Matern Child Health J (2016) 20:2527–2538
DOI 10.1007/s10995-016-2078-x

Dietary Patterns During Pregnancy are Associated with Gestational Weight Gain

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Published online: 25 July 2016

Abstract *Objective* The role of diet during pregnancy on gestational weight gain is unclear. This study aimed to evaluate the hypothesis that dietary patterns during pregnancy are differentially associated with the adequacy of gestational weight gain at different stages of pregnancy. *Methods* A total of 391 pregnant women in National Health and Nutrition Examination Survey (NHANES) 2003–2006 were included. Dietary intake was obtained using a National Cancer Institute's food-frequency questionnaire. *Results* Three dietary patterns were identified by factor analysis with 36 food groups among pregnant women, and they were named according to food group factor loadings: 'mixed', 'healthy', and 'western'. The 'mixed' pattern characterized by a high intake of meat, dairy products, fruits, vegetables, potatoes, nuts and seeds and sweets. After adjusting for maternal sociodemographic variables and physical activity level, women in the highest tertile of 'mixed' pattern score had significantly greater odds of being in the inadequate gestational weight gain compared to those in the lowest tertile (adjusted odds ratio (AOR) 4.72; 95 % CI 1.07–20.94). Women in the mid tertile of the 'mixed' pattern had significantly lower odds of being in the excessive gestational weight gain compared to those in the lowest tertile (AOR 0.39; 95 % CI 0.15–0.99). *Conclusion* These results suggest that a diet high in meat, dairy products, fruits, vegetables, potatoes, and nuts and seeds during pregnancy might be associated with reducing excessive gestational weight gain.

Keywords Dietary patterns · Gestational weight gain · Pregnancy · Factor analysis

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Significance

What is already known about this topic? In 2009, the Institute of Medicine published gestational weight gain guidelines for how much a pregnant woman should gain during pregnancy to optimize health outcomes for both the mother and offspring (Institute of Medicine, 2009). However, these guidelines focused on ranges of weight gain that women need to achieve during pregnancy without offering dietary recommendations on how to gain weight. It is of great importance to cross-examine dietary patterns during pregnancy and the adequacy of gestational weight gain for providing dietary recommendations to help pregnant women to achieve recommended gestational weight gain.

What does this study add? Three dietary patterns during pregnancy were identified: 'mixed', 'healthy', and 'western'. Overall, 'mixed' dietary patterns during pregnancy characterized by a high consumption of dairy products, fruit drinks, fruits, vegetables, legumes, meat, nuts and seeds, snacks and sweets was inversely associated with excessive gestational weight gain after controlling for maternal sociodemographic variables, prepregnancy BMI, and physical activity. These results suggest that a diet high in meat, dairy products, fruits, vegetables, potatoes, and nuts and seeds during pregnancy may be associated with reducing excessive gestational weight gain.

Introduction

Health outcomes for both the mother and the offspring have been associated with the amount of weight gain during pregnancy. Specifically, excessive gestational weight gain has been associated with gestational diabetes mellitus (Hedderson et al. 2010; Shin and Song 2015), pregnancy-induced hypertension (Li et al. 2013), preeclampsia (Liu et al. 2015), large-for-gestational-age infants (Ferraro et al. 2012), cesarean section (Langford et al. 2011), postpartum hemorrhage (Zhang et al. 2015), postpartum weight retention at 1 year (Vesco et al. 2009), and child adiposity at age 3 years (Oken et al. 2007). Using the 2006–2012 birth certificate data from the Ohio Department of Health (Chen et al. 2015), of 869,531 pregnancies, more than half of normal weight, 70 % of overweight, and 60 % of obese women before pregnancy had gestational weight gain beyond the Institute of Medicine's 2009 guidelines (Institute of Medicine 2009). This increasing number of pregnant women gaining excessive gestational weight gain and its subsequent adverse health consequences on the mother and offspring provide the need to reduce the number of women achieving excessive gestational weight gain. Preventing excessive gestational weight gain to optimize maternal, fetal, and infant health outcomes is of great importance.

A randomized study of 232 pregnant women examined nutritional counseling with or without nutritional monitoring in relation to gestational weight gain (Thornton et al. 2009). The group with the additional nutritional monitoring intervention had a significantly lower mean gestational weight gain compared to the group without nutritional monitoring (mean difference −9.07, 95 % confidence interval [CI] −10.90 to −7.24). A systematic review was conducted to evaluate the effect of modifiable risk factor for excessive gestational weight gain in pregnant women through interventions (Skouteris et al. 2010). Among ten intervention studies that focused on behavioral changes including physical activity and/or diet to reduce excessive gestational weight gain, six studies reported significantly less gestational weight gain in the intervention groups compared to the control groups, and only three studies showed that women in the intervention group were more likely to achieve gestational weight gain within the recommendation. However, due to different study populations with the high collinearity among lifestyle factors including physical activity, diet, comorbidities, medications and sociodemographic variables, the independent role of dietary factors in relation to gestational weight gain remains unclear.

