ± 6.5	49.5 ± 6.0	51.2 ± 6.4	49.5 ± 5.6*	48.9 ± 6.6	51.3 ± 6.0***
Fiber, g/1000 kcal	10.2 ± 3.1	11.7 ± 3.7	8.7 ± 2.3***	9.5 ± 3.5	11.0 ± 2.8***	8.7 ± 3.1	11.8 ± 2.9***
Added sugars, % energy	8.8 ± 4.1	7.2 ± 3.8	10.4 ± 4.1***	10.3 ± 5.2	8.0 ± 3.3***	10.3 ± 4.9	7.1 ± 2.7***
Protein, % energy	16.6 ± 3.0	17.1 ± 3.5	16.3 ± 2.9*	15.1 ± 2.5	18.0 ± 2.8***	16.0 ± 2.8	17.6 ± 3.3***
Total fat, % energy	34.8 ± 4.8	34.1 ± 5.6	35.3 ± 4.2	35.4 ± 5.1	34.2 ± 4.4	36.2 ± 4.6	33.2 ± 4.8***
Saturated fat, % energy	10.5 ± 1.8	9.8 ± 1.8	11.1 ± 1.6***	10.6 ± 1.9	10.4 ± 1.6	11.6 ± 1.8	9.4 ± 1.5***
Monounsaturated fat, % energy	13.5 ± 2.5	13.4 ± 3.0	13.5 ± 1.9	13.8 ± 2.7	13.3 ± 2.0	13.8 ± 2.2	13.4 ± 2.9
Polyunsaturated fat, % energy	8.0 ± 2.0	8.3 ± 2.5	7.8 ± 1.5*	8.2 ± 2.5	7.8 ± 1.7	7.8 ± 1.7	7.9 ± 2.0

Values represent mean ± SD or *n* (%).

[a]Higher score indicates greater adherence to dietary pattern.

[b]Western includes high positive loadings for cakes, pies, and cookies, American mixed dishes, candy, salty snacks, sweetened beverages, and processed meat.

[c]Fruits and vegetables includes high positive loadings for nonstarchy vegetables, whole fresh fruit, meat and vegetable soups, beans and peas, and starchy vegetables.

*$p < 0.05$; ***$p < 0.0001$ (p-values were derived using one-way ANOVA for continuous variables and chi-squared test for categorical variables, comparing all three tertiles).

ANOVA, analysis of variance; HEI-2015, Healthy Eating Index-2015; PCA, principal component analysis; SD, standard deviation; T1, tertile 1 (lowest); T3, tertile 3 (highest).

Table 3. Measures of Gestational Weight Gain and Birthweight z-Score by Tertiles of Principal Component Analysis-Derived and Healthy Eating Index-2015 Adherence Scores, Starting Early Trial, 2012–2014 (N = 500)

