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Maternal Sociodemographic Characteristics and Prenatal Diet Quality

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MATERNAL SOCIODEMOGRAPHIC CHARACTERISTICS

AND PRENATAL DIET QUALITY

BY

HALEY WYNNE PARKER

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Abstract

Studies examining prenatal diet quality in the US indicate that pregnant women are not currently meeting national dietary recommendations. Though prenatal diet quality is generally poor, certain population sub-groups may be disproportionately impacted, however, few studies have examined diet quality disparities in pregnant women. In order to better understand disparities in prenatal diet quality, this study seeks to characterize the relationship between maternal sociodemographic factors and prenatal diet quality, specifically examining socioeconomic status, race, pre-pregnancy BMI, and gestational weight gain as an exploratory aim. Cross sectional data from the Infant Feeding Practices Study II informed this secondary analysis. To explore these relationships, we used generalized linear models to examine the associations between socioeconomic status, race, pre-pregnancy BMI, and gestational weight gain and Alternative Health Eating Index for Pregnancy (a measure of diet quality during pregnancy) total and component scores. Models were adjusted for age, energy intake, and relevant covariates. Post-hoc testing with Tukey adjustment was used to compare scores between groups. Findings indicated that prenatal diet quality disparities were present in women with middle- and low-income, non-Hispanic Black women, and women with overweight and obese pre-pregnancy BMIs.

Preface

The manuscript format was used for this thesis. The manuscript was prepared in accordance with submission guidelines of the Journal of the Academy of Nutrition and Dietetics. This manuscript has not yet been submitted for review.

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Abstract:

Background: Prenatal diet can influence life-long health trajectories for the child. Current prenatal diet quality is poor yet population groups at increased risk for poor prenatal diet quality have yet to be adequately defined.

Objective: To examine differences in prenatal diet quality by socioeconomic status (SES), race, pre-pregnancy BMI, and gestational weight gain ((GWG) exploratory analysis).

Design: Cross sectional data from the Infant Feeding Practices Study II informed this secondary analysis.

Participants: 1,444 women who completed the Diet History Questionnaire during the third trimester of pregnancy.

Exposure variables: Self-reported SES (household poverty income ratio (PIR) and Women, Infants, and Children (WIC) participation), race, pre-pregnancy BMI, and GWG.

Main outcome measures: Prenatal diet quality, measured by the Alternative Healthy Eating Index for Pregnancy (AHEI-P).

Statistical analyses performed: Generalized linear models were used to examine the relationships between SES, race, pre-pregnancy BMI, and gestational weight gain and AHEI-P total and component scores. Models were adjusted for age, energy intake, and relevant covariates. Post-hoc testing with Tukey adjustment was used to compare scores between groups.

Results: Disparities in prenatal diet quality were detected in SES, race, and pre-pregnancy BMI. High-income women (PIR>4) had significantly higher diet quality than their low- and medium- income (PIR<4) and WIC participating counterparts (61.8 vs 57.7-58.3). Women in the Other races group scored significantly higher than non-Hispanic Black women (61.5 vs 57.3). Women with normal weight pre-pregnancy BMIs (60.6) had significantly higher AHEI-P scores compared to women with pre-pregnancy overweight (58.7) and obesity (58.2). Exploratory analyses showed that the relationship between GWG and AHEI-P score varied according to pre-pregnancy BMI.

Conclusions: In this sample, having higher income, identifying as Other races, and having normal pre-pregnancy BMI were all protective of prenatal diet quality. Further research should explore sociodemographic predictors of prenatal diet quality in larger, more diverse samples.

Introduction:

Evidence suggests that lifelong obesity and chronic disease risk is partially determined in early life (i.e.: prenatal to 2 years of age).[1] During this time, the fetus is particularly vulnerable and nutritional, hormonal, and environmental exposures can result in physiological adaptations that persist through adulthood, influencing chronic disease risk.[2–4] For example, maternal pre-pregnancy obesity and excessive gestational weight gain are risk factors for giving birth to a high birthweight infant, which increases the infant's risk of obesity and chronic disease development later in life.[5] In the presence of maternal pre-pregnancy obesity and/or excessive gestational weight gain, the fetus is exposed to increased inflammation and adipokines (signaling protein from adipose), as well as altered insulin, glucose, and lipid metabolism in utero, which are thought to contribute to metabolic alternations in the infant leading to an increase in obesity and chronic disease risk later in life.[2,5] The mother's diet before and during pregnancy is the sole source of fuel for fetal growth and the overall quality of diet consumed impacts the fetus's development and lifelong health trajectories,[2] which makes prenatal diet a desirable target for improving population health.

The risk of poor lifelong health outcomes for the offspring can be mitigated by improving prenatal adherence to dietary recommendations. Current studies assessing prenatal diet quality in the US using diet quality indices adapted for pregnancy indicate that the average prenatal diet is poor.[6,7] For example, the average Healthy Eating Index (HEI-2010) score of pregnant women participating in the National Health and Nutrition Examination Survey (NHANES) from 2003-2012 was 50.7 out of 100,[6] which is nearly 30 points below the score recommended for disease prevention.[8] Furthermore, studies

have indicated that the majority of pregnant women are not consuming enough fiber,[7,9] whole grains,[6,9–11] fruits,[6,7,10] or vegetables[6,7,10] and consuming excessive amounts of sodium,[6,12] and fat[9,13,14] in the form of heavily processed foods.[6,9]

Though evidence indicates that pregnant women in the US generally have poor diet quality, it is unlikely that all populations are proportionately impacted. In examining dietary choices, it is important to consider the influences from various levels of the socioecological model including public policy, community, and interpersonal.[15] In the broader US population, individuals with low socioeconomic status (SES), of minority racial groups, and individuals with higher BMIs experience disparities in both health and diet quality.[16–18] While these disparities may be similarly present in populations of pregnant women, to date, relatively few high-quality studies have examined diet quality disparities in pregnant women. In the current literature, pregnant women of higher socioeconomic status (SES) generally have better adherence to a healthful diet.[6,7,10,11] However, many of the studies examining prenatal diet quality utilized samples comprised of either mostly high or mostly low income women[7,10,11] and few studies have examined whether participation in nutrition assistance programs (e.g.: Women Infants and Children (WIC)) improves prenatal diet quality. Similarly, studies examining differences in prenatal diet quality among racial groups in the US do not consistently find that racial minorities have poorer or healthier dietary quality than their white counterparts, though analysis of nationally-representative data suggest that racial disparities in diet quality may be confounded by SES,[19] which was rarely controlled for in studies examining pregnant women.[6,7,10,11] Lastly, studies consistently find that normal pre-pregnancy BMI is associated with higher prenatal diet quality,[6,7,11] however, few studies have examined if

gestational weight gain (GWG) influences the relationship between pre-pregnancy BMI and prenatal diet quality. In conclusion, a more thorough examination of the risk factors for poor prenatal diet quality in a diverse sample and using adjustment for confounding variables is currently needed.

Since populations at high-risk of poor prenatal diet quality are currently inadequately defined, this study seeks to help identify population subgroups experiencing disparities in prenatal diet quality so that limited resources for public health interventions and nutrition assistance programs can target these high-risk populations. We aimed to specifically examine the relationships between socioeconomic status (SES), race, and pre-pregnancy BMI, and prenatal diet quality in the Infant Feeding Practices II (IFPS II) cohort. In exploratory analyses, we additionally tested to see if gestational weight gain (GWG) modified the association between BMI and prenatal diet quality. Consistent with the existing literature, we hypothesize that higher SES, NHW, normal pre-pregnancy BMI, and adequate GWG will be associated with higher prenatal diet quality.

Methods:

Study design and sample population:

This secondary, cross-sectional analysis was completed using data from the Infant Feeding Practices Cohort II (IFPS II), a publicly available, longitudinal study conducted by the Centers for Disease Control and Prevention and the Food and Drug Administration.[20] The aim of IFPS II was to better understand infant feeding practices and how they impact infant health.[20] Details regarding data collection methods have been

previously reported.[20] About 4,900 women who were approximately seven months

pregnant were recruited between May and December of 2005 from a national consumer

opinion panel of over 500,000 households. Follow-up surveys were mailed approximately

each month until the infant was 12-months old and one follow up survey was completed

when the child was 6-years old. Women were included in the study if they and their

infant were free of health conditions that impact feeding, and if their infant was born after

34 weeks of gestation, was a singleton, had a birthweight above 5 lbs., and had not stayed

in the intensive care unit longer than 3 days. For the original IFPS II study, the Food and

Drug Administration's Research Involving Human Subjects Committee and the US

Office of Management and Budget reviewed and approved the study procedures and

participant materials. The University of Rhode Island Institutional Review Board deemed

this secondary analysis exempt from review.

Exposure variables – maternal characteristics:

    Socioeconomic status: Two variables, poverty income ratio (PIR) and WIC

participation status, were combined to create a variable for socioeconomic status so that

the influence of WIC participation and income could be assessed in the same analysis.

PIR obtained from participant demographic data and WIC participation data was obtained

from the prenatal survey where mothers were asked about their WIC participation status

in the past month (note: mothers who indicated that only their child was enrolled in WIC

were not counted as WIC participants). These two variables (PIR and the mother's

prenatal WIC participation status) were combined to form a single variable to indicate

socioeconomic status. Women were categorized into 4 groups: WIC participants, low-

income (PIR ≤ 1.85 but not participating in WIC), middle-income (PIR >1.85 but <4), and high-income (PIR ≥ 4).

Race: Similar to household income, data for participant self-reported race and ethnicity were obtained from the either panel database or the demographic questionnaire if demographics were not available in the panel database. Women identified as either non-Hispanic White (NHW), non-Hispanic Black (NHB), Hispanic, Asian/Pacific Islander, or other. In previous research, racial disparities in prenatal diet quality existed between NHW and NHB women. Therefore, in this study, women who identified as Hispanic, Asian/Pacific Islander, or other were grouped together into the Other races group.

Pre-pregnancy BMI and gestational weight gain: Participant self-reported pre-pregnancy weight and height on the prenatal survey were used to calculate pre-pregnancy BMI. Women were categorized into one of four BMI groups defined by the Centers for Disease Control and Prevention: underweight (<18.5 kg/m^2), normal weight (≥18.5-24.9 kg/m^2), overweight (≥25.0-29.9 kg/m^2), or obese (≥30.0 kg/m^2).[21] Using categorized pre-pregnancy BMI, adequate GWG ranges were determined according to the 2009 Institute of Medicine's pre-pregnancy BMI-dependent GWG recommendations (**Table S1**).[22] Using self-reported GWG in pounds on the neonatal survey (sent 1 month after birth) and recommended ranges of GWG, women were categorized into 3 GWG groups: inadequate (self-reported GWG < recommended GWG), adequate (self-reported GWG within recommended range), or excessive (self-reported GWG > recommended GWG).

Outcome variable – AHEI-P:

Of the total sample of 4,902 women, 1,444 pregnant women also completed a modified Diet History Questionnaires (DHQ), a validated food frequency questionnaire developed by the National Cancer Institute during the third trimester of pregnancy.[23] The following modifications were made to the DHQ to better assess prenatal diet: intakes reflected the past month rather than the past year, and questions were included about foods of particular interest in pregnancy (e.g. fish) and supplementation. The DHQ was mailed between May and August of 2005 to women who completed and returned the prenatal questionnaire with adequate time to complete the DHQ prior to birth. Using the National Cancer Institute's Diet*Calc software, the DHQ responses were analyzed for intake of food groups, nutrients, and other dietary constitutes.