Dietary pattern analysis provides a unique opportunity in terms of they account for synergetic effects of combinations in foods and nutrients instead of identifying individual nutrients or foods (Hu 2002). Dietary pattern approaches provide a broader picture of food and nutrient consumption and may be more predictive of health outcomes than individual foods or nutrients (Hu 2002). In a population-based cohort of the Generation R study (Tielemans et al. 2015), dietary patterns during pregnancy derived by principal component analysis were examined in relation to gestational weight gain. Women in the highest quartile scores on the "margarine, sugar and snacks" pattern was associated with gaining excessive gestational weight gain compared to women in the lowest quartile (odds ratio (OR) 1.45; 95 % CI 1.06–1.99). The prospective Norwegian Mother and Child Cohort Study (Hillesund et al. 2014) evaluated the associations of dietary patterns during pregnancy measured by the New Nordic Diet score with gestational weight gain. Adherence to the New Nordic Diet includes a large consumption of fruits and vegetables, whole grains, potatoes and fish during pregnancy. Women of prepregnancy BMI <25 kg/m^2 in the highest tertile of the New Nordic Diet score were associated with lower risk of gaining excessive gestational weight gain (OR 0.93; 95 % CI 0.87–0.99) compared to women in the lowest tertile of the New Nordic Diet score. We previously examined the diet quality during pregnancy assessed by the Healthy Eating Index-2005 (HEI-2005) in relation to the adequacy of gestational weight gain in the NHANES 2003–2006 (Shin et al. 2014). In this study, the HEI-2005 was not significantly associated with the adequacy of gestational weight gain. The independent role of dietary patterns during pregnancy in relation to gestational weight gain may not be established due to inconsistent and scattered findings. We hypothesized that dietary patterns during pregnancy are differentially associated with the adequacy of gestational weight gain.

Methods

Study Population

Data from the NHANES 2003–2006 represented the total civilian, non-institutionalized population in the U.S. for those years. The NHANES is a program of studies cross-sectionally designed to assess the health and nutritional status of civilian, non-institutionalized population in the U.S. conducted by the National Center for Health Statistics (NCHS), Centers for Disease Control and Prevention (CDC). The NHANES uses a stratified multistage

Table 1 Recommended gestational weight gain by prepregnancy BMI and month of pregnancy. *Source* N.C. Department of Health and Human Services; Women's and Children's Health Section. Prenatal weight gain chart. *Adapted from* Institute of Medicine, 2009. Weight gain during pregnancy: reexamining the guidelines. Washington, DC. National Academies Press; Committee to Reexamine IOM Pregnancy Guidelines (Institute of Medicine 2009)

Prepregnancy BMI (kg/m^2)	Month									
	1	2	3	4	5	6	7	8	9	10
Underweight (<18.5)										
Min (lbs)	0.4	1.2	2.2	5.0	9.0	13.0	17.0	20.0	24.0	28.0
Max (lbs)	1.2	3.6	6.6	10.0	15.0	20.0	25.0	30.0	35.0	40.0
Normal weight (18.5–24.9)										
Min (lbs)	0.4	1.2	2.2	5.0	8.0	11.0	15.0	18.0	22.0	25.0
Max (lbs)	1.2	3.6	6.6	10.0	14.0	18.0	22.0	27.0	31.0	35.0
Overweight (25.0–30)										
Min (lbs)	0.4	1.2	2.2	4.0	6.0	7.0	9.0	11.0	13.0	15.0
Max (lbs)	1.2	3.0	6.6	9.0	11.0	14.0	17.0	20.0	22.0	25.0
Obese (≥30)										
Min (lbs)	0.2	0.6	1.1	2.0	4.0	5.0	7.0	8.0	10.0	11.0
Max (lbs)	0.6	2.4	4.4	6.0	8.0	11.0	13.0	15.0	18.0	20.0

probability sample that was based on the selection of counties, blocks, households, and finally persons within households. NHANES 2003–2006 was conducted in 2-year cycles. For the purpose of the current study, we pooled data for all 4 years to obtain a maximal sample size of pregnant women. The NHANES 2003–2006 dataset was used for the present study as the survey during those years oversampled pregnant women of all ages from the U.S. representative population (Centers for Disease Control and Prevention, & National Center for Health Statistics 2009). The NHANES survey is unique in that it combines interviews and physical examinations. The participants were interviewed for the information of age, race/ethnicity, education level, marital status, family poverty income ratio, parity, month of pregnancy and physical activity. Reproductive health interviews obtained information on month of gestation at the time of the survey. Pregnancy status was based on a positive urine pregnancy test.

The 2003–2006 NHANES dataset included 674 pregnant women. Subjects were excluded if they had missing data of measured weight (n = 88), self-reported prepregnancy weight (n = 3), gestational age in month (n = 108), and daily food frequency responses (n = 84). The final analytic sample size was 391 pregnant women. With NHANES survey data set, instead of deleting participants due to missing information (42 %), we used a domain analysis with the appropriate sample weight in survey procedures as recommended by National Center Health Statistics (Centers for Disease Control and Prevention, & National Center for Health Statistics 2014). The suggested procedure allows us to analyze correctly the survey data of subpopulations. By using subpopulation (or domain) analysis, the findings are generalizable to the population level.

Dietary Assessment

In the NHANES 2003–2006, a food frequency questionnaire (FFQ) was administered to participants older than 2 years who provided at least one 24-h dietary recall, in order to collect information on the frequency of food consumption during the past 12 months. The FFQ was developed by National Cancer Institute based on a 216-item food frequency instrument without portion size information (Subar et al. 2006). Participants were asked to choose from eleven possible frequency responses, ranging from never to six or more times per day, for each food. The selected frequency category for each food item is converted to a daily intake based on algorithms within Diet*Calc software (Centers for Disease Control and Prevention, & National Center for Health Statistics 2008). For example, a response of '1 time per week' is converted to 0.14 times per day.

Outcome Variable

Gestational weight gain was calculated by subtracting the self-reported prepregnancy weight from the measured weight at the specific month of pregnancy (1–10 months) during the survey. Adequacy of gestational weight gain status (inadequate, adequate, excessive gain) was determined by comparing the actual gestational weight gain of each pregnant woman in reference to the Institute of Medicine's 2009 gestational weight gain guidelines by using the self-reported prepregnancy weight status (underweight, normal, overweight, obese) (Table 1). The inadequate gestational weight gain status group consisted of pregnant women whose gestational weight gain was less than the minimum recommended weight gain for the month of pregnancy for each prepregnancy weight status. The adequate gestational weight gain status group consisted of pregnant women whose gestational weight gain was between the minimum and maximum recommended gestational weight gain. The excessive gestational weight gain status group consisted of pregnant women whose gestational weight gain exceeded the maximum recommended gestational weight gain.