		PCA-derived scores											
		Western				Fruits and Vegetables				HEI-2015 score			
	Overall	T1	T2	T3	p[a]	T1	T2	T3	p[a]	T1	T2	T3	p[a]
GWG, kg[b]	9.9 ± 5.4	9.8 ± 5.1	9.9 ± 5.1	10.1 ± 6.0	0.86	10.2 ± 5.2	9.8 ± 5.2	9.7 ± 5.7	0.65	10.4 ± 5.7	9.7 ± 5.2	9.6 ± 5.3	0.38
GWG adequacy[c]													
Inadequate	188 (37.6)	66 (39.5)	58 (34.7)	64 (38.6)	0.82	61 (36.5)	64 (38.3)	63 (38.0)	0.99	61 (36.5)	68 (40.7)	59 (35.5)	0.85
Adequate	177 (35.4)	55 (32.9)	65 (38.9)	57 (34.3)		59 (35.3)	58 (34.7)	60 (36.1)		58 (34.7)	58 (34.7)	61 (36.8)	
Excessive	135 (27.0)	46 (27.5)	44 (26.4)	45 (27.1)		47 (28.1)	45 (27.0)	43 (25.9)		48 (28.7)	41 (24.6)	46 (27.7)	
Birthweight, kg[b,d]	3.4 ± 0.5	3.4 ± 0.5	3.4 ± 0.5	3.3 ± 0.5	0.13	3.4 ± 0.5	3.4 ± 0.4	3.4 ± 0.5	0.71	3.3 ± 0.5	3.4 ± 0.5	3.4 ± 0.5	**0.02**
Birthweight z-score[b,d]	–0.02 ± 0.9	0.03 ± 0.9	–0.01 ± 0.8	–0.1 ± 0.8	0.48	–0.1 ± 0.9	–0.1 ± 0.8	0.1 ± 0.9	0.23	–0.2 ± 0.8	–0.004 ± 0.9	0.1 ± 0.9	**0.02**
Adequacy for GA[c,d]													
SGA	35 (7.0)	13 (7.8)	11 (6.6)	11 (6.7)	0.45	14 (8.4)	13 (7.8)	8 (4.8)	0.09	14 (8.4)	11 (6.6)	10 (6.1)	0.84
AGA	426 (85.5)	141 (84.9)	139 (83.2)	146 (88.5)		141 (84.9)	146 (87.9)	139 (83.7)		142 (85.5)	142 (85.0)	142 (86.1)	
LGA	37 (7.4)	12 (7.2)	17 (10.2)	8 (4.9)		11 (6.6)	7 (4.2)	19 (11.5)		10 (6.1)	14 (8.4)	13 (7.9)	

[a] *p*-Values were derived using one-way ANOVA for continuous variables and chi-squared test for categorical variables, comparing all three tertiles (bolded values indicate $p < 0.05$).

[b] Values represent mean ± SD.

[c] Values represent *n* (%).

[d] N = 498.

AGA, adequate for gestational age; GA, gestational age; GWG, gestational weight gain; LGA, large for gestational age; SGA, small for gestational age; T2, tertile 2.

Table 4. Associations of Maternal Dietary Patterns With Measures of Gestational Weight Gain and Birthweight, Starting Early Trial, 2012–2014

		PCA-derived scores		
		Western	Fruits and vegetables	HEI-2015 total score
Measures of GWG		**β (95% CI)[a]**	**β (95% CI)[a]**	**β (95% CI)[a]**
GWG, kg[b]	T1	Ref.	Ref.	Ref.
	T2	0.7 (–0.6 to 1.9)	–0.4 (–1.5 to 0.8)	–0.6 (–1.7 to 0.5)
	T3	1.3 (–0.5 to 3.0)	0.1 (–1.5 to 1.3)	–0.6 (–1.8 to 0.6)
		OR (95% CI)[a]	**OR (95% CI)[a]**	**OR (95% CI)[a]**
GWG adequacy[b]				
Inadequate weight gain	T1	Ref.	Ref.	Ref.
	T2	0.7 (0.4 to 1.3)	1.1 (0.6 to 1.8)	1.1 (0.7 to 1.9)
	T3	0.8 (0.4 to 1.8)	1.1 (0.6 to 2.1)	1.0 (0.6 to 1.8)
Excessive weight gain	T1	Ref.	Ref.	Ref.
	T2	0.9 (0.5 to 1.6)	1.1 (0.6 to 1.9)	0.8 (0.5 to 1.5)
	T3	1.2 (0.5 to 3.0)	1.1 (0.5 to 2.2)	0.9 (0.5 to 1.6)
Birthweight measures		**β (95% CI)[a]**	**β (95% CI)[a]**	**β (95% CI)[a]**
Birthweight z-score[c]	T1	Ref.	Ref.	Ref.
	T2	0.005 (–0.2 to 0.2)	0.1 (–0.1 to 0.3)	0.1 (–0.1 to 0.3)
	T3	0.03 (–0.3 to 0.3)	**0.3 (0.1 to 0.5)***	**0.2 (0.04 to 0.4)***
		OR (95% CI)[a]	**OR (95% CI)[a]**	**OR (95% CI)[a]**
Adequacy for gestational age[c]				
SGA	T1	Ref.	Ref.	Ref.
	T2	0.7 (0.3 to 1.8)	0.8 (0.3 to 1.8)	0.8 (0.3 to 1.8)
	T3	0.6 (0.1 to 2.4)	0.4 (0.1 to 1.2)	0.6 (0.3 to 1.6)
LGA	T1	Ref.	Ref.	Ref.
	T2	1.2 (0.5 to 3.0)	0.6 (0.2 to 1.8)	1.3 (0.6 to 3.3)
	T3	0.5 (0.1 to 2.1)	2.3 (0.9 to 6.2)	1.1 (0.4 to 2.7)