Data from the DHQ responses and Diet*Calc output were used to calculate prenatal diet quality using the Alternative Healthy Eating Index for Pregnancy (AHEI-P), a modified version of the Alternative Healthy Eating Index (AHEI-2010), a validated measure of diet quality.[24] The version of the AHEI-P used in this study was adapted by Poon et al.,[25] who updated an earlier version of the AHEI-P[7] to reflect the updated AHEI-2010.[24] The AHEI-P includes 10 out of the 11 AHEI-2010 components (**Table S2**) including vegetables, whole fruit, whole grains, sugar-sweetened beverages and fruit juice (SSB), nuts and legumes, red and processed meat, *trans* fat, long-chain fatty acids, polyunsaturated fatty acids, and sodium. Modifications made to the AHEI-2010 for use in pregnancy included the addition of 3 components for micronutrients important during pregnancy (calcium, iron, and folate) and the omission of the alcohol component (in this sample, less than 9% of respondents reported any alcohol consumption on the DHQ). The AHEI-P is comprised of 13 components which all contribute equally (10

points/component) to the total maximum score of 130 points. In a previous study by Poon et al, AHEI-P scores were divided into tertiles and scores in the highest tertile ranged from 63-98.[25]

Intermediate intakes were scored proportionately. For example, four servings of whole fruit per day correlates with a maximum score of ten points so an intake of two servings per day equates to five points. Components were classified as either moderation or adequacy components. Moderation components (sugar-sweetened beverages and fruit juice, red and processed meat, *trans* fat, and sodium) are scored inversely (i.e.: lower intake results in a higher score) because limited intake is recommended. Higher scores for adequacy components (e.g.: whole fruit, whole grains, vegetables) indicate better adherence to recommendations for healthful foods.

Covariates:

Covariates examined included self-reported maternal age, parity, education, and smoking status from the demographics data/survey and the prenatal survey as well as energy intake, which was calculated using the DHQ responses. Maternal age was left as a continuous variable. Education from the demographics data was recategorized from the original 7 categories (ranging from some grade school to post-college graduate education) into 3 categories: high school or less, some college, and college graduate. Women were categorized as primiparous or multiparous based the mothers' reported previous births. Smoking status during pregnancy was categorized into non-smoking (0 cigarettes per day) and smoking (>0 cigarettes per day) using responses from the prenatal survey. The Diet*Calc analysis of the DHQ responses informed energy intake (in kcals per day).

Statistical analyses:

The analysis was completed using SAS 9.4 and the significance level was set at $p < 0.05$. All exposure and outcome variables and covariates were examined for normality and outliers. In BMI, one outlier was identified (where BMI = 9) and 122 energy intakes above 4777 or below 1075 kcals (identified and validated by Meltzer et al as realistic energy intake values during pregnancy)[26] were removed from the analytic dataset. Generalized linear models compared total and component AHEI-P scores among different SES, racial, pre-pregnancy BMI and GWG groups. We tested for interactions between variables that have been found to be related in previous studies. The interactions tested included: (1) SES and kcals, (2) race and a) BMI and b) PIR, (3) BMI and a) kcals and b) PIR, (4) GWG and a) BMI and b) race, using a threshold of $p < 0.05$ to determine significance. If a significant interaction was detected, we conducted a stratified analysis.

Preliminary models were adjusted for age since age tends to be correlated with diet quality.[27] Potential confounding variables included age, parity, education, and smoking which were identified by reviewing the previous studies examining prenatal diet quality.[7,10,11,28] Covariates were included in adjusted models if they were both (1) significant when added singly into the model and (2) were determined by the researchers to be impactful on group scores in comparison to age-adjusted scores. Initial models were adjusted for age and the final models were adjusted for age and energy intake as well as any relevant covariates. The final models for SES, included covariates for age, race, smoking and energy intake. The final models for race included covariates for age, PIR, smoking, WIC participation, and energy intake. The final models for BMI included covariates for age, PIR, smoking status, WIC participation, race and energy intake.

Lastly, the final models for GWG included covariates for age, PIR, smoking, parity, WIC participation and energy intake. Intermediate models were additionally adjusted for all significant variables except for energy intake. Fully adjusted models were adjusted for age, all significant covariates, and energy intake by adding daily caloric intake into the model. If a significant main effect was detected in the overall model, post hoc between group comparisons were made using the Tukey adjustment.

Results:

Maternal characteristics

The sample was comprised of 1,444 women who were generally highly educated (39% college graduates), multiparous (70.6%), and non-Hispanic White (84%) with a mean age of 28.9±5.6 years (**Table 1**). Nearly 30% participated in WIC and approximately 41% of women reported household incomes that were WIC-eligible. The mean AHEI-P score was 60.6 (out of 130 points).

Socioeconomic Status (Income and WIC participation)

In the age- and multivariable- adjusted models, AHEI-P scores were different across the 4 SES groups. In the age-adjusted model (**Table 2**), post-hoc comparisons indicated that high-income women (62.5±0.7) scored significantly higher than WIC participants (59.7±0.6) but similar to the middle (60.7±0.5) and low (60.1±0.7) income non-participants. Associations were similar after multivariable adjustment, with high-income women scoring significantly higher (61.8±1.0) than middle income women (59.6±0.8), low income women (58.3±0.9), and WIC participants (57.8±0.8).

In the fully adjusted component score models, higher AHEI-P total scores in the high-income group appear to be influenced by component scores for whole fruit, SSB, red and processed meat, and *trans* fat. In the whole fruit component, high-income women (4.4±0.2) scored significantly higher than all other groups (3.5±0.2 for WIC participants, 3.4±0.2 for low-income women, 3.7±0.2 for middle-income women). In the sugar sweetened beverages and fruit juice component, women in the high-income group scored significantly higher than WIC participants and low-income women. In the red and processed meat component, high-income women scored significantly higher than WIC participating women and in the *trans* fat component, high-income women scored significantly higher than low-income women.

Race

In all models, AHEI-P scores were significantly different across NHB, NHW, and Other races. Post-hoc comparisons in the age-adjusted model (**Table 3**) indicated that women identifying as Other races (63.0±0.9) scored significantly higher than NHW (60.4±0.3) and NHB (58.3±1.3) women and there were no differences in diet quality observed among NHW and NHB women. After further adjustment for age, PIR, smoking status, and WIC participation, and energy intake, women in the Other races group still scored higher than NHB women but NHW women (59.9±0.5) scored similarly to both NHB women (57.3±1.4) and women in the Other races group (61.7±0.9).

Differences in total AHEI-P scores among racial groups appeared to be influenced by component scores for vegetables, whole fruits, SSB, nuts and legumes, long chain fatty acids, iron, folate, and calcium. Women in the Other races group scored significantly higher than NHW women on the vegetables and whole fruit components and

NHW women scored significantly higher than women with Other races on the SSB component. NHW women scored significantly higher than NHB women on the component score for nuts and legumes and NHB women scored significantly higher than NHW women on the long chain fatty acids component. NHB and NHW women scored significantly lower on components for iron and folate than women in the Other races group. Lastly, NHB women (7.69±0.23) and women in the Other races group (8.19±0.15) scored significantly lower on the calcium component than NHW women (8.55±0.09).

Pre-pregnancy BMI

In the models examining pre-pregnancy BMI, AHEI-P scores were significantly different across pre-pregnancy BMI groups. In post-hoc comparisons of the age adjusted model (**Table 4**), women with underweight and normal weight scored significantly higher than women with obesity and women with normal weight also scored significantly higher than women with overweight. After adjustment for age, smoking status, PIR, race, and WIC participation, and energy intake, women with normal weight (60.6±0.8) scored significantly higher than women with overweight (58.7±0.9) and obesity (58.2±0.8), who scored similarly to each other. Women with underweight (60.7±1.4) did not score significantly different from any of the other groups.

In post-hoc comparisons of fully adjusted component scores, significant differences were present in components for whole grains, red and processed meat, *trans* fat, iron, and folate. Compared to women with obesity, women with normal weight scored significantly higher on components for whole grains (2.1 vs. 2.5), red and processed meats (3.4 vs. 4.3), and *trans* fat (4.7 vs. 5.1). Women with obesity scored significantly lower than all other groups on the iron component (5.7 vs. 6.1-6.3). On the

folate component, women with underweight (6.9±0.2) and normal weight (6.8±0.1) scored significantly higher than women with obesity (6.3±0.1) and women with normal weight also scored significantly higher than women with overweight (6.5±0.1).

Gestational Weight Gain

We tested whether GWG modified the association between BMI and AHEI-P in an exploratory analysis due to missing data for approximately 32% of participants. The interaction between BMI and GWG was significant (p=0.0153), and thus these analyses were stratified by pre-pregnancy BMI (underweight, normal weight, overweight, obese). In age-adjusted models, diet quality differed among women with inadequate, adequate, and excessive GWG in all BMI groups except for women with obesity (p<0.05 in under, normal, and overweight, p=0.0844 in obese). Significant post hoc differences were seen in the underweight group between women with inadequate (54.1±3.3) and adequate (62.3±2.2) GWG. Fully adjusted GWG models were significant in all pre-pregnancy BMI groups, however, no significant post hoc group differences were identified in the fully adjusted models. While not significant, the women with adequate GWG scored higher than women in the inadequate and excessive GWG in models for underweight and normal weight however, in the overweight model, women with inadequate GWG had the highest total scores and in the obese model, women with excessive GWG had the highest scores.

In component score analyses, post hoc comparisons revealed significant differences in the red and processed meat component for women with overweight and obesity. In women with overweight, red and processed meat scores were significantly higher for women with adequate GWG compared to women with excessive GWG. In

women with pre-pregnancy obesity, scores for red and processed meat were significantly lower for women with adequate GWG compared to women with inadequate and excessive GWG.

Discussion:

In this secondary analysis of the IFPS II cohort, overall AHEI-P scores were relatively low (60.6±11.1 out of 130 maximum total points). Overall component scores were lowest in SSB, nuts and legumes, long chain fatty acids, and whole grains and highest in the micronutrients (folate, iron, and calcium) and PUFA. Differences in AHEI-P scores were observed across different SES, race, pre-pregnancy BMI, and GWG groups. Differences among SES were mostly present in moderation component scores where in race, differences were mostly present in micronutrient and adequacy components (e.g.: whole fruits, vegetables, whole grains, etc.), and in pre-pregnancy BMI analyses, differences were seen in micronutrients and moderation components. In this section, main exposure variables (SES, race, pre-pregnancy BMI, and GWG (exploratory aim)) will be discussed separately.

Socioeconomic status

Results from this study support existing research showing that SES is related to diet quality among pregnant women.[6,7,10,11] Contrary to our hypothesis, a disparity in AHEI-P scores was only present between high-income women (PIR≥4) and all of the lower SES groups (including middle-income [1.85<PIR<4], low-income WIC nonparticipants [PIR≤1.85], and WIC participants). Further examination of component scores revealed

that high-income women mostly differed from other groups for AHEI-P moderation component scores (SSB, red and processed meat, and *trans* fats) rather than adequacy components (excluding whole fruit); thus, it is likely that differences in prenatal diet quality across SES groups were driven by differences in unhealthful (rather than healthful) food consumption. Taken together, this finding suggests that higher SES may be protective against overconsuming unhealthful foods during pregnancy.

Our findings could potentially be explained by cost barriers to healthful eating during pregnancy. Food costs, or more specifically, differences in food prices according to healthfulness, have been proposed as driving factors for diet quality and health disparities.[29] Previous research has highlighted that many factors (e.g. taste, convenience, cultural norms, and costs) influence food purchasing decisions.[29] However, given that food cost and energy density are inversely associated, it is important to also consider how financial constraints can lead to the selection of unhealthful, energy-dense, nutrient-poor foods in order to meet energy needs.[30] In line with financial constraints, food insecurity was not evaluated in this study but it's possible that the presence of food insecurity may have been influential in food purchasing decisions in this study.[31] Future research is needed to understand the role of food costs, food insecurity, and income on the food choices that influence prenatal diet quality.