Covariates

Analyses were adjusted for prepregnancy BMI, maternal age, race/ethnicity, family poverty income ratio, education, marital status, parity, and physical activity. Prepregnancy BMI (kg/m^2) was categorized into four groups (<18.5, 18.5–24.9, 25–29.9, ≥30). Maternal age was divided into three groups (≤24, 25–34, ≥35 years). The study group consists of Mexican–American or other Hispanic, non-Hispanic White, non-Hispanic Black, or other races. Family poverty income ratio was divided into three categories (≤1.85, 1.85–4, >4). Maternal education was grouped by the number of completed years of school (≤11th grade, high school grade, ≥ college). Marital status was divided into three groups (married, widowed/divorced/separated/living with partner, single). Parity was divided into three groups (none, 1–3, ≥4). Physical activity was divided into three groups (0 to <500, 500 to <1,000, ≥1,000 MET-min/week).

Statistical Analyses

To extract dietary patterns, data analysis was performed in two steps. In the first step, we reduced the number of food items in the FFQ from 216 individual items to 36 predefined food groups (Table 2), which are comparable with the grouping schemes reported in the Food Patterns Equivalents Database (FPED) (Bowman et al. 2014). In the second step, dietary pattern analysis was derived using factor analysis of 36 food groups (Expressed as frequency of consumption per day). We conducted the analysis using the PROC FACTOR procedure in SAS software (version 9.3; SAS Institute, Cary, NC). Scree plots and the interpretability of each component were also used to determine the appropriate number of components to select. Varimax rotation was employed to aid the interpretation of components. Each component describes a dietary pattern and the linear combination allows the calculation of a component score for each pregnant woman; the higher the score, the more likely this pattern is present in an individual's diet. The patterns described by each component may be interpreted by its factor loadings, which are the correlations between the component and each input variable. Large positive or negative factor loadings indicate the foods that are important in that component; loadings with magnitude of at least 0.2 were considered when describing dietary patterns. The proportion of variance explained by each dietary pattern was calculated by dividing the sum of the squares of the respective factor loadings by the number of food groups. All individuals received a factor score for each pattern calculated by summing the intakes of food groups weighted by their factor loadings.

For all dietary patterns, we calculated adjusted ORs for inadequate or excessive gestational weight gain across dietary pattern score tertiles, with the lowest tertile as the reference using multivariable logistic regression after controlling for covariates. To analyze the magnitude of collinearity among covariates, the variance inflation factor (VIF) were used to test with VIF <5 set as the acceptable level (O'Brien 2007). We calculated *P* for trend by modeling the dietary pattern score as a continuous variable. SAS-callable SUDAAN were used to account for the stratified, multi-stage probability design used in the NHANES 2003–2006. Appropriate sample weights were applied in all statistical analyses to produce estimates of means and percentiles that can be generalized to the healthy U.S. adult population. All analyses were carried out using SAS software (version 9.3; SAS Institute, Cary, NC). All tests were set at the 0.05 level of significance.

Results

The final study consisted of 391 pregnant women. Table 3 shows the maternal characteristics according to the adequacy of gestational weight gain. Women in the excessive gestational weight gain group were more likely to be non-Hispanic white and overweight before pregnancy. Women in the inadequate gestational weight gain group were more likely to be underweight prior to pregnancy. Multicollinearity between age, race/ethnicity, family poverty income ratio, education, marital status, parity number, trimester of pregnancy, prepregnancy weight status, and physical activity did not exist. The VIF for the confounding variables ranged from 1.1 to 1.9.

Three dietary patterns were identified among the pregnant women, and they were named according to food group factor loadings on them as 'mixed', 'healthy', and 'western'. The 36 food groups with factor loading values on the dietary patterns are presented in Table 4. 'Mixed' pattern was characterized by high loadings of added sugar, butter, cheese, cold breakfast cereals, cured meat, dairy products, fruit drinks, fruits, vegetables, high-energy drinks, legumes, nuts and seed, pizza, potatoes, poultry, refined and whole grains, salad dressings, seafood, and snacks. The 'healthy' pattern was characterized by the consumption of