[a]All models are adjusted for maternal age (years), parity, marital status, education, prepregnancy BMI (kg/m^2), physical activity, and total energy (kilocalories).

[b]$N = 500$.

[c]$N = 498$; calculated from infant birthweight, gestational age, and sex based on Fenton growth curves.

*$p < 0.05$.

CI, confidence interval; Ref., reference group.

Although some food groups that were created to represent traditional Hispanic cuisine did not load strongly on either dietary pattern (*e.g.,* rice dishes, tortilla dishes), the Fruits and Vegetables pattern included several foods common in Hispanic cuisine, including nonstarchy and starchy vegetables, whole fruits, beans and peas, and meat and vegetable soups (*e.g.,* menudo, posole). In urban settings, such as that of the current study, Hispanic adults born outside the United States may reside in neighborhoods that provide greater access to culturally preferred whole foods,[32] which may preserve nutrient-dense dietary patterns.

Associations between prenatal dietary patterns and GWG are mixed. A systematic review and meta-analysis including studies with *a priori* and *a posteriori* methods found that high adherence to healthy dietary patterns was weakly associated with greater GWG, but there was no association between unhealthy dietary patterns and GWG.[7] In the current study, dietary patterns were not associated with GWG. However, mean GWG was lower in

Table 5. Associations of Maternal Dietary Patterns With Birthweight z-Score by Infant Sex, Starting Early Trial, 2012–2014

		PCA-derived scores				HEI-2015 total score	
		Western		Fruits and vegetables			
		Male	Female	Male	Female	Male	Female
		β (95% CI)[a]	β (95% CI)[a]	β (95% CI)[a]	β (95% CI)[a]	β (95% CI)[a]	β (95% CI)[a]
Birthweight z-score[b]	T1	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
	T2	0.07 (–0.3 to 0.3)	–0.05 (–0.3 to 0.2)	0.03 (–0.3 to 0.3)	0.1 (–0.1 to 0.4)	0.2 (–0.09 to 0.5)	0.1 (–0.2 to 0.3)
	T3	–0.02 (–0.5 to 0.4)	0.1 (–0.3 to 0.5)	**0.4 (0.03 to 0.7)***	0.2 (–0.1 to 0.5)	**0.3 (0.03 to 0.6)***	0.1 (–0.1 to 0.4)

[a]All models are adjusted for maternal age (years), parity, marital status, education, prepregnancy BMI (kg/m^2), physical activity, and total energy (kilocalories).

[b]$N = 498$; calculated from infant birthweight, gestational age and sex based on Fenton growth curves.