Nutrition assistance programs, such as WIC, may help to mitigate SES disparities in prenatal diet quality. Therefore, in this study, we sought to examine the potential impacts of WIC participation on prenatal diet quality. Since prenatal WIC food packages provide only pre-approved, nutritious foods (including: juice, milk, cereal, eggs, legumes, and peanut butter),[32] it was hypothesized that WIC participants would have higher diet quality

than low-income non-participants. However, in our study, WIC participants scored similarly to their low-income, WIC nonparticipating counterparts on AHEI-P total and component scores. To our knowledge, only one previous study has examined prenatal WIC participation and diet quality, finding that women participating in WIC consumed more protein, iron and calcium than women who were income-qualified non-participants.[33] Though our findings do not corroborate these prior findings, this may be due to the fact that the prior study was conducted almost 30 years ago and the food environment has changed considerably since publication of this study.[33]

While our findings for the relationship between WIC participation and prenatal diet quality were unexpected, there are a few potential explanations. First off, the receipt of WIC benefits could have increased diet quality in WIC participating women from baseline and since prenatal diet quality was only measured once, we are unable to test this hypothesis. In other words, it's possible that WIC benefits may have resulted in an improvement in diet quality and without these benefits, WIC participants might have had lower diet quality.

Additionally, our overall SES findings indicated that there were mostly differences in unhealthful (rather than healthful) food consumption among high versus lower SES groups. If disparities in prenatal diet quality among SES groups are driven by consumption of unhealthful foods, the provision of healthful foods from WIC to low-income pregnant women might not modify their consumption of unhealthful foods. The WIC food packages are intended to be supplemental. Therefore, the foods provided could have been consumed in addition to the normal diet (rather than modifying the diet) to meet increased energy needs during pregnancy. If this were the case, we would not

expect to see decreased unhealthful food intake in WIC participants, which is consistent with our findings that WIC participants had similar prenatal diet quality to low- and middle- income women.

Furthermore, it's possible that there were unmeasured differences between low-income women that differentiated WIC non-participating women from WIC participants. Previous research has shown that structural barriers such as time, child care, and transportation may contribute to the decision not to participate in WIC.[34] Therefore, it is possible that similar diet quality scores between WIC participants and income-eligible non-participants were driven by unmeasured differences between the two groups.

It should also be noted that changes made to the WIC package in 2009 increased the amount of high quality foods provided to participating pregnant women.[35] These changes to the WIC package came into effect after IFPS II data collection which to place from 2005-2007. With the 2009 revisions, which called for less fruit juice, more fruits and vegetables, and replacement of refined grains with whole grains,[36] WIC participation could have a more substantial impact on prenatal diet quality. Therefore, further research is needed to examine the influence of the updated WIC package on prenatal diet quality.

Race

Results from the race analyses in this study agree with previous research indicating that differences in prenatal diet quality are present among different racial groups,[6,7,10,11] however, our findings conflicted with the previous research in terms of which groups were different. We found that diet quality was highest in women of Other races who scored similarly to NHW woman, but significantly higher than NHB women. Higher

scores in components for whole fruit, vegetables, iron, and folate contributed to higher

overall scores for women identifying as Other races, however, women in the Other races

group also had the lowest scores for SSB. In the remaining moderation components

(including red and processed meats, *trans* fat, and sodium), scores were similar across

racial groups, indicating that differences were largely driven by higher healthful food

consumption by women in the Other races group.

In previous research evaluating the differences in prenatal diet quality across racial

groups, findings were inconclusive. In an unadjusted NHANES analysis by Shin et al,

women with Other races scored the highest on the HEI and NHW women scored

significantly lower than all minority groups (including NHB, Mexican American or

Hispanic, and Other races).[6] However, Rifas-Shiman et al found that after adjusting for

education (and other covariates), women in the Project Viva cohort scored similarly

across all racial groups (NHW, NHB, and Other).[7] Our findings somewhat agreed with

both of these studies as women of Other races scored the highest, congruent with Shin's

findings,[6] and NHW women scored similarly to the other racial groups, congruent with

Rifas-Shiman's findings.[7] However, none of these findings regarding racial differences in

prenatal diet quality are consistent with findings from the broader US population where

racial and ethnic minority groups are at increased risk of experiencing diet-related

disparities.[37] This discrepancy with our findings may be explained by the generally

higher SES of the women participating in IFPS II. In this sample, women in the Other

races group represented several different minority racial and ethnic groups including

Hispanic (n=94), followed by Asian or Pacific Islander (n=39) and other (n=30). Due to

the diversity within our Other races group, it is difficult to speculate on the mechanism

underlying these racial and ethnic differences however, it's important to remember that there is likely substantial variation in dietary patterns within the Other races groups. For example, factors such as dietary acculturation, language barriers, and cultural norms may be particularly influential on diet quality in minority populations.[37] Furthermore, since only English-speaking women were included in the IFPS II sample, our findings are not reflective of the overall population. In a sensitivity analysis (**Table S4**) where Hispanic women were removed from the Other races group (as Hispanic is considered an ethnicity rather than a race[38]), findings were similar to the findings in the original analysis, however, the average score in the Other races group increased by approximately one point (61.5 vs 62.4) when Hispanic women were removed from the Other races group. Hispanic women scored an average of 61.3 ± 10.3 on the AHEI-P which was higher than the overall average of 60.6 ± 11.1 but lower than the average scores of women who identified as Asian/Pacific Islander (66.5 ± 10.8) and other (62.5 ± 13.7).

It should be noted that in this analysis, NHB women oftentimes had descriptively (but not significantly) lower scores compared to NHW and Other races women. The sample size for the NHB group relatively small (NHB, n= 67; NHW, n=1163; Other races, n= 163) and standard errors tended to be larger for NHB women which makes it difficult to detect significant differences. For example, in the vegetables component, NHW women scored significantly lower than women in the Other races group in however, NHB women had the lowest scores out of all three groups (but not significantly different). Similarly, in the SSB component, NHW women scored significantly higher than women with Other races yet NHB women had the lowest score. Therefore, it is possible that there are disparities between NHW and NHB women that were not seen in this analysis due to

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sample size constraints. In order to better understand racial disparities in prenatal diet quality, future research is needed in large and diverse samples of pregnant women.

Pre-pregnancy BMI

Consistent with previous research, we observed an inverse association between pre-pregnancy BMI and prenatal diet quality.[6,7,11] In this study, women with normal weight had higher diet quality than women with overweight or obesity. Compared to women with obesity, women with normal weight had higher scores for whole grains, *trans* fat, and red and processed meats and differences across all groups were observed in iron and folate scores (higher scores for women with under- and normal weight, lower scores for overweight and obese).

In the previous research examining pre-pregnancy BMI and diet quality, women with lower BMI's generally had higher diet quality compared to women with higher BMI's.[6,7,11] Our findings were similar to Shin et al's findings in an NHANES analysis of prenatal diet quality using the HEI-2010 where women with normal weight had the highest scores, followed by women with underweight and overweight, and women with obesity scored the lowest.[6] Additionally, Rifas-Shiman et al found that higher BMI was associated with lower AHEI-P scores and component score analyses indicated differences were influenced by scores for fruit, red to white meat ratio, fiber, *trans* fat, calcium, and folate.[7] We similarly observed differences in red and processed meat (red to white meat ratio in original AHEI), *trans* fat, whole grains (fiber in original AHEI), and folate between BMI groups. Together, these findings suggest that compared to women with pre-pregnancy normal weight, women who enter pregnancy with overweight and obese pre-pregnancy BMIs may be more likely to overconsume unhealthful foods, resulting in

lower overall diet quality. Given these findings, dietary interventions or nutrition education seeking to improve outcomes in pregnant women with pre-pregnancy overweight or obesity may be most effective by encouraging moderation in unhealthful food consumption.

Due to associations with poor pregnancy and health outcomes, achieving a healthy weight prior to conception is encouraged.[39] Though weight loss prior to conception in women with excess weight would be ideal, very few studies have assessed interventions for weight loss prior to conception and findings were mixed.[40] Therefore, it's currently unclear how to best reduce the prevalence of pre-pregnancy overweight and obesity. However, there is evidence to suggest that high prenatal diet quality is associated with improved health outcomes, across all pre-pregnancy BMI groups. For example, regardless of BMI, higher prenatal diet quality can lead to lower fetal adiposity, lower risk of developing preeclampsia, and lower risk of some congenital malformations.[41–43] Moreover, while it can be difficult to target pre-pregnancy BMI as a risk factor, consumption of a healthful prenatal diet as well as adherence to GWG guidelines promote desirable outcomes regardless of pre-pregnancy BMI.[44]

Gestational Weight Gain

Since pre-pregnancy BMI and GWG both independently and jointly influence outcomes,[44] we completed an exploratory analysis to examine how GWG may modify the relationship between pre-pregnancy BMI and prenatal diet quality. After conception, pre-pregnancy BMI is non-modifiable and might not accurately reflect dietary changes made during pregnancy. Therefore, GWG may be an important predictor of prenatal diet quality. In this sample, about 450 women were missing data for GWG; consequently, our

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findings for GWG are limited due to missing data. In comparing GWG reporters and non-reporters, significant differences were present in race, parity, education, age, smoking status, and WIC participation (**Table S3**). Due to the significant interaction between pre-pregnancy BMI and GWG, the analysis for prenatal diet quality by GWG group was stratified by BMI.

Findings differed across pre-pregnancy BMI groups, however, no significant post-hoc score differences were observed. In women with pre-pregnancy underweight, diet quality was non-significantly highest in the excessive GWG category ($\geq$40 lb). Since maternal underweight prior to pregnancy is a risk factor for low birthweight and many subsequent health issues,[45] it's possible that underweight women who aimed to lessen the risk of adverse outcomes consumed a high-quality diet while exceeding the recommended amount of GWG. In women with pre-pregnancy normal weight, we observed the non-significantly highest AHEI-P scores in the adequate GWG group (25-35 lbs.). It's possible that in women who started pregnancy at a healthy weight, those who adhered to dietary recommendations during pregnancy (leading to higher AHEI-P scores) also sought to adhere to GWG recommendations. In women with pre-pregnancy overweight, AHEI-P scores were non-significantly highest in women with inadequate GWG (<15 lbs.) and in women with pre-pregnancy obesity, AHEI-P scores were non-significantly highest in women with excessive GWG (> 20 lbs.). Women entering pregnancy with overweight who make efforts to minimize weight gain may also adhere to dietary recommendations in order to reduce the risk of adverse outcomes associated with both pre-pregnancy overweight and excessive GWG. The range for adequate GWG in women with obesity is very narrow (11-20 lbs.) which could make adherence difficult to obtain,

therefore, women with obesity in the excessive GWG group may have chose to focus on meeting dietary recommendations, rather than meeting GWG recommendations, resulting in higher diet quality.

One previous study has examined GWG and prenatal diet quality in an NHANES sample, finding that gestational weight gain was not associated with HEI-05 scores.[46] However, since NHANES is a nationally representative study, few pregnancy-specific outcomes are measured and the researchers assessed GWG according to month of pregnancy rather than total GWG, it's possible that the month-based assessment of GWG was not reflective of total GWG. Therefore, future research is needed to further understand the relationship between GWG and prenatal diet quality.

Strengths and limitations

There are some strengths and limitations worth mentioning in this study. In this analysis, we examined the relationship between WIC participation and gestational weight gain with prenatal diet quality, relationships that has seldom been examined previously. However, our analyses for GWG and SES were somewhat limited in that there was substantial missing data for GWG and IFPS II surveys did not include questions about SNAP benefits, which could potentially influence the relationship between WIC participation and prenatal diet quality. Regardless, this study indicates that WIC participation and gestational weight gain are in need of further examination.