Table 2 Thirty-six pre-defined food groups to extract dietary patterns

#	Food groups	Food items
1	Added sugar	Maple syrup on pancakes/etc., sugars/honey/not in coffee/tea, sugars/honey/all in coffee or tea, artificial sweetener in coffee/tea
2	Beer	Beer
3	Butter	Butter/regular on bread/pan/waffle, butter/reduced fat on bread/pan/waffle, butter/regular on pot/veg/grains, butter/reduced fat on pot/veg/grains
4	Cheese	Cottage/ricotta cheese
		Cheese/regular, cheese/low fat, cream cheese/regular, cream cheese/low fat, macaroni and cheese
5	Coffee	Coffee/regular/no cream/sugar, coffee/decaf/no cream/sugar
6	Cold breakfast cereals	RTE cereal/< half whole grain, RTE cereal/> half whole grain
7	Cured Meat	Ham/not luncheon, sausage/regular, sausage/turkey/low fat, hot dogs/regular, hot dogs/turkey/low fat, short ribs/spareribs, cold cuts/regular, cold cuts/low fat, cold cuts/poultry, ham/cold cut/lunch meat/regular, ham/cold cut/lunch meat/low fat
8	Dairy products	Ice cream/regular, ice cream/ice milk/low fat, milk/whole in cereal, milk/2 % in cereal, milk/1 % in cereal, milk/nonfat/skim in cereal, milk/rice/in cereal, milk/whole to drink, milk/2 % to drink, milk/1 % to drink, milk/nonfat to drink, milk/rice/to drink, milk/whole in coffee or tea, milk/2 % in coffee or tea, milk/1 % in coffee or tea, milk/nonfat/skim in coffee or tea, milk/evaporated/condensed in coffee or tea, milk/rice in coffee or tea, meal replacement/liquid, milk, unpasteurized not in coffee/tea, milk, unpasteurized in cereal, milk, unpasteurized in coffee/tea, milk/other to drink, milk/other in cereal, milk/other in coffee/tea, yogurt/all, frozen yogurt/ices/sorbet/etc.
9	Dark green vegetables	Raw spinach/greens, cooked spinach/greens, no fat added, broccoli, no fat added, lettuce/dark green
10	Eggs	Eggs/regular, eggs/whites only, eggs/substitutes, eggs/salad
11	Fruit drinks	Fruit drinks/regular, fruit drinks/diet, orange/grapefruit juice/all, other juice, tomato/veg juice/all, apple juice, grape juice
12	Fruits	Oranges/tangelo etc., grapefruit, apples, applesauce/cooked apples, pears, peaches/nectarines/plums, bananas, melons, strawberries, grapes/all, dried fruit, other fruits, pineapple
13	High-energy drinks	Soft drinks/regular/caffeine, soft drinks/regular/decaf
14	Legumes	Beans, peas, no fat added
15	Liquor	Alcoholic beverage/liquor
16	Low-energy drinks	Soft drinks/diet/caffeine, soft drinks/diet/decaf
17	Margarine	Margarine/regular on bread/pan/waffle, margarine/low-fat on bread/pan/waffle, margarine/regular on pot/veg/grains, margarine/diet on pot/veg/grains
18	Meat	Beef/steaks/regular, beef/steaks/lean, beef/roast, beef stews/pot pies/mixtures, beef/burgers/lean, beef/burgers/regular, beef/gr/meatballs/loaf/mixtures, pork, bacon/regular, bacon/lean/Canadian, liver/liverwurst, roast beef in sandwich
19	Nuts and seeds	Nuts/seeds/whole, nuts/seeds/butters
20	Oils	Oils/olive, oils/corn, oils/canola, oils/other
21	Other vegetables	Sweet potatoes, no fat added, corn, no fat added, lettuce, not dark green, chili, pickled veg/fruit, string beans, no fat added, cabbage/sauerkraut, coleslaw, cauliflower/Brussels Sprouts, no fat added, peppers, no fat added, onions, no fat added, veg med, no fat added, other vegetables, no fat added, cucumbers, squash, carrots, no fat added
22	Pizza	Lasagna/rav/shells/etc., pizza/with meat, pizza/without meat
23	Potatoes	Potatoes/white, no fat added, potatoes/fried, potato salads
24	Poultry	Chicken/fried/light w/skin, chicken/fried/light wo/skin, chicken/fried/dark w/skin, chicken fried/dark wo/skin, chicken/light w/skin, chicken/light wo/skin, chicken/dark w/skin, chicken/dark wo/skin, chicken/turkey ground, chicken/mixtures, turkey
25	Refined grains	English muffin/bagel, breads/rolls/white, stuffing/dumplings, cornbread/muffins, biscuits/all, donuts/sweet rolls/danish/pop tarts,
		Muffins/dessert breads, pancake/waffle/French toast, rice/grains/white, pasta/no fat added, pasta/fat added, pasta/meatless red sauce, pasta/meat/fish sauce, bread/not white, crackers, pasta salad, hot breakfast cereals/(not oatmeal)
26	Salad dressings	Salad dressing/all on salad or veg, mayonnaise/regular, mayonnaise/diet
27	Seafood	Fish/smoked, sushi/raw fish, sushi/no raw fish, tuna canned, fish fried, fish/not fried, fish/oysters
28	Snacks	Popcorn, pretzels, tortillas/tacos/corn, tortillas/tacos/wheat, potato/other chips (not corn)/regular, potato/other chips (not corn)/low-fat, corn chips/regular, corn chips/low-fat

Table 2 continued

#	Food groups	Food items
29	Solid fats	Non-dairy cream/powdered/regular in coffee or tea, non-dairy cream/powdered/diet in coffee or tea, non-dairy cream/liquid/r regular in coffee or tea, non-dairy cream/liquid/diet in coffee or tea, cream/regular or 1/2&1/2 in coffee or tea, sour cream/regular, sour cream/low-fat, gravy
30	Soups	Soups/broth w noodles/rice, soups/w veggies, soups/bean-type, soups/creamed
31	Soy products	Milk/soy/in cereal, milk/soy/to drink, milk/soy in coffee or tea, tofu/soy meats
32	Sweets	Puddings/custards, cookies/brownies, cakes, pies/fruit, pies, cream/custard/other, crisps/cobblers, candy/chocolate, candy/not chocolate, jams/jelly/fruit butters
33	Tea	Tea/regular/no cream/sugar, tea/decaf/no cream/sugar
34	Tomatoes	Tomatoes/raw, tomato salsa, tomato catsup
35	Whole grain	Granola bars, oatmeal, rice/grains/whole grain
36	Wine	Wine

cheese, coffee, dairy products, dark green vegetables, eggs, fruits, legumes, nuts and seeds, oils, poultry, seafood, and tomatoes and low consumption of high-energy drinks and liquor. Lastly, the 'western' pattern was characterized by a high consumption of added sugar, beer, butter, cheese, cured meat, fruit drinks, liquor, margarine, meat, pizza, salad dressing, and solid fats (Table 4).