*$p < 0.05$.

our sample,[33] with higher rates of inadequate GWG and lower rates of excessive GWG, than national averages and other US Hispanic cohorts,[33,34] which may have limited our ability to detect an association. Although factors contributing to lower GWG are unclear, women were from households with lower incomes,[35] lived in an urban environment where walking and public transit are common, and may have experienced other social, cultural, environmental, and financial factors that influenced GWG.[35]

Two meta-analyses concluded that healthy dietary patterns were associated with higher birthweight, while associations for unhealthy dietary patterns were mixed.[7,8] Healthy dietary patterns may increase the supply of nutrients needed for optimal fetal growth,[36] which is supported by our findings that total vegetables, dark greens and beans, and whole grains explained the relationship between the HEI pattern and birthweight z-score. Greater adherence to healthy patterns was also characterized by high intakes of protein, which has been positively associated with fat-free mass in children.[37] A previous study found that the HEI-2015 score was inversely associated with infant fat mass at 6 months,[38] suggesting that higher birthweight may be attributed to gains in fat-free mass, rather than adiposity.[39]

However, the relationship between the Fruits and Vegetables pattern and birthweight z-score may partly reflect an association with total intake, as greater adherence to the Fruits and Vegetables pattern was associated with higher energy intake. The associations between dietary patterns and birthweight z-score were only evident in male infants. Differences in fetal growth by infant sex are documented, with research showing that males are heavier than females and may have more efficient placentas,[40–42] but sex-specific associations between dietary patterns and birthweight are inconsistent or not investigated in other studies.[43,44]

Strengths of this study include the use of *a priori* and *a posteriori* methods to examine associations between prenatal dietary intake and perinatal outcomes. The *a priori* method measured alignment to evidence-based dietary guidelines,[45] while the *a posteriori* method revealed cohort-specific food consumption patterns. This study also had limitations. A single FFQ was used to assess diet, which relied on the memory of usual food intake over the past year, and may not reflect dietary changes made during pregnancy. The HEI was not constructed for pregnancy and may not adequately account for dietary components that contribute to weight-related pregnancy outcomes. Although *a posteriori* dietary components were created using frequencies and quantities from the FFQ, scores were not calculated based on energy density; thus, despite adjusting models for energy intake, higher *a posteriori* scores may partly reflect total intake.

For women without a measured weight at ≤12 weeks of gestation, we used self-report to capture prepregnancy weight. We also used self-report to measure physical activity, which limited our ability to determine meaningful categories of physical activity or calculate intensity. Finally, our cohort of pregnant Hispanic women with low incomes, in an urban environment, and with lower GWG than other US Hispanic cohorts may not be generalizable to other Hispanic populations.

Conclusions

Among pregnant Hispanic women with low incomes, those born outside the United States had a greater adherence to healthy dietary patterns. There were no associations between dietary patterns and measures of GWG or adequacy for gestational age. Greater adherence to healthy dietary patterns was modestly associated with increased birthweight z-score, with sex-specific associations evident only in male infants. These findings are consistent with previous studies in diverse populations, suggesting that healthy prenatal dietary patterns are positively associated with fetal growth. Future studies with larger sample sizes are needed to further investigate associations with clinically relevant birth outcomes, such as adequacy for gestational age.

Impact Statement

Among a cohort of culturally diverse Hispanic women, adherence to healthy dietary patterns during pregnancy was modestly associated with increased birthweight, with sex-specific associations evident only in male infants. These findings contribute to the growing literature that suggests that healthy prenatal dietary patterns are positively associated with fetal growth.

Acknowledgments

We would like to thank the StEP staff and study participants. Portions of this article were previously posted as part of a dissertation on ProQuest (ProQuest No. 13880601; Available at: http://ezproxy.med.nyu.edu/login?qurl=https%3A%2F%2Fwww.proquest.com%2Fdissertations-theses%2Fprenatal-diet-quality-low-income-hispanic-women%2Fdocview%2F2243809994%2Fse-2%3Faccountid%3D35139).

Authors' Contributions

L.T.B. conducted statistical analyses and wrote the article. M.J.M. and R.S.G. designed and conducted the StEP research study. A.L.D., K.W., M.J.M., and R.S.G. contributed to critical discussions and revisions to the article, and all authors reviewed and approved the final article.