Previous studies examining prenatal diet quality across socioeconomic, racial, and pre-pregnancy BMI groups oftentimes did not use a holistic diet quality index and had inadequate control for confounding variables. This study includes both a holistic

evaluation of diet quality with control for confounding variables, adding to the current understanding of the factors that influence prenatal diet quality. The use of a large sample of pregnant women recruited from a national consumer panel was a strength of this study however it should be noted that the IFPS II data was collected over ten years ago. Although our sample was comprised of primarily white women with higher education which lessens the generalizability of the results, disparities were still present among SES and racial groups. Additionally, though the AHEI-P is based off the validated AHEI, the AHEI-P is not validated. To our knowledge, there are no validated diet quality indexes for pregnancy. Validating a diet quality index for pregnancy is a critical step in furthering the collective understanding of the predictors of prenatal diet quality.

Conclusion:

In this sample of women in the IFPS II cohort, diet quality differed across SES, race, pre-pregnancy BMI, and GWG groups. Although further research is warranted in large, diverse, national samples, findings in this study indicate that middle- and low-income women, NHB women, as well as women with pre-pregnancy overweight and obesity, are at increased risk of poor prenatal diet quality. Public health programs and nutritional interventions are needed to improve prenatal diet quality in all populations, however, higher priority should be given to increased-risk population subgroups.

Table 1 – Maternal characteristics for the subsample of 1,444 women in the Infant

Feeding Practices Study II who also completed the prenatal Diet History Questionnaire

Maternal Characteristic	Mean ± SE or n (%)
Age	28.9±5.6
Socioeconomic status	
WIC[a] participant	415 (29.6%)
Low income (≤1.85)	257 (18.3%)
Middle income (>1.85, <4)	484 (34.5%)
High income (≥4)	246 (17.6%)
Education	
High school or less	276 (21.18%)
Some college	521 (39.98%)
College graduate	506 (38.83%)
Race	
Non-Hispanic White	1163 (83.5%)
Non-Hispanic Black	67 (4.81%)
Other[b]	163 (11.7%)
Pre-pregnancy BMI	
Underweight	73 (5.28%)
Normal weight	637 (46.1%)
Overweight	326 (23.6%)
Obese	347 (25.1%)
Gestational weight gain[c]	
Inadequate	157(15.96%)
Adequate	373 (37.91%)
Excessive	454 (46.14%)
Smoking status	
Nonsmokers	1246 (89.26%)
Parity	
Primiparious	403 (29.37%)
AHEI-P total score[d]	60.6±11.1

[a] Women, Infants, and Children participation during pregnancy

[b] Other includes including Hispanic, Asian/Pacific Islander, multiracial, and other

[c] Gestational weight gain category was determined according to the 2009 Institute of Medicine's pre-pregnancy BMI-dependent GWG recommendations

[d] Alternative Healthy Eating Index for Pregnancy

Table 2 – Age and multivariable adjusted Alternate Healthy Eating Index for Pregnancy total and component scores by income and Women, Infants, and Children participation status of participants in the IFPS II (n= 1402)

	Total AHEI-P Score[1]	Vegetables, servings/d	Whole fruit, servings/d	Whole grains, g/d	Sugar sweetened beverages,[2] servings/d	Nuts and legumes, servings/d	Red and processed meat, servings/d	Trans fat, % of energy	Long chain (n=3) fats,[3] mg/d	PUFA,[4] % of energy	Sodium, mg/d	Iron, mg/d	Folate, mg/d	Calcium, mg/d
Age adjusted model (n=1402)														
WIC participant[5]	59.71±0.56^a	5.52±0.14^a	3.66±0.14	2.59±0.09	1.39±0.17^a	2.51±0.12	3.89±0.15^a	4.90±0.07	2.55±0.12	6.40±0.09	4.52±0.16^a	6.41±0.11^a	6.84±0.12^a	8.53±0.11
Low income[6]	60.10±0.68	5.33±0.17	3.48±0.17	2.70±0.10	1.92±0.20^{a,b}	2.51±0.14	4.31±0.18^{a,b}	4.64±0.09^a	2.72±0.14	6.62±0.11	4.69±0.20^{a,b}	6.20±0.14	6.64±0.14	8.34±0.13
Middle income[7]	60.68±0.51	4.98±0.13^b	3.60±0.13	2.70±0.08	2.47±0.15^{b,c}	2.64±0.11	4.60±0.19^b	4.84±0.07^a	2.44±0.11	6.47±0.08	5.20±0.15^{b,c}	6.01±0.10	6.43±0.10^b	8.30±0.10
High income[8]	62.51±0.72^b	5.07±0.18	4.13±0.18	2.60±0.11	3.07±0.21^c	2.56±0.15	5.21±0.19^c	5.17±0.09^b	2.47±0.15	6.36±0.11	5.66±0.21^c	5.73±0.14^b	6.27±0.15^b	8.28±0.14
Fully adjusted model – adjusted for age, smoking, race, and kcals (n=1268)														
WIC participant	57.77±0.76^a	5.26±0.19	3.46±0.19^a	2.24±0.11	1.22±0.24^a	2.04±0.16	3.79±0.21^a	4.86±0.11	2.63±0.16	6.54±0.13	4.99±0.13	6.05±0.10	6.53±0.11	8.14±0.12
Low income	58.34±0.87^a	5.22±0.22	3.39±0.22^a	2.46±0.13	1.38±0.28^a	2.05±0.19	4.02±0.24	4.65±0.13^a	2.93±0.19	6.72±0.15	4.87±0.15	6.08±0.12	6.58±0.12	7.96±0.14
Middle income	59.58±0.80^a	5.10±0.20	3.74±0.20^a	2.51±0.12	1.84±0.26	2.35±0.17	4.08±0.22	4.84±0.12^a	2.82±0.17	6.57±0.14	4.93±0.13	6.14±0.11	6.62±0.11	8.03±0.13
High income	61.76±0.95^b	5.30±0.24	4.39±0.24^b	2.44±0.14	2.38±0.30^b	2.29±0.21	4.56±0.26^b	5.15±0.14^b	2.83±0.21	6.49±0.16	5.12±0.16	6.00±0.13	6.64±0.13	8.17±0.16

Scores with different superscripted letters indicate significant post hoc differences between groups (p<0.05). Higher scores indicate better adherence to dietary recommendations. Inverse scoring (where lower consumption equates to a higher score) was used for the following categories: sugar sweetened beverages (and fruit juice), red and processed meat, trans fat, and sodium.

[1]Component scores are out of 10 possible points, total scores are out of 130 possible points, [2] Sugar sweetened beverages includes fruit juices, [3] Long chain fats component consists of EPA and DHA, [4] Polyunsaturated fatty acids. [5] Women, Infants, and Children participant during pregnancy (n=415), [6] Poverty income ratio less than or equal to 1.85 (WIC income-eligible) and not participating in WIC during pregnancy (n=257), [7] Poverty income ratio of 1.86-4 (n=484), [8] Poverty income ratio of greater than 4 (n=246)

Table 3 – Age and multivariable adjusted Alternate Healthy Eating Index for Pregnancy total and component scores by race of participants in the IFPS II (n= 1393)

	Total AHEI-P Score[1]	Vegetables, servings/d	Whole fruit, servings/d	Whole grains, g/d	Sugar sweetened beverages,[2] servings/d	Nuts and legumes, servings/d	Red and processed meat, servings/d	Trans fat, % of energy	Long chain (n=3) fats,[3] mg/d	PUFA,[4] % of energy	Sodium, mg/d	Iron, mg/d	Folate, mg/d	Calcium, mg/d
Age adjusted model (n=1393)														
NHB[5]	58.28±1.34a	4.97±0.34	3.84±0.33	2.53±0.20	1.17±0.40a	2.00±0.28	4.04±0.37	4.77±0.18	3.34±0.28a	6.68±0.21	5.01±0.39	5.95±0.27	6.35±0.27a	7.61±0.26a
Other[5]	62.96±0.85b	5.86±0.22	4.41±0.21a	2.72±0.13	1.64±0.26	2.68±0.18	4.34±0.23	5.10±0.11	2.91±0.18b	6.55±0.13	4.79±0.25	6.55±0.17a	7.16±0.17a,b	8.24±0.17
NHW[6]	60.38±0.32a	5.13±0.08	3.57±0.08a	2.64±0.05	2.28±0.10a	2.57±0.07	4.49±0.09	4.86±0.04	2.43±0.07a,b	6.43±0.05	5.03±0.09	6.05±0.06a	6.47±0.07b	8.42±0.06a
Fully adjusted model - adjusted for age, poverty income ratio, smoking, WIC participation, and kcals **(n=1268)**														
NHB	57.27±1.41a	4.86±0.36	3.69±0.36	2.18±0.21	1.39±0.45	1.73±0.31a	3.82±0.38	4.83±0.21	3.22±0.31a	6.74±0.24	5.25±0.24	5.70±0.19a	6.18±0.20a	7.69±0.23b
Other	61.47±0.91b	5.77±0.23a	4.27±0.23a	2.46±0.14	1.49±0.29a	2.41±0.20	4.13±0.25	5.13±0.13	2.69±0.20	6.49±0.16	4.88±0.15	6.44±0.12b	7.10±0.13b	8.19±0.15b
NHW	59.87±0.52	5.19±0.13b	3.54±0.13b	2.67±0.08	2.23±0.17b	2.47±0.11b	4.25±0.14	4.92±0.08	2.36±0.11b	6.40±0.09	4.87±0.09	6.08±0.07a	6.55±0.07a	8.55±0.09a

Scores with different superscripted letters indicate significant post hoc differences between groups (p<0.05). Higher scores indicate better adherence to dietary recommendations. Inverse scoring (where lower consumption equates to a higher score) was used for the following categories: sugar sweetened beverages (and fruit juice), red and processed meat, trans fat, and sodium.

[1]Component scores are out of 10 possible points, total scores are out of 130 possible points, [2] Sugar sweetened beverages includes fruit juices, [3] Long chain fats component consists of EPA and DHA, [4] Polyunsaturated fatty acids.

[4] Non-Hispanic Black (n= 67)[5]Other races (n=163) was comprised of the following races/ethnicities: Hispanic (n=94), Asian/Pacific Islander (n=39), and other (n=30). Mean scores for the subgroups were: 61.3±10.3 for Hispanic, 66.5±10.8 for Asian/Pacific Islander, and 62.5±13.7 for other.[6] Non-Hispanic White (n=1163)

Table 4 – Age and multivariable adjusted Alternate Healthy Eating Index for Pregnancy total and component scores by pre-pregnancy BMI of participants in the IFPS II (n=1383)