Women with a higher 'mixed' pattern score (Tertile 3) tended to have a history of 1–3 previous live births. Women with a higher 'healthy' pattern score (Tertile 3) tended to be 26–35 years old and married, whereas women with a higher 'western' pattern score tended to be non-Hispanic white, physically active, and have family poverty income ratio between 1.85 and 4, above college level education, and normal prepregnancy weight (Table 5).

In the unadjusted analysis, there was no significant association between dietary patterns and the adequacy of gestational weight gain. After adjustment for prepregnancy BMI, age, race/ethnicity, family poverty income ratio, education level, and marital status, there was still no significant association of dietary patterns with gestational weight gain. After adjusting for physical activity level, women in the highest tertile of 'mixed' pattern had significantly greater odds of inadequate gestational weight gain compared to those in the lowest tertile (adjusted OR (AOR) 4.72; 95 % CI 1.07–20.94). Women in the mid-tertile of 'mixed' pattern had significantly lower odds of excessive gestational weight gain compared to those in the lowest tertile (AOR 0.39; 95 % CI 0.15–0.99). No significant associations were found for the other two dietary patterns, 'healthy' and 'western' patterns in relation to the adequacy of gestational weight gain (Table 6).

Discussion

In our study, we identified three dietary patterns during pregnancy, namely 'mixed', 'healthy', and 'western'. The first dietary pattern, the 'mixed' pattern was characterized by a high consumption of added sugar, butter, cheese, cold breakfast cereals, fruits, vegetables, legumes, meat, and nuts and seeds was inversely associated with excessive gestational weight gain after controlling for maternal sociodemographic variables, prepregnancy BMI, and physical activity. In the Norwegian Mother and Child Cohort Study of 66,597 pregnant women, normal weight pregnant women of prepregnancy BMI < 25.0 kg/m^2 who adhered to a New Nordic Diet had lower odds of excessive gestational weight gain (OR 0.93; 95 % CI 0.87–0.99) (Hillesund et al. 2014). The New Nordic Diet score was characterized by a high consumption of fruits and vegetables, whole grains, potatoes, fish, milk and drinking water pregnancy. Although 'mixed' dietary pattern contains unhealthy food groups such as added sugar or butter, both 'mixed' dietary pattern and the New Nordic Diet include frequent intake of fruits and vegetables, whole grains, and dairy products. These overlapping food groups may play a role in reducing excessive gestational weight gain in our study. It is possible that pregnant women with inadequate gestational weight gain may consume both healthy and unhealthy diets if they recognize that their gestational weight gain is under control.

A retrospective study of 3360 Finnish pregnant women (Uusitalo et al. 2009) examined dietary patterns during the 8 month of pregnancy using principal component analysis in relation to weekly gestational weight gain rate (kg/week). Out of the seven dietary patterns identified, 'healthy' dietary pattern characterized by high loadings of fruits and vegetables, fish, roots, berries, poultry, low-fat dairy was not associated with gestational weight gain. Consistent with this finding, 'healthy' dietary pattern characterized by high loadings of dairy products, dark green vegetables, fruits, legumes, and nuts and seeds and low loadings of high energy drinks, was not associated with gestational weight gain in the present study. In the Finnish study, the 'fast food' pattern was significantly positively associated with gestational weight gain rate per week ($ß = 0.010$,

Table 3 Distributions of maternal characteristics by the adequacy of gestational weight gain groups and vice versa (n = 391)

	Adequacy of gestational weight gain						*P* value[d]
	Inadequate (n = 111)		Adequate (n = 76)		Excessive (n = 200)		
	Wt'd[a] % (row[b])	Wt'd % (column[c])	Wt'd % (row)	Wt'd % (column)	Wt'd % (row)	Wt'd % (column)	
Age							
≤25	40.6	31.4	37.8	17.7	35.0	50.9	0.34
26–35	56.6	29.8	57.3	18.3	52.5	51.9	
≥35	2.9	9.8	4.9	10.2	12.4	80.0	
Race							
Mexican–American or other Hispanic	29.2	42.2	23.6	20.7	13.7	37.1	0.01
Non-Hispanic white	43.8	20.3	66.5	18.7	70.1	61.0	
Non-Hispanic black	18.9	41.8	6.1	8.2	12.0	50.0	
Other including multi-racial	8.1	44.2	3.8	12.6	4.2	43.2	
Family poverty income ratio							
≤1.85	53.4	44.9	25.6	13.0	26.7	42.1	0.007
1.85–4	29.7	25.6	31.2	16.3	35.9	58.1	
>4	16.9	14.9	43.2	23.1	37.5	62.0	
Education level							
≤11th	42.8	46.4	32.3	21.2	15.9	32.3	0.003
High School Graduate	9.9	26.2	6.7	10.8	12.7	63.0	
≥College	47.3	21.7	61.0	16.9	71.5	61.4	
Marital status							
Married	62.8	26.7	67.9	17.5	69.9	55.8	0.67
Widowed/divorced/separated/living with partner	15.4	25.2	17.4	17.2	18.8	57.6	
Single	21.7	41.8	14.7	17.2	11.4	41.0	
Parity (n = 264)							
None	3.8	9.6	23.8	30.4	13.7	60.1	0.23
1–3	89.2	32.7	69.5	13.0	84.1	54.3	
≥4	7.0	48.5	6.7	23.8	2.3	27.7	
Gestational age in months							
1–3	42.8	43.8	26.8	16.6	20.6	39.6	0.19
4–6	31.1	26.4	28.0	14.4	37.2	59.2	
7–10	26.1	19.6	45.2	20.7	42.2	59.7	
Prepregnancy weight status							
Underweight	19.3	58.2	2.1	3.8	6.7	38.0	0.07
Normal	30.9	19.4	61.9	23.5	48.5	57.1	
Overweight	16.8	24.7	12.6	11.3	23.2	64.0	
Obese	33.0	37.6	23.4	16.2	21.6	46.2	
Physical activity (n = 232)							
0 to <500 MET-min/week	42.2	23.2	39.0	12.9	47.7	63.9	0.58
500 to <1000 MET-min/week	24.6	20.2	43.3	21.5	29.1	58.3	
≥1000 MET-min/week	33.3	33.1	17.7	10.6	23.2	56.3	