Funding Information

This study was supported by the National Institute of Food and Agriculture, the United States Department of Agriculture (Award: 2011-68001-30207), and the Eunice Kennedy Shriver National Institute of Child Health and Human Development (K23HD081077, PI: Rachel S. Gross). Dr. Lauren T. Berube is supported by grant T32HP22238 from the Health Resources and Services Administration.

Author Disclosure Statement

No competing financial interests exist.

Supplementary Material

Supplementary Figure S1
Supplementary Table S1
Supplementary Table S2
Supplementary Table S3
Supplementary Table S4

References

1. Voerman E, Santos S, Patro Golab B, et al. Maternal body mass index, gestational weight gain, and the risk of overweight and obesity across childhood: An individual participant data meta-analysis. PLoS Med 2019;16(2):e1002744; doi: 10.1371/journal.pmed.1002744
2. Woo Baidal JA, Locks LM, Cheng ER, et al. Risk factors for childhood obesity in the first 1,000 days: A systematic review. Am J Prev Med 2016;50(6):761–779; doi: 10.1016/j.amepre.2015.11.012
3. International Weight Management in Pregnancy Collaborative Group. Effect of diet and physical activity based interventions in pregnancy on gestational weight gain and pregnancy outcomes: Meta-analysis of individual participant data from randomised trials. BMJ 2017;358:j3119; doi: 10.1136/bmj.j3119
4. Skinner AC, Ravanbakht SN, Skelton JA, et al. Prevalence of obesity and severe obesity in US children, 1999–2016. Pediatrics 2018;141(3):e20173459; doi: 10.1542/peds.2017-3459
5. Ogden CL, Fryar CD, Hales CM, et al. Differences in obesity prevalence by demographics and urbanization in US children and adolescents, 2013–2016. JAMA 2018;319(23):2410–2418; doi: 10.1001/jama.2018.5158
6. Ogden CL, Carroll MD, Fakhouri TH, et al. Prevalence of obesity among youths by household income and education level of head of household—United States 2011–2014. MMWR Morb Mortal Wkly Rep 2018;67(6):186–189; doi: 10.15585/mmwr.mm6706a3
7. Abdollahi S, Soltani S, de Souza RJ, et al. Associations between maternal dietary patterns and perinatal outcomes: A systematic review and meta-analysis of cohort studies. Adv Nutr 2021;12(4):1332–1352; doi: 10.1093/advances/nmaa156
8. Chia AR, Chen LW, Lai JS, et al. Maternal dietary patterns and birth outcomes: A systematic review and meta-analysis. Adv Nutr 2019;10(4):685–695; doi: 10.1093/advances/nmy123
9. Burggraf C, Teuber R, Brosig S, et al. Review of a priori dietary quality indices in relation to their construction criteria. Nutr Rev 2018;76(10):747–764; doi: 10.1093/nutrit/nuy027
10. Kant AK. Dietary patterns and health outcomes. J Am Diet Assoc 2004;104(4):615–635; doi: 10.1016/j.jada.2004.01.010
11. Tucker KL. Dietary patterns, approaches, and multicultural perspective. Appl Physiol Nutr Metab 2010;35(2):211–218; doi: 10.1139/H10-010
12. Thomas Berube L, Messito MJ, Woolf K, et al. Correlates of prenatal diet quality in low-income Hispanic women. J Acad Nutr Diet 2019;119(8):1284–1295; doi: 10.1016/j.jand.2019.02.004
13. Tarrade A, Panchenko P, Junien C, et al. Placental contribution to nutritional programming of health and diseases: Epigenetics and sexual dimorphism. J Exp Biol 2015;218(Pt 1):50–58; doi: 10.1242/jeb.110320
14. Dearden L, Bouret SG, Ozanne SE. Sex and gender differences in developmental programming of metabolism. Mol Metab 2018;15:8–19; doi: 10.1016/j.molmet.2018.04.007
15. Gross RS, Mendelsohn AL, Gross MB, et al. Randomized controlled trial of a primary care-based child obesity prevention intervention on infant feeding practices. J Pediatr 2016;174:171–177.e172; doi: 10.1016/j.jpeds.2016.03.060
16. Yisahak SF, Mumford SL, Grewal J, et al. Maternal diet patterns during early pregnancy in relation to neonatal outcomes. Am J Clin Nutr 2021;114(1):358–367; doi: 10.1093/ajcn/nqab019
17. NutritionQuest. Questionnaires and Screening; 2014. Available from: https://nutritionquest.com/assessment/list-of-questionnaires-and-screeners/ [Last accessed: August 1, 2016].