	Total AHEI-P Score[1]	Vegetables, servings/d	Whole fruit, servings/d	Whole grains, g/d	Sugar sweetened beverages,[2] servings/d	Nuts and legumes, servings/d	Red and processed meat, servings/d	Trans fat, % of energy	Long chain (n=3) fats,[3] mg/d	PUFA,[4] % of energy	Sodium, mg/d	Iron, mg/d	Folate, mg/d	Calcium, mg/d
Age adjusted model (n=1383)														
Underweight[6]	63.0±1.3a,b	5.9±0.3a	4.3±0.3b	2.9±0.2a,b	1.4±0.4	2.9±0.3	4.4±0.3	4.8±0.2	2.8±0.3	6.2±0.2	4.0±0.4a	6.8±0.3a	7.4±0.3a	8.9±0.3
Normal weight[7]	62.1±0.4a	5.3±0.1	3.9±0.1b	2.8±0.1a	2.1±0.1	2.7±0.1	4.7±0.1a	5.0±0.1a	2.5±0.1	6.5±0.1	4.9±0.1	6.3±0.1a	6.8±0.1a	8.4±0.1
Overweight[8]	59.5±0.6b,c	4.8±0.2b	3.6±0.1	2.5±0.1b,c	2.2±0.2	2.4±0.1	4.5±0.2	4.9±0.1	2.5±0.1	6.3±0.1	5.3±0.2b	5.9±0.1b	6.3±0.1b	8.3±0.1
Obese[9]	58.6±0.6c	5.2±0.2	3.3±0.1a	2.4±0.1c	2.2±0.2	2.4±0.1	4.0±0.2b	4.6±0.1b	2.6±0.1	6.6±0.1	5.0±0.2	5.7±0.1b	6.2±0.1b	8.2±0.1
Fully adjusted model – adjusted for age, smoking, poverty income ratio, WIC participation[5], race, and kcals (n=1252)														
Underweight	60.7±1.4a,c	5.5±0.4	4.2±0.4	2.5±0.2	1.3±0.4	2.1±0.3	4.4±0.4	4.8±0.2	3.0±0.3	6.4±0.2	4.9±0.2	6.3±0.2a	6.9±0.2a,b	8.2±0.2
Normal weight	60.6±0.8a	5.3±0.2	3.9±0.2	2.5±0.1a	1.7±0.2	2.3±0.2	4.3±0.2a	5.1±0.1a	2.7±0.2	6.6±0.1	5.0±0.1	6.3±0.1a	6.8±0.1a	8.2±0.1
Overweight	58.7±0.9b,c	5.0±0.2	3.8±0.2	2.3±0.1	1.6±0.3	2.2±0.2	4.0±0.2	4.9±0.1	2.8±0.2	6.4±0.2	5.1±0.1	6.1±0.1a	6.5±0.1b,c	8.2±0.1
Obese	58.2±0.8b,c	5.3±0.2	3.6±0.2	2.1±0.1b	1.9±0.3	2.2±0.2	3.7±0.2b	4.7±0.1b	2.9±0.2	6.7±0.1	5.2±0.1	5.7±0.1b	6.3±0.1c	8.0±0.1

Scores with different superscripted letters indicate significant post hoc differences between groups (p<0.05). Higher scores indicate better adherence to dietary recommendations. Inverse scoring (where lower consumption equates to a higher score) was used for the following categories: sugar sweetened beverages (and fruit juice), red and processed meat, trans fat, and sodium.

[1]Component scores are out of 10 possible points, total scores are out of 130 possible points, [2] Sugar sweetened beverages includes fruit juices, [3] Long chain fats component consists of EPA and DHA, [4] Polyunsaturated fatty acids, [5]Women, Infants, and Children participant during pregnancy.

[6] BMI < 18.5 (n=73), [7] BMI ≥ 18.5-24.9 (n=637), [8] BMI ≥ 25.0-29.9 (n=326), [9] BMI ≥ 30 (n=324).

Table 5 – Age and multivariable adjusted Alternate Healthy Eating Index for Pregnancy total and component scores by gestational weight gain of participants in the IFPS II, stratified by pre-pregnancy BMI (n= 984)

	Total AHEI-P Score[1]	Vegetables, servings/d	Whole fruit, servings/d	Whole grains, g/d	Sugar sweetened beverages,[2] servings/d	Nuts and legumes, servings/d	Red and processed meat, servings/d	Trans fat, % of energy	Long chain (n=3) fats,[3] mg/d	PUFA,[4] % of energy	Sodium, mg/d	Iron, mg/d	Folate, mg/d	Calcium, mg/d
Age adjusted model (n= 984)														
Underweight (n=48)														
Inadequate (n=10)	54.1±3.3ᵃ	4.3±0.9	3.1±1.0	1.9±0.6ᵃ	0.5±0.7	1.5±0.7	5.0±1.0	5.0±0.5	2.2±0.7	5.8±0.5	6.0±0.9ᵃ	5.0±0.7ᵃ	5.9±0.7ᵃ	7.6±0.5ᵃ
Adequate (n=22)	62.3±2.2ᵇ	5.0±0.6	4.4±0.7	3.5±0.4	0.8±0.5	2.5±0.5	4.7±0.7	4.9±0.3	2.5±0.5	5.8±0.4	4.1±0.6	7.3±0.5ᵇ	7.6±0.5	9.3±0.3ᵇ
Excessive (n=16)	67.9±2.6	6.7±0.7	5.0±0.8	3.9±0.5ᵇ	1.5±0.5	3.6±0.5	4.3±0.8	5.0±0.4	3.3±0.6	5.9±0.4	2.7±0.7ᵇ	8.1±0.5ᵇ	8.5±0.6ᵃ	9.5±0.5ᵇ
Normal weight (n=461)														
Inadequate (n=71)	60.5±1.3	5.0±0.3	3.6±0.3	2.8±0.2	2.0±0.4	2.5±0.3	4.6±0.4	4.7±0.2	2.4±0.3	6.6±0.2	4.9±0.4	6.2±0.3	6.7±0.3	8.3±0.3
Adequate (n=230)	63.0±0.7	5.1±0.2	4.0±0.2	3.0±0.1	2.4±0.2	2.7±0.2	5.1±0.2	5.2±0.1	2.5±0.1	6.5±0.1	5.3±0.2	6.3±0.1	6.7±0.1	8.3±0.1
Excessive (n=160)	61.7±0.9	5.4±0.2	3.8±0.2	2.8±0.1	1.9±0.3	2.8±0.2	4.6±0.2	5.0±0.1	2.6±0.2	6.7±0.1	4.9±0.2	6.2±0.2	6.6±0.2	8.4±0.2
Overweight (n=238)														
Inadequate (n=13)	64.1±3.0	5.4±0.8	3.2±0.7	3.2±0.5	2.8±0.9	4.2±0.6ᵃ	2.8±0.8ᵇ	4.4±0.4	3.4±0.6	7.2±0.5	4.1±0.9	7.1±0.6	7.5±0.6	8.8±0.6
Adequate (n=72)	58.8±1.3	4.6±0.3	3.0±0.3	2.4±0.2	2.5±0.4	2.4±0.3ᵇ	5.3±0.3ᵃ	4.7±0.2	2.2±0.2	6.2±0.2	5.7±0.4	5.7±0.3	6.0±0.3	8.1±0.3
Excessive (n=153)	59.6±0.9	4.9±0.2	3.9±0.2	2.6±0.1	2.1±0.3	2.5±0.2ᵇ	4.2±0.2ᵇ	4.9±0.1	2.4±0.2	6.4±0.2	5.1±0.3	6.0±0.2	6.3±0.2	8.4±0.2
Obese (n=237)														
Inadequate (n=63)	56.6±1.4	4.7±0.3	2.8±0.3	2.2±0.2	3.0±0.4	1.7±0.3ᵃ	4.8±0.3ᵇ	4.5±0.2	2.2±0.3	6.3±0.2	5.9±0.4	5.2±0.2	5.7±0.3	7.6±0.3ᵃ
Adequate (n=49)	57.5±1.6	5.0±0.4	3.1±0.4	2.0±0.2	2.6±0.5	2.8±0.3ᵇ	3.0±0.4ᵃ	4.5±0.2	2.6±0.3	6.8±0.2	4.8±0.4	5.7±0.3	6.3±0.3	8.4±0.3
Excessive (n=125)	59.8±1.0	5.5±0.2	3.6±0.2	2.4±0.1	1.9±0.3	2.5±0.2ᵇ	4.3±0.2ᵇ	4.6±0.1	2.6±0.2	6.8±0.1	4.8±0.3	5.8±0.2	6.3±0.2	8.5±0.2ᵇ
Fully adjusted model – adjusted for age, smoking, parity, poverty income ratio, WIC participation[5], and kcals (n= 890)														
Underweight														
Inadequate	54.1±4.0	4.2±1.3	4.5±1.1	1.9±0.7	0.0±1.0⁶	1.2±0.7	5.3±1.3	5.0±0.8	1.9±1.2	5.7±0.8	5.9±0.8	5.8±0.7	6.5±0.8	7.1±0.7
Adequate	59.3±3.6	4.2±1.2	4.9±1.0	2.7±0.6	0.1±0.9	1.6±0.7	6.2±1.2	4.5±0.7	1.8±1.1	6.0±0.7	5.7±0.8	6.8±0.7	6.8±0.7	8.0±0.7
Excessive	63.0±3.5	5.5±1.2	5.0±1.0	3.0±0.6	1.7±0.9	2.6±0.7	5.2±1.2	4.7±0.7	2.8±1.1	6.3±0.7	5.1±0.7	6.6±0.7	6.7±0.7	8.0±0.7
Normal weight														
Inadequate	58.9±1.5	4.9±0.4	3.4±0.4	2.4±0.2	1.9±0.5	2.4±0.3	4.5±0.4	5.0±0.2	2.3±0.3	6.3±0.3	5.0±0.2	6.0±0.2	6.5±0.2	8.3±0.3
Adequate	60.7±1.1	4.0±0.3	3.7±0.3	2.5±0.2	2.2±0.4	2.5±0.3	4.8±0.3	5.4±0.2	2.2±0.3	6.2±0.2	5.3±0.2	6.0±0.2	6.6±0.2	8.2±0.2
Excessive	59.1±1.2	5.2±0.3	3.4±0.3	2.3±0.2	1.8±0.4	2.6±0.3	4.3±0.3	5.2±0.2	2.4±0.3	6.6±0.2	5.1±0.2	5.8±0.2	6.4±0.2	8.2±0.2
Overweight														
Inadequate	62.2±2.9	4.9±0.7	3.0±0.7	2.6±0.5	2.7±1.0	4.0±0.7	3.3±0.8	4.7±0.5	3.5±0.6	7.1±0.5	4.8±0.5	6.4±0.4	6.9±0.4	8.5±0.5
Adequate	60.5±1.6	4.8±0.4	3.2±0.4	2.3±0.3	2.5±0.5	3.0±0.4	4.9±0.4ᵃ	4.9±0.3	2.7±0.3	6.5±0.3	5.2±0.3	5.9±0.2	6.2±0.2	8.5±0.3
Excessive	59.1±1.5	4.7±0.4	3.7±0.4	2.2±0.3	2.0±0.5	2.9±0.4	3.9±0.4ᵇ	5.1±0.3	2.6±0.3	6.5±0.3	5.1±0.3	5.7±0.2	6.2±0.2	8.5±0.3
Obese														
Inadequate	59.1±1.8	5.5±0.5	2.9±0.4	2.4±0.2	3.6±0.6	2.0±0.4	4.6±0.5ᵇ	4.7±0.3	2.2±0.4	6.3±0.3	5.0±0.3	5.6±0.2	6.2±0.2	8.2±0.3
Adequate	57.6±2.0	5.2±0.5	3.1±0.5	1.9±0.2	2.9±0.7	2.9±0.4	2.9±0.5ᵃ	4.6±0.3	2.5±0.4	6.7±0.3	4.4±0.3	5.7±0.2	6.2±0.2	8.5±0.3
Excessive	60.5±1.5	5.9±0.4	3.5±0.4	2.3±0.4	2.4±0.5	2.6±0.3	4.3±0.4ᵇ	4.8±0.2	2.5±0.3	6.8±0.2	4.7±0.2	5.8±0.2	6.2±0.2	8.8±0.2

Scores with different superscripted letters indicate significant post hoc differences between groups (p<0.05). Higher scores indicate better adherence to dietary recommendations. Inverse scoring (where lower consumption equates to a higher score) was used for the following categories: sugar sweetened beverages (and fruit juice), red and processed meat, trans fat, and sodium.

Participants were categorized according to adherence to the Institute of Medicine's 2009 gestational weight gain guidelines which are based on pre-pregnancy BMI.

[1] Component scores are out of 10 possible points, total scores are out of 130 possible points, [2] Sugar sweetened beverages includes fruit juices, [3] Long chain fats component consists of EPA and DHA, [4] Polyunsaturated fatty acids.

[5] Women, Infants, and Children participant during pregnancy

[6] The least squares mean score on the sugar sweetened beverages component for women with an underweight pre-pregnancy BMI and inadequate gestational weight gain was -0.92 due to adjustment on this unbalanced subsample however, scores cannot go below zero. The mean score on the sugar sweetened beverages component for women with an underweight pre-pregnancy BMI and inadequate gestational weight gain was 0.56.