[a] *Wt'd %* Weighted percentage. Sample weights are created in NHANES to account for the complex survey design (including oversampling of some subgroups), survey non-responses, and post-stratification. When a sample is weighted in NHANES, it is representative of the U.S. civilian non-institutionalized Census population

[b] The row percentage is the cell's percentage of the total frequency for its row

[c] The column percentage is the cell's percentage of the total frequency for its column. Weighted percentages may not sum up to 100 due to rounding

[d] *P* obtained from Chi square tests

Table 4 Factor loading matrix for dietary patterns from food-frequency questionnaires completed by pregnant women

#	Food group	Dietary patterns		
		'Mixed'	'Healthy'	'Western'
1	Butter	**0.33**[a]	0.05	**0.58**
2	Cold breakfast cereals	**0.45**	0.13	−0.13
3	Cured meat	**0.65**	0.11	0.17
4	Dairy products	**0.52**	**0.30**	−0.08
5	Fruit drinks	**0.50**	0.05	**0.20**
6	Fruits	**0.49**	**0.53**	−0.14
7	High-energy drinks	**0.47**	**−0.33**	0.15
8	Margarine	**0.38**	−0.01	**0.54**
9	Meat	**0.64**	**0.23**	0.17
10	Nuts and seeds	**0.31**	**0.49**	0.14
11	Pizza	**0.65**	−0.01	**0.20**
12	Potatoes	**0.58**	0.09	0.18
13	Refined grains	**0.62**	**0.39**	0.18
14	Salad dressings	**0.31**	**0.21**	**0.55**
15	Snacks	**0.43**	**0.22**	−0.19
16	Soups	**0.31**	**0.31**	0.08
17	Sweets	**0.70**	0.16	0.08
18	Tomatoes	**0.21**	**0.49**	−0.02
19	Whole grain	**0.22**	**0.51**	−0.07
20	Cheese	**0.27**	0.18	**0.33**
21	Other vegetables	**0.27**	**0.73**	0.09
22	Poultry	**0.26**	**0.39**	0.11
23	Dark green vegetables	−0.05	**0.68**	**0.28**
24	Eggs	0.01	**0.39**	**0.43**
25	Legumes	0.13	**0.56**	−0.13
26	Seafood	0.12	**0.45**	0.17
27	Oils	0.10	**0.36**	−0.05
28	Soy products	−0.14	**0.31**	0.05
29	Solid fats	−0.03	**0.22**	**0.30**
30	Coffee	−0.04	**0.26**	**0.28**
31	Added sugar	0.17	0.01	**0.38**
32	Beer	0.04	−0.09	**0.69**
33	Liquor	−0.05	−0.15	**0.43**
34	Wine	−0.08	−0.01	**0.47**
35	Tea	0.15	0.00	**0.56**
36	Low-energy drinks	0.01	0.06	**0.22**
	Variance explained (%)	13.4	10.8	9.1

[a] Factor loadings represent the magnitude and direction of association with factors (dietary patterns) and can range from −1.0 to 1.0. Food groups with factor loading values ≥|0.20| are indicated in bold

standard error (SE) = 0.003), whereas the 'alcohol and butter' pattern was significantly inversely associated with gestational weight gain rate per week (ß = −0.010, SE = 0.003). The 'fast food' pattern was characterized by high loadings of fast foods, sweets and desserts, fried potatoes, soft drinks, fruit juices, white bread, and processed meats, while the 'alcohol and butter' pattern was characterized by high intake of alcoholic beverages, butter, salad drinks, soft drinks. Interestingly, the 'western' pattern characterized by high loadings of butter, alcoholic beverages, added sugars, fruit juices and solid fats in our study was similar to the combinations of both 'fast food' and 'alcohol and butter' patterns identified from the Finnish study. A positive relationship of the 'fast food' pattern and