18. Johnson BA, Herring AH, Ibrahim JG, et al. Structured measurement error in nutritional epidemiology: Applications in the Pregnancy, Infection, and Nutrition (PIN) Study. J Am Stat Assoc 2007;102(479):856–866; doi: 10.1198/016214506000000771
19. United States Department of Agriculture, Agricultural Research Service. USDA Food and Nutrient Database for Dietary Studies, 1.0. Agricultural Research Service, Food Surveys Research Group: Beltsville, MD; 2004.
20. Krebs-Smith SM, Pannucci TE, Subar AF, et al. Update of the Healthy Eating Index: HEI-2015. J Acad Nutr Diet 2018;118(9): 1591–1602; doi: 10.1016/j.jand.2018.05.021
21. Reedy J, Lerman JL, Krebs-Smith SM, et al. Evaluation of the Healthy Eating Index-2015. J Acad Nutr Diet 2018;118(9):1622–1633; doi: 10.1016/j.jand.2018.05.019
22. National Cancer Institute. SAS Code; 2018. Available from: https://epi.grants.cancer.gov/hei/sas-code.html [Last accessed: August 1, 2019].
23. Institute of Medicine (US) and National Research Council Committee to Reexamine IOM Pregnancy Weight Guidelines. The National Academies Collection: Reports Funded by National Institutes of Health. In: Weight Gain During Pregnancy: Reexamining the Guidelines. (Rasmussen KM, Yaktine AL. eds.). National Academies Press (US) and National Academy of Sciences: Washington, DC; 2009.
24. Fenton TR, Kim JH. A systematic review and meta-analysis to revise the Fenton growth chart for preterm infants. BMC Pediatr 2013;13:59; doi: 10.1186/1471-2431-13-59
25. Centers for Disease Control and Prevention Division of Nutrition, Physical Activity, and Obesity. A Data Users Guide to the BRFSS Physical Activity Questions: How to Assess the 2008 Physical Activity Guidelines for Americans. CDC: Atlanta, GA; 2011.
26. STATA Data Analysis and Statistical Software [Computer Program]. Version 15.0. StataCorp: College Station, TX; 2018.
27. Shin D, Lee KW, Song WO. Pre-pregnancy weight status is associated with diet quality and nutritional biomarkers during pregnancy. Nutrients 2016;8(3):162; doi: 10.3390/nu8030162
28. Laraia BA, Bodnar LM, Siega-Riz AM. Pregravid body mass index is negatively associated with diet quality during pregnancy. Public Health Nutr 2007;10(9):920–926; doi: 10.1017/s13689800 07657991
29. Deierlein AL, Ghassabian A, Kahn LG, et al. Dietary quality and sociodemographic and health behavior characteristics among pregnant women participating in the New York University Children's Health and Environment Study. Front Nutr 2021;8:639425; doi: 10.3389/fnut.2021.639425
30. Harley K, Eskenazi B, Block G. The association of time in the US and diet during pregnancy in low-income women of Mexican descent. Paediatr Perinat Epidemiol 2005;19(2):125–134; doi: 10.1111/j.1365-3016.2005.00640.x
31. Sofianou A, Fung TT, Tucker KL. Differences in diet pattern adherence by nativity and duration of US residence in the Mexican-American population. J Am Diet Assoc 2011;111(10): 1563–1569.e1562; doi: 10.1016/j.jada.2011.07.005
32. Zhang D, van Meijgaard J, Shi L, et al. Does neighbourhood composition modify the association between acculturation and unhealthy dietary behaviours? J Epidemiol Community Health 2015;69(8):724–731; doi: 10.1136/jech-2014-203881