Appendix 1

Supplementary Table 1 – The 2009 Institute of Medicine gestational weight gain

guidelines[31]

Pre-pregnancy BMI	Adequate gestational weight gain range
Underweight (<18.5)	28-40 lbs.
Normal weight (18.5-24.9)	25-35 lbs.
Overweight (25.0-29.9)	15-25 lbs.
Obese (≥30.0)	11-20 lbs.

Appendix 2

Supplementary Table 2 – Alternative Healthy Eating Index Component score means for participants in IFPS II (n=1444)

Component	Unit	Maximum score criteria	Mean±SE
Vegetables[a]	Servings/day	5 servings	5.24±2.53
Whole fruit[b]	Servings/day	4 servings	3.71±2.74
Whole grains[c]	Grams/day	75 grams	2.63±1.66
Sugar sweetened beverages[d]	Servings/day	0 servings	2.15±3.37
Nuts and legumes[e]	Servings/day	1 serving	2.55±2.33
Red and processed meat[f]	Servings/day	0 servings	4.44±2.98
Trans fat[g]	% kcals/day	≤0.5% kcals	4.88±1.46
Long chain fatty acids[h]	mg/day	250 mg	2.56±2.31
PUFA[i]	% kcals/day	≥10% kcals	6.47±1.74
Sodium[j]	Deciles	Lowest decile	5.00±3.16
Folate[k]	mcg/day	600 mcg	6.56±2.25
Calcium[k]	mg/day	1200mg	8.34±2.17
Iron[k]	mg/day	27 mg	6.10±2.20

[a]Per the AHEI, vegetables does not include white potatoes. To calculate, we used servings of total vegetables(DHPveg) and subtracted servings of white potatoes (DHPwhpot).

[b]Per the AHEI, whole fruit does not include juice. We calculated fruit servings using AHEI guidelines: 1 serving = ½ c. berries or 1 medium fruit and for other fruits, 1 c = 1 serving. For pies and cobblers, the USDA's Food-a-Pedia was used to determine how much of each serving was comprised of fruit.[43]

[c]Whole grains in the DHQ data was reported in servings per day and the AHEI guidelines call for grams per day. Per the USDA, only 16 grams out of 32 grams (one ounce) need to be comprised of whole grains in order to be considered an ounce equivalent of whole grains. We the DHQ variable for servings of whole grains, DHPwgrains, and multiplied by 16 grams to obtain grams of whole grains.

[d]Sugar sweetened beverages (SSB) includes fruit juice in the AHEI. To calculate, we use frequency and serving size data from the DHQ. Since 1 serving of SSB is equivalent to 8 fl oz per the AHEI, we calculated the total ounces of reported SSB and fruit juice consumption per day and divided by 8 fl oz.

[e] In the Diet*Calc output, USDA ounce equivalents (to lean meat) of nuts were reported (DHPnutsds). Since a half an ounce of nuts is equivalent to one (lean meat) ounce equivalent of nuts, we divided by 2 to obtain ounces of nuts consumed per day. Then, we added this value to the number of servings of beans and peas (DHPbeannpea) to obtain servings of nuts and legumes.

[f] For the red and processed meat component, we used the serving size and frequency data from all of the red and processed meat questions on the DHQ. According to the AHEI guidelines, 1 serving equates to 1.5 ounces of processed meat or 3 ounces of red meat.

[g] Grams of trans fat were reported (DHPtfatacid). This value was multiplied by 9 to obtain calories from trans fat, then divided by total calories consumed and multiplied by 100.

[h] Per the AHEI, long chain fatty acids include EPA and DHA. We took the values for EPA and DHA (DHPfat205 and DHPfat226), which were reported in grams, and multiplied by 1000 to obtain milligrams.

[I] Using grams of polyunsaturated fats consumed per day (DHPpfat), we multiplied by 9, divided by total calories consumed and multiplied by 100.

[j] Eleven deciles were formed per AHEI guidelines, the lowest decile received 10 points and the highest received 0. Intermediate deciles were scored proportionally.

[k] Values for folate were reported in micrograms and calcium and iron were reported in milligrams.

Appendix 3

Supplementary Table 3 – Comparisons between gestational weight gain reporters and

non-reporters

Variable	Reporters [n(%)]	Non-reporters [n(%)]	P value from χ^2
Overall	984 (68.1%)	460 (31.9%)	
Race			0.0026
NHW	836 (71.9%)	327 (28.1%)	
NHB	36 (53.7%)	31 (46.3%)	
Other	107 (65.6%)	56 (34.4%)	
Parity			0.0474
Primiparious	270 (67%)	133 (33%)	
Multiparious	701 (72.3%)	268 (27.7%)	
Education			<0.0001
High school or less	173 (62.7%)	103 (37.32%)	
Some college	370 (71.0%)	151 (29.0%)	
College graduate	396 (78.3%)	110 (21.7%)	
PIR			0.0677
≤1.85	392 (67.7%)	187 (32.3%)	
1.86-4	399 (70.0%)	171 (30.0%)	
>4	193 (75.7%)	62 (24.3%)	
BMI			0.3315
Underweight	48 (65.8%)	25 (34.3%)	
Normal weight	461 (72.4%)	176 (27.6%)	
Overweight	238 (73.0%)	88 (27.0%)	
Obese	237 (68.3%)	110 (31.7%)	
Age			0.0001
18-25	266 (61.3%)	168 (38.7%)	
26-35	604 (72.6%)	228 (27.4%)	
35+	114 (64.0%)	64 (36%)	
Smoking status			0.0003
Nonsmoking	893 (71.7%)	353 (28.3%)	
Smoking	86 (57.3%)	64 (42.7%)	
WIC participation			0.0001
Participant	261 (62.9%)	154 (37.1%)	
Nonparticipant	722 (73.2%)	265 (26.9%)	

Supplementary Table 4 - Sensitivity analysis – Race without Hispanic women included

	Total AHEI-P Scores	Total AHEI-P Scores with Hispanic women omitted from the Other races group
Age adjusted model (n=1299)		
NHB[1]	58.28±1.34[a]	58.35±1.34[a]
Other[2]	62.96±0.85[b]	64.59±1.31[b]
NHW[3]	60.38±0.32[a]	60.41±0.32[a]
Fully adjusted model - adjusted for age, poverty income ratio, smoking, WIC participation, and kcals (n=1180)		
NHB	57.27±1.41[a]	57.33±1.42[a]
Other	61.47±0.91[b]	62.36±1.33[b]
NHW	59.87±0.52	59.88±0.54

Alternative Healthy Eating Index for Pregnancy (AHEI-P) scores with different superscripted letters indicate significant post hoc differences between groups ($p<0.05$). Higher scores indicate better adherence to dietary recommendations.

[1]Non-Hispanic Black (n= 67)

[2]Other races (n=163) was comprised of the following races/ethnicities: Hispanic (n=94), Asian/Pacific Islander (n=39), and other (n=30). Mean scores for the subgroups were: 61.3±10.3 for Hispanic, 66.5±10.8 for Asian/Pacific Islander, and 62.5±13.7 for other.

[3] Non-Hispanic White (n=1163)

Appendix 5

Extended literature review

Introduction

A growing body of evidence suggests that life-long obesity and chronic disease

risk may be partially predetermined by nutritional exposures during the gestational

period.[47] While the association between prenatal diet and various pregnancy outcomes

(e.g.: high or low birthweight, fetal and maternal mortality, and congenital

malformations) has long been understood, recent studies have found that prenatal diet

may also influence appetite control,[48] taste preferences,[49] glucose and insulin

metabolism,[50] and other factors that contribute to life-long health trajectories. Since

gestational nutritional exposures (e.g.: prenatal diet and maternal nutritional status) can

have a pervasive influence on the child's risk of developing obesity and chronic disease

later in life,[1] public health efforts seeking to improve population health may be most

effective when targeting pregnant women.

Despite the growing evidence that prenatal diet influences many short- and long-

term health outcomes in the mother and child, current adherence to dietary

recommendations in US pregnant women is inadequate.[6,7,9–11,33] The average Healthy

Eating Index (HEI-2010) score of pregnant women participating in the National Health

and Nutrition Examination Survey (NHANES) from 2003-2012 was 50.7[6] out of 100,[6]

which is nearly 30 points below the score recommended for disease prevention.[8]

Research on prenatal diet quality using indices such as HEI-2010[10] and the Alternative

Healthy Eating Index for Pregnancy (AHEI-P) indicate that on average, the diets of

pregnant women in the US meet between 50-66% of nutrient and/or food group

recommendations.[6,7] Specifically, the majority of pregnant women are not consuming enough fiber,[7,9] whole grains,[6,9–11] fruits,[6,7,10] or vegetables[6,7,10] and consuming excessive amounts of sodium,[6,12] and fat[9,13,14] in the form of heavily processed foods.[6,9]

While average prenatal diet quality in the US is poor, it is likely that some populations are disproportionally impacted by poor prenatal diet quality and subsequent adverse health outcomes. In the broader US population, some high-risk population subgroups such as low-income individuals, minority racial groups, and individuals with high BMI's, experience disparities in diet quality.[16–18] However, relatively few studies to date have examined the predictors of prenatal diet quality and currently, groups at high-risk of poor prenatal diet quality are insufficiently defined. Identifying high-risk populations is a vital step in improving health outcomes as it allows nutrition interventions and public health programs seeking to increase prenatal diet quality to target high-risk groups and subsequently improve long-term health outcomes in mothers and children.

Therefore, the objective of this literature review is to discuss the importance of prenatal diet on health outcomes and identify what is currently known regarding the predictors of prenatal diet quality. During the first part of this review, background will be provided on the following topics: long- and short-term health impacts of prenatal diet, recommendations for pregnancy (dietary, pre-pregnancy BMI, and gestational weight gain), followed by an overview of diet quality and disparities. The second part of this paper will provide a synthesis of the previous research examining predictors of prenatal diet quality, specifically examining socioeconomic status (SES), race, pre-pregnancy BMI and gestational weight gain (GWG).

Part 1: Background

Impact of prenatal diet on health outcomes

  The first 1000 days of life (from conception to 2 years of age) has been identified as a life stage where long-term health trajectories are shaped by various exposures including those of the nutritional, epigenetic and hormonal nature.[1,51] During pregnancy, a time of rapid growth and development, the fetus is said to be plastic, i.e. it is able to adapt accordingly to various intrauterine exposures.[52] Systemic tissue plasticity is unique to early life, therefore, adaptations made in utero persist and influence life-long health, hence the term 'fetal programing' which describes the programing of fetal tissues that occurs during pregnancy.[52] Therefore, nutritional exposures during pregnancy influence the programming of various tissues including those that impact the infants' cognitive, endocrine, and metabolic outcomes.[2]

  Researchers have identified probable mechanisms through which maternal diet influences fetal programing, perhaps most understood is the influence of maternal nutrition on birth weight and subsequent long-term outcomes.[53] Prenatal undernutrition can result in low birthweight, which is not only an indicator of inadequate fetal growth, but also a risk factor for the later development of many chronic diseases such as obesity, type 2 diabetes, and cardiovascular disease.[53] It is thought that fetal adaptations that increase metabolic efficiency for survival in the presence of low nutrient availability remain present later in life and these adaptations become problematic when the nutrient supply is no longer limited as it is in obesogenic environments.[54] Furthermore, when nutrient availability is inadequate, the supply is directed towards essential organ

development (e.g. the brain) and less-essential organs (e.g. pancreas) might not fully develop and this can result in lifelong alterations in insulin production and metabolism.[2]