Table 5 Maternal characteristics by the tertiles of dietary pattern score

	'Mixed' dietary pattern							'Healthy' dietary pattern							'Western' dietary pattern						
	Tertile 1		Tertile 2		Tertile 3		P^b	Tertile 1		Tertile 2		Tertile 3		*P*	Tertile 1		Tertile 2		Tertile 3		*P*
	n	Wt'd[a] %	n	Wt'd %	n	Wt'd %		n	Wt'd %	n	Wt'd %	n	Wt'd %		n	Wt'd %	n	Wt'd %	n	Wt'd %	
Age																					
≤25	42	34.4	50	30.9	68	34.6	0.57	69	52.2	52	27.2	39	20.5	<0.0001	61	25.6	55	33.7	44	40.8	0.47
26–35	78	28.6	74	38.6	53	32.7		54	29.3	72	37.4	79	33.3		61	19.9	69	48.1	75	32.0	
≥35	10	36.4	7	14.6	9	49.0		7	13.0	7	12.3	12	74.7		8	19.6	7	27.0	11	53.4	
Race																					
Mexican American or other Hispanic	49	28.5	38	34.9	39	36.6	0.51	23	15.0	45	34.4	58	50.6	0.0013	72	48.5	34	33.9	20	17.6	<0.0001
Non-Hispanic white	59	32.0	74	33.6	58	34.4		72	38.1	70	34.9	49	27.0		38	11.6	70	42.8	83	45.6	
Non-Hispanic black	11	23.4	16	43.0	28	33.6		30	59.6	12	18.6	13	21.8		15	25.3	21	42.6	19	32.2	
Other including multi-racial	11	55.8	3	8.0	5	36.2		5	40.5	4	12.3	10	47.2		5	35.5	6	42.5	8	22.1	
Family poverty income ratio																					
≤1.85	57	20.5	56	34.8	76	44.7	0.21	65	37.4	59	28.4	65	34.2	0.70	82	36.7	60	34.3	47	29.0	0.02
1.85–4	26	32.9	37	34.0	32	33.1		34	42.5	30	29.4	31	28.1		25	16.8	35	39.4	35	43.9	
>4	47	41.4	38	32.4	22	26.2		31	29.2	42	37.0	34	33.8		23	11.9	36	49.6	48	38.6	
Education level																					
≤11th grade	39	27.2	47	28.7	62	44.1	0.38	54	46.6	46	22.4	48	31.1	0.30	72	37.6	50	36.9	26	25.5	0.0013
High school grade	22	43.9	15	27.2	19	29.0		20	32.7	22	42.7	14	24.6		18	33.2	13	22.1	25	44.7	
Above college	69	31.1	69	37.0	49	31.9		56	32.8	63	33.4	68	33.8		40	13.5	68	46.0	79	40.6	
Marital status																					
Married	97	32.0	92	36.8	69	31.2	0.69	66	26.4	93	38.1	99	35.5	0.0007	83	19.8	88	43.7	87	36.4	0.51
Widowed/divorced/separated/ living with partner	19	31.5	18	26.7	23	41.7		22	55.0	20	15.3	18	29.7		22	18.8	17	41.1	21	40.1	
Single	14	28.8	21	28.3	38	42.9		42	60.1	18	20.9	13	19.0		25	35.4	26	28.2	22	36.3	
Parity (n = 264)																					
None	11	56.9	2	3.0	6	40.1	0.08	6	45.4	4	9.1	9	45.4	0.26	3	9.1	8	42.0	8	48.9	0.64
1–3	80	28.2	74	34.9	77	36.9		70	33.3	82	33.0	79	33.7		83	23.7	73	40.9	75	35.4	
≥4	3	14.4	6	53.4	5	32.2		6	58.0	4	27.7	4	14.2		3	23.1	6	20.2	5	56.7	
Trimester of pregnancy																					
1st trimester	28	34.9	22	32.3	20	32.7	0.50	32	40.6	22	34.3	16	25.1	0.82	20	15.2	29	45.4	21	39.4	0.81
2nd trimester	58	38.0	57	35.4	44	26.5		53	35.3	58	33.6	48	31.0		53	24.1	51	41.4	55	34.5	
3rd trimester	44	23.0	52	33.3	66	43.7		45	34.3	51	27.6	66	38.1		57	25.1	51	37.3	54	37.6	
Prepregnancy weight status																					
Underweight	9	10.8	16	47.9	15	41.3	0.08	10	20.2	12	21.1	18	58.7	0.20	14	21.9	19	62.1	7	16.0	0.23

Table 5 continued

	'Mixed' dietary pattern							'Healthy' dietary pattern							'Western' dietary pattern						
	Tertile 1		Tertile 2		Tertile 3		P^b	Tertile 1		Tertile 2		Tertile 3		P	Tertile 1		Tertile 2		Tertile 3		P
	n	Wt'd[a] %	n	Wt'd %	n	Wt'd %		n	Wt'd %	n	Wt'd %	n	Wt'd %		n	Wt'd %	n	Wt'd %	n	Wt'd %	
Normal	68	35.9	56	26.8	58	37.3		65	40.7	55	25.3	62	34.0		53	22.1	57	38.3	72	39.6	
Overweight	34	44.4	34	32.1	28	23.4		28	39.0	38	37.3	30	23.7		35	23.6	32	49.6	29	26.7	
Obese	19	21.1	25	42.4	29	36.6		27	32.9	26	42.2	20	24.9		28	20.4	23	31.1	22	48.5	
Physical activity (n = 232)																					
0 to <500 MET-min/week	37	31.5	44	29.6	39	38.8	0.44	36	35.0	44	24.3	40	40.7	0.54	33	21.2	44	41.0	43	37.8	0.12
500 to <1000 MET-min/week	20	38.6	14	31.8	19	29.5		13	26.9	20	43.4	20	29.7		18	10.8	21	62.5	14	26.7	
≥1000 MET-min/week	20	18.0	21	47.3	18	34.7		17	29.2	18	40.1	24	30.7		14	11.3	21	36.6	24	52.2	

[a] Wt'd %: Weighted %. Sample weights are created in NHANES to account for the complex survey design (including oversampling of some subgroups), survey non-responses, and post-stratification. When a sample is weighted in NHANES, it is representative of the U.S. civilian non-institutionalized Census population. Weighted percentages may not sum up to 100 due to rounding

[b] *P* obtained from Chi square tests

an inverse relationship of alcohol and butter consumption with gestational weight gain may eliminate the overall effect of 'western' pattern on gestational weight gain in this study.