33. Deierlein AL, Messito MJ, Katzow M, et al. Total and trimester-specific gestational weight gain and infant anthropometric outcomes at birth and 6 months in low-income Hispanic families. Pediatr Obes 2020;15(3):e12589; doi: 10.1111/ijpo.12589
34. Centers for Disease Control and Prevention. Reproductive health. Weight gain during pregnancy; 2022. Available from: https://www.cdc.gov/reproductivehealth/maternalinfanthealth/pregnancy-weight-gain.htm [Last accessed: February 22, 2023].
35. Arzhang P, Ramezan M, Borazjani M, et al. The association between food insecurity and gestational weight gain: A systematic review and meta-analysis. Appetite 2022;176:106124; doi: 10.1016/j.appet.2022.106124
36. Lowensohn RI, Stadler DD, Naze C. Current concepts of maternal nutrition. Obstet Gynecol Surv 2016;71(7):413–426; doi: 10.1097/ogx.0000000000000329
37. Tielemans MJ, Steegers EAP, Voortman T, et al. Protein intake during pregnancy and offspring body composition at 6 years: The Generation R Study. Eur J Nutr 2017;56(6):2151–2160; doi: 10.1007/s00394-016-1255-4
38. Tahir MJ, Haapala JL, Foster LP, et al. Higher maternal diet quality during pregnancy and lactation is associated with lower infant weight-for-length, body fat percent, and fat mass in early postnatal life. Nutrients 2019;11(3):632; doi: 10.3390/nu11030632
39. Gallagher D, Rosenn B, Toro-Ramos T, et al. Greater neonatal fat-free mass and similar fat mass following a randomized trial to control excess gestational weight gain. Obesity (Silver Spring) 2018;26(3):578–587; doi: 10.1002/oby.22079
40. Eriksson JG, Kajantie E, Osmond C, et al. Boys live dangerously in the womb. Am J Hum Biol 2010;22(3):330–335; doi: 10.1002/ajhb.20995
41. Roland MC, Friis CM, Godang K, et al. Maternal factors associated with fetal growth and birthweight are independent determinants of placental weight and exhibit differential effects by fetal sex. PLoS One 2014;9(2):e87303; doi: 10.1371/journal.pone.0087303
42. Thornburg KL, Marshall N. The placenta is the center of the chronic disease universe. Am J Obstet Gynecol 2015;213(4 Suppl): S14–S20; doi: 10.1016/j.ajog.2015.08.030
43. Raghavan R, Dreibelbis C, Kingshipp BL, et al. Dietary patterns before and during pregnancy and birth outcomes: A systematic review. Am J Clin Nutr 2019;109(Suppl 7):729s–756s; doi: 10.1093/ajcn/nqy353
44. Raghavan R, Dreibelbis C, Kingshipp BL, et al. Dietary patterns before and during pregnancy and maternal outcomes: A systematic review. Am J Clin Nutr 2019;109(Suppl 7):705s–728s; doi: 10.1093/ajcn/nqy216
45. Morze J, Danielewicz A, Hoffmann G, et al. Diet quality as assessed by the healthy eating index, alternate healthy eating index, dietary approaches to stop hypertension score, and health outcomes: A second update of a systematic review and meta-analysis of cohort studies. J Acad Nutr Diet 2020;120(12):1998–2031.e1915; doi: 10.1016/j.jand.2020.08.076

Address correspondence to:
Lauren T. Berube, PhD, MS, RDN
Department of Population Health
New York University Grossman School of Medicine
180 Madison Avenue, 7th Floor
New York, NY 10016
USA

E-mail: lauren.thomas@nyulangone.org