On the other hand, fetuses subject to excess nutrients are at increased risk of being born at high birthweights, which is also a risk factor for subsequent chronic disease development seen in low birthweight infants.[55] However, the mechanisms differ. Mothers who enter pregnancy with obesity and/or gain excess gestational weight exhibit systemic inflammation and resulting increased adipokines (signaling protein from adipose), as well as altered insulin, glucose, and lipid metabolism;[5] these exposures are thought to influence fetal hypothalamic development resulting in an increased risk of chronic disease development.[54] It is important to note that abnormal birthweight, in itself, is not the causal pathway for increased chronic disease risk.[56] Rather, the influence of intrauterine exposures as well as the influence of environment (particularly during early life) interact to influence chronic disease risk.[54] Though obesity and chronic diseases are complex etiologically, perinatal diet determines nutritional exposures in utero and subsequently influences programing, making maternal diet a target for modifying overall health trajectories and chronic disease risk.[57]

Recommendations for pregnancy

Prenatal dietary recommendations aiming to improve pregnancy-related and postnatal health outcomes have been developed by various professional and governmental organizations (e.g.: Academy of Nutrition and Dietetics, the US Department of Agriculture, the American College of Obstetricians and Gynecologists, etc.). Similar to dietary recommendations for the general population, prenatal dietary

recommendations encourage the consumption of a high quality diet rich in fruits, vegetables, whole grains, healthy fats, and lean proteins.[58] Moreover, energy needs and some nutrient needs are increased during pregnancy to accommodate fetal growth, which is dependent on the mother's nutrient stores and intake.[58] For example, needs increase for iron (RDA increases from 15 mg to 27 mg[59]) and folate (RDA increases from 400 mcg DFE (dietary folate equivalents) to 600 mcg DFE[60]) during pregnancy. Increased nutrient needs during pregnancy are the result of the increased risk of poor outcomes seen with deficiencies; folate deficiency can result in neural tube defects and iron deficiency anemia (which impacts approximately 17.4% of pregnant women in developed countries[61]) can increase the risk of low birth weight, preterm delivery, and fetal death.[62] Therefore, meeting nutrient recommendations during pregnancy can help to reduce the risk of adverse outcomes.

Meeting nutrient needs, however, is not the sole prenatal dietary concern for optimizing health outcomes. Caloric needs are increased during pregnancy and both failing to meet or exceeding calorie needs can impact outcomes.[53] Two measures can be used to broadly assess energy balance before and during pregnancy: pre-pregnancy BMI and gestational weight gain (GWG). It is recommended that women enter pregnancy with a BMI in the normal range and regardless of pre-pregnancy BMI, women should adhere to the IOM's recommendations for GWG (determined by pre-pregnancy BMI).[63] Both entering pregnancy with overweight or obesity and gaining an excessive amount of GWG increases the mother's risk of developing gestational diabetes mellitus (GDM), gestational hypertension, and giving birth to an infant with high birthweight.[39,64–66] On the other hand, entering pregnancy with underweight and failing to reach GWG

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guidelines are both independently associated with low birth weight,[45,64–66] which is associated with neonatal mortality and increased risk of the offspring developing a disability or disease.[55,67–70] In addition to adhering to nutrient recommendations during pregnancy, entering pregnancy with a normal BMI and meeting the GWG recommendations can help to reduce chronic disease risk in the offspring.

Diet quality

While entering pregnancy with a healthy BMI and adhering to prenatal recommendations for nutrient intake and GWG can help to prevent adverse outcomes, these factors fail to account for overall prenatal diet quality. Micronutrient recommendations, particularly for iron and folate, can be met by consuming highly-processed, fortified foods and thus, adherence to micronutrient recommendations is not a good proxy for overall diet quality.[71] Measuring overall diet quality better assesses multiple dimensions of the diet simultaneously including: micro- and macro- nutrients and food group while considering total energy intake.[71] Assessing compliance to dietary recommendations can be measured by using a diet quality index (e.g. Healthy Eating Index (HEI-2010) or Diet Quality Index for Pregnancy (DQI-P)). The HEI-2010, for example, measures compliance to the Dietary Guidelines for Americans[72,73] which includes adequate intake of fruits, vegetables, whole grains, lean protein, and low-fat dairy and moderated intake of refined grains, empty calories, sodium and added fats.[74] Recent studies indicate that consuming a high quality diet during pregnancy can reduce the risk of various adverse outcomes such as risk of congenital malformations and excess infant adiposity.[42,75–77] Furthermore, consuming a high quality diet during pregnancy can

reduce the risk of developing GDM and pre-eclampsia, regardless of pre-pregnancy

BMI,[41,78] suggesting that prenatal diet quality may be a better measure of diet-related risk

than measures such as pre-pregnancy BMI. However, prenatal diet quality in the US is

poor and it is unclear how diet quality differs among various groups of pregnant women.

Disparities

In US adults, certain population subgroups (e.g.: minority racial and ethnic groups

and individuals with low SES) are disproportionally impacted by poor diet quality and

poor health outcomes.[79] For example, higher income is associated with better adherence

to dietary recommendations where being non-Hispanic Black (NHB) is associated with

lower adherence.[16] The causes of health disparities are complex but disparities are

believed to be rooted in biological and environmental differences as well as social and

cultural factors that collectively result in limited access to resources.[79] Health disparities

are evident starting in infancy where racial disparities are seen in infant mortality rates

which occur in non-Hispanic black infants at more than double the rate of occurrence

seen in non-Hispanic white infants.[80] Thus, given the influence of prenatal diet on health

outcomes, it is reasonable to consider whether the origin of health disparities begins in

utero.

Some health disparities have been previously identified among population

subgroups of women who are pregnant or of childbearing age. Racial disparities can be

seen in obesity prevalence in women of childbearing age; where 26.9% of non-Hispanic

white (NHW) women have obesity, the prevalence more than doubles in NHB women

(56.2%).[81] Pre-pregnancy obesity is a risk factor for a myriad of adverse health outcomes

including the development of gestational diabetes mellitus (GDM) and preeclampsia.[82] Furthermore, disparities in adherence to gestational weight gain (GWG) recommendations have been identified among different racial and income groups.[83] Compared to NHW women, NHB women are more likely to gain an inadequate amount of weight during pregnancy.[83] However, rates of excessive GWG are comparable among NHW and NHB women.[83] Disparities in GWG recommendation adherence can also be seen across SES groups where women with low income (<185% FPL) are at increased risk of exceeding GWG guidelines.[84]

Disparities influencing pregnancy outcomes not only impact the child's long-term health but can also have transgenerational effects (i.e. exposure influencing later generations).[70] Collins et al investigated transgenerational impacts of the maternal grandmother's residence in a poor neighborhood (as compared to an affluent neighborhood) during her pregnancy with the mother on her grandchild's birthweight and found that when the maternal grandmother resided in a low income neighborhood during her pregnancy, the grandchild was at increased risk of being low birthweight, regardless of the mother's neighborhood income level,[85] demonstrating that exposures during the grandmother's pregnancy persist for multiple generations. Since much of the child's long-term health trajectory is programmed during pregnancy, improving pregnancy outcomes in disadvantaged populations may help to alleviate health disparities. Though some risk factors for poor health outcomes are non-modifiable, prenatal diet is modifiable, making it a desirable target for influencing health outcomes.

Part 2: Predictors of Prenatal Diet Quality

Disparities in prenatal diet are likely present, however, relatively few studies to date have examined the predictors of prenatal diet quality so groups at high-risk of poor prenatal diet are insufficiently defined. Identifying high-risk populations is a vital step in improving health outcomes because once identified, nutrition interventions and public health programs seeking to increase prenatal diet quality can target high-risk groups. In order to effectively allocate limited resources to populations at increased risk of poor prenatal diet quality, we must first understand the predictors of prenatal diet quality. Maternal characteristics such as: race,[6,7,10] income,[6,7,11] pre-pregnancy BMI,[6,7,11] parity,[7,10,11] age,[6,7,10,11] education,[6,7,10,11] food security,[86,87] physical activity,[6,11] and smoking status[6,11,33] have been identified as potential predictors of prenatal diet quality though further research is needed to fully understand these associations. In the reviewed literature, the consistency of findings varied by maternal characteristic. Though some characteristics, such as non-smoking status and normal pre-pregnancy BMI, were consistently associated with higher diet quality, the current literature has mainly consisted of regional samples that were socioeconomically skewed,[7,10,11] many of the studies lacked adjustment for confounding variables,[6,10,11] and several studies used diet quality indicators that awarded points for the consumption of fortified and processed foods.[10,11] Due to these methodologic concerns, it is important to rigorously evaluate predictors of prenatal diet quality before defining the relationship between aforementioned factors and prenatal diet quality.

Age,[6,7,10,11] parity,[7,10,11] smoking status,[6,11,33] SES[6,7,10,11] and pre-pregnancy BMI[6,7,11] are consistently associated with prenatal diet quality. Increasing age[6,7,10,11] and non-

smoking status[6,11,33] have examined in four studies each and both have been consistently

associated with higher prenatal diet quality. Primiparity has been associated with higher

diet quality in 3 out of 4 studies examining parity.[7,10,11] Higher SES and lower pre-

pregnancy BMI are also consistently associated with prenatal diet quality.[6,7,10,11]

However, SES and pre-pregnancy BMI are in need of further examination due to

limitations in the current literature that reduce the quality of evidence. Additionally, some

characteristics, such as race, had inconsistent associations and some characteristics, such

as gestational weight gain and WIC participation, have been seldom examined.

Socioeconomic status and prenatal diet quality

A variety of variables can be used to measure socioeconomic status (SES),

including: education, income, and occupation.[88] Higher socioeconomic status is

consistently associated with higher diet quality in samples of US adults.[16,89,90] In samples

of pregnant women, higher SES generally is associated with better adherence to a

healthful diet.[6,7,10,11] However, many of the studies examining prenatal diet quality looked

at samples comprised of mostly regional samples comprised of majority high or low

income women.[7,10,11] Additionally, few studies to date have examined how WIC

participation may improve prenatal diet quality in low-income women. Therefore, it is

important that the relationship between prenatal diet quality and SES is further examined.

Income and education

Higher education was associated with higher diet quality in 4 out of 5 included

studies.[6,7,10,11,33] One study found no association between education and diet quality.[33]

However, this study involved a small sample (n=335) of low SES women; 42% had not

completed high school and 56% were WIC recipients,[33] which may have explained this inconsistent finding. Since healthier diets are generally more costly than unhealthy diets,[29] income may be a better measure of SES when examining diet quality disparities.

All three included studies examining income and prenatal diet quality in pregnant US women found that higher income was associated with higher diet quality.[6,10,11] When using income as an indicator of SES, poverty income ratio (PIR), a measure of household income: federal poverty level (for reported household size) is commonly used due to its interpretability. In an NHANES (2003-2012) sample, higher-income pregnant women (family income greater than or equal to 400% of the poverty income ratio) had significantly higher diet quality (HEI-2010=55.1±1.9, p<0.05) compared to lower income pregnant women (family income less than or equal to 185% of the poverty income ratio, HEI-2010=47.1±1.1).[6] Two studies examined diet quality in the Pregnancy, Infection, and Nutrition (PIN) sample using the DQI-P and found that higher income was associated with higher diet quality.[10,11] It should be noted that the PIN sample was comprised mainly of low- and middle-income women.[11] One study compared diet quality component scores among income groups in the PIN study and found that higher income women consumed more vegetables and less calories from fat compared to their lower-income counterparts.[10] However, the lower income women consumed more folate and iron than the higher income women which could be driven by increased consumption of fortified processed foods.[10]

Though the current body of evidence consistently indicates that higher income and higher education are protective of prenatal diet quality, most of the included studies examining the relationship between SES and prenatal diet quality involved samples that

were sociodemographically skewed and few of the studies controlled for confounding variables.[6,7,10,11] Further research in more diverse samples with adjustment for covariates is needed before conclusions can be drawn. Additionally, future studies should examine component score differences among income groups as well as total diet quality score differences.