The association between dietary patterns and sociodemographic and lifestyle behaviors indicate that healthy food choices are part of larger pattern of health-related behaviors (Randall et al. 1991; Kerver et al. 2003). Our study has shown that pregnant women who adhered to 'healthy' dietary pattern are more likely to be older, Mexican–American, and married, whereas pregnant women who adhered to 'western' dietary pattern were more likely to be non-Hispanic white, and had mid-income, and mid-education. Advanced maternal age may possess a role for 'healthy' dietary pattern. This may be due to older women may be more disciplined regarding lifestyle choices such as diet (Hillesund et al. 2014). Non-Hispanic whites generally adhered to the 'western' dietary pattern, which was found to be associated with poor diet quality (Reedy et al. 2010). Laraia et al. (Laraia et al. 2007) reported that black pregnant women had significantly better diet quality during pregnancy assessed by Diet Quality Index for Pregnancy compared to white pregnant women (55.5 ± 12.4 vs. 54.3 ± 11.1, respectively) in the prospective Pregnancy, Nutrition, and Infection study of 2,394 pregnant women. Rifas-Shiman et al. (Rifas-Shiman et al. 2009) reported that African-American pregnant women demonstrated similar Alternate HEI, modified for Pregnancy (AHEI-P) scores in comparison to white pregnant women (mean difference 1.6 points, 95 % CI −3.1 to −0.1) in the U.S. prospective cohort study of 1777 pregnant women. These inconsistent findings may be due to the different indices used to assess diet quality during pregnancy (DQI-P vs. AHEI-P), different pregnancy time periods when the diet quality was assessed (26–28 weeks' gestation vs. the first trimester of pregnancy), and different categorization of race/ethnicity in each study.

There are several limitations that pertain to this study. Total gestational weight gain, which is the difference between weight before pregnancy and before delivery, was not available in this study. Instead, we used gestational weight gain obtained at each month of pregnancy. For future research, multiple aspects and observations of gestational weight gain need to be considered including weekly, total, and patterns of weight gain from the first trimester to the third trimester. Hence, Tobias and Bao (Tobias and Bao 2014) recommended that randomized clinical trials are needed to examine the role of dietary factors on gestational weight gain. Overall, the findings did not clearly indicate the association between dietary patterns and gestational weight gain. This may be due to using exploratory factor analysis when extracting dietary patterns. For future research, a confirmatory factor

Table 6 Crude and adjusted odds ratios for being in the excessive or inadequate gestational weight gain compared with the adequate (reference) gestational weight gain by the tertiles of dietary pattern scores

	Excessive versus adequate gestational weight gain (reference)			Inadequate versus adequate gestational weight gain (reference)		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Mixed dietary pattern score						
Tertile 1	1.00	1.00	1.00	1.00	1.00	1.00
Tertile 2	0.59	0.50	0.39	3.01	2.79	3.49
	(0.21–1.70)	(0.17–1.47)	(0.15–0.99)*	(0.89–10.20)	(0.87–8.95)	(0.79–15.41)
Tertile 3	0.98	1.08	1.82	2.49	2.84	4.72
	(0.23–4.19)	(0.33–3.59)	(0.49–6.74)	(0.49–12.57)	(0.66–12.22)	(1.07–20.94)*
P-trend	0.99	0.83	0.31	0.40	0.25	0.10
Healthy dietary pattern score						
Tertile 1	1.00	1.00	1.00	1.00	1.00	1.00
Tertile 2	0.74	0.87	1.41	0.80	0.94	2.05
	(0.17–3.17)	(0.18–4.12)	(0.29–6.92)	(0.16–3.93)	(0.17–5.18)	(0.28–15.13)
Tertile 3	1.39	1.78	2.60	0.73	0.59	0.77
	(0.47–4.17)	(0.54–5.89)	(0.49–13.83)	(0.24–2.22)	(0.16–2.23)	(0.10–5.62)
P-trend	0.58	0.33	0.25	0.59	0.50	0.86
Western dietary pattern score						
Tertile 1	1.00	1.00	1.00	1.00	1.00	1.00
Tertile 2	2.23	2.04	1.07	2.30	3.57	2.01
	(0.87–5.70)	(0.65–6.42)	(0.29–3.92)	(0.74–7.19)	(0.92–13.79)	(0.40–10.23)
Tertile 3	1.61	1.52	1.34	0.82	1.88	0.64
	(0.45–5.75)	(0.43–5.42)	(0.28–6.44)	(0.23–2.96)	(0.55–6.42)	(0.12–3.43)
P-trend	0.63	0.68	0.64	0.66	0.55	0.39

Model 1 Crude association between dietary patterns and gestational weight gain (n = 391)

Model 2 Adjusted for prepregnancy BMI, age, race/ethnicity, family poverty income ratio, education level, and marital status (n = 391)

Model 3 Adjusted for model 2 + physical activity level (n = 232)

* $P < 0.05$

analysis approach using both theory and empirical findings are warranted to investigate the association between dietary patterns during pregnancy and gestational weight gain.

Due to the cross-sectional study design of the NHANES, the cause-effect relationship cannot be proven. Although our study does not provide causality between diet patterns during pregnancy and gestational weight gain, overall findings support that consumption of both healthy and unhealthy diets is inversely associated with gestational weight gain. Dietary pattern approach help capturing the complexity of diet (Hu 2002), however, the complexity possess subjective interpretation or researchers' bias when labeling the name of dietary patterns. The significant inverse association between 'mixed' dietary pattern during pregnancy and excessive gestational weight gain needs to be considered in public health nutrition policies and interventions. This finding may be important for the prevention of excessive gestational weight gain, postpartum weight retention in their later lives, and its subsequent adverse health effects for the offspring.

Acknowledgments Dayeon Shin would like to appreciate the College of Agriculture and Natural Resources at Michigan State University for providing a dissertation completion fellowship to conduct this research. The study was based on Dayeon Shin's doctoral dissertation for Michigan State University. All authors acknowledge the support from the Department of Food Science and Human Nutrition at Michigan State University.

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