WIC Participation

Poor food access, high food prices, lack of education and time, built environment, and culture have been proposed as mechanisms driving the relationship between low SES and poor diet quality.[88] In low income populations, nutrition assistance programs aiming to improve income-related disparities may be a mechanism for mitigating poor diet quality in low income populations. Therefore, participation in government programs that aim to increase food access, such as the Supplemental Nutrition Assistance Program (SNAP) and Women, Infants, and Children (WIC) are important considerations when examining SES and diet quality.

WIC is a nutrition assistance program that targets low-income pregnant and nursing women, infants, and children who are at nutritional risk.[91] WIC benefits provide recipients with supplemental foods however, WIC benefits are structured, allowing recipients to receive specified amounts of mostly healthful foods (juice, milk, cereal, eggs, fruits and vegetables, whole wheat bread, legumes, and peanut butter).[92] It is possible that WIC participation may help to modify the relationship between low income and poor prenatal diet quality. In this literature review, one study examined the impact of WIC participation on prenatal diet quality, finding that women participating in WIC consumed more protein, iron and calcium than women who were income-qualified non-

participants.[33] It should be noted that this study was published in 1990 and involved a small, convenience sample of less than 300 WIC income-eligible women from Massachusetts.[33] While this study provided valuable insight on the potential association between WIC participation and prenatal diet quality, replication of this association in a recent, diverse cohort is needed. If findings support that WIC participation during pregnancy can alleviate income-based disparities in diet quality, public health efforts can be made to increase prenatal WIC participation in low income women.

Race and prenatal diet quality

Studies examining differences in prenatal diet quality among racial groups in the US do not consistently find that racial minorities have poorer or healthier dietary quality than their white counterparts.[6,7,10,11] In 4 included studies that examined prenatal diet quality and race, two found that NHB women had higher scores than NHW women[6,11] and two found that NHW and NHB women scored similarly.[7,11] Most of the studies assessing prenatal diet quality disparities between racial groups examined socioeconomically-skewed, regional samples using the DQI-P (a diet quality index that does not holistically assess diet) without adjusting for covariates.

In a nationally representative sample Shin et al, compared prenatal diet quality among pregnant women participating in NHANES (2003-2012).[6] In unadjusted analyses, NHB (53.1±1.2), Mexican American or Hispanic (53.5±1.4), and other/multi-racial (59.8±2.7), scored significantly higher on the HEI-2010 than NHW women (50.6±1.4, $p<0.05$). [6] However, adjustment for covariates is an important consideration when examining race and diet quality.

Although only a handful of studies have examined diet-related racial disparities in pregnant women,[6,7,10,11] multiple high quality studies have evaluated this association in the broader US population.[16,27,89,90,93] In unadjusted analyses of NHANES samples of US adults, NHB adults had consistently lower diet quality than their NHW counterparts.[16,27,89,94] Kirkpatrick et al suspected income confounds the association between race and diet quality, given the strong correlations between race and income.[16,90] Previous research indicates that socioeconomic status (e.g.: income and/or education) is strongly associated with diet quality in the greater US population[16,89,90] and in pregnant women.[6,10,11] Furthermore, in an adjusted analysis of NHANES data, NHW and NHB populations had similar diet quality and racial differences in diet quality were confounded by education and income.[19]

None of the included studies examining race and prenatal diet quality adjusted for income although one study adjusted for education found no significant differences in prenatal diet quality among races.[7] Rifas-Shiman et al analyzed racial differences in prenatal diet quality in the Project Viva cohort using the AHEI-P. Findings indicated no significant differences in diet quality among different races after adjustment for age, pre-pregnancy BMI, parity, race, and education.[7] According to the researchers, prior to adjustment for covariates, NHB women (regression estimate= -1.6 [-3.1,-0.1]) and other/multi-racial women (-1.4 [-2.7,-0.1]) had lower scores than NHW women (reference group). After adjustment, NHB (1.3 [-0.2, 2.8]), other/multi-racial (0.1 [-1.2, 1.4]), and NHW women (reference group) all scored similarly and the association was primarily confounded by age and education.[7] While this study adjusted for a socioeconomic covariate (education), an essential consideration when examining

differences in prenatal diet quality by race, the sample examined was fairly homogenous.[7]

Project Viva recruited pregnant women in urban and suburban Massachusetts and the

sample was comprised of mostly older (average age of 32.4 years) and educated (65%

had a college degree) women. Therefore, results are not generalizable to the broader US

population of pregnant women.

Use of a socioeconomically skewed and/or regional sample was not a unique

limitation to Rifas-Shiman's analysis of Project Viva, rather, convenience sampling was

major limitation of most (3 of the 4) included studies examining race and diet quality.

The remaining two studies examining prenatal diet quality among racial groups both

analyzed the PIN sample from Wake County, NC.[10,11] This sample was predominantly

low- and middle-socioeconomic status and approximately half of the participants had less

than or equal to 12 years or a high school education and reported WIC qualified incomes.

It is important to note that both analyses of the PIN sample using the DQI-P

yielded differing results. Laraia et al found that NHB women participating in the PIN

study scored higher than NHW women before and after adjustment for covariates (age,

physical activity, and vitamin use),[11] though in adjusted analyses, NHB women had an

odds ratio of 0.57 (0.44-0.76) when the NHW women were used as the reference group.[11]

Conversely, in an unadjusted analysis by Bodnar et al, there were no significant

differences in prenatal diet quality among different races.[10] Ongoing recruitment in the

PIN study is a likely explanation for the differing results. In addition to inconsistent

findings in the PIN sample, both of the PIN studies shared a limitation of using the DQI-

P to measure diet quality.[10,11]

In this literature review, studies examining race and prenatal diet quality commonly relied on a potentially invalid diet quality index, the DQI-P. The DQI-P is a version of the DQI, modified for pregnancy. The DQI-P simply measures adequate food group and micronutrient intake without considering moderated intakes of empty calories and nutrient-poor foods.[11] Thus, unlike the HEI-based indices commonly used in the other studies (AHEI-P and HEI-2010), a diet receiving a favorable score by the DQI-P may receive a low score when evaluated by an HEI-based index because the scoring criteria for HEI-based indices penalize for intake of nutrient poor, processed foods (e.g.: refined grains, fortified processed foods) whereas DQI-P awards points for intakes of the same foods.[11] Most scoring components in the DQI-P, such as folate, iron, fruit, and grains, can be satisfied with processed foods such as refined and fortified grain-based foods and fruit juices, which are not consistent with healthful dietary patterns.[95,96] Furthermore, the DQI-P does not adjust for total energy intake, making it difficult to distinguish between a nutrient dense diet and one where more overall (healthy and unhealthy) foods are consumed. Characterizing the association between race and prenatal diet quality requires adjustment for socioeconomic status and diet quality must be assessed with a more robust measure of overall diet quality such as the AHEI-P.

Pre-Pregnancy BMI and GWG

Pre-pregnancy BMI is associated with many pregnancy and health outcomes.[63] Related to, but independent from pre-pregnancy BMI, GWG may be associated with diet quality via similar mechanism. BMI is commonly categorized as underweight (<18.5), normal weight (18.5-24.9), overweight (25.0-29.9), or obese (>30).[21] The Institute of

Medicine's GWG recommendations are based on pre-pregnancy BMI and adequate GWG ranges are: 28-40 lbs. for underweight, 25-35 lbs. for normal weight, 15-25 lbs. for overweight, and 11-20 lbs. for obese women.[63] GWG may be a more comprehensive indicator of prenatal diet quality than prenatal BMI because GWG reflects adherence to diet and weight gain related recommendations during pregnancy. Since GWG and pre-pregnancy BMI have been independently and jointly associated with birth outcomes,[44] it is important to examine the relationship between both variables and prenatal diet quality.

Healthy/lower BMI was associated with higher diet quality in the 3 studies examining pre-pregnancy BMI and diet quality.[6,7,11] In an NHANES (2003-2012) sample, Shin et al found that women with normal weight had the highest HEI-2010 scores (55.2±1.6) followed by women with underweight (54.7±2.1) and women with overweight (52.3±2.8) while women with obesity had the lowest scores (48.8±2.0, p=0.0074 for trend) after adjustment for covariates.[6] Significant differences among BMI groups were seen in component scores for total and whole fruit and sodium. Analyzing the PIN cohort, Laraia et al found that women with obesity (53.3±12.0) had significantly lower unadjusted DQI-P scores than women with normal (55.3±11.3) or under-weight (57.2±11.7, p<0.05); differences were driven by lower scores in the vegetable and meal pattern component scores.[11] Lastly, in the Project Viva cohort, Rifas-Shiman et al found that after adjustment for covariates, each additional 5 kg/m^2 was associated with a reduction of 0.9 [-1.3,-0.4] AHEI-P points; this reduction was driven by reduced scores in the fruit, read:white meat, fiber, trans fat, calcium, and folate components.[7]

Though normal pre-pregnancy BMI was associated with higher prenatal diet quality in three studies examining this relationship, there was no consensus regarding the

component scores driving the association. In the current literature, adjustment for confounding variables was present in two of the three studies, however two of the study samples were fairly homogenous. The association between pre-pregnancy BMI and prenatal diet quality must be further examined in a regionally diverse sample while adjusting for income, race, and age, in order to determine whether pre-pregnancy BMI is an independent predictor of prenatal diet quality.

Currently, only one study within a sample of pregnant women participating in NHANES (2003-2006) has examined the association between GWG and prenatal diet quality measured with the HEI-2005.[46] Overall diet quality was not significantly associated with GWG, however, low scores on the vegetables and oils components were associated with excessive GWG.[46] Although no significant overall association was found, the differences in component scores suggest that GWG may be an important consideration for predictors of prenatal diet quality. Additionally, limitations within this study may have biased conclusions.[46] GWG is generally represents self-reported total weight gained during pregnancy, in reference to adequate weight gain ranges based on pre-pregnancy BMI. Since NHANES is a cross-sectional study that is nationally representative (not a pregnancy cohort), GWG in the pregnant participants was determined using self-reported pre-pregnancy height and weight (to calculate BMI), current weight measured on the interview day, and self-reported month of pregnancy.[46] Therefore, assessment of GWG was based on the recommended weight gain for the reported month of pregnancy, as opposed to endpoint assessment where total weight gained during pregnancy is subtracted by usual weight. This method may be subject to error because the range of adequate weight gain is very narrow during earlier months (ex:

5-10 lbs. total weight gain for normal weight at four months). Minor fluctuations in weight (due to morning sickness, water retention, etc.) may result in misclassification. Also, in this study, GWG recommendations were not linear but rather reflected stepwise increases between months of gestation.[46] For example, if a women at the end of her sixth month of pregnancy was 1 pound above the recommendation for six months, she would be categorized as having excessive GWG, even if a few days later, she would be in the adequate range for seven months. Future research is needed, using GWG as an endpoint in order to better understand this association.

Conclusions

Prenatal diet has a pivotal influence on the child's lifelong health outcomes however, current prenatal diet quality is inadequate. Diet quality disparities likely exist among population subgroups of pregnant women but the current literature is inconclusive. There were a number of limitations in the included studies examining the associations between maternal characteristics (specifically race, SES, pre-pregnancy BMI, and GWG) and prenatal diet quality. Many of the included studies did not adjust for confounding variables, analyzed sociodemograhpically homogenous samples, and used a diet quality indicator that did not holistically measure diet quality. Though some maternal characteristics were consistently associated with prenatal diet quality, there is a demonstrated need for a robust investigation of these determinants, including determinants with consistent findings in the reviewed studies (pre-pregnancy BMI and SES) as well as those with less consistent or infrequently examined associations (race, prenatal WIC participation, and GWG) within a national, diverse, and large sample of

pregnant women with control for confounding variables. Characterizing the association

between maternal factors and prenatal diet quality will help identify high risk populations

and groups with disparities so that public health programs can more efficiently allocate

limited resources.

Appendix 6